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IoT and Cloud Computing for Societal Good

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Preface

Internet of Things (IoT) and Cloud Computing are two recent innovations that have transformed business and industry. These innovations have immense potential for societal good. The main purpose of this book is to highlight the applications of IoT and cloud computing for the benefit of humankind. To fulfil this purpose, the book is organized into four parts focusing on different aspects of IoT and cloud computing.

Part I focusses on perhaps the most important aspect that has the widest societal implications – on tackling climate change. Cloud computing infrastructure requires massive amount of energy, sometimes exceeding the requirement of a mid-size town. In this regard, Chap. 1 discusses research directions and methodological approach towards energy-efficient cloud computing. Chapter 2 presents a solution for IoT-based smart air quality control system and discusses its role in the prevention of Covid-19. Chapter 3 digs deeper into this aspect and focusses on the forecasting of particulate matter. Such systems may prove to be useful for pollution control and environmental planning. Chapter 4 focusses on smart agriculture and discusses the problem of fruit segregation and taxonomy system. Chapter 5 takes a social perspective and discusses the creation of a web-based platform for bike-sharing, a potential solution to reduce vehicular pollution by promoting the use of shared bicycles.

Part II of the book covers a variety of applications from diverse domains. Chapter 6 provides a general introduction to applications from areas such as agriculture, health, and military. Chapters 7 and 8, respectively, focus on the use of artificial intelligence and personal assistants in the domain of digital health. Moving to digital learning, Chap. 9 discusses the application of digital technologies in the area of corporate learning, and Chap. 10 takes an applied perspective and examines the behavioral intentions of Generation-Z towards the adoption of digital learning applications. Chapter 11 looks at how IoT and smart factories underpin lean manufacturing in the context of Industry 4.0.

Part III deals with the optimization of existing IoT and cloud technology. Chapter 12 discusses multi-modal feature analysis for precise human hand gesture recognition. This would find useful application particularly in the domain of virtual reality. Chapter 13 offers plausible risk management models for the integration of cloud and IoT by calculating the optimal frequency of maintenance, addressing an important infrastructural issue in IoT and cloud. Chapter 14 focusses on the provision of middleware for IoT protocol interoperability. This is crucial since currently IoT protocols are not standardized. Chapter 15 moves towards a more intangible asset of information and discusses how active influential nodes can be mined to assess information diffusion in social networks.

Finally, Part IV of the book deals with the security and privacy in IoT and cloud computing. Chapter 16 discusses the application of artificial intelligence for enhancing security of IoT devices. Chapter 17 takes an outward perspective by focusing on cyber-attacks, attack vectors, and remedies in the context of IoT devices. Chapter 18 proposes a privacy-secure link utilization routing algorithm for improving performance in IoT and cloud computing. Finally, Chap. 19 outlines the design of a smart home appliances controlling application with a highly secretive system to ensure privacy.

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Jitendra Kumar Verma is Assistant Professor (Senior Grade) of Indian Institute of Foreign Trade (IIFT), New Delhi in IT Discipline. Prior to joining IIFT, he served at Amity University Haryana, Galgotias University and Deen Dayal Upadhyaya College (University of Delhi). He received his degree of M.Tech and Ph.D. in computer science from Jawaharlal Nehru University, New Delhi in 2013 and 2017, respectively. He obtained his degree of B.Tech in Computer Science & Engineering from Kamla Nehru Institute of Technology (KNIT), Sultanpur in 2008. Over his short career, he has published numerous papers in peer-reviewed international journals, books with renowned publishers, conference proceedings papers, and book chapters. He has organized several international conference, seminars, and workshops. He also delivered several invited talks and seminars at several platforms of national and international repute. Dr. Verma authored one book, Green Cloud Computing (Lambert Academic Publishing, 2016), and edited three books, Applications of Machine Learning (Springer Verlag, 2020), Computational Intelligence and Its Applications in Healthcare (Elsevier Academic Press, 2020), Advances in Augmented Reality and Virtual Reality (Springer Verlag, 2021).

He is an awardee of the prestigious DAAD "A new Passage to India" Fellowship (2015–16) funded by the Federal Ministry of Education and Research – BMBF, Germany, and German Academic Exchange Service. He worked at Julius-Maximilian University of Würzburg, Germany (mother of 14 Nobel Laureates), as a visiting research scholar.

His core research interest includes software engineering, Internet of Things, social computing, image processing, artificial intelligence, and soft computing techniques. Dr. Verma has organized several international conference, seminars, and workshops. He has delivered several invited talks. He is associate editor and guest editor of many international journals. Dr. Verma is a member of several societies and professional bodies including ACM, IEEE Industrial Applications Society, IEEE Young Professional, IEEE, Hyderabad Deccan ACM Chapter, and Institut De Diplomatie Publique. He serves as a reviewer for various international journals, conferences, and workshops.

Deepak Saxena is assistant professor at Birla Institute of Technology & Science, Pilani. Prior to this, he was a research fellow at the Trinity Centre for Digital Business. He holds a Ph.D. in business from Trinity Business School, Trinity College Dublin (Ireland), and M.Tech. (industrial and management engineering) from the Indian Institute of Technology Kanpur.

Before moving to Ireland for his Ph.D., he worked with the Indian Space Research Organisation, Council for Scientific and Industrial Research, and Defence Research and Development Organisation. He is interested in the area of digital transformation, with a special focus on public service organizations.

Dr. Saxena has previously taught at Trinity College Dublin, Dublin Institute of Technology, and American College Dublin. His research is published in the *Australasian Journal of Information Systems*, *Journal of Information Science*, *Electronic Journal of Information Systems Evaluation*, and *Electronic Journal of e-Government*. He has presented his papers in the British Academy of Management, European Conference of Information Systems, European Academy of Management Conference, the UK Academy for Information Systems Conference, and the Midwest Association for Information Systems Conference.

Vicente González-Prida currently works for a private company as project manager sharing his professional performance with teaching activities for degree programs in Spain and LATAM, as well as the development of research projects for the university.

In the academia, he has been honored with the following recognitions:

- Extraordinary Prize of Doctorate by the University of Seville
- National Award for Ph.D. Thesis on Dependability-RAMS by the Spanish Association for Quality
- National Award for Ph.D. Thesis on Maintenance by the Spanish Association for Maintenance
- Best Nomination from Spain for the Excellence Master Thesis Award bestowed by the European Federation of National Maintenance Societies
- First Class Honours in the Executive Master in Business Administration, by the Chamber of Commerce

Dr. González-Prida has edited four books, (IGI-Global 2015, 2017, and 2019; Springer Verlag 2018), regarding maintenance modelling, RAMS, asset management, and decision making, and authored two books (Confemetal 2018; Springer Verlag 2014) about ISO-55000 and after-sales management.

His research works have been presented in conferences such as WCEAM, ESREL, IEEE, and ESREDA, and published in journals such as *Reliability Engineering and System Safety*, *Production Planning and Control*, *IMA Journal of Management Mathematics*, and *Computers in Industry*, among others.

His main interest is related to ILS, RAMS, life cycle optimization, as well as the Industry 4.0 and disrupted technologies.

Finally, Dr. González-Prida is member of the Technical Committee of the Engineering Institute of Spain, fellow of the Club of Rome (Spanish Chapter), and member of the Technical Advisory Board for the Observatory of Intelligence, Security and Defence, among other institutions.

Part I
Tackling Climate Change

Chapter 1
Towards Energy Efficient Cloud Computing: Research Directions and Methodological Approach

Jitendra Kumar Verma and Deepak Saxena

1.1 Introduction

Massive data centers containing thousands of servers are now commonplace due to the faster rate of cloud computing adoption. Public cloud providers like Google, Amazon, Microsoft, and Rackspace own large-scale data centers around the globe and provide cloud users with many cloud services. Meanwhile, the growing number of user requests for cloud services has led to a significant increase in data center energy consumption. In [1], Koomey projected that data centers' worldwide power consumption increased by 56% during 2005–2010 which amounts to between 1.1% and 1.5% of total electricity use. Figures 1.1 and 1.2 show energy consumption pattern of servers and data centers worldwide during the years 2000–2010 and 2010–2017, respectively [2]. Currently, data centers powering massive internet applications consume approximately 1.3% of total electricity use worldwide, and [1, 3] was expected to increase up to 8% by 2020.

In the meantime, Gartner projects that energy consumption in individual data centers is rapidly increasing by 8–12% per year [4]. Huge supply of electricity is used to power IT systems (such as servers, storage, and networking equipment) and facility components (e.g., air-conditioning systems, power distribution units, and uninterruptible power supply systems). The increase in energy consumption is being driven by users installing more equipment and the increasing power requirements

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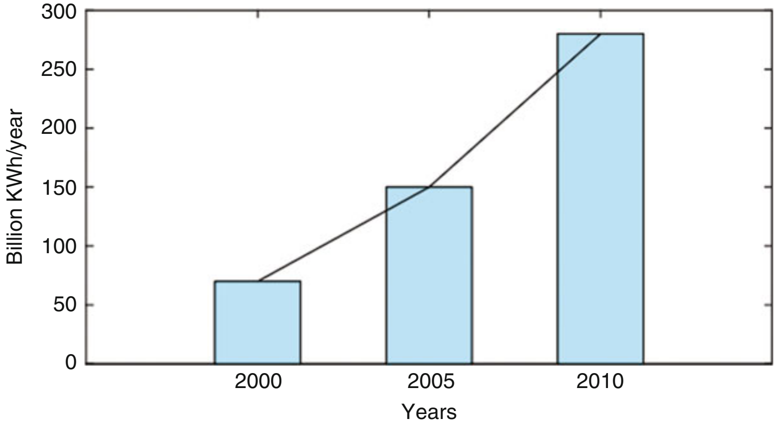


Fig. 1.1 Worldwide Energy consumption by data centers during the years 2000–2010

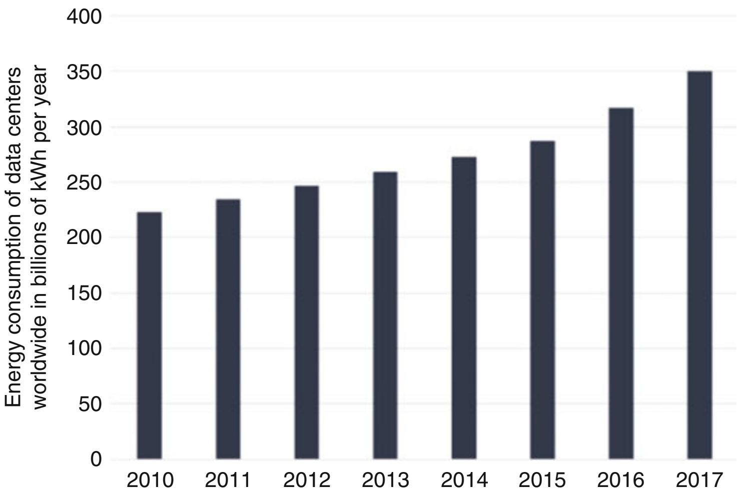


Fig. 1.2 Worldwide Energy consumption by data centers during the years 2010–2017

of high-density server architectures. While Data Center Infrastructure Management (DCIM) tools monitor and model the use of energy across the data center, server-based energy management software tools are specifically designed to measure the use of energy within server units. They are usually an upgrade to existing server management tools, such as HP Systems Insight Manager (HP SIM) or IBM Systems Director. These software tools are essential for accurate and real-time measurements of the amount of energy used by a particular server. These data can then be fed into a reporting tool or a wider set of DCIM tools. Data will also be an important trigger for real-time changes that will drive the real-time infrastructure. For example, a change in energy consumption can lead to a process to move the application from one server to another facilitated through virtualization technology. Virtualization is backbone of cloud computing technologies which allows slicing down a physical hardware into multiple Virtual Machines (VMs) and migration of these VMs from one server to another depending on VM migration criteria.

1.2 Background Motivation

The cost of electricity has become a major expense for data centers that can be understood by knowing the fact that 3% reduction in energy consumption for a large company like Google costs saving into a million dollars [5]. Half of this energy is getting wasted due to inefficient allocation of data center's resources. High power consumption not only increases operational cost of the data center but also increases the carbon dioxide emission by the data center. Current carbon dioxide emission of the ICT infrastructure is estimated around 2% of the global carbon emission which is equivalent to the carbon emission by aviation industry [6] that significantly contributes towards greenhouse effect and therefore contributes towards global warming. Energy consumption by the data centers will continue to increase steeply unless energy aware resource provisioning solutions are developed and applied. The environmental impact caused by carbon emission and high energy cost has become a major concern among research communities and are challenged to design energy efficient solutions and techniques.

To address the issue of high energy consumption, it is necessary to avoid inefficiencies and wastage caused by inefficient way of delivering electrical energy to the computing resources and the methodologies used by computing resources to handle the application workloads. Improvements in resource management and resource allocation policies, and reconfiguration of physical infrastructure paves way to reduce inefficiencies. It is evident from a report Open Compute project, Facebook Oregon data center achieved the Power Usage Effectiveness (PUE) ratio to be 1.08 which indicates computing resources of the data center alone consumed 91% of electricity supplied and signifies upon advancement in data center's design to achieve efficiency.

The primary source of energy wastage lies in the inefficient usage of computing resources. Most of the time servers operate at 10–50% of their full capacity and utilization rarely approaches to 100% despite the fact that resources are non-ideal most of the time. Apart from this, the problem of low resource utilization is exacerbated due to narrow calibration of dynamic power state ranges of the servers. Even completely ideal server causes energy consumption about 70% of its peak usage [7]. Such over-provisioning of resources causes extra expenses leading to high Total Cost of Acquisition (TCA) [8] and Total Cost of Ownership (TCO). Thus, underutilized servers in a Cloud data center are very costly from the perspective of energy consumption. However, delivering the desired level of QoS to the Cloud users is very critical for satisfying customers' expectations and data centers' performance. QoS parameters are characterized by Service Level Agreements (SLAs) that define required performance levels.

This chapter focuses on the problem of energy efficient resource management of Cloud data center resources and ensures that computing resources are efficiently utilized to serve the hosted application workloads while minimizing energy consumption and maintaining required QoS between data centers and their users.

1.3 Power Consumption and Energy Efficient Dynamic VM Consolidation

As shown in Fig. 1.3, power management can be broadly categorized into static and dynamic power management techniques. Static power management techniques work at the level of hardware and software both where hardware level techniques are further categorized into circuit level, logic level, and architecture level. Similarly, dynamic power management techniques are classified into hardware and software level both where software level techniques may deal with single server, multiple severs or data centers, and cloud level architectures.

Server consolidation or VM consolidation is an effective strategy to optimize resource utilization and energy efficiency in a cloud computing environment [9, 10]. It leverages the benefits of virtualization technologies that allow sharing of resources of servers or physical hosts among multiple isolated platforms called Virtual Machines (VM). Each of the VM is capable of running one or more applications. Virtualization technology enables live VM migrations which is a capability of transferring VMs among physical servers of a data center. In server consolidation method, live VM migration allows the migration of VMs from multiple underutilized or normal loaded physical servers to fewer physical servers and either puts the idle servers into minimum power consumption mode or switches

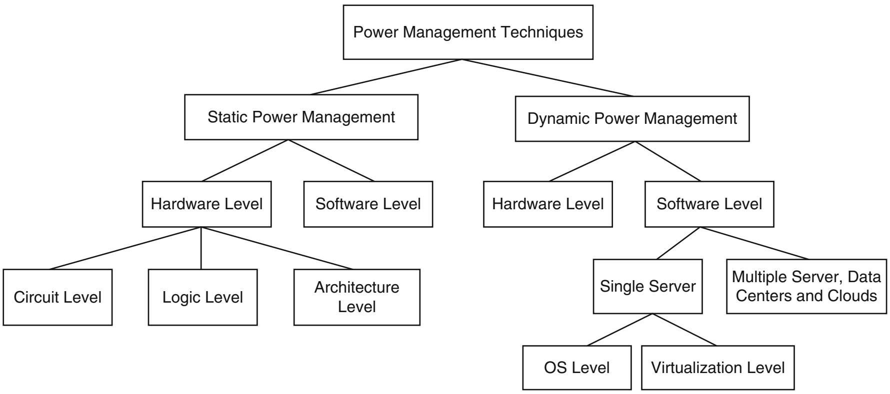


Fig. 1.3 Taxonomy of energy consumption

them off. However, live migration of VMs causes negative impact on performance of applications during migration that running in the migrating VM.

The problem of server consolidation is mapped with a bin-packing problem so that migrated VMs can be efficiently packed on the servers. The bin-packing problem is actually an NP-hard problem; therefore, no unique solution exists, and the problem might be solved by finding nearly optimal or approximate solutions.

Figures 1.4 and 1.5 show the overview of approaches to improve the energy efficiency of computing nodes and network resources [11]. Sometimes, maximum energy efficiency does not guarantee maximum performance. Therefore, proper balance should be struck between energy efficiency and performance trade-offs. The Green Grid [12], a global consortium, has defined two popular metrics to quantify the relationship between the power consumption by a data center and its various equipment, Power Usage Effectiveness (PUE) and Data Center Infrastructure Effectiveness (DCiE) [11].

$$\mathrm{PUE} = \frac{\text{Total data center Power}}{\text{Total Power Supplied}} \tag{1.1}$$

$$\mathrm{DCiE} = \frac{1}{\mathrm{PUE}} = \frac{\text{IT Equipment Power}}{\text{Total Power Supplied}} \tag{1.2}$$

Server consolidation helps to keep a system energy efficient. One of the popular approaches for server consolidation to achieve energy efficiency in cloud computing environment is programming using the MapReduce framework. The key feature of this approach is to turn a Hadoop node into a sleep node when a node has finished its job or is waiting for new jobs. However, high server consolidation generates poor QoS, and thus violations of SLAs will occur [13]. Hence, several criteria should be considered while designing a distributed dynamic VM consolidation algorithm for predefined objectives of energy optimization problem.

In the data center, jobs can be classified into compute-intensive, data-intensive, and I/O-intensive jobs based on their different behaviors [14]. Energy-efficiency evaluation models include VM consolidation that relies on CPU utilization rates majorly. In this chapter, VM consolidation is achieved through VM selection, VM migration, and resource provisioning to the VMs after migration to another host. There are two problems that need to be addressed in VM consolidation:

1. Total cost of running a physical host;
2. Total cost of penalty caused by SLA violations.

The cost of running a physical host is dependent on energy consumption by it. Every CPU clock consumed during active, idle, and sleep period of a host causes power consumption. The power consumption is directly proportional to the CPU processor clocks/frequency used in computation [15]. Energy spent while the host is not in sleep mode includes the period when either the host is performing computation or the host is in idle mode. On the other hand, energy spent on hosts

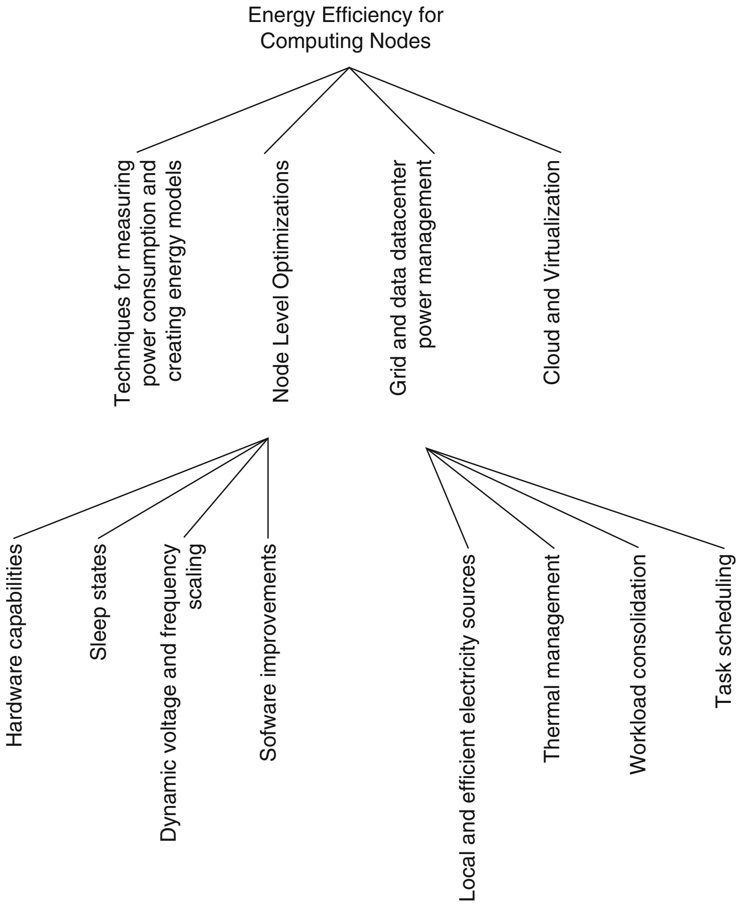


Fig. 1.4 Energy efficiency for computing nodes

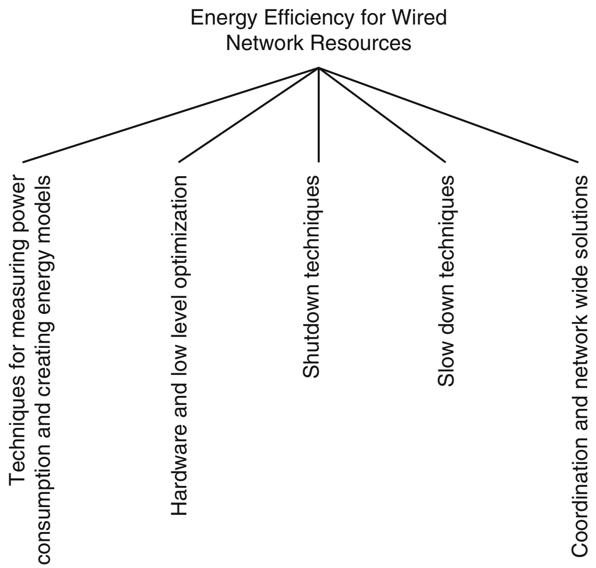
that are in sleep mode includes the period when the host is in sleep mode or lowest power consumption mode and the transition period when the host moves from sleep state to wake-up mode. The proposed relationships are shown in (1.3) and (1.4).

$$E_{sleep} = P_{sleep} + E_{transition} \tag{1.3}$$

$$E_{nosleep} = P_0 t + (cV^2 f) \cdot t \tag{1.4}$$

where E_{sleep} and P_{sleep} are energy and power consumption while the host is in sleep mode, $E_{nosleep}$ and $P_{nosleep}$ are energy and power consumption while the host is not in sleep mode. $E_{transition}$ is the energy consumption when the host is switching

Fig. 1.5 Energy efficiency for networking resources



to idle/active state from sleep mode. P_0 is the idle host power consumption, c is constant, V is the voltage, and f is CPU frequency.

Furthermore, the SLA violations occur when the total demand for the CPU resources exceeds the available CPU capacity of a particular physical host. Let us assume that C_p is the cost of power required for running an active physical host and C_v is the cost of SLA violation by a physical host due to excessive resource demand [16]. We define overall cost function as shown in (1.5).

$$minimize\ C = \sum_{t=t_0}^{T} \left(c_p \sum_{i=0}^{n} a_{t_i} + c_v \sum_{j=0}^{n} v_{t_j} \right) \tag{1.5}$$

where $c_p \in \mathbb{R}^+$, $c_v \in \mathbb{R}^+$, $C_p, C_v \neq 0$ and $a_{t_i} \in \{0, 1\}$ and $v_{t_j} \in \{0, 1\}$. a_{t_i} is "1" if the host is active and "0" if the host is idle, similarly, v_{t_j} is "1" if the host is suffering from SLA violations and "0" if there are no-SLA violations for the corresponding host. T is the total period of observation, t_0 is the starting point of time when observation starts and n is the number of physical hosts in Cloud computing environment. It is necessary to minimize energy consumption so that C could become minimum that involves C_p and C_v both while achieving energy efficiency through VM allocation policies.

Although large amount of research has been already conducted in energy and performance management issue for VM consolidation models but still this has a big thrust in this area. Therefore, balancing the trade-offs between energy efficiency and QoS is an open research problem. In this chapter, we focus upon software level improvements to tackle energy and performance management issue.

1.4 Defining Objective and Setting Research Questions

This section discusses research challenges of energy and performance management of distributed dynamic VM consolidation in large-scale infrastructure clouds environment with regard to QoS constraints that is popularly known as Infrastructure as a Service (IaaS). The key Research Questions (RQ) to be investigated are as follows:

– RQ1: When to migrate a VM?
  Dynamic VM consolidations involve two basic processes for overloaded and underloaded servers: (1) Migration of VMs from the overloaded servers to avoid potential SLA violations, (2) Migration of VMs from the underloaded server to avoid potential energy consumption and improve resource utilization. In both situations, determining the best time to migrate the VM is crucial decision that is taken to minimize energy consumption and avoid potential SLA violations.
– RQ2: Which VM to migrate?
  Once the decision to migrate a VM from server is initiated, it is required to identify one or more suitable VMs from the set of VMs allocated to the server and that has to be allocated to the other servers. The problem lies in determining best subset of VMs for migration to achieve optimized reconfiguration of the system that are allocated to the server.
– RQ3: How many VMs to migrate?
  The server that is running with least utilization level is declared underloaded and all VMs from this server are migrated. Meanwhile, the server running beyond the threshold of utilization needs live migration of as many VMs as it makes the host running below the utilization threshold.
– RQ4: Where to migrate the VM?
  Determining best server to host the migrated VM is another important aspect of VM consolidation problem. Careful decision on finding suitable server improves the quality of VM consolidation and energy efficiency of the system.
– RQ5: What are the suitable criteria to trigger VM migration?
  A VM type is characterized by three parameters that are amount of CPU allocated, memory allocated, and dedicated bandwidth allocated to it. Another possible dimension is number CPU cores assigned to the VM. Depending upon the nature of applications utilizing VM, single or composite criteria may be devised for live migrations for the purpose of VM consolidation.
– RQ6: When and which server to be switched on/off?
  A server declared underloaded causes migration of all the VMs and incurs ideal power consumption therefore this shall be turned off. To optimize the energy consumption and avoid SLA violations with regard to QoS parameter it is necessary to identify properly that which host should be deactivated against ideal power consumption and which host should be reactivated to handle surge in resource demand.
– RQ7: How to design the algorithm for distributed dynamic VM consolidation?

To avoid single point failure and provide scalability to an algorithm it is essential to design the dynamic VM consolidation algorithm in distributed manner. Meanwhile traditional resource management algorithms are centralized in nature; therefore, an alternative approach is required to develop a dynamic VM consolidation algorithm to be distributed.

1.5 Methodological Approach

The methodological approach to develop a solution to achieve energy efficiency are summarized below:

– Design and develop distributed dynamic VM consolidation methods that are based on heuristics and meta-heuristics motivated from insights from the theoretical competitive analysis and derived cloud computing management model of [17, 18]. Scaled VM management models for large scale data centers may be developed based statistical analysis of past historical data derived during lifetime of VMs.
– Validation of proposed approaches can be performed by evaluating them on very popular CloudSim Simulation Toolkit that is able to conduct discrete event cloud simulations and extended to support power and energy aware simulations. Since cloud computing systems provide large-scale computing resources for the user on-demand, therefore, it is essential to validate the proposed methods on a large-scale data center infrastructure. However, conducting large-scale experimentations on a real infrastructure is extremely difficult due to lack of such hardware resources and procuring them incurs huge monetary cost. Therefore, to ensure the repeatability and reproducibility experimentations as well as carrying out experimentations on a large-scale infrastructure, discrete event simulations are the best alternative to write and run the simulations in a quick way and test out the proposed methods in a complex environment like grids, cluster and clouds [19, 20]. A discrete event simulation imitates the real clock time for the traditional analytical and mathematical models and represents a system in fixed point of time [21]. Hence, it is able to model and show the dynamic behavior of the system on modification in values of state variables at discrete point of time due to occurrence of any random event. Therefore, we recommend discrete event simulation as the best alternative to ensure repeatability, reproducibility, evaluation, and validation of the proposed approaches. The evaluation process of algorithms comprises series of experimentation that utilize synthetic and realistic workloads to ensure the correctness.
– For applicability of simulation-based evaluation of proposed methods, real world workload data sets can be utilized that are available publicly. The workload is PlanetLab2 data provided as the part of CoMon project that is a monitoring infrastructure of PlanetLab Servers. This project produces data from more than a thousand VMs on CPU usage that is reported in every 5 min. Each of the

folder corresponds to the workload traces of an entire day and the files in the folder corresponded to the number of VMs issued on that day. These VMs are hosted by the servers located at more than 500 places around the world. The VMs are created and managed by independent users and cloud provider is not aware of the application workloads in these VMs, therefore, the workload from these VMs is representative of an IaaS Cloud computing service model such as Amazon EC23. The overall system workload comes from multiple heterogeneous applications working independently that also corresponds to the IaaS type of Cloud computing service model. It differs from public cloud provider such as Amazon EC2 only in the sense that PlanetLab infrastructure is mainly used for the research purpose and the application hosted are close to HPC type that are computationally intensive and less dynamic in resource utilization unlike the web servers. Meanwhile, the CPU utilization data of VMs comes from the single core as it can be noticed from the type of data and for the same reason amount of RAM is divided by the number of cores for each VM type. For VM consolidations, it is easy to handle HPC type workload due to infrequent variation in resource demand and resource utilizations. Thus, data from PlanetLab VMs and Google Cluster may be used to validate the proposed approach.

1.6 Conclusion

In this chapter, we have taken global view of problem of huge energy consumption posed by cloud infrastructure worldwide leading to high metered bill cost and high carbon emission contributing towards global warming. With reference to the Gartner's report, Koomey's and Hintemann et al. work, we provide trend of energy consumption by IT equipment worldwide during the 2000–2017 which substantiate our motivation behind writing this chapter followed by a literature survey. Furthermore, we present mathematical modeling of energy consumption model for a single server, energy consumption by a server during sleep mode non-sleep mode, followed by overall cost function by whole data center encompassing cost of energy consumption due to SLA violations occurred due to excessive workload on servers. However, energy saving can be archived by counterbalancing factor of energy consumption due to no-SLA violations and energy consumption due to SLA violations both. To gain energy efficiency one must define sever research questions and accordingly apply the different approaches to counter excessive energy consumption. The work illustrated in this chapter is very useful for researchers and practitioners in the area of Cloud Data centers.

As a future scope, we propose to work on a general framework which may be helpful for beginners to align their work in the direction of green cloud computing.

References

1. J. Koomey et al., Growth in data center electricity use 2005 to 2010. A report by Analytical Press, completed at the request of The New York Times **9**(2011), 161 (2011)
2. R. Hintemann, S. Hinterholzer, Energy consumption of data centers worldwide, in *The 6th International Conference on ICT for Sustainability (ICT4S)*, Lappeenranta, 2019
3. P.X. Gao, A.R. Curtis, B. Wong, S. Keshav, It's not easy being green. ACM SIGCOMM Comput. Commun. Rev. **42**(4), 211–222 (2012)
4. Definition of advanced server energy monitoring tools - Gartner information technology glossary. https://www.gartner.com/en/information-technology/glossary/advanced-server-energy-monitoring-tools. Accessed on 19 Feb 2021
5. A. Qureshi, R. Weber, H. Balakrishnan, J. Guttag, B. Maggs, Cutting the electric bill for internet-scale systems, in *Proceedings of the ACM SIGCOMM 2009 Conference on Data Communication*, 2009, pp. 123–134
6. C. Pettey, Gartner estimates ICT industry accounts for 2 percent of global CO2 emissions. Dostupno na:. 14, 2013 (2007). https://www.gartner.com/newsroom/id/503867
7. X. Fan, W.-D. Weber, L.A. Barroso, Power provisioning for a warehouse-sized computer. ACM SIGARCH Comput. Archit. News **35**(2), 13–23 (2007)
8. L.A. Barroso, U. Hölzle, The case for energy-proportional computing. Computer **40**(12), 33–37 (2007)
9. A. Beloglazov, R. Buyya, Y.C. Lee, A. Zomaya, A taxonomy and survey of energy-efficient data centers and cloud computing systems, in *Advances in Computers*, vol. 82 (Elsevier, New York, 2011), pp. 47–111
10. L. Deboosere, B. Vankeirsbilck, P. Simoens, F. De Turck, B. Dhoedt, P. Demeester, Efficient resource management for virtual desktop cloud computing. J. Supercomput. **62**(2), 741–767 (2012)
11. A.-C. Orgerie, M.D. de Assuncao, L. Lefevre, A survey on techniques for improving the energy efficiency of large-scale distributed systems. ACM Comput. Surv. **46**(4), 1–31 (2014)
12. A. Hawkins, Unused servers survey results analysis. The Green Grid (2010)
13. J.K. Verma, C.P. Katti, P.C. Saxena, MADLVF: an energy efficient resource utilization approach for cloud computing. Int. J. Inf. Technol. Comput. Sci. **6**(7), 56–64 (2014)
14. J. Jiang, Y. Feng, J. Zhao, K. Li, DataABC: a fast ABC based energy-efficient live VM consolidation policy with data-intensive energy evaluation model. Fut. Gener. Comput. Syst. **74**, 132–141 (2017)
15. A. Berl, E. Gelenbe, M. Di Girolamo, G. Giuliani, H. De Meer, M.Q. Dang, K. Pentikousis, Energy-efficient cloud computing. Comput. J. **53**(7), 1045–1051 (2010)
16. J.K. Verma, S. Kumar, O. Kaiwartya, Y. Cao, J. Lloret, C.P. Katti, R. Kharel, Enabling green computing in cloud environments: network virtualization approach toward 5G support. Trans. Emerg. Telecommun. Technol. **29**(11), e3434 (2018)
17. A. Beloglazov, Energy-efficient management of virtual machines in data centers for cloud computing. PhD thesis, 2013
18. J.K. Verma, Energy-efficient approaches for cloud computing framework. PhD thesis (2017)
19. A. Ashraf, B. Byholm, I. Porres, A session-based adaptive admission control approach for virtualized application servers, in *2012 IEEE Fifth International Conference on Utility and Cloud Computing* (IEEE, New York, 2012), pp. 65–72
20. R.N. Calheiros, R. Ranjan, A. Beloglazov, C.A.F. De Rose, R. Buyya, Cloudsim: a toolkit for modeling and simulation of cloud computing environments and evaluation of resource provisioning algorithms. Softw. Pract. Exp. **41**(1), 23–50 (2011)
21. F. Farahnakian et al., Energy and performance: management of virtual machines: provisioning, placement, and consolidation (2016)

Chapter 2
IoT-Based Smart Air Quality Control System: Prevention to COVID-19

Somya Goyal

2.1 Introduction

An extensive research demonstrates that polluted air has adverse impact on health. The poor air quality has always been a major concern for both health officials and the public. According to a report from the World Health Organization, around 3.7 million people died due to exposure to polluted air [1]. The short-term or/and long-term exposure to air pollution causes high mortality and increases the chances of other diseases including the COVID-19. As per the report, exposure to polluted air contaminated with traffic pollutants over 24 h, increases the hospitalizations regarding cardiovascular and respiratory issues [2]. The latest news report shows that a person exposed to such high pollution loses 7 years of his life on average [3]. The poor air quality in the Indo-Gangetic plains causes a reduction in life span of an average person by 7 years. As per World Health Organization (WHO) standard, 20 micrograms per cubic meter is acceptable concentration of particulate matter in air. The air quality in Indo-Gangetic plains does not meet the standard [3]. Health emergency has been declared by concerned authorities in few regions. The records clearly indicate that the maximum number of COVID-19 patients were from the highly polluted areas. The conditions of patients in polluted area were more severe than from that from the less polluted areas. The mortality rate is two times higher than that of less polluted regions [4].

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2.1.1 Motivation

The pollutants from atmosphere enter the indoor arena and become about 1000 times prone to get transmitted to the lungs and cause respiratory diseases and COVID-19 [5]. Air quality control is essential to prevent the spread of disease – COVID-19. Constant monitoring of indoor air helps to control the air quality and to ensure the reduced exposure of humans to the contaminated air, IoT-based smart devices and air purifiers are needed to be developed and used.

2.1.2 Contribution

This study brings the attention to environmental issues beyond the scope of the human eye and contributes to prevent spread of COVID-19 disease. The smart unit is designed using a microprocessor and sensors to detect the presence of particulate matter-carbon monoxide (CO) and carbon dioxide (CO_2) in the air and their concentrations. GSM module is also embedded to wirelessly send an alert message to the user. It stores the collected data on a cloud to monitor and control the quality of air. The accuracy of proposed smart unit is verified for the purpose of monitoring the air quality and the storing the data on cloud for applications.

The accuracy of proposed smart unit is verified for the purpose of monitoring the air quality and the storing the data on cloud for applications. It is effective to prevent the spread of COVID-19.

In this way, the entire work contributes to develop a smart device to check the air quality to control it effectively and hence to prevent the spread of coronavirus.

2.1.3 Organization

This chapter is organized in following sections. Section 2.2 discusses the related work. The proposed model with working is given under Sect. 2.3. Section 2.4 reports the results and analysis. The work is concluded in Sect. 2.5 with references to future work.

2.2 Related Work

This section brings a short discussion about the literature contributing for air quality control using IoT. In recent years, Internet of Things (IoT) and cloud computing are being deployed to develop the real-time monitoring devices for air quality control. The studies [6–14] are dedicated to monitor the air quality of indoor systems. They have integrated new emerging technologies to monitor the air quality. These studies are dedicated to collect real-time data using IoT-based smart devices. They have not integrated the wireless sensor network to transmit data on remote locations.

The idea of this work is to fill this gap between the emerging technology and existing smart air sensors. This chapter provides a platform to integrate the features of cloud computing with the benefits of IoT. This work launches a smart device to monitor and control the indoor air quality precisely and to upload the data collected in real time to a cloud server.

The agenda is to prevent the spread of COVID-19 by constant monitoring of air quality and to issue alert messages to the people. It is shown that high agglomeration of air pollutants facilitates the spread of the virus [15]. The poor quality of air results in high mortality rate due to COVID-19 [16, 17]. Hence, if the quality of air is constantly monitored and the low-quality alerts are issued to human, then the spread of COVID-19 can be prevented effectively. The study [18] shows that the target messaging to alert people about poor air quality brings behavioural change in people. They become alert and avoid excessive exposure to contaminated air.

2.3 Proposed Model

The proposed model is shown in Fig. 2.1. It has basically two parts – (1) sensing part and the web server. The sensing part is comprised of a set of sensors. The sensors are installed to sense the quantity of corresponding content of air and to control the quality. The sensor data collected by sensing part is sent to the web server part. It is achieved with LTE module which connects the sensing part and web server part. The target is to judge the air quality and analyse the data to alert the people. Web server is connected to cloud server to store the data on cloud server and apply machine learning to detect dangerous patterns of poor air quality. The cloud computing integration to the web server allows speedy analysis and fast accessibility. The web server processes a large amount of data, to support air quality control system. Users can access the web server via browsers to see the status of air pollution level manually.

For implementation, Amazon Web Services (AWS) is used for cloud storage. A GSM module is also integrated to automatically alert the users via SMS in case the quality of air crosses the threshold values.

The entire setup is built on IoT architecture (shown in Fig. 2.2) and its three layers: (i) layer to take readings from the environment, perception layer; (ii) a layer to provide connectivity between the input layer and processing layer, a network layer; and (iii) the processing and output layer, presentation layer [19].

The idea is to gather the environmental factors via sensors and store to analyse the gathered data on cloud. From the uploaded data, the degree of quality of air is judged, and then the targeted messages are broadcast to the registered users. The flowchart of proposed system is shown in Fig. 2.3.

The main components of the system are [21] described as follows:

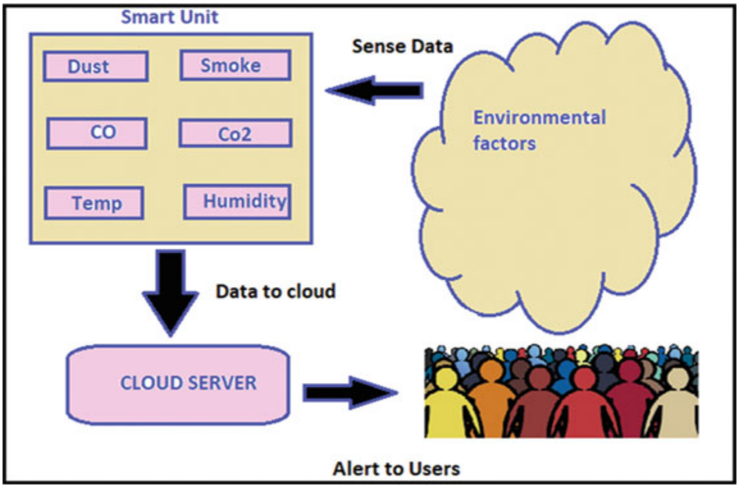

Fig. 2.1 Model of proposed system

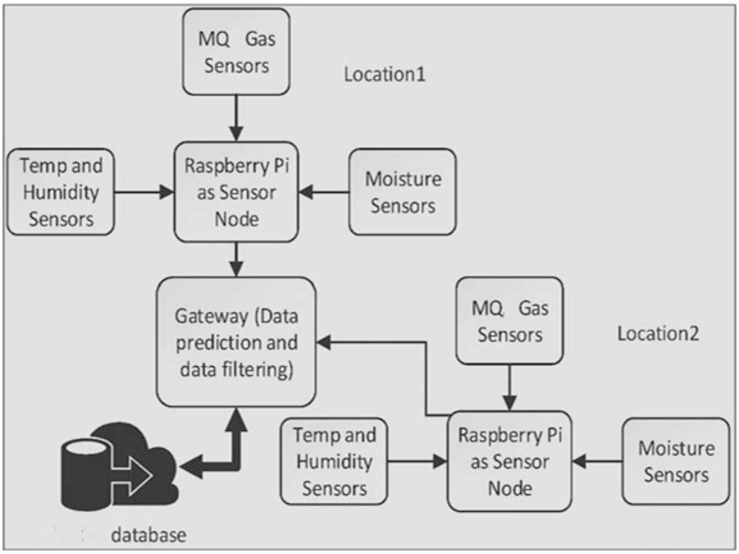

Fig. 2.2 IoT architecture

(a) *Raspberry Pi*

In the proposed model, the environment is being sensed via sensors, but the sensors cannot work autonomously; they need some processor. This processing unit controls, directs and helps the sensors to handle the data. In this proposed model, Raspberry Pi is being used. Raspberry Pi is a small computer and it has a built-in Wi-Fi module and multifunctionalities.

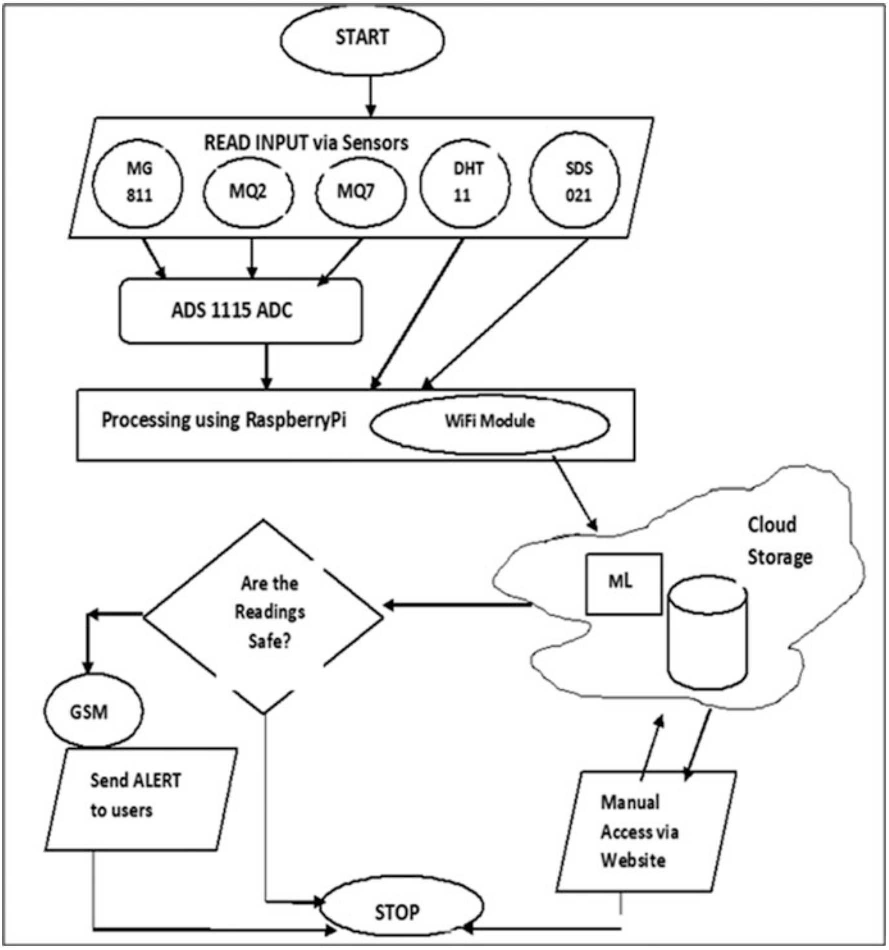

Fig. 2.3 Flowchart of proposed model

(b) *Sensors*

Sensors are devices which allow smart system to interact with the external environment. It allows to access the environmental factors and sense the data. In this proposed system, the MQ-2 sensor is used to detect smoke. Sensor MQ-7 is installed to detect carbon monoxide (CO). Sensor MG811 is assembled to detect carbon dioxide (CO2). Another sensor DHT11, to take readings of live temperature and to read the humidity of air in the ambiance, has been installed. To measure the PPM levels of PM 2.5 and PM 10 particulate matters, SDS021 sensor has been used along with other sensors.

(c) *Analog-to-digital converter*

ADS1115 ADC is used to connect MQ-2, MQ-7 and MG811 gas sensors to Raspberry Pi. It converts analog signals from the above sensors into digital signals and provides the digital output to Raspberry Pi for processing. The outputs of the sensors, SDS021 and DHT11, are digital.

(d) *Web service*

This research allows to access the real-time data to its authentic users via website. It is achieved through a cloud platform.

(e) GSM module

To alert the registered users about the poor air quality, GSM module is embedded. If the air quality does meet the WHO guidelines, then an alert SMS is broadcasted to the users automatically.

2.4 Results and Discussion

The device is installed, and readings are recorded to analyse the pattern of harmful levels of poor air quality. The standards state [20] that the content of pollutant in air is tolerable with concentration as mentioned – CO (ppm) $\leq$10; CO_2 (ppm) $\leq$1000; VOCs (µg/m3) $\leq$ 400. Figure 2.4 shows the constant readings of CO. Figure 2.5 shows the readings for CO_2.

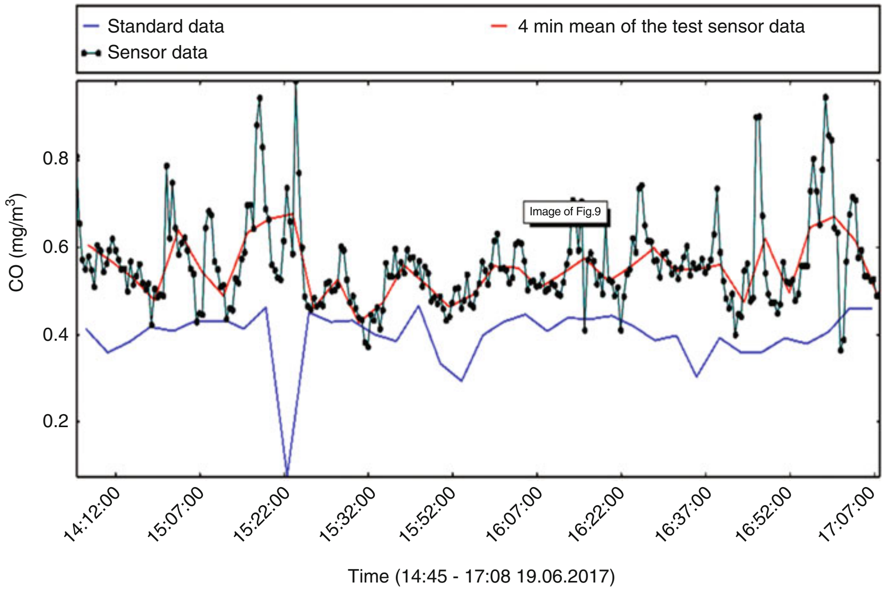

Fig. 2.4 Glimpse of data collected through sensor-CO

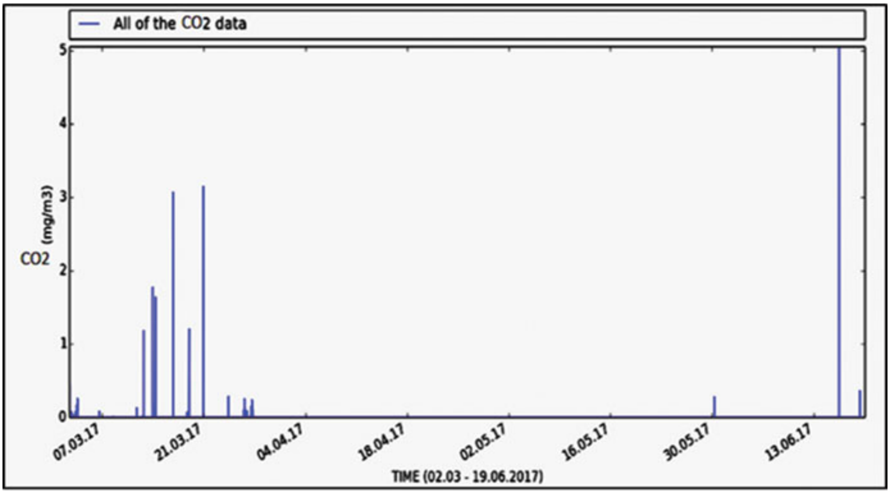

Fig. 2.5 Analysis of data collected through sensor-CO_2

In this way, the data can be seen live, and it gets uploaded on cloud server in parallel. On the cloud, data is continuously being monitored and analysed for crossing the threshold levels. If the concentration level crosses the threshold, then GSM module automatically triggers an SMS on the registered number of the user. In this way, the users are sent alert automatically and manually can be assessed through interface.

The experimental work shows that the sensor-based smart unit works well to detect the poor quality of air in the surroundings. The proposed model alerts the user in case their surroundings are contaminated, and hence they can avoid exposure to the contaminated air. Hence, the spread of COVID-19 is prevented effectively.

2.5 Conclusion and Future Scope

The study is dedicated to alert the human if the quality of air is poor in their ambiance. The agenda is to prevent the spread of COVID-19. As it is scientifically proven that the coronavirus spreads faster and easily if the air is polluted. Hence, this work is a short attempt in this direction and works with good accuracy. In future, it can be extended to a broad range of sensors and wider range of applications.

References

1. World Health Organization, *Ambient air pollution: a global assessment of exposure and burden of disease*. (World Health Organization, Geneva, 2016). https://apps.who.int/iris/handle/10665/250141 121 p. ISBN:9789241511353
2. E. Samoli et al., Associations of short-term exposure to traffic-related air pollution with cardiovascular and respiratory hospital admissions in London, UK. Occup. Environ. Med. **73**(5), 300–307 (2016). https://doi.org/10.1136/oemed-2015-103136
3. https://www.hindustantimes.com/india-news/north-india-under-smog-grip-rohtak-most-polluted-place-in-the-world/story-0BbY5FTLT49PCWeXUlX2nO.html. Accessed 10 Nov 2020
4. A. Frontera, C. Martin, K. Vlachos, G. Sgubin, Regional air pollution persistence links to COVID-19 infection zoning. J. Infect. **81**(2), 318–356., ISSN 0163-4453 (2020). https://doi.org/10.1016/j.jinf.2020.03.045
5. United States Environmental Protection Agency, Managing air quality – air pollutant types October 2018, https://www.epa.gov/air-quality-management-process/managing-air-qualityair-pollutant-types
6. G. Marques, C. Ferreira, R. Pitarma, Indoor air quality assessment using a CO2 monitoring system based on Internet of Things. J. Med. Syst. **43**(3), 67 (2019)
7. M. Tastan, H. Gokozan, Real-time monitoring of indoor air quality with internet of things-based E-nose. Appl. Sci. **9**(16), article 3435 (2019)
8. A. Rackes, T. Ben-David, M.S. Waring, Sensor networks for routine indoor air quality monitoring in buildings: Impacts of placement, accuracy, and number of sensors. Sci. Technol. Built Environ. **24**(2), 188–197 (2018)
9. M. Benammar, A. Abdaoui, S. Ahmad, F. Touati, A. Kadri, A modular IoT platform for real-time indoor air quality monitoring. Sensors **18**(2), 581 (2018)
10. S. Wang, S. Chew, M. Jusoh, A. Khairunissa, K. Leong, A. Azid, WSN based indoor air quality monitoring in classrooms. AIP Conference Proceedings **1808**, article 020063 (2017)
11. S. Kamble, S. Mini, T. Panigrahi, Monitoring Air Pollution: An IoT Application, in 2018 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), Chennai, India, March 2018
12. GSMA, Air Quality Monitoring Using IoT and Big Data: A Value Generation Guide for Mobile Operators, 2018, September 2018, https://www.gsma.com/iot/wp-content/uploads/2018/02/iot_clean_air_02_18.pdf
13. H. Ghayvat, S. Mukhopadhyay, X. Gui, N. Suryadevara, WSN- and IOT-based smart homes and their extension to smart buildings. Sensors **15**(5), 10350–10379 (2015)
14. K. Gupta, N. Rakesh, IoT based automobile air pollution monitoring system, in 2018 8th International Conference on Cloud Computing, Data Science & Engineering (Confluence), Noida, India, January 2018
15. L. Martelletti, P. Martelletti, Air pollution and the novel Covid-19 disease: A putative disease risk factor. SN Compr. Clin. Med. **2**, 383–387 (2020). https://doi.org/10.1007/s42399-020-00274-4
16. D. Contini, F. Costabile, Does air pollution influence COVID-19 outbreaks? Atmos. **11**, 377 (2020)
17. Isphording, Ingo E. and Pestel, Nico, Pandemic Meets Pollution: Poor Air Quality Increases Deaths by COVID-19 (2020). CESifo Working Paper No. 8495, Available at SSRN: https://ssrn.com/abstract=3680352
18. D. D'Antoni, V. Auyeung, H. Walton, G.W. Fuller, A. Grieve, J. Weinman, The effect of evidence and theory-based health advice accompanying smartphone air quality alerts on adherence to preventative recommendations during poor air quality days: A randomised controlled trial. Environ. Int. **124**, 216–235., ISSN 0160-4120 (2019). https://doi.org/10.1016/j.envint.2019.01.002

19. C. Stergiou, K. Psannis, B. Kim, B. Gupta, Secure integration of IoT and cloud computing. Futur. Gener. Comput. Syst. **78**, 964–975 (2018)
20. WHO Guidelines for Indoor Air Quality: Selected Pollutants. World Health Organization (2010)
21. https://www.mysensors.org/build/gas. Accessed on 5 Dec 2020

Chapter 3
Forecasting of Air Pollution via a Low-Cost IoT-Based Monitoring System

Tushar Saini, Duni Chand Rana, Suresh Attri, Pratik Chaturvedi, and Varun Dutt

3.1 Introduction

Air pollution is a serious issue world over [1]. The air pollution index of million plus cities in India shows that more than 50% of cities have moderate to poor air pollution [2]. In recent years, the problem has only been made severe. The major cause of ever-increasing air pollution can be attributed to industrialization, vehicular emissions, crop burning, and other activities like burning crackers [3]. At least 140 million individuals in India breathe air that is 10 times or more above the acceptable limits of the WHO, according to a report [2]. Long exposure to particulate matter may lead to diseases such as asthma, bronchitis, lung cancer, and heart attack [1, 4]. In fact, pollution has led to around two million premature deaths of Indians every year [1]. According to the WHO report [1], India is home to 13 of the world's most polluted cities. According to a report by Greenpeace Southeast Asia [1], India is estimated to bear a loss of 3.39 lakh rupees per second due to air pollution.

Due to the air pollution problem in India, it is imperative to develop new methods and techniques, which can help us monitor and timely alert public about deteriorating air pollution. The first step in curbing air pollution is to establish monitoring stations, which could sense air pollution in real time. Currently, there

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are various techniques which are used to monitor air pollution in real time [5]; however, most of these methods and very expensive, and the high cost limits their deployment [5]. With the introduction of low-cost IoT-based systems for air pollution monitoring, the cost of these systems has been reduced considerably [5]. However, the accuracy of these systems and their sensors may be lesser than those systems that are costly.

As there are differences in cost and accuracy, it is important to compare the air pollution values from the low-cost IoT-based systems to those from the commercially available costly systems. For this purpose, one could evaluate the performance of the low-cost IoT-based systems against costly systems for certain pollutants (e.g., particulate matter) over a period of time. To evaluate the performance, one would need to measure the pollutant values from both low-cost and costly systems for certain pollutants over time and then use standard error metrics (e.g., root mean squared error or correlation) to compare the values of the low-cost system against the values of the costly system. Prior literature has compared certain low-cost systems with the costly systems [5]. However, there have only been a handful of attempts at comparing low-cost and costly systems for air pollution monitoring.

To enhance the accuracy of low-cost air pollution monitoring systems while keeping their cost down, one may predict the values of the costly systems from the values of the low-cost systems. For this purpose, one may rely upon certain statistical models in literature [6, 7], where input into these methods is the pollutant values of the low-cost system and the output from these methods are the pollutant values of the costly system. Researchers have explored various statistical models for forecasting particulate matter. Likewise, researcher [8] developed three models, namely, multiple linear regression, autoregressive integrated moving average (ARIMA), and a combination of two, for forecasting particulate matter. The data used were collected at Delhi and Hong Kong. Another study [9] used an ARIMA model, principal component regression, and a combination of these two methods for forecasting the AQI at Delhi, India. Although some of these approaches have used statistical methods for predicting certain pollutants, however, there has been less research that has explored the use of these methods for predicting the pollutant values of the costly systems from the values of the low-cost systems.

In this paper we explored a novel approach, in which we forecasted the particulate concentration of an industrial-grade costly air pollution monitoring system using a low-cost IoT-based air pollution monitoring system. Both the systems were deployed at a cement factory, and the data were collected over a period of 1 day at a frequency of one reading per hour from both systems simultaneously. First, we investigated the VAR, VARMA, and SARIMAX models individually to forecast the values of the costly system from the values of the low-cost system. Then, we explored a weighted average ensemble model which combined the values of the individual statistical models to forecast the values of the costly system from the values of the low-cost system. To the best of authors' knowledge, this study would be the first of its kind that tries to forecast the values of a costly air pollution monitoring system from the values of a low-cost air pollution monitoring system.

In what follows, we first describe related work undertaken in this domain. Next, we described the methodology and the setup of the experimentation, where we compared the pollutant values from costly and low-cost air pollution monitoring systems. Then, we discuss different statistical models and how these models were optimized for forecasting the values of a costly air pollution system from those of a low-cost air pollution system. Finally, we detail the results and discuss the outcomes from this study.

3.2 Related Work

Reference [6] used a hybrid VAR model for the prediction of particulate matter of size 2.5 μm or smaller ($PM_{2.5}$). Data were collected at Pingtung and Chaozhou cities of China. They calibrated the hybrid VAR model using a particle swarm optimization method. The developed model was not benchmarked against any other models like VARMA, SARIMAX, or an ensemble. Reference [9] developed models like MLP, SVM, VARMA, and ARIMA for the forecasting of particulate matter of size 10 μm or smaller (PM_{10}) in the city Oviedo (Northern Spain). The data was collected between 1 January 2010 and 31 July 2017 by the air pollution department of the Government of the Principality of Asturias. Again, no ensemble approach was investigated, and benchmarking was only limited. Reference [10] investigated ARIMA, VARMA, MLP, SVM, and multivariate adaptive regression splines (MARS) for the prediction of PM_{10}. The data were collected at the town of Gijón, located on the north coast of Spain, between January 2010 and June 2018. Again, an ensemble of the developed models was not investigated. Reference [11] employed a statistical SARIMAX model and a LSTM model for the forecasting of $PM_{2.5}$ levels. Data were provided by the pollution control department, Thailand, and these data were collected between 07 June 2016 and 30 June 2018. The grid-search method was used for optimizing the hyperparameters of the SARIMAX and LSTM models. In this research, only these two models were explored, and an ensemble of the developed models was not investigated. Finally, the methodologies followed in the above cited studies were the forecasting of measured particular matter by different machine learning models. However, none of the above cited studies have undertaken the task of predicting the particulate matter measured by a costly air pollution monitoring system by using the values of the particulate matter measured by a low-cost system. This latter exercise is what we attend to in this book chapter.

3.3 Methodology

3.3.1 Data

Data in the experiment were collected via a low-cost IoT-based air pollution monitoring system and a costly industrial-grade air pollution monitoring system. The low-cost system was designed and developed by the authors of this book chapter. Both the low-cost and costly systems were installed at a cement factory in the Bilaspur district, Himachal Pradesh, India. The low-cost system used a PM laser dust sensor manufactured by DF Robot [12]. The PM sensor used the laser scattering theory to sense particulate concentration [12]. The industrial-grade air pollution monitoring system was a product name Spirant BAM manufactured by Ecotech Pvt. Ltd., India, and it was used to measure particulate matter in the air [13]. Data were collected over a period of 1 day at a frequency of one reading per hour from both systems. Both systems monitored two pollutants, namely, $PM_{2.5}$ and PM_{10}, in real time. Figure 3.1 shows the time plot of the data collected at the site from both systems. The y-axis in Fig. 3.1 represents the value of the pollutant concentration in $\mu g/m^3$ over time (in hours; x-axis). The suffix "-I" represents the data collected by the costly industry-grade air pollution monitoring system; whereas the suffix "-LC" represents the data collected by the low-cost IoT-based air pollution monitoring system. These data were used for the purpose of comparison and prediction in this study.

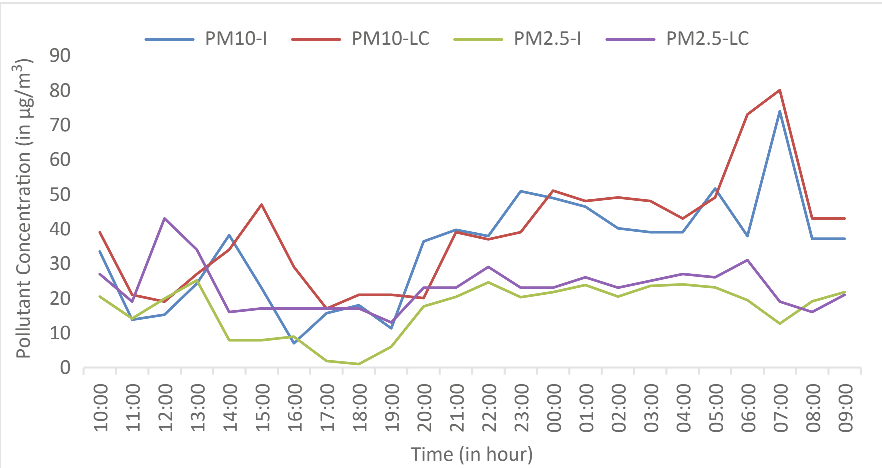

Fig. 3.1 Data collected at the cement factory by the low-cost and industrial-grade air pollution monitoring systems

3.3.2 Models

Vector Autoregression (VAR) Vector autoregression is a stochastic type statistical model [14]. It is best suited for problems in which multiple parameters change over time [14]. VAR is built upon the AR model, and, like AR model, each variable has an equation modeling its evolution over time. An ordinary AR(p) model can be described by the following equation:

$$Y_t = \gamma + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \cdots + \alpha_p Y_{t-p} + \in_t \tag{3.1}$$

where γ is the intercept, and $\alpha_1, \alpha_2, \ldots, \alpha_p$ are the lags coefficients of Y till order p. Here, order "p" represents lags up to p of Y used as predictors in the equation. The $\in_t$ is the error, which represents the white noise.

In VAR, each parameter is modeled as a linear combination of its own past values and the past values of the other parameters. For a two time series system, Y_1 and Y_2, the VAR (1) equations is:

$$Y_{1,t} = \gamma_1 + \alpha_{11,1} Y_{1,t-1} + \alpha_{12,1} Y_{2,t-1} + \in_{1t} \tag{3.2}$$

$$Y_{2,t} = \gamma_1 + \alpha_{21,1} Y_{1,t-1} + \alpha_{22,1} Y_{2,t-1} + \in_{2t} \tag{3.3}$$

where, $Y_{1,\,t\text{-}1}$ is the first lag value of time series Y_1 and $Y_{2,\,t\text{-}1}$ is the lag value of time series Y_2. Equations (2) and (3) refer to VAR model of order one as it contains up to one lag value of each parameters Y_1 and Y_2. In our experiment, we had two time series, namely, PM_{10}-I and $PM_{2.5}$-I. The lag value was a free parameter, which was optimized.

Vector Autoregressive Moving Average (VARMA) VARMA is again a stochastic type statistical model, which is built upon the ARMA model. The model is proven to improve the forecasting accuracy by modeling the variables, which have interrelated dependency in multivariate time series data [9]. Prior research suggests that for certain set of problems, the VARMA models have higher degree of accuracy than the VAR models. Similar to the ARMA model, a VARMA model has two parameters which needs optimization: "p" the autoregressive order and "q" the moving average order. In our experiments, we varied both these parameters using a grid-search procedure.

Seasonal Autoregressive Integrated Moving Average with Exogenous variables (SARIMAX): The SARIMAX is a statistical forecasting model for multivariate time series data [15]. Beyond the input and output time series, this model also considers exogenous variables and seasonality in its prediction. Seasonality is a characteristic of a time series data in which these data experience regular changes that recur every specific interval [15]. SARIMAX model has the ability to capture the covariance between the exogenous and target variable. The standard SARIMAX model has eight hyperparameters, namely, p, d, q, P, D, Q, m, and trend t. Here p, d, and q are the trend autoregression order, trend difference order, and trend moving average order, respectively. While P, D, and Q are the seasonal autoregressive order, seasonal differencing order, and seasonal moving average order; m is the seasonality (a number of time steps for a single seasonal period), and t is the trend [15]. These hyperparameters were optimized in the SARIMAX model using a grid-search procedure.

Ensemble Model Ensemble modeling is a technique in which we employ an ensemble of various models for forecasting [16]. In this research, we ensembled all the abovementioned models, namely, VAR, VARMA, and SARIMAX. We used a weighted average method to assigns weight to each model, where the weights defined the importance of each model in the calculation of the predicted value [17]. The higher the weight of a model, the more it contributed toward the calculation of the prediction. The weights that provided the least error for the ensemble model while training data were chosen as the final weights in the model for testing. The following equation states how the final prediction was made in the ensemble model:

$$Y_t = W_{VAR}M_{VAR} + W_{VARMA}M_{VARMA} + W_{SARIMAX}M_{SARIMAX} \tag{3.4}$$

where, W_{MLP}, W_{LSTM}, W_{CNN}, and $W_{SARIMAX}$ were the four weights in the range [0, 1] representing the weight of each model. Furthermore, M_{MLP}, M_{LSTM}, M_{CNN}, and $M_{SARIMAX}$ represented the trained individual models' predictions.

3.3.3 Model Calibration

The objective of the experiment was to forecast the particulate concentration of the industrial-grade air pollution monitoring system using the particulate concentration of low-cost air pollution monitoring system. Table 3.1 shows the parameters of each model that were optimized using grid-search method. The root mean squared error (RMSE) [17] was used to evaluate the performance of different models. Hence, the parameter's value that resulted in the least RMSE was considered the best configuration for the respective model. For the VAR model, the p-order was varied in range of 0–3. For the VARMA model, the p-order was again varied from 0 to 3, and the d-order was varied from 0 to 3. For SARIMAX model, the parameters were varied in range: p (0, 1, 2); d (0, 1, 2); q (0, 1, 2); P (0, 1, 2); D (0, 1, 2); Q (0, 1, 2); m (0, 1, 2); and t (null, nonzero (n), a constant (c), trend with time (t), and both c and t (ct)). Lastly, for the ensemble model, each of the W_{VAR}, W_{VARMA}, and $W_{SARIMAX}$ parameters was varied in steps of 0.01 in the range [0, 1].

Table 3.1 Parameters and their ranges optimized in different models

Model	Parameter	Range
VAR	p-order	0, 1, 2
VARMA	p-order	0, 1, 2
	d-order	0, 1, 2
SARIMAX	p-order	0, 1, 2
	d-order	0, 1, 2
	q-order	0, 1, 2
	P-order	0, 1, 2
	D-order	0, 1, 2
	Q-order	0, 1, 2
	m	0
	t	Null, n, c, t, ct
Ensemble	W_{VAR}	[0–1] in steps of 0.01
	W_{VARMA}	[0–1] in steps of 0.01
	$W_{SARIMAX}$	[0–1] in steps of 0.01

Table 3.2 Correlation of observed parameters

Correlation between	Correlation value
PM_{10}-LC & PM_{10}-I	0.77
$PM_{2.5}$-LC & $PM_{2.5}$-I	0.66

Table 3.3 RMSE value between industrial-grade and low-cost air pollution monitoring systems

Parameter	RMSE value (in $\mu g/m^3$)
PM_{10}-LC and PM_{10}-I	9.47
$PM_{2.5}$-LC and $PM_{2.5}$-I	8.42

3.4 Result

Table 3.2 shows the Pearson correlation coefficient of the pollutant concentration observed by the costly air pollution monitoring system with the pollutant concentration observed by the low-cost air pollution monitoring system. As can be observed from Table 3.2, the correlation coefficient value observed between PM_{10}-LC and PM_{10}-I was 0.77 and between $PM_{2.5}$-LC and $PM_{2.5}$-I was 0.66. These correlation coefficient values are very high and show a strong correlation between the particulate values recorded by the two systems.

Table 3.3 shows the RMSE value (in $\mu g/m^3$) between the values observed by the costly air pollution monitoring system and the value observed by the low-cost air pollution monitoring system. As can be observed from Table 3.3, the RMSE value between PM_{10}-LC and PM_{10}-I was 9.47 $\mu g/m^3$ and between $PM_{2.5}$-LC and $PM_{2.5}$-I was 8.42 $\mu g/m^3$. These RMSE values were relatively small and show a correspondence between the two systems.

Table 3.4 shows the optimized parameters of the models which resulted in the best RMSE. As can be observed from the table, the p-order of VAR forecasting model for both PM_{10} and $PM_{2.5}$ was found out to be 2. For VARMA model, the p-order was 2, and d-order was 1 for both PM_{10} and $PM_{2.5}$ values. For SARIMAX

Table 3.4 Optimized parameters of the developed models

Model	Optimized parameter value
VAR	PM_{10} (p-order: 2)
	$PM_{2.5}$ (p-order: 2)
VARMA	PM_{10} (p-order: 2, d-order: 1)
	$PM_{2.5}$ (p-order: 2, d-order: 1)
SARIMAX	PM_{10} (p, 1; d, 0; q, 2; P, 0; D, 0; Q, 0; t, "t"; m, 0)
	$PM_{2.5}$ (p, 0; d, 1; q, 2; P, 0; D, 0; Q, 0; t, "t"; m, 0)
Ensemble	PM_{10} (W_{VAR}, 0.83; W_{VARMA}, 0; and $W_{SARIMAX}$, 0.17)
	$PM_{2.5}$ (W_1, 0.96; W_2, 0; W_3, 0.04)

Table 3.5 RMSE values for developed models on training dataset

Model	RMSE (PM_{10}-I) (in $\mu g/m^3$)	RMSE ($PM_{2.5}$-I) (in $\mu g/m^3$)
VAR	14.25	6.87
VARMA	16.62	8.07
SARIMAX	20.49	8.42
Ensemble	13.92	6.80

Table 3.6 RMSE values for developed models on test dataset

Model	RMSE (PM_{10}-I) (in $\mu g/m^3$)	RMSE ($PM_{2.5}$-I) (in $\mu g/m^3$)
VAR	17.21	7.07
VARMA	19.32	9.37
SARIMAX	22.17	9.49
Ensemble	16.46	6.21

model, the optimized value of the parameters for the PM_{10} were p, 1; d, 0; q, 2; P, 0; D, 0; Q, 0; t, "t"; and m, 0; and, for $PM_{2.5}$, the parameters value were p, 0; d, 1; q, 2; P, 0; D, 0; Q, 0; t, "t"; and m, 0. For the weighted average ensemble model, the weights obtained from the grid-search procedure were W_{VAR}, 0.83; W_{VARMA}, 0; and $W_{SARIMAX}$, 0.17 for PM_{10} values; and, for $PM_{2.5}$ values, the weights were W_{VAR}, 0.96; W_{VARMA}, 0; and $W_{SARIMAX}$, 0.04.

Table 3.5 shows the RMSEs for the training dataset of the developed models. As can be observed from the table, the weighted ensemble model had the least RMSE for both $PM_{2.5}$ and PM_{10} among all models. VAR performed the second best having an RMSE of 14.25 for PM_{10}-I and 6.87 for $PM_{2.5}$-I, respectively. Among all models, the SARIMAX performed the worst having an RMSE of 20.49 for PM_{10}-I and 8.42 for $PM_{2.5}$-I, respectively.

Table 3.6 shows the RMSEs for the test dataset of the developed models. As can be observed from the table, the weighted ensemble model again performed the best having the least RMSE for both $PM_{2.5}$ and PM_{10} among all the models. VAR performed the second best having RMSE of 17.21 for PM_{10}-I and 7.07 for $PM_{2.5}$-I, respectively. Among all models, the SARIMAX performed the worst having an RMSE of 22.17 for PM_{10}-I and 9.49 for $PM_{2.5}$-I, respectively.

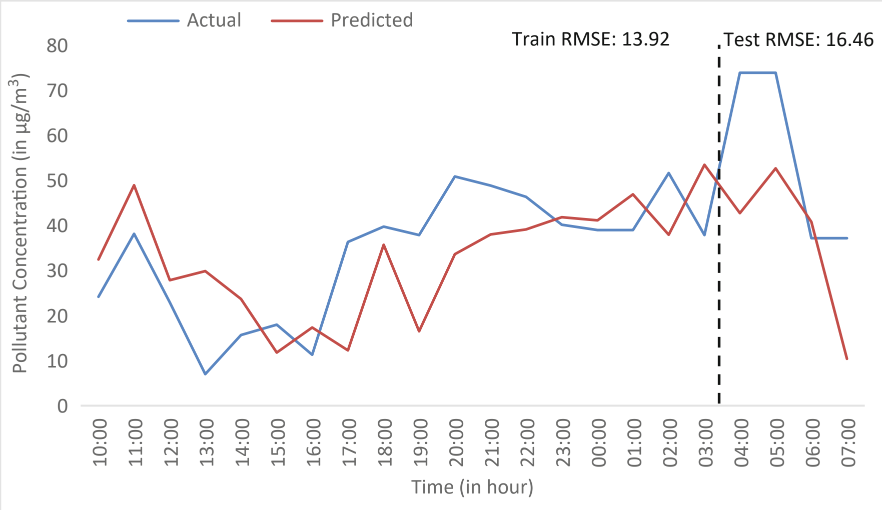

Fig. 3.2 Forecast plot of ensemble model for PM_{10}-I

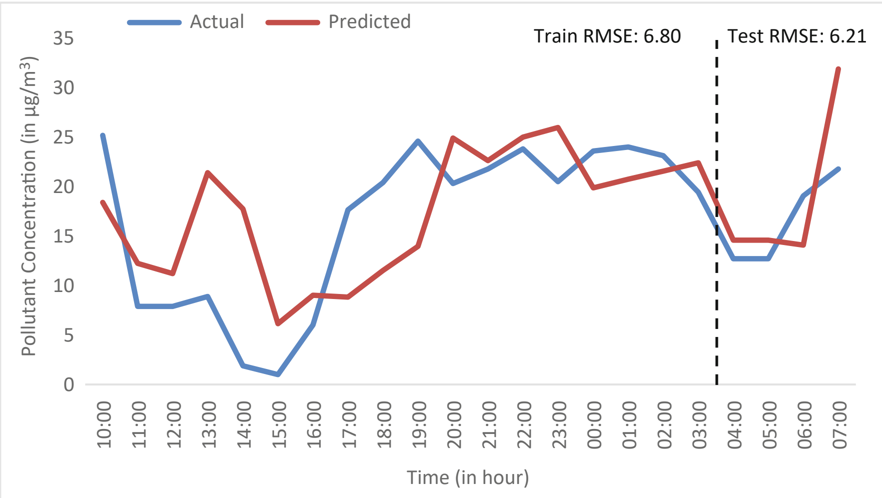

Fig. 3.3 Forecast plot of ensemble model for $PM_{2.5}$-I

Figures 3.2 and 3.3 shows the plot of actual values and the predicted values from the ensemble model for PM_{10}-I and $PM_{2.5}$-I, respectively. In both the figures, the dotted line separates train and test data. As can be observed from Fig. 3.1, the blue line shows the actual PM_{10}-I values, and the red line shows the ensemble model's forecasted PM_{10} values. Similarly, in Fig. 3.2, the blue line represents the actual PM_{10}-I values, and the red line represents the ensemble model's forecasted $PM_{2.5}$ values.

3.5 Discussion and Future Work

Air pollution is a serious issue world over [1]. The air pollution index of million plus cities in India shows that more than 50% of cities have moderate to poor air pollution [2, 3]. In fact, air pollution-related adverse health effects are well-known, and long exposure to particulate matter of 2.5 μm or less can cause lung cancer, asthma, and heart diseases. Its adverse effect over economy is also well-stated in the literature. Overall, it is of utmost important to formulate methods which can help policymakers to make informed decision.

The primary goal of this research was to develop statistical and ensemble forecasting models which could forecast the particulate matter concentration with high degree of accuracy. Specifically, we tried to forecast the $PM_{2.5}$ and PM_{10} concentration of a costly industrial-grade system using the values of $PM_{2.5}$ and PM_{10} concentration sensed by a low-cost IoT-based air pollution monitoring system. The models trained were the vector autoregression (VAR), the Vector Autoregressive Moving Average (VARMA), and a weighted ensemble model. Our research revealed that the ensemble model performed the best having the least RMSE.

First, the weighted ensemble model, which was a linear combination individual models, performed better than all the other models. A likely reason behind this finding could be that the ensemble model took the best out of the forecasts of the individual models by weighing different individual predictions. Again, these findings agree with the prior research [7, 8] where, ensemble models have performed better than individual models. Among the other models which were investigated in this research, the VAR model performed the second best, while the SARIMAX model performed the third best. The VARMA model performed the worst among all the models having the highest RMSE.

The research proposed has a number of real-world implications. For example, the developed models could be used by policymakers or even individuals to make informed decisions based on the forecasting of air pollution by low-cost systems. Based on the forecast made, early warnings may be generated over phone and other media. These warnings may allow us to timely reduce the pollution by eliminating the sources of air pollution. Overall, the proposed models could be deployed with a low-cost IoT-based system instead of a costly system, making the forecasts cost-effective.

Future research may build upon this work and develop and compare other models that could forecast pollutant concentration in multistep manner ahead of time. Thus, models could forecast longer-term pollution values. Another aspect of future research could be a comparison of the models in this paper with other machine learning models like decision trees, K-nearest neighbor, and support vector machines.

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References

1. WHO, Ambient (outdoor) air pollution. https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health
2. Bernard, S., et al.: Dirty air: how India became the most polluted country on earth. (2019)
3. Want govt to build 1600 km green wall along Aravalli, Indian Express (2019)
4. OECD, The economic consequences of outdoor air pollution.: https://www.oecd.org/environment/indicators-modelling-outlooks/Policy-Highlights-Economic-consequences-of-outdoor-air-pollution-web.pdf
5. R. Sharma et al., An Online Low-Cost System for Air Quality Monitoring, Prediction, and Warning, in *International Conference on Distributed Computing and Internet Technology*, (Springer, Cham, 2020)
6. Hashimzade, N., et al.:, "Vector Autoregressive Models.", *Handbook of Research Methods and Applications in Empirical Macroeconomics*, 2013
7. P. Goyal, A.T. Chan, N. Jaiswal, Statistical models for the prediction of respirable suspended particulate matter in urban cities. Atmos. Environ. **40**(11), 2066–2077 (2006)
8. S. Abdullah et al., Evaluation for Long Term PM 10 Concentration Forecasting using Multi Linear Regression (MLR) and Principal Component Regression (PCR) Models. *EnvironmentAsia* **9**(2), 101–110 (2016)
9. P.J. García Nieto et al., PM10 concentration forecasting in the metropolitan area of Oviedo (Northern Spain) using models based on SVM, MLP, VARMA and ARIMA: A case study. Sci. Total Environ. **621**, 753–761 (2018)
10. S.F. Lasheras et al., Evolution and forecasting of PM10 concentration at the port of Gijon (Spain). Sci. Rep. **10**, 11716 (2020). https://doi.org/10.1038/s41598-020-68636-5
11. K. Thaweephol, N. Wiwatwattana, Long Short-Term Memory Deep Neural Network Model for PM2. 5 Forecasting in the Bangkok Urban Area. 17th International Conference on ICT and Knowledge Engineering (ICT&KE). IEEE, (2019)
12. DF Robot, Introduction to PM sensor. https://wiki.dfrobot.com/PM2.5_laser_dust_sensor_SKU_SEN0177
13. Spirant BAM. Specification of Spirant BAM. https://www.ecotech.com/product/particulates/ambient/spirant-bam/
14. F. Canova, The economics of VAR models, in *Macroeconometrics*, (Springer, Dordrecht, 1995), pp. 57–106
15. S. Moisan et al., A dynamic multiple equation approach for forecasting PM2. 5 pollution in Santiago, Chile. Int. J. Forecast. **34**(4), 566–581 (2018)
16. V. Kotu et al., *Data Science*, 2nd edn. (2019), pp. 19–37
17. R.J. Busemeyer et al., *Cognitive Modeling* (SAGE Publications, Inc, Los Angeles, 2009)

Chapter 4
Internet of Things Based Best Fruit Segregation and Taxonomy System for Smart Agriculture

Ganesh Khekare, Kapil Wankhade, Urvashi Dhanre, and Bhushan Vidhale

4.1 Introduction

The system is proposed in this chapter which is a programmed bundling instrument with thing identifying of unpracticed fruits. Nowadays PC screening is making its zenith need in different parts wherein robotization is an imperative segment. It is critical to do the entire system routinely, as a rebate in manual efforts is required. The bundling business is developing quickly, veiling a foreseen several a huge number of American creation ventures by means of various unrivaled man-made reasoning methods. A remarkable arrangement of profit, span, and endeavor had been contributed by means of numerous businesses with the expectation to go over the item effectively right using a simple photograph. Various sorts of predominant man-made brainpower (AI) systems additionally are used by different bundling enterprises. Altering was one of the most troublesome of the business, the essential driver of the bundling endeavor is currently to refine the item by means of picture

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printing procedures and to offer item high-caliber to the shopper. The significant rationale of item arranging is to make an appropriately reasonable framework in order to find the deformities and channel out extraordinary contraptions through photo checking that is one of the basic business' requesting circumstances. The device needs to simply acknowledge things in sync with the habitations of various shapes and colorings. This diminishes the man-put forth attempts made by methods for actual span and gives to the publicizing span. The crucial to update the gadget which could kind various sorts of lemon in order to fluctuate from shapes, hues, and deformities rather than each extraordinary. Item separating is essential in a market wherein stock are delivered on a major scale. This framework is disentangled by utilizing robotization. A contraption kiran [10] utilizing picture handling thoughts is used. Things are sorted essentially dependent on different variables comprising of surface, shade, and weight. Shading based absolutely changing is utilized in heaps of enterprises which incorporate colored pencil manufacturing plants, farming apparatus comprehensive of various types of fruits and grains. The system kit helps clients for doing obligations pleasantly with images caught from the camera conference, the shade of items being perceived the utilization of a shading recognition set of rules. This shade got watched for use as a thing get out parameter by means of Raspberry Pi. This assignment is refreshing the arrangement of rules for the recognition of shading location. The planned framework might be done in differing parts for different capacities comprising of Defense, business purposes, games, robotization, authentication, following, etc. Indeed, such structures likewise shows a significant situation in subject of radar and route comprising of distinguishing, following of a moving shading object, and so on. All these connectivity among different units is possible just because of use of Internet of Things in best manner.

4.2 Literature Review

IoT plays an important in smart agriculture sector. The use of IoT devices increasing day by day. It provides automation to farmers as well as industry to make process of work smooth. Automatic irrigation becomes easier through IoT devices. In green house various devices are connected through IoT to maintain water, humidity, temperature, and soil moisture level. From home, farmers can monitor the status of their crops. Weather prediction is also becomes easier with the help of IoT. Smart drone can be used to monitor the farm. Data generated by IoT devices can be gathered through cloud computing and processed through data analytics concept. IoT also helps in segregation of fruits or crops to identify the quality as discussed in this book chapter.

Gr Specialists and researchers are quick to find the plantations by methods for utilize remarkable observing systems. Vidal et al. [19], analyzed the normal relationship of shading range for standard fruits the utilization of a PC stage while on some other hand Dorj et al. [4], assessed crop impediments on lemon the utilization of natural product securing. Shading based absolutely separating is utilized by numerous businesses, for example, agrarian gear in an assembling office which incorporates rice, beans, nuts, and numerous others.

The inference of shading photograph hindrances dependent on the locale of number juggling shading. The simple thing secured is to find the edges of fruit, the shading trigon, elements of the shading subtleties. In this paper are a method for finding the verge as far as trigon comparability the use of RGB shading and science line location the utilization of triangulation. The calculation recreation on this paper shows that the picture limit utilized in the customary manner is substantially less perfect and has solid forestalling occasions. The creator, thusly, presumed that the reception of shade picture deterrents dependent on the locale of math conceal is helpful.

Walt et al. [20] offered exploration at neighborhood conceal fame calculation for RGB tints. The thought previously secured on this paper is set the improved Kuwahara get out, the decision of a pivoting empty, and the thinning calculation. The theme identified with this page has been modern is conceal recognition through an improved calm onlooker. The results appeared in that article has indicated the limit for item is more prominent as compared to Laplace administrator, the Marhildreth administrator, and 0-go administrator. The essayist, subsequently, presumed that the shading disengagement set of rules inside the RGB shading is additional green.

In Sustek et al. [15] inspected the situating of green and yellow organic products in outside circumstances of automated bundles with the guide of offering in the paper roughly the shade joining, sifting, and sharpness way required for rural robot bundles. Related points for folks by method for K strategy calculation coordination, round thing assurance, and natural product securing. The check result affirmed the correct separation, legitimate unwinding period, and rest pleasant. The creators referenced that the technique investigate on foods grown from the ground revelation significantly adds to picture handling.

In Khekare and Janardhan [11] have analyzed in current day inquire about on organic product notoriety the utilization of the hues and surfaces of capacities. This procedure portrayed utilizing wavelet change and yield signals. A related subject is noticed that is the organic product acknowledgment and expulsion trademark. The investigate result passed on all the insights alongside 15 particular stages, pre enhancing the area of leisure activity extraction set of rules. The outcome demonstrates that a powerful method might be distinguished and look at the natural product depending on the hue and surface. The creators finish that organic product acknowledgment utilizing surface and shade is as viable as it could technique handling and secure perfection based at the shade and surface of the detail.

Szabó et al. [17] tried to calculate the profit factor of crops at the plantation by means of organic product selection. The arrangement of rules gave incorporate numerous means to change RGB into HSV, to go into an edge, to procure an orange shade, to dispose of the commotion, to ship a separation by segment of home incorporated to get a superior outcome. This article additionally describes at the evaluation among the included natural product depend calculation and the organic product creation charge by methods for bloom checking. The results of the analysis affirmed that the arrangement of rules to unearth and lemon tallying the use of mixture exchange can be finished in heaps of approaches. The creators have accordingly accentuated that this arrangement of rules for identifying and figuring fruit by means of retrieving approach is right and amazing.

Bhargava and Bansal [3] have propelled their spic and span examine on foods grown from the ground incredible tests the utilization of a following where the technique has been developed that conveys pre-preparing, order, natural product, and vegetable extraction essentially dependent on different piece, and characterization. The paper likewise remarked on an examination of different contemplations provided with the guide of investigators for decent affirmation. The outcome changed into keen on that the musings proposed might be utilized as a different tinge space to remove the shading trademark and the gadget created by methods for them is liberated from inclination.

Sahana and Anita [13] tried the checked distinguishing proof of Regional Fruit the utilization of AI in their exploration by means of using the yield acquired from naturally and Fourier highlights utilizing the DTNB grouping. Notwithstanding this vibe of Apple suppers utilizing hyperspectral proliferation, this technique has been tried with the guide of Huang and Lu [5]. Methods for folks at the hyperspectral method for apportioning coarse apple and also beginning to scatter is given. Based at the shape and shading plan tried the observed Vegetable picture device based at a similar component. This paper presents the scale-invariant trademark exchange (SIFT) just as the alright – Neighborhood calculation and SVM set of rules. So also, work yet each in turn has been finished by method, Jana et al. [6]. The article manages the acknowledgment of mechanized organic products from home grown symbolism the utilization of shading and surface to present surface capacities. The related ensured subjects on device bolster system, the KNN classification, K-way bunching calculation. The furthermore referred to the scientific detail is transmitted as free shading connections. The equivalent framework is used to find a Macintosh class strategy that utilizations picture tree investigation dependent on picture assessment exactness of 84% and future measurements the use of smooth PC method with better precision. Over end creators concluded utilizing procedures set of rules that deliver a superior outcome subsequently the ones strategies might be seen to be material and successful.

The method of picture following or PC handling has a determination of uses which can be utilized especially for sifted robots. Numerous such projects were suggested by utilizing numerous specialists. For example, Szabo and Lie [16] spoken to in investigate at the utilization of computerized node tinge. The system is explained in this article which is an order, oversee, faraway, robot arm, sequential face get together, and utilization of the lynx development AL5A robot arm. So also, some other utility has been accessible organic products in the outer circumstances gave the guide of Ozturk et al. [12] of their current watch.

Sharma et al. [14] numerous pc reenactments and photos were utilized to group final product and veggies and their illnesses. A large portion of these techniques have 3 most significant advances: extraction, extraction, and training and portrayal.

In Zawbaa et al. [21], Apple's sort frameworks, there are a couple of basic variables, for example, what type of apple is being isolated, what are the attributes of the division, and the manner in which long Apple is isolated. Having this type of realities shows that the program might be viable. Judgment transformed into especially identified with parameters, including the partition of the foundation photograph and the celestial quality.

Kalantri and Bakr [7] used natural product size machine, which fuses mechanics, oversee devices, individual zone, sensor cells and impact control surfaces, is incorporated with genuine time systems and non-ongoing LANs. The gadget would technique be able to up to 15 natural products reliable with second and set up them steady with their weight, length and shading. In Zhang et al. [22], the observer offered evidence that gadget innovative and perceptive is an untrustworthy sifting component. Demo model of the proposed model. The creation is lightweight and easily open. The arrangement of rules works viably and can be changed occasionally depending on exceptional gentle circumstances. Likewise, a few assortments of perfection can be modified with minor changes in accordance with the calculation.

Behera et al. [2] caught pictures were recently completed to uncover the wavelet. Next, the spatial area and wavelet properties are summed up. The neural systems in the front of the feed course are utilized to teach the places of chose surfaces and waveform markers each in turn. Affectability, exactness, precision, recommend mistakes, and ROC bends are utilized as generally execution parameters. The consequences of the spatial capacity and wavelet investigate impacts are thought about. Paradoxically, the wavelet highlights got better exactness of the outcomes in contrast with the spatial highlights. In this way, it's far feasible to examine the capacities of the wave inside the organic product picking or riding method the utilization of a mechanical view.

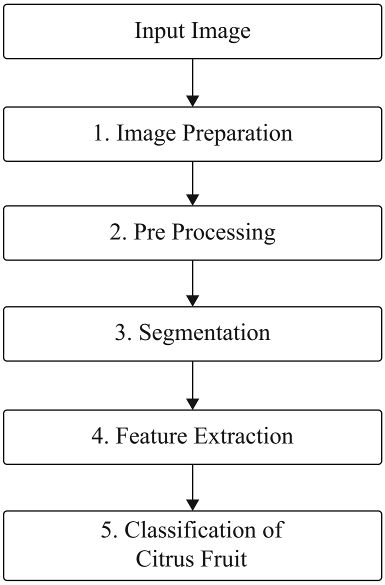
Picture notoriety utilizing shade and surface has wide projects to stick out the attribute of final product and greens even different articles were distributed on photograph extension inside the foods grown from the ground division that offers different considerations in regards to programmed picture notoriety methods which analyzes objective to make strategies that helpful to order the thing by explicit qualities essentially dependent on shade and immersion. The impacts screen that the advanced calculation diminish the time accurately and isolate the utilized and unused citrus utilizing the caught photograph.

4.3 Methodology

The thought process of this methodology has been to streamline the regard oranges creation framework dependent on its shading sooner than establishment. In this works of art, an assigned fruit has been gathered sooner than getting ready, so this methodology will help recognize fruit relying upon its hue and surface. The way step is appeared in Fig. 4.1. It shows the orange partition process the utilization of the pre-preparing and detachment picture on the grounds that the primary technique, while the subsequent advance shows the element extraction to isolate the thing saw through the last advance of assessing among gifted and trial pictures.

Fig. 4.1 Acquired image of premature (green) and mature (yellow) citrus fruits

Fig. 4.2 Process of image detection



After the detachment of the oranges, the drift of the calculation to profit the entirety of the methodology utilized inside as shown in Figs. 4.1, 4.2 and 4.3.

In the initial phase, the advanced camera will peruse the information photo in RGB format which also upgrades the improvement system comprising of developing the elements of the age. From that point forward progression may involve photo veil utilizing framework since it provides at least pictures in parallel shape. Eventually, method of minimization result to fruition by wavelet varieties which isolate virtual section into numerous sections. Type is really straightforwardness of a photograph that makes understanding and is anything but difficult to examine.

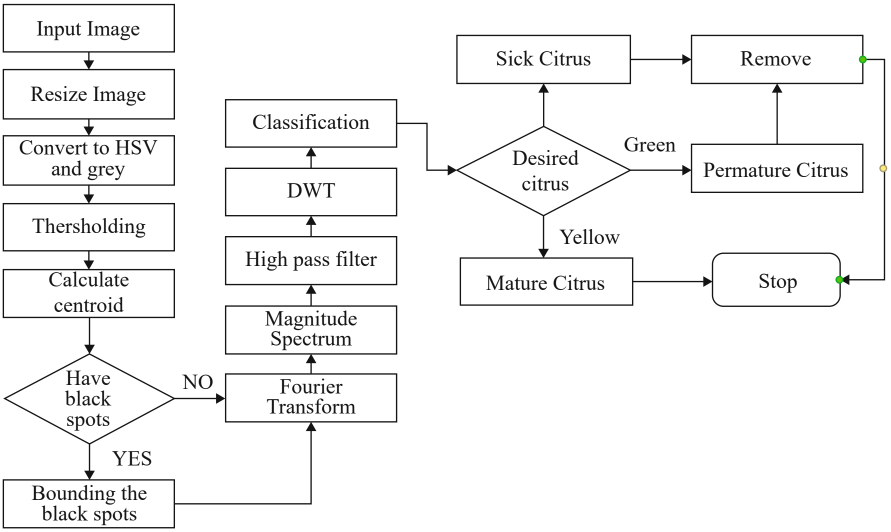


Fig. 4.3 Workflow model of image processing

4.4 Software/Hardware Tool Used

4.4.1 Software Part

The idea at the rear of this technique is the advancement of picture which amplifies highlights with the guide of improving the photograph, conceal trade, and unnecessary interruption. The fruit photo inside the RGB type as information picture develop yellowish fruit or light green unwell and develop fresh fruit. Next way that bolsters this photo preparing incorporates accompanying advances: changing over a RGB picture into HSV, sound disposal, fresh photo, amazing transformation, and afterward considering a scenery for fruit photograph handling that is going into the establishment method utilizing an obstruction sensor.

Convert RGB into HSV picture: Colors convey specific measurable insights about devices. A couple of tinge choices are available that utilizes the essential shades that are depicted to the Cartesian scope of 0–255 i.e. R (255, 0, 0) G (0, 255, 0) B (0, 0, 255), that utilization of cyan, red, yellow and dark. The highly contrasting incorporates (0, 0, 0) to (255, 255, 255) separately.

HSV utilizes best one channel to diagram the shading, making it extra precise to choose the shade as demonstrated in Fig. 4.4. The HSV hue space conveys the resulting three parts.

Partition of hue sections: The methodology uses a photo of idea of HSV that keeps on being recognized by utilizing its excellent vitality, shadows, and vitality. To get this procedure the most extreme basic component is to consider the HSV ideal shade by fluttering. To gaining green fruits, HSV cost by yellowish and unpracticed

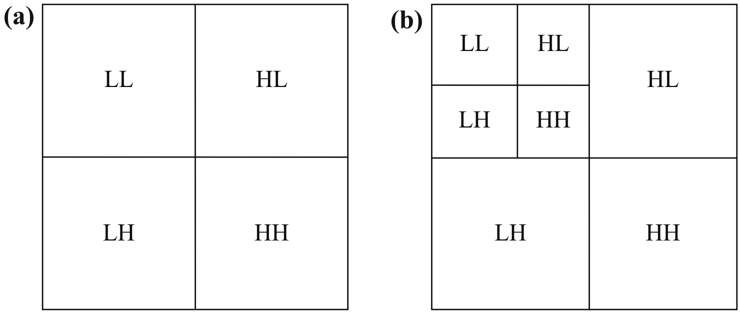


Fig. 4.4 (**a**) One level decomposition (**b**) Two level decomposition

in higher which speaks to quantities of extra dots and fewer which speaks to quantities of more brilliant dots. They are commonly executed in parallel pix to segregate. The sources of info strategy by photos, piece with widening of 6 × 6 frameworks.

Threshold: Tho et al. [18] characterized limitation as a strategy which impacts choice to increase a precise item. Methods for deciding piece of a thing with the guide of checking it to be collected. The picture histogram bet incorporates dark pixel devices at the rear of the brilliant pixel that they're each composed into conspicuous methodologies after which its dim degree graph is portrayed by f (u, v). In some other case it will be a separation picture spoke to as point g (x, y). The idea of used technique is spoken to in underneath condition 1 and 2.

If f (u, v) > the number of divisions.

Then f (u, v) = 0

$$\text{Else f (u, v)} = 255 \tag{4.1}$$

$$g\,(x, y) = \begin{cases} 1, \; if \;\; f\,(u, v) > T \\ 0, \; if \;\; f\,(u, v) \leq T \end{cases} \tag{4.2}$$

Wavelet Transform: An interesting wavelet exchange stage can be seen in shading pix that exchange every hue airplane and coordinate every airplane each in turn. The portrayed by methods, Arlimatti [1]. That view of balance is totally demonstrative by abilities comprehensive of big wavelenghts. Fourier Transform changed into research different utilization of recurrence letter. In recurrence zone of 2D pix, DFT (discrete Fourier Transform) changed into utilized thus figuring recurrence and ascertaining DFT and calculation become produced as Fast Fourier Transform (FFT). In order to achieve well known photograph portrayals it's miles basic to have four adjustments in the X and Y bearings. The utilization of Pywavelets helps in with the guide of joining straightforward significant level interface with low degree in general execution. It helps in by methods for applying computerized wavelet redesign to an image. This design is important in expressions of adjustments of difficulties and force range of sign. The first rate foundation of the wavelet adjust can be found in shading photos which revamp each shade plane and figured every airplane each in turn. Wavelets are highlights created from a straightforward capacity by method for expansion and interpretations. The ideas of wavelet change is essentially plainly to show any discretionary capacities as superposition of wavelets. Wavelets over Fourier Transform have greatest tremendous preferences as recurrence range of sign tells around inverse time inside the ideal sign. It boost up getting period adequacy portrayal of sign by plotting time territory sign.

For this methodology numerous calculation has been determined for the three planes of hues pix. Each shading planes has wavelet coefficients that represents outstanding correlations, it is portrayed through Wouwer. The central thought concerning Fourier wavelets change is a reinforce technique for sign and photo assessment that is related with recurrence and time goals properties. New method of DWT is speaks to as 2D-DWT, expressions of photo, units moved and widened wavelet abilities φLH, φHL, φHH and scaling capacity $\varnothing$LL. Fourier Transform is utilized to look at the different channels utilizing recurrence characteristics. For recurrence region of 2D photographs, Discrete Fourier Transform is utilized so ascertain the frequency and to compute the Discrete Fourier Transform and set of rules has been produced as Fast Fourier Transform. The frequency outline of pictures it's far imperative to be Fourier change in every X and Y rules. By pondering photographs as sign $x(t) = A \sin(2 \pi f^*t)$, sign tested to frame discreet sign in occasional range $[-\pi, \pi]$or $[0,2 \pi]$ or $[0,N]$ for N-factor DFT. The library Numpy bundle np.Fft.Fft2 () gives that element to search Fourier change by means of enter photograph as grayscale photograph and strength of similar elements. The output is recurrence change it is easier to choose the greatness range. Also, limit identification activity the extraordinary technique to utilize is better skip sifting that displays swell system called bell results that are utilized for concealing.

4.4.2 Hardware Part

This undertaking speaks to a programmed uncooked, yellowish, and unhealthy object. From obvious review and representation it is partitioned in sub factors, for example, surface and shading. This machine, Khekare et al. [9], will work underneath the control of a raspberry pi in order to control the discovery and arranging of fruits by means of pc preparing. The program will comprise of a transport line and laser bar by IR sensor to tally engine of uncommon channels. The fruit photo adapt to numerous parts of handling which incorporates the partition of shade channels, edges, clamor end and waveforms. So it will assist with creating an incredible item for establishment and prepare it to convey cost solidly to the client by methods for sparing an assortment of time and lessening manual difficult work.

This procedure has been inspected by utilizing the utilization of atleast various experiences, awkward. This experiences recognition framework caught through CMOS lenses and isolate by unnecessary force steel devices powerful engine.

Raspberry Pi: Various added substances are accessible inside commercial center for picture preparing and oversee influenced device. The Raspberry Pi is a significantly rarely utilized system, has registration issue and openly available on online platform. C and C ++ is likewise be altered in JAVA and Python. It bears flexibility to introduce or provide facility to alterations to the framework effectively. Various systems are propelled on the Raspberry Pi based at the buyer's assistance.

USB Enabled Camera: The USB digital photo taker or computerized images cam which utilizes USB 3.Zero age through various dots records. The advanced photo taker have communication utilization of indistinguishable USB age. The USB advanced camera utilized in this crucial the B31508 helping USB2.Zero period, photograph goals upto 24 MB and casing cost of 35 fps (outlines as 2d).

Servomotor: Bidirectional current upheld powerful engine, potentiometer, rigging gathering, and an unmistakable device errand. That rigging meeting is applied to decrease turn decrease reliable with moment and development the force, in view of this the place of pot is most important for the principal job of engine part to increase a yield potentiometer with 0 electrical signs. The related electric confirmation has been doled out to a different enter terminal of the deficiency electronic indicator. Presently to recognize the two pointers, response method can be examined and final product may be offered by mix-up system. The powerful engine is rotational operator or precise and straight direction, speed, and increasing speed. That incorporates reasonable systems outfitted as capacity identifier, moreover seeking a confused device, by and large devoted model intended to utilize. Regardless of the way that a period servomotor is consistently used to call a car reasonable to be utilized in a shut control framework.

4.5 Design and Implementation

Different foods grown from the ground had been handling after numerous enterprises have appeared. With parcels many improve time into ventures numerous human work has been diminished. PC vision has presented another degree of adjustments in the region of photo preparing procedure of robotization in all divisions by supporting the people in daily lives by diminishing span eating techniques. In the proposed strategy assorted new systems have been proposed for identifying citrus natural product. This citrus natural product needs to enter numerous exceptional strategy before moving into further way. This citrus natural product have been isolated into establishment of shading i.E yellow and green. The citrus will get recognized through high centering computerized camera with centering focal point which is controlled by means of the power present inside the controller dealt with by methods for the pc. This natural product the will provided by method for the gentle through quality flexibly which at that point get experience into comparatively set of rules. This technique will decide the dark spot blessing on the floor of citrus and furthermore decide the significance range, Fourier revamp of

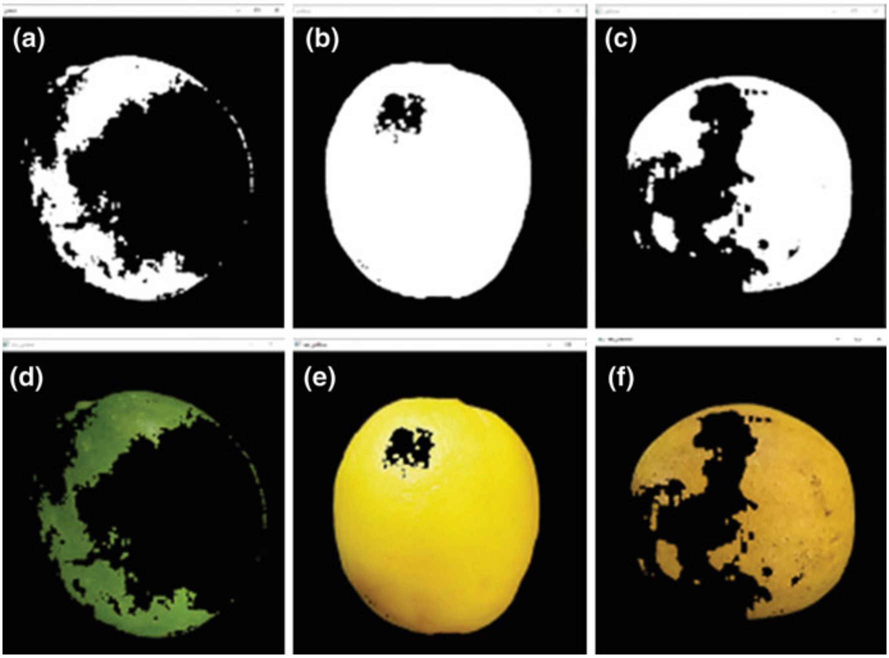


Fig. 4.5 Background separation of input citrus fruit (**a**) masking of premature citrus (**b**) masking of mature citrus (**c**) masking of sick citrus (**d**) result after joining masked and original image of premature citrus (**e**) result after joining masked and original image of mature citrus (**f**) result after joining masked and original image of sick citrus

careful wavelet redesign and histogram with the guide of identifying its shading and observing of the thing.

4.5.1 Background Separation of Image

On account of citrus, by methods for putting off legacy it'll prompt just consideration at the vital trademark/object. It will pass out the pointless part inside the picture through conferring us the significant article. The partition legacy picture of caught has demonstrated in Fig. 4.5a–c. In authentic past detachment, leading inconsequential part has been recognized by means of masking methods. The clean component in Fig. 4.5a–c speaks to the necessary component and unwinding dark speaks to the superfluous piece of photographs. Obtained covered photo namely Fig. 4.5a–c converged one of a kind photograph wherein white shading supplanted with the guide of the extraordinary tinge of untimely, develop and wiped out citrus natural product photo.

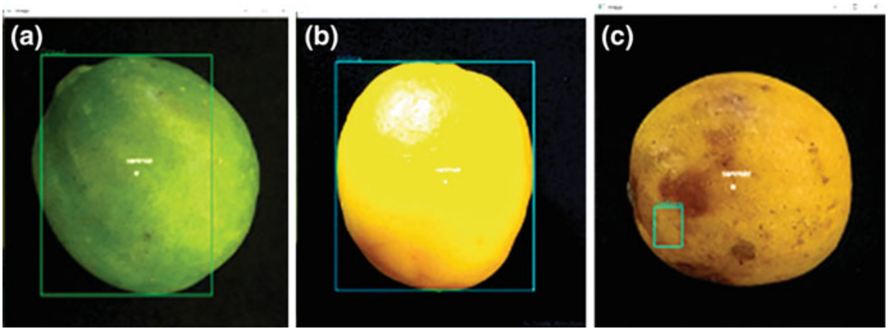


Fig. 4.6 Centre of blob (**a**) Pre-mature Citrus (**b**) Mature Citrus (**c**) Sick Fruit

4.5.2 Calculating the Center of Blob

It is anything but difficult to compute the focuses of the regular old states of circle, triangle, square, square shape and numerous others. In any case, while it go discretionary size it's miles impossible to degree the real center of the pictures as it is not regular hindrances. The indistinguishable issue happens simultaneously as working for photo preparing to figure the mass. Here in proposed strategy have utilized the OpenCV in python to ascertain the center of size as basic of entirety of the variables. The shapes may not be double every so often so for that we have to make it paired. Every shape are result of pixels so centroid can be actually the normal weighted of the entirety of the pixel factors establishing the shapes as shown in Fig. 4.6.

4.5.3 Calculating Black Dots

The dark thing in the center is a type of parasite on account of 'Guignardiacitricarpa' which is an Ascomycota growth that contaminates plantations in every single low atmosphere, causing a diminishing in natural product size and widespread fine. The personality of the dark place perceives the circuit as debilitated natural product. The methodology of the adaptive edge is utilized rather than OTSU because of reality the dark legacy mixed up the verge figuring inside the OTSU technique, though to pick up the dark specks the utilization of related added substances and separating length the adaptive edge has utilized as shown in Fig. 4.7.

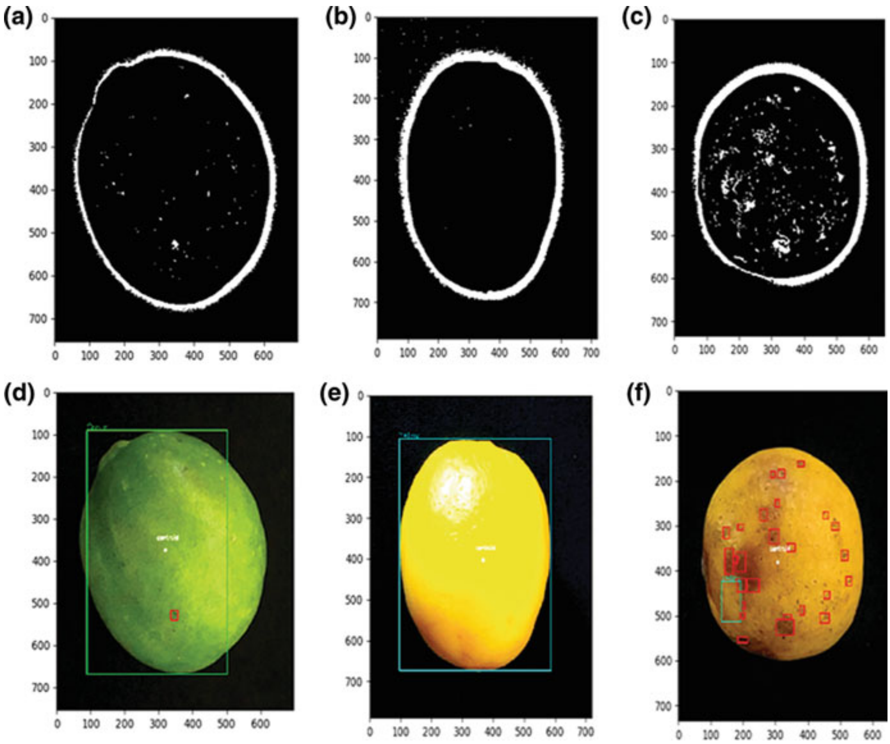


Fig. 4.7 Calculating black spots by grayscale image of (**a**) pre-mature citrus (**b**) mature Citrus (**c**) sick citrus (**d**) premature citrus with one black spot (**e**) mature citrus without black spot (**f**) sick citrus with numerous black spot

4.5.4 Fourier Transform

Fourier changes is an apparatus for picture handling used to part a photograph into added substances i.e. the mathematical sin and cos in recurrence region. In the recurrence territory photograph, every point speaks to a chose recurrence consists of info area picture. This is utilized to imply the assorted get out by method for perusing its recurrence. The Fourier redesign produces the yield photograph as both a genuine and nonexistent component or with worth and fragment. It remembers data for the geometric structure of the space picture. The yield photograph likewise has a significantly more assortment than that of a valid spatial territory photograph.

Magnitude Spectrum
Fort worth range, gray scale pix of less than ideal, develop and sick have been taken as an info photo, as a first contention and the subsequent contention as to decide the elements of the yield cluster. It changes with the elements of a photo, on the off chance that is seen more as an enter photograph, the picture may be cushioned has

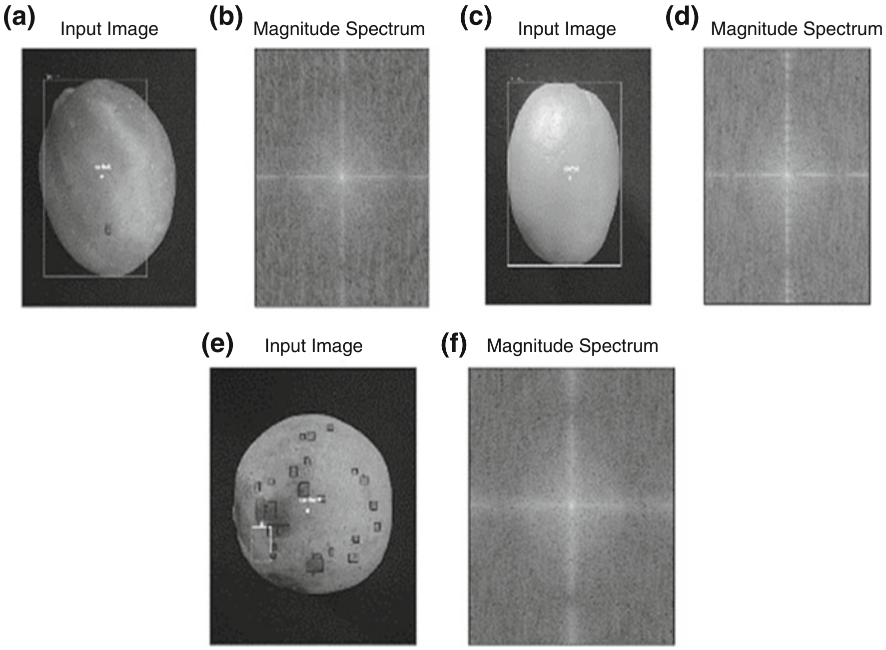


Fig. 4.8 (**a**) Grayscale Pre-mature Citrus (**b**) Magnitude Spectrum of premature (**c**) Grayscale Mature Citrus (**d**) Magnitude Spectrum of mature (**e**) Grayscale Sick Citrus (**f**) Magnitude Spectrum of sick

null preceding which provides FFT and on the off chance that it saw to be lesser than the photograph may be trimmed as shown in Fig. 4.8.

The DC cost of picture as a unique assortment of coefficients is basically too enormous to even consider being shown therefore those expense is by all accounts dark by means of utilizing a logarithmic change to the photos. All the results are appeared as far as frequencies anyway their importance gets littler while frequencies development, hence photograph having low frequencies include different realities than better frequencies. The changed photograph demonstrates that there are two overwhelming headings inside the range picture, one passing vertically and one on a level plane through the center. These start from the ordinary styles out of sight of the one of a kind photograph.

High Pass Band Filter

The recognizable proof of significance range assorted channels were done on caught pix alongside low skip channels, extreme pas channels and band skip channels. High skip channel helps in putting off minimum frequencies methods for ensuring the territory picture and backwards move utilizing np.Fft.Ifftshift(). Subsequent to reverse DFT photo, it'll experience opposite FFT which is done through the use of np.Ifft2 (). The final product as a mind boggling values. The outcomes display

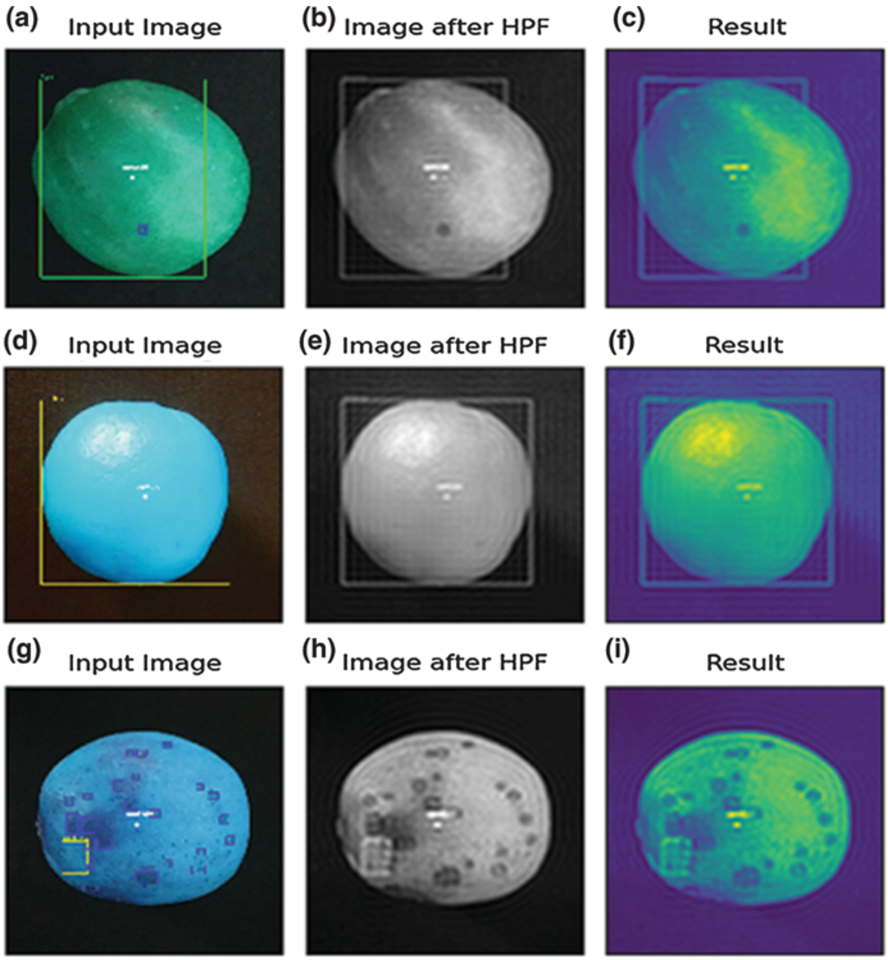


Fig. 4.9 High Pass Filter (**a**) grayscale Pre-mature Citrus (**b**) HPF on premature citrus (**c**) result of premature (**d**) grayscale mature citrus (**e**) HPF on Mature (**f**) result of mature citrus (**g**) grayscale sick citrus (**h**) HPF on sick citrus (**i**) result of sick

the maximum skip sifting as a section identification activity which shows the vast majority of the photos values are available as a minimum frequencies area range as shown in Fig. 4.9.

DWT

Wavelet Transforms are utilized to examinations, de-noising, and pressure of cautions and pics. It is finished by pywavelets include in python. This conveys extraordinary capacity i.e. Dwt() trademark which is utilized to play out a signal dimensional disconnect wavelet rebuild which 3 spatial area picture i.e. Level, upword down and corner to corner information as demonstrated in Fig. 4.10. The

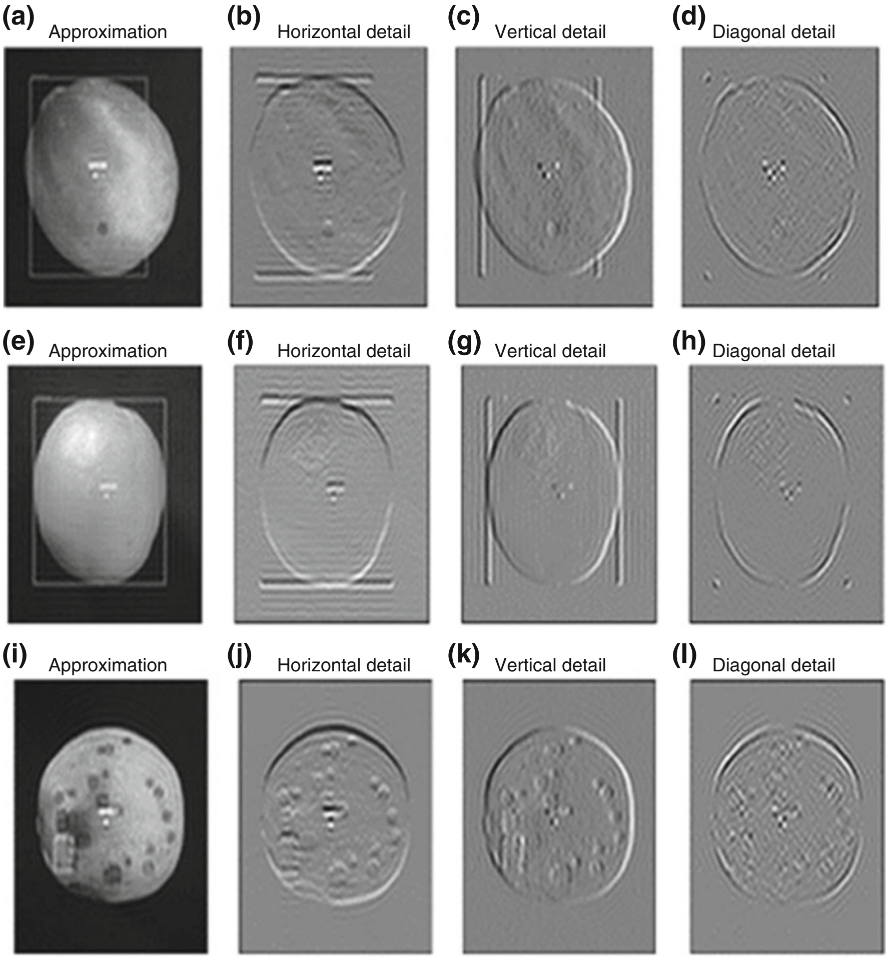


Fig. 4.10 DWT (**a**) Grayscale Pre-mature Citrus (**b**) Horizontal view (**c**) Vertical view (**d**) Diagonal view (**e**) Grayscale Mature Citrus (**f**) Horizontal view (**g**) Vertical view (**h**) Diagonal view (**i**) Grayscale Sick Citrus (**j**) Horizontal view (**k**) Vertical view (**l**) Diagonal view

accompanying thing assists with plotting the estimation and subtleties the ideal photo.

As shown in Fig. 4.10 proposes level, vertical and corner to corner subtleties for develop, less than ideal is decayed into 4 parts as exceptional coefficients with put away in LL, LH, HL, HH.L represents unadulterated detour sign L (low recurrence) in which as H represents regular sign H (max recurrence).

LL: It is top left side obstruct in single phase disintegration that consist of imaginary picture i.e. Figure 4.10a, e, i for inauspicious, develop and unwell circuit separately, conveys the entirety of the coefficients of caught photograph which cleaned by utilizing concentrating low pass filter close by the columns. This square is connoted as LL that speaks to the adaptation of caught picture at a large portion of the goals. This resultant photograph again experiences into low detour get out which results the relating segments.

HL/LH: It has position left and top right square in a phase decay with the Fig. 4.10b, c for awkward circuit, Fig. 4.10f, g to develop citrus and Fig. 4.10j and (alright) to debilitated circuit have been separated h and g elective for lines and sections. The HL square comprises of even weights and LH square conveys upword down sides of picture that have gone through to minimum sidestep get out.

HH: The lessening appropriate part in a phase decay for the Fig. 4.10d, h, l for inconvenient, develop and sick circuit individually, is vice versa of approximated picture on the grounds that the photograph utilizes the investigation of unreasonable detour get out g belongs to wavelet. The square is deciphered as the spot wherein weights of caught photo is askew way. The square is analogs to top left quadrant in a phase deterioration.

Histogram

Histogram of a photo offers basic realities roughly its profundity circulation of a picture which plot with pixel esteem beginning from zero to 255 in the x-hub and a relating assortment of pixels present inside the photograph on the y-pivot. Histogram states around the detail data concerning the framework that had been executed at the picture by utilizing giving its appraisal, splendor, profundity appropriation and so forth. The left area shows the darker measure of pixel found in a photograph like the correct area demonstrates a more splendid measure of pixels. It encourages to improve the visual nearness of the photo and educate what kind regarding photo handling has been applied by method for assessing histograms of pictures since it spared pixel esteems, each pixel has conceal profundity and histogram are recurrence dispersion for these worth which emerge in a photo as shown in Fig. 4.11.

Working of the System

In the ventures, the vast majority of the perfection or greens get bundled while not having right separation. Some of the time, bundle isn't more right than wrong to utilize or to eat up, some climax or veggies are spoiled some are acceptable. So the best approach to find that the issues which may be getting handled for bundling are amazing in excellent or not? Underneath outline demonstrates the Schematic work process of bundling strategy in Figs. 4.12 and 4.13 individually. All units are connected by using Internet of Things Khekare et al. [8]. All electrical, mechanical, interfacing and synchronization work among different units is done with the help of Internet of Things.

In this endeavor, research on the discovery of the article so one can classes the item dependent on conceal, surface, shape, and greatest likely length, much sooner than bundling. It will even distinguish what kind of perspective is being preparing and could advise that it has a place with natural products or fruit and afterward consequently it'll packed. Complete procedure is mentioned below:

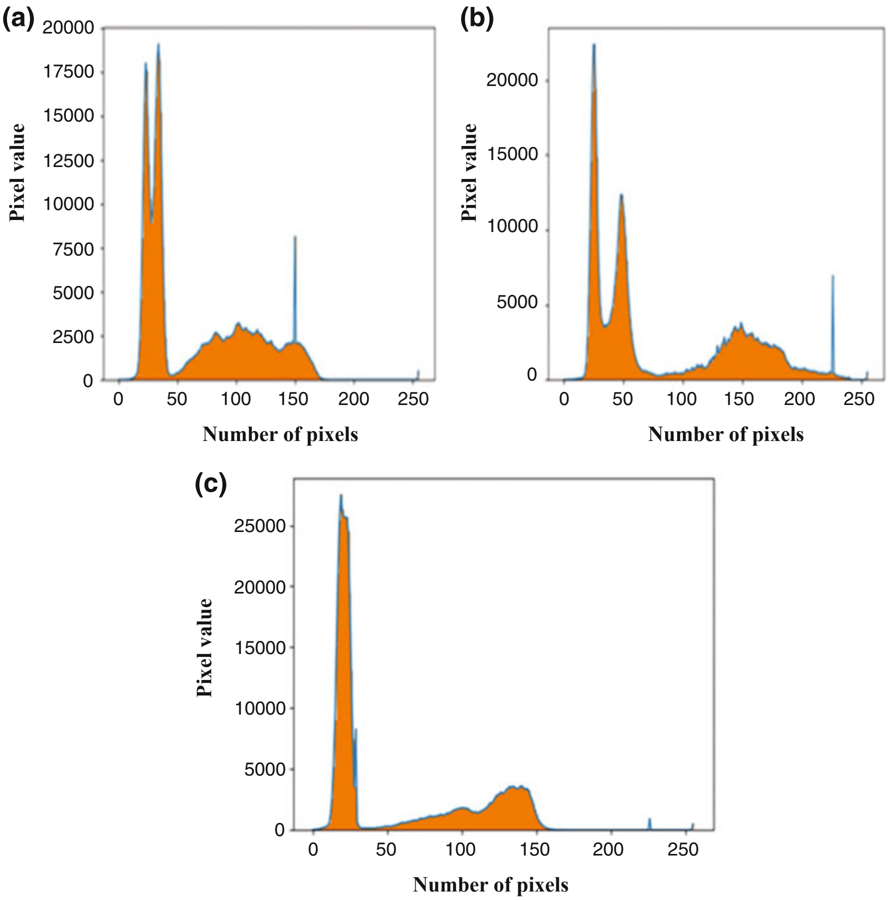


Fig. 4.11 (**a**) Histogram of processed image of (**a**) premature citrus (**b**) mature citrus (**c**) sick citrus

1. The fruit situated in transport line Infrared sensor hit upon fruit and transport line is stopped, camera test fruit and run over that.
2. Discovery of fruit principally dependent on its tinge, checked picture is changed over GBR to HSV (tint immersion charge).
3. This changed over picture is as contrasted and the HSV shading assortment. On a off chance that the appraisal is legitimate, at that point this lemon is classed.
4. The discovery of shading is cultivated in the HSV assortment in inclination to the GBR assortment. After the identification of fruit, the transport line begins arranging.
5. The powerful engine categories fruit in 3 classes which may be full grown lemon, pre-developed lemon, and unwell fruit.
6. Similarly, on the off chance that there’s any exceptional thing, at that point it will consent to the indistinguishable technique, and natural product will set

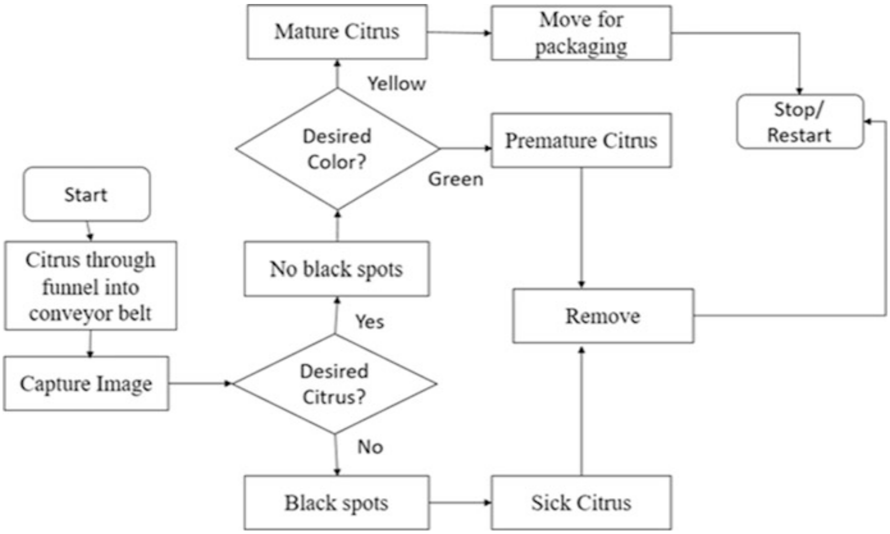


Fig. 4.12 Workflow model of Packaging machine

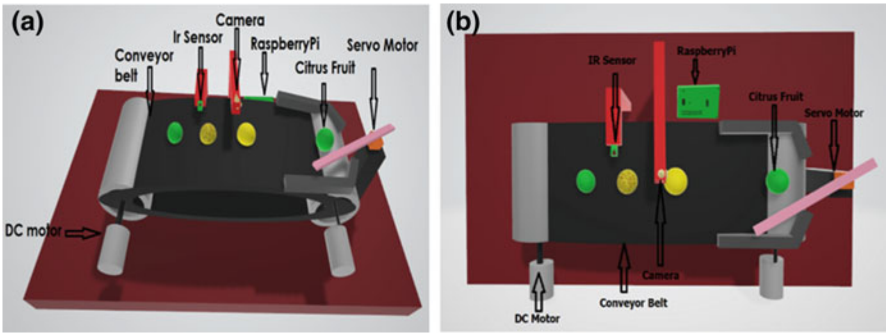


Fig. 4.13 (**a**) Side view of Packaging machine (**b**) Top view of Packaging machine

everything straight by using powerful engine and hence that will correspondingly proceed for bundling.

4.6 Conclusion

This book chapter provides a system for best fruit segregation and taxonomy for smart agriculture using Internet of Things. It features the utilization of machine becoming acquainted with and picture handling in practically each subject of nourishment and farming. The thing required is the best of items like its hue, surface, dimension, and weight. A large portion of the business is practiced, therefore sparing a lot of time, it's going to moreover diminish manual artistic creations. The natural product is isolated the utilization of an edge strategy from its authentic past by including edge charge, afterward it will experience reinforce abilities of Fourier change which comprise of significance range, high skip sifting, discrete wavelet revamp, and afterward its histogram.

In this manner subsequent to working on various sorts of citrus organic product, we've inferred that outcomes came out inside the type of the pixel appeared looking like histogram graph. Subsequently the way has moreover support inside the arranging of unused circuit organic product. Along these lines proposed strategy have demonstrated. This methodology is extra amazing and productive and no longer time-eating as it empowers to decrease manual works of art through arranging and distinguishing the utilized and unused citrus organic product on conceal through the use of Fourier change.

The assessment of various isolation and bundling machines is finished in this content. In view of that a fresh out of the plastic new gadget is proposed which utilizes picture handling. The proposed machine takes care of the issue of manual bundling with negligible expense. Connectivity among different units using Internet of Things makes the concept of smart agriculture more effective and most of the work becomes automated and without human inputs through cloud computing processing. Additionally, it likewise distinguishes the thing dependent on its shade and isolates it with no difficulty if there should arise an occurrence of fruit. This contraption gets valuable to work inside each kind of business where large scale manufacturing is made.

References

1. S.R. Arlimatti, Window based method for automatic classification of apple fruit. Int. J. Eng. Res. Appl. **2**(4), 1010–1013 (2012)
2. Behera, S. K., Mishra, N., Rath A. K., and Sethy P. K. 2018. "A Novel Approach for Classification of Apple Using on-Tree Images Based on Image Processing"
3. A. Bhargava, A. Bansal, Fruits and vegetables quality evaluation using computer vision: A review. J. King Saud Univ. Comput. Inf. Sci. (2018). https://doi.org/10.1016/j.jksuci.2018.06.002
4. U.O. Dorj, M. Lee, Y.S. Seok, An yield estimation in citrus orchards via fruit detection and counting using image processing. Comput. Electron. Agric. **140**, 103–112 (2017). https://doi.org/10.1016/j.compag.2017.05.019
5. M. Huang, R. Lu, Apple mealiness detection using hyperspectral scattering technique. Postharvest Biol. Technol. **58**(3), 168–175 (2010). https://doi.org/10.1016/j.postharvbio.2010.08.002
6. S. Jana, S. Basak, R. Parekh, Automatic fruit recognition from natural images using color and texture features, in *Proceedings of 2nd International Conference on 2017 Devices for Integrated Circuit (DevIC) 2017*, (2017), pp. 620–624. https://doi.org/10.1109/DEVIC.2017.8074025
7. L.S. Kalantari, M.H. Bakr, Wideband cloaking of objects with arbitrary shapes exploiting adjoint sensitivities. IEEE Trans. Antennas Propag. **64**(5), 1963–1968 (2016). https://doi.org/10.1109/TAP.2016.2521880

8. G. Khekare, P. Verma, U. Dhanre, S. Raut, G. Yenurkar, Analysis of Internet of Things based on characteristics, functionalities, and challenges. Int. J. Hyperconnectivity Internet Things (IJHIoT) 5 (2021): 1, Accessed (January 02, 2021). https://doi.org/10.4018/IJHIoT.2021010103
9. G.S. Khekare, U.T. Dhanre, G.T. Dhanre, S.S. Yede, Design of optimized and innovative remotely operated machine for water surface garbage assortment. Int. J. Comput. Sci. Eng. **7**(1), 113–117 (2019). https://doi.org/10.26438/ijcse/v7i1.113117
10. M.P. Kiran, Smart Home Gardening System Using Raspberry Pi. **8**(2), 302–305 (2017)
11. S. Khekare, S. Janardhan, Stability analysis of a vector host epidemic model. Asian J. Math. Comput. Res. **21**(3), 98–109 (2017)
12. B. Ozturk, M. Kirci, E.O. Gunes, Detection of green and orange color fruits in outdoor conditions for robotic applications, in *5th International Conference Agro-Geoinformatics, Agro-Geoinformatics. 1*, (2016), pp. 5–9. https://doi.org/10.1109/Agro-Geoinformatics.2016.7577641
13. Sahana M., and Anita, H. B. 2017. “Automatic classification of south indian regional fruits using image processing.” Indian J. Sci. Technol., 10(13): 1–4. doi: 10.17485/ijst/2017/v10i13/110462
14. A. Sharma, R. Kumar, V. Mansotra, Proposed stemming algorithm for Hindi information retrieval. Int. J. Innov. Res. Comput. Commun. Eng. (An ISO Certif. Organ.) **3297**(6), 11449–11455 (2016). https://doi.org/10.15680/IJIRCCE.2016
15. M. Šustek, M. Marcaník, P. Tomášek, Z. Úředníček, DC motors and servo-motors controlled by Raspberry Pi 2B. MATEC Web Conf. **125** (2017). https://doi.org/10.1051/matecconf/201712502025
16. R. Szabo, I. Lie, Automated colored object sorting application for robotic arms, in *10th International Symposium on Electronics and Telecommunications ISETC 2012 – Conference Proceedings*, (2012), pp. 95–98. https://doi.org/10.1109/ISETC.2012.6408119
17. R. Szabó, A. Gontean, L. Lie, Cheap live color recognition with webcam, in *23rd International Symposium on Information, Communication and Automation Technologies ICAT*, (2011). https://doi.org/10.1109/ICAT.2011.6102103
18. T.P. Tho, N.T. Thinh, N.H. Bich, Design and Development of the Vision Sorting System, in *Proceedings – 3rd International Conference on Green Technology and Sustainable Development GTSD*, (2016), pp. 217–223. https://doi.org/10.1109/GTSD.2016.57
19. A. Vidal, P. Talens, J.M. Prats-Montalbán, S. Cubero, F. Albert, J. Blasco, In-Line Estimation of the Standard Colour Index of Citrus Fruits Using a Computer Vision System Developed For a Mobile Platform. Food Bioprocess Technol. **6**(12), 3412–3419 (2013). https://doi.org/10.1007/s11947-012-1015-2
20. S.V.D. Walt, S.C. Colbert, G. Varoquaux, The NumPy array: a structure for efficient numerical computation. Comput. Sci. Eng. **13**(2), 22–30 (2011). https://doi.org/10.1109/MCSE.2011.37
21. H.M. Zawbaa, M. Abbass, M. Hazman, A.E. Hassenian, Automatic fruit image recognition system based on shape and color features. Commun. Comput. Inf. Sci. **488**, 278–290 (2014). https://doi.org/10.1007/978-3-319-13461-1_27
22. F. Zhang, H. Cheng, W. Sun, Y. Zhang, X. Wang, Color image edge detection arithmetic based on color space, in *Proceedings – 2012 International Conference on Computer Science and Electronics Engineering ICCSEE*, (2012), pp. 217–220. https://doi.org/10.1109/ICCSEE.2012.186

Chapter 5
Toward the Creation of a Web-Based Platform "Bike Sharing" in the Local Transport System

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5.1 General Formulation of the Problem

The amount of new knowledge in the last century is growing exponentially. To quickly find information and use it correctly, many web services and applications are created, which greatly facilitate the search and sorting of information. Every day there are more and more new services are being offered, which differ significantly from their predecessors in terms of functionality, speed, user interface, support and upgradation of old services. Currently, the most promising type of economic activity in which IT technologies are introduced is tourism, which cannot be realized without the provision of services in the field of transport rental, including cycling.

There are various services for renting a bike. Such services allow to raise the popularity of cycling, to involve people in an active rhythm of life in order to improve the physical condition of the person as a whole and meet the needs of cyclists. In addition, in most European countries, special bicycle paths, bicycle areas, and parking lots have been developed, and special state programs have been introduced to promote this type of transport. All this determines the relevance of the implementation of web-based national platform "bike sharing".

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5.2 Analysis of Recent Research and Publications

The development of the scientific approach has been influenced by the work of domestic and foreign scientists and practitioners who study and solve problems of transport infrastructure development and ensure its sustainable operation. Among them are Banister D [1], Berechman J [1], Danuta Tarka [2], J. Bicura, S. Bogachova, B. Danilishina, G. Deyli, V. Ivanova, G. Mayer, D. Medous, M. Mesarovich, E. Pestel, O. Shubravska, etc. In their works, scientists focus on a systematic approach to the development of transport infrastructure in stimulating the processes of economic growth of the territories of different administrative-territorial divisions of the state. This creates the conditions necessary to ensure the mobility of people, goods, and information. This is an important factor influencing the competitiveness of the economy, influencing its openness and innovation. The historical development of public transport is presented in the works Paul J. DeMaio [3]. The author notes that cycling programs for public use have been successfully implemented in European cities since 1995, but in the twenty-first century, smart bikes are gaining popularity, which are designed to complement existing transport and encourage greater use of all public transport systems. Factors influencing the choice of general bicycles and electric bicycles are described in detail in scientific work [4]. Much attention was paid to the study of the development of transport enterprises in domestic science during the Soviet period. The study of the problem is complicated by the fact that the works in that period were politicized and ideologized; some lost their economic significance. However, the foundation was laid for the study of new scientific directions of development of transport enterprises of the country. The scientific works of domestic scientists O. Belarus, I. Burakovsky, A. Kredisov, and others are important in regulating the development of domestic transport enterprises. Various methods of assessing efficiency in the form of increasing the competitiveness of the territory, increasing labor productivity, improving the environmental situation, and in the whole development of human capital and improving the quality of life play a significant role in improving the work of a smart city and business entities. Domestic scientists are working on the analysis of existing information and analytical solutions for smart cities with various methods of assessing efficiency. So, in the work [5] presented a complex information-analytical solution for improving the efficiency of energy management in municipalities. In [6], the methodology of the primary analysis of the given data is given and the function of the future value. In [7], the criteria for maximum efficiency are presented for the systems of burning business. In [8], an adaptation of the methodology of key indicators of efficiency to the assessment of the efficiency of functioning of systems for ensuring thermal comfort in Budivly is presented. In [9–11], the principle of assessing the efficiency of the implementation of solutions for the heat modernization of the budget using the well-developed discounted method is presented. In [12], the authorization of the discounted method of estimation of the supply of autonomous energy supply systems is given. In [13], information warehouses have been introduced for the introduction of energy-saving entry into the business. In [14], the formalization and definition of the optimization criterion in the energy system are given. In [15], a study of modern opportunities for the information uses technologies, namely, the adaptation of accounting and analytical support in the context of the spread of socioeconomic values to improve the well-being of the population. In the works of the authors [16–18], it is determined that active implementation of innovative technologies will give new opportunities, that will open approaches for business-environment to save labor productivity and suitable level of profitability from entrepreneurship. Innovative economy changes traditional approaches to labor organization, as well as social and labor relations, that promotes development of prerequisites to overcoming the decreasing of economic indicators and continuous production process at the enterprises, solves the issues of unemployment and labor migration, creates new flexible forms of employment, and increases level of state's competitiveness in conditions of economic globalization.

5.3 Selection of Previously Unsolved Parts of the Overall Problem

Market principles of management, the changing economic situation, and the imperfect regulatory framework have necessitated the appropriate adaptation of the transport system. In addition, the imbalance in the transport services market and the current pandemic has intensified competition among commercial carriers. There is a mismatch between the volume and quality of supply of transport services to effective demand. As a result, the functioning of the country's transport system is characterized by unsustainable development. Based on this, there is a need to know the depth of the processes and phenomena that occur and the introduction of new transport systems that will be safe in today's conditions and have a positive impact on the physical condition of man. In this regard, it is necessary to offer the use of a bicycle for daily movements, which is especially advantageous for short distances. According to research conducted in the European Union, the average distance of most traffic in cities does not exceed a few kilometers. In the European Union, half of car journeys are in the 5–14 km range. At such distances – given traffic congestion – a bicycle can be faster than a car and public transport. They began to popularize, taking into account the numerous problems associated with their functioning in cities and the emergence of congestion and air pollution.

The use of bicycles is an important element of transport infrastructure in cities, in which the development of this mode of movement is simultaneously perceived as a kind of "cycling revolution." Instead of buying a bicycle, the user of such a system buys the right to use it according to his own needs, so he does not need to service the bicycle, and he does not need to worry about its storage or parking. The user can choose different bikes in 1 day to meet their transportation needs. Therefore, an important task to be solved in this matter is the proper integration of the bicycle system into the urban space. This task should be taken into account at the planning stage of assumptions about the overall strategy of transport in cities, and their proper preparation is the responsibility of local authorities, which are responsible for developing communication policy in these areas. The most important of the identified benefits can be seen in the following aspects [19, 20]: security, constant monitoring of rent, robust construction, regular maintenance, bicycle patrols, and dual security system; branding, responding to social demand, promoting a healthy lifestyle, integrating residents, and developing trade and services; efficiency, supplementation of public transport, simplification of planning of city transport services, calmer traffic in the central districts of the city, and integration with the tariff of city tickets; ecology, less noise and CO_2 emissions, reduction of infrastructure consumption, and promotion of green areas; ease of use, easy parking in the area of the bicycle station, the impact on reducing congestion in public transport, and the ability to reach even hard-to-reach places by bike; functionality, the first 15–20 min of free driving, the first hour cheaper than a ticket for public transport, the fare favorable to the resident, and the possibility of using dedicated cards, such as active cards of employees in the field of sports and recreation (e.g., MultiSport card).

The main problems associated with urban bicycle systems relate to the following elements [21]: changing the mentality and habits of residents, providing conditions for flexible and easy installation of the system, monitoring with the ability to track bicycles in real time, the ability to use the latest mobile solutions (smartphones), programs, NFC technology), technology platform stability, and bicycle distribution optimization.

Currently more than 140 bicycle rental systems are available in more than 165 countries [22], for example: Amsterdam – Macbike Vondelpark, Barcelona – El Biking, Berlin – Bicycle on Call and Nextbike, Budapest – Bubi, Dublin – Coca Cola Zero Dublinbikes, London – Bicycle rental Barclays, Milan – BikeMi, Paris – Vélib' bike-sharing offering more than 20 thousand bicycles at more than 1800 stations and stops, Stockholm – Stockholm bicycles, Vienna – Citybike Wien, Netherlands, Belgium – Villo, Moscow – Velobike, Moscow, Washington – SmartBike, USA – Bcycle, Mexico – EcoBici, China: Wuhan and Hangzhou, where 60,000 bicycles are available for rent.

Therefore, a bicycle can in some situations replace travel by car and public transport. This was the reason to pay special attention to the possibility of creating a city bicycle system and its mobile support by creating a mobile application.

5.4 Statement of Research Tasks

The aim of the study is to form a conceptual approach to create a web-based platform "bike sharing" to meet the diverse transport needs of cities and their users based on the formalization of the components of business processes.

The task of the work are:

– Analysis of foreign experience of city bicycle rental
– Identifying the advantages and disadvantages of existing bicycle rental systems
– Description and research of business processes based on existing systems

5.5 Material and Research Results

Bicycle rental is carried out using a web-based platform “bike sharing”, the essence of which is that for convenient bicycle rental, special rental points have been developed, where everyone has the opportunity to rent a bike. Such systems are called bike sharing.

Bicycle sharing system, which has also been called a way to solve the rental problem, allows you to rent a bike at one of the automated stations and after the trip to return the bike to any rental point installed in the same city [23, 24]. The main goals of the bicycle sharing system are, first of all, the development of bicycle infrastructure and the creation of conditions for increasing the number of cyclists by building bicycle infrastructure within the framework of the target program of reforming and developing the city’s housing and communal services; promoting the development of small and medium-sized businesses with a focus on cycling; improving the ecological condition and developing the tourist attractiveness of the city; and popularization and encouragement of city citizens to an active and healthy lifestyle. Such systems exist in most major European and North American cities. Their purpose is to provide residents, as well as guests (tourists) of the city with free or cheap bicycles for short-term short trips. The program is at the national level, which combines a typical rental system with several of the above systems, national rail operators or infrastructure partners of the national cycling organization, and others to create a system closely related to public transport. These programs usually allow longer rental times of up to 24 or 48 h, as well as for tourists and cruises. Some German cities with tracks offer bike rental called Call a Bike.

In China (Guangzhou), Guangzhou’s private high-speed public transportation system includes bike lanes and a public bicycle system. In some cases, such as the Santander Cycles in London, the bicycle exchange system belongs to the public transport organization itself. In other cases, such as EnCicla in the city of Medellin (Colombia, South America), the division of the bicycle system is linked to other modes of transport, such as the metro.

In addition, bike sharing cooperates fruitfully with parking operators. Some parking operators, such as Vinci Park in France, rent bicycles to their customers, who park their cars.

One of the largest bicycle sharing systems is the Velib network in Paris, which has more than 1200 points (stations) and 20,000 bicycles. This network serves about 100,000 trips daily. The stations are located at a distance of 300 m from each other. An example of bicycle rental in Ukraine is the Nextbike system (see Fig. 5.1).

The service menu contains brief information on how to interact with the application, locations where the customer can rent a bike, the price of services, and

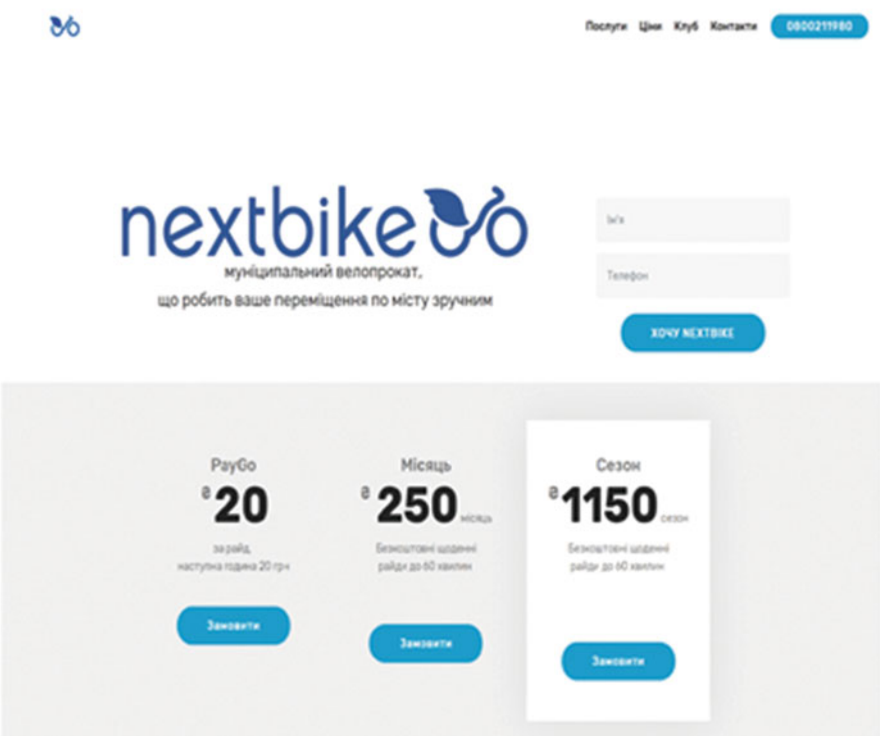

Fig. 5.1 The main page of “Nextbike”

news of this service. After registration, the client has the opportunity to pay a season ticket for bicycle rental. This service provides the following opportunities: the ability to search for stations online and book bicycles, reporting, and preservation of the city’s ecology and accessibility of bicycles for everyone and control the location of the bike with a GPS tracker mounted on the bike.

Despite the fact that this service has an intuitive interface and a fairly developed system, it has some drawbacks. Important disadvantages of the service are not quite modern interface, lack of online customer consultation, lack of possibility to route to rental points, and poor optimization of online service. Therefore, we can conclude that the public bike rental “Nextbike” needs improvement, modernization of the user interface, adding the possibility of online customer consultation through a web service, as well as the ability to route to rental points. In addition, a rather useful feature is the offer of routes for cycling using a web service or mobile application.

The lack of a modern and user-friendly interface is one of the most important reasons for improving the existing system. In addition, no less important reason is the lack of national bike sharing systems and any competition, which in turn leads to higher prices and reduced quality of service.

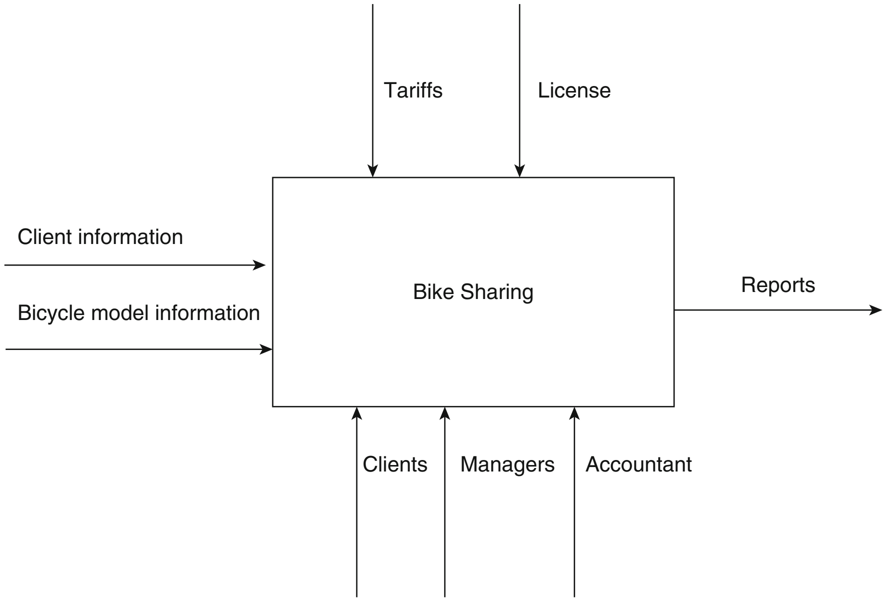

Fig. 5.2 Context diagram of business processes

In each system, you can select individual business processes, which makes the process of modeling business processes one of the most important in the project. Business process modeling (BPM) is a formalized, performed according to certain rules description of the sequence of actions of specialists in the form of logical flowcharts that determine the choice of further action based on the situational fact [24]. The purpose of business process modeling is usually business documentation of the company; preparation of business processes (which usually begins with an analysis of the actual situation); preparation and automation of IT support for business systems; and determination of process indicators.

BPwin was chosen to model the business process. This application allows you to create complex business process models. It supports three methodologies IDEF0, IDEF3, and DFD. Each of them is designed to solve its specific tasks. All control signals are displayed in the same way. This model is one of the most progressive models and is used in the organization of business projects and projects based on modeling of all processes, both administrative and organizational. The context diagram of business processes of bicycle rental service in the IDEF0 notation is shown in Fig. 5.2.

This diagram shows the functional unit of bike sharing, namely, the rental of a bicycle. The input data of the subsystem are customer data and the bicycle fleet. This data is converted by the functional unit for input production. A specific type of input is control. It is responsible for regulating when and under what circumstances the functional unit is performed. Management part in this subsystem are generalized

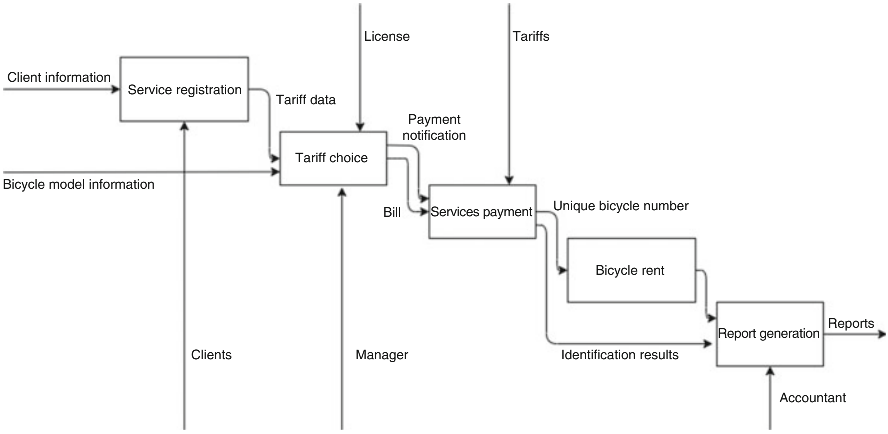

Fig. 5.3 Diagram of the first level of the business process "bicycle rental service activities"

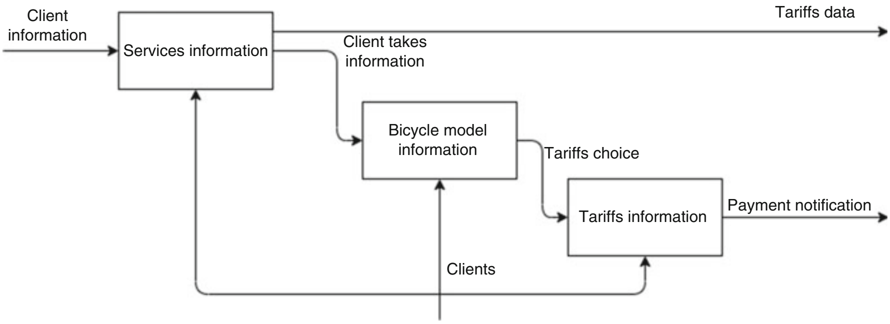

Fig. 5.4 Second level business process diagram "customer registration"

norms and license. Mechanisms are a resource that directly performs a modeling action. The subsystem that is being developed by the mechanism has the staff of the subsystem. The result of the functional unit is the initial data in the form of rent and report. The following diagram shows in more detail the business process that is being developed (Fig. 5.3).

The customer who applies for services to the bicycle rental service must provide their data for registration in the service and form their needs in order to choose the required tariff. The next step is to pay the fare and get a unique bike number. In order to confirm the user's intention to rent this bike and unlock it, the customer must scan the barcode on the bike. Based on all the data provided by the client and the actions taken, reporting is formed for the supervisory authorities. Figure 5.4 presents a diagram of the second level of the business process "customer registration."

To register, the customer must provide the name, contact phone number, e-mail, and card details. If the client has already been serviced in the system, he can edit the information in the database; otherwise, the data is entered into the database and

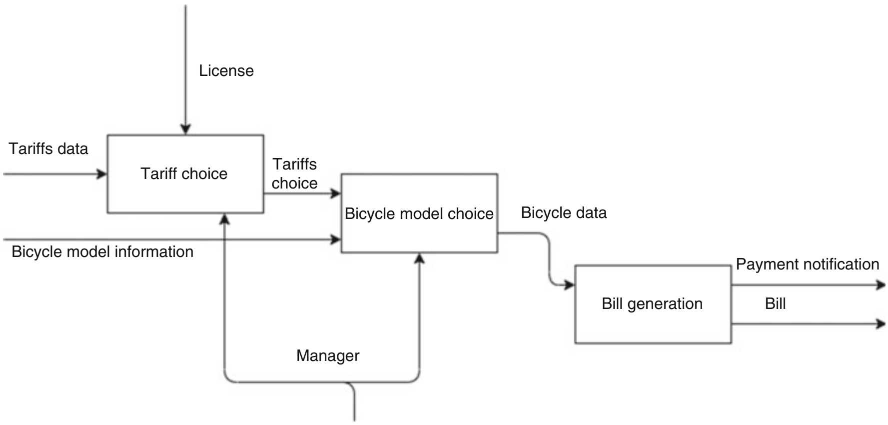

Fig. 5.5 Diagram of the second level of the business process “payment for services”

a new user is created. Figure 5.5 presents a diagram of the second level “payment for services.”

After the client has already registered in the system, the tariff is selected. If the customer has any questions about tariffs, he can contact the manager of the rental station and get a free consultation. The next step is to pay the tariff. After payment, the customer will receive a receipt in the application and a copy to his e-mail, which was specified at the time of registration. After passing the payment stage, the customer begins the identification stage.

After the customer pays the selected tariff, the identification process begins. At this stage, the customer receives a unique bicycle code, which is located at the bike station near the customer. The user must find this bicycle by the number provided and scan the barcode on the bicycle to confirm the bicycle rental. Data flow diagram is a design model, a graphical representation of “streams” of data in the information system. The data flow diagram can also be used to visualize data processing processes (structural design). It is considered customary for the developer to first draw a context-level data flow diagram to show how the system interacts with external modules. This diagram is further refined by detailing the processes and data flows in order to show the extensive system being developed [23]. Data flow charts contain four types of graphics:

– Processes are the transformation of data within the described system, data warehouses (repositories), and external to the system of essence.
– Data flows between elements of the three previous types. The context diagram of the bicycle rental service in DFD notation is shown in Fig. 5.6.

Node.js was chosen as a programming language for the development of the server part of the service, because this language is based on the very popular JavaScript, which provides access to many already integrated libraries that simplify the process of writing code and project support.

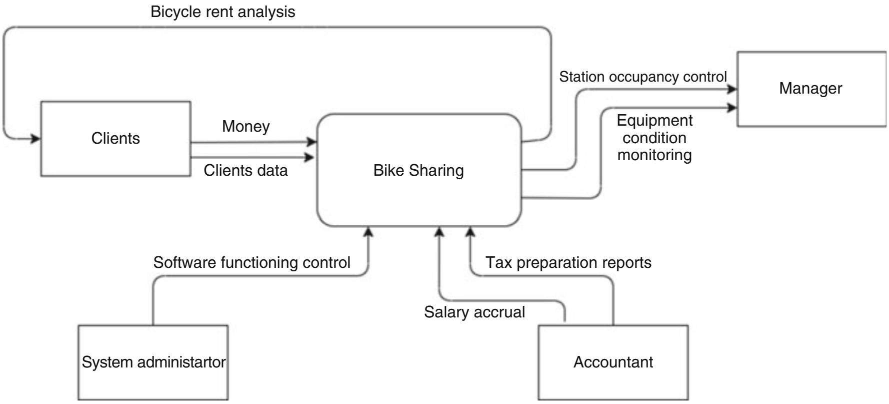

Fig. 5.6 Context diagram of "bike sharing" system

A DBMS with sql approach support was used for data storage, as it is planned to store a large amount of structured information. MySQL was chosen for such purposes.

5.6 Conclusions

The above research allows us to draw the following conclusions: first, the city bicycle is an increasingly common way to travel in cities, and analyzing the facts about the use of such systems abroad, we can note that such systems are very popular and needed in our society. Such systems allow to save time spent on moving around the city, to save the budget of an individual family, to reduce the load of traffic on the roads of an individual city, and to significantly reduce the impact of transport on the environment; secondly, due to the analysis of existing bicycle rental systems, their main advantages and disadvantages were highlighted. The analysis revealed the main business processes of the service, which are presented in the form of IDEF0 notation diagrams, which allows you to illustrate in detail the individual processes. The effect of such business processes will be characterized by studying an array of security documents of different countries and open sources of scientific and technical information in order to identify among them a description of a technical solution similar to the studied, which will be the basis for future research.

References

1. D. Banister, J. Berechman, *Transport Investment and Economic Development* (UCL Press, London, 2000)

2. D. Tarka, Transport infrastructure in UE countries – Taxonomic analysis. Econ. Manag. **4**, 88–100 (2012)
3. J. DeMaio Paul, Smart bikes: Public transportation for the 21st century. Transp. Q. **57**(1), 9–11 (2003)
4. A.A. Campbell, C.R. Cherry, M.S. Ryerson, X. Yang, Factors influencing the choice of shared bicycles and shared electric bikes in Beijing. Transp. Res.. Part C Emerg. Technol. **67**, 399–414 (2016)
5. A. Perekrest, V. Shendryk, P. Pijarski, Y. Parfenenko, S. Shendryk, Complex Information and Technical Solutions for Energy Management of Municipal Energetics, in *Proceedings of the SPIE 10445*, Photonics applications in astronomy, communications, industry, and high energy physics experiments 2017, 1044567 (2017)
6. A. Perekrest, O. Chornyi, O. Mur, V. Kuznetsov, Y. Kuznetsova, A. Nikolenko, Preparation and preliminary analysis of data on energy consumption by municipal buildings. East. Eur. J. Enterp. Technol. **6**(896), 32–42 (2018)
7. A. Perekrest, I. Konokh, M. Kushch-Zhyrko, Administrative Buildings Heating Automatic Control Based on Maximum Efficiency Criterion, in 2019 IEEE International Conference on Modern Electrical and Energy Systems (MEES), Kremenchuk, Ukraine. pp. 202–205 (2019)
8. A. Perekrest, M. Kushch-Zhyrko, V. Ogar, O. Zalunina, O. Bilyk, Y. Chebotarova, Key Performance Indicators Assessment Methodology Principles Adaptation for Heating Systems of Administrative and Residential Buildings, in 2020 IEEE Problems of Automated Electrodrive. Theory and Practice (PAEP), Kremenchuk, Ukraine, pp. 1–4 (2020)
9. A. Perekrest, Y. Chebotarova, O. Herasimenko, Information and Analytical Set of Tools for Assessing Efficiency of the Civil Buildings Heating Modernization, in 2017 International Conference on Modern Electrical and Energy Systems (MEES), Kremenchuk, pp. 216–219 (2017)
10. A. Perekrest, Y. Chebotarova, H.A. Al-Issa, Principles of Designing and Functioning of the Expert System of Assessing the Efficiency of Introducing Energy Conservation Measures, in 2019 IEEE 2nd Ukraine Conference on Electrical and Computer Engineering, (UKRCON), Lviv, pp. 871–875 (2019)
11. Y. Chebotarova, A. Perekrest, V. Ogar, Comparative Analysis of Efficiency Energy Saving Solutions Implemented in the Buildings, in 2019 IEEE International Conference on Modern Electrical and Energy Systems (MEES), Kremenchuk, Ukraine, pp. 434–437 (2019)
12. I. Zachepa, O. Chornyi, A. Perekrest, N. Zachepa, O. Zbyrannyk, G. Mykhalchenko, Technical and Economic Assessment of Use Local Autonomous Sources of Energy Supply, in 2020 IEEE Problems of Automated Electrodrive. Theory and Practice (PAEP), Kremenchuk, Ukraine, pp. 1–6 (2020)
13. O. Zalunina, A. Perekrest, V. Ogar, O. Zbyrannyk, Formation of Informational Support in Construction for the Implementation of Energy Saving Measures, in 2019 IEEE International Conference on Modern Electrical and Energy Systems (MEES), Kremenchuk, Ukraine, pp. 526–529 (2019)
14. O. Zalunina, A. Kasych, V. Ogar, A. Perekrest, S. Serhiienko, M. Kushch-Zhyrko, Energy System Control Optimization Criterion Development, in 2020 IEEE Problems of Automated Electrodrive. Theory and Practice (PAEP), Kremenchuk, Ukraine, pp. 1–5 (2020)
15. V. Druzhynina, G. Likhonosova, G. Lutsenko, I. Kushal, Innovative technology in terms of socio-economic value diffusion: Accounting and analytical support. Eur. J. Sustain. Dev. **9**(3), 476–489 (2020)
16. V. Druzhynina, G. Likhonosova, Y. Viedienina, L. Sakun, Creative analysis of innovation as a Catalizer of socialization of structural change. Eur. J. Sustain. Dev. **9**(2), 349–365 (2020)
17. V. Druzhynina, G. Likhonosova, G. Lutsenko, Assessment welfare of the population in the synergetic system of socio-economic exclusion. Market. Manag. Innov. **2**, 54–68 (2018)
18. V. Druzhynina, G. Likhonosova, Strategic imperatives ensuring population welfare under transformation exclusion conditions. Balt. J. Econ. Stud. **3**(5), 135–146 (2017)
19. Nextbike, https://www.nextbike.ua/uk/, last accessed 2020/10/22

20. M. Kozłowski, Analiza możliwości wdrożenia systemu roweru publicznego w Kortowie, in Projekt "GREEN UNIVERSITY", Zeszyty Naukowe Instytutu Pojazdów, 2014, No. 2(98) (2014)
21. M. Dębowska-Mróz, P. Lis, A. Szymanek, T. Zawisza, Rower miejski jako element systemu transportowego w miastach, Efektywność transportu, in Autobusy, vol. 6, pp. 1173–1182 (2017)
22. L. Zhili, J. Xudong, C. Wen, Solving the last mile problem: Ensure the success of public bicycle system in Beijing. Procedia. Soc. Behav. Sci. **43**, 73–78 (2012)
23. Rower. Rower miejski – wypożyczalnia rowerów. http://wrower.pl/miasto/rower-miejski-wypozyczalniarowerow,2183.html. (Last accessed 2020/10/18)
24. Pomysł na bike-sharing dla małych miast: вебсайт. https://www.miasto2077.pl/pomysl-na-bike-sharing-dla-malych-miast/. (Last accessed 2020/10/18)

Part II
Digital Health, Learning and Industry

Chapter 6
A Survey of Societal Applications of IOT

A. Sharmila, E. L. Dhivya Priya, and K. R. Gokul Anand

6.1 Introduction

The forthcoming reporting is predominantly between computers to devices and devices to devices. They have the potential of presenting with each other and can interchange particulars without any human intervention and interactions. The number of things interconnected using IoT will increase drastically by years than the users of IoT. It establishes a platform between the natural world and the information world with the help of sensors which gather information from the real world and convert it into a machine-understandable format that is transmitted among the devices connected to the sensors.

Communication is done through the internet so that high-speed internet connectivity is mandatory. 5G internet connection will come to existence which takes IoT to remote areas and in densely populated regions with high-speed internet. Which can carry an excess amount of data and process the data with sufficient security.

Security is an added advantage in IoT. Data send and receive over the internet are highly secured from unauthorized persons. Internet of Things works well with wireless communications with the help of wireless sensor networks. All the devices utilized in our routine life can be tracked and superintendence by IoT. Sensors

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are accomplished in all individual spots in inclusion sensors alters naturalistic particulars into data alters gesture assists conveys them to the mentioned govern midfield. In this manner, the system permits to observe habitat subverts distantly from whatever residue of the globe through a computer network.

6.2 Motivation

IoT links the Physical world to the digital world. The paper narrates in short effectually the internet of things the dawning, progression, postulation of IoT. The motivation beyond the article is to have a brief note on the Internet of Things, understand IoT to a great extent, and its deployment in every application. In the future, trillions of devices are going to get connected through the internet of things and can have control over one another.

6.3 IOT

Internet of Things (IoT) is described as the interdependence of miscellaneous gadgets that can be predominance and grouping abstracted through a wireless substructure inwards instruct to inflate hominid interchange and upgrade fruitlessness.

Internet of Things is a transpire practice of communication between gadgets to gadgets, computer to devices, electronic gadgets, animals, humans with replication identity. IoT assists in conveying and acquire particulars through the internet in light of determining protocols not having the benefit of any human interference. Provides end to end communication with guaranteed security. Enables storage of data and can process data in the cloud through IoT.

6.4 Trends in the Internet of Things

- Security.
- SaaS – Software being a Service.
- Data Analytics.
- Smart City.
- Industrial IoT.
- Smart Home.
- Health Care.
- Environment.
- Global Connectivity.

6.5 Comparison with the Existing System

The proposed chapter proffers an epitome elucidation of the application of the Internet of Things. The chapter narrates in short effectually the internet of things the dawning, progression, IoT, application. The existing chapter of the application of the Internet of Things explores a limited number of applications of IoT. The proposed chapter instead of discussing the same, explore the smart home, smart cities, smart railways, smart health care, intelligent agriculture, smart military applications of IoT in recital. The chapter also narrates the commitment of IoT, phases, and its deployment in all fields.

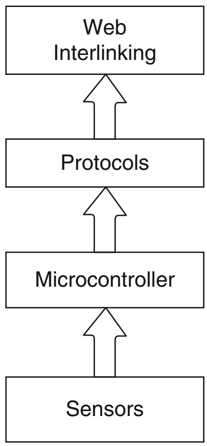
6.6 Agriculture Applications of IoT

6.6.1 Monitoring of Irrigation in Agriculture with IoT

IoT has a noticeable deployment in the field of agriculture. The gigantic deployment of IoT reframed many technologies without exception in industry inclusive of agriculture as a smarter one, IoT turned out the agriculture from prevailing method to modern methods [1]. The progressive changes are responsible for the current farming strategies and assists in getting rigid of difficulties prevail in agriculture [1]. The amalgamation of disparate sensors, to monitor the reputation of crops, the influence of climatic fluctuations and to irrigate plants in the stipulation to obtain better yield is substantiated with IoT in [1] (Fig. 6.1).

IoT gadgets and correspondence techniques related to remote sensors experienced in farming applications are examined. Sensors are inclusive of a temperature sensor, humidity sensor to aggregate the humidity constellation of the field soil,

Fig. 6.1 Irrigation monitoring with IoT



CO_2 sensor to compute carbon-dioxide consignment to conclude whether to irrigate or later and to monitor the crops assisting [1] web interlinking. Promotes Smart irrigation by diminution the excessive utilization of energy assets devoid of human arbitrament. The system in inclusion contributes to superior yield [1]. The particulars from the sensors are transferred to server assists protocols and are accessible by the client from the database in all aspects.

6.6.2 Smart Agriculture

IoT-based Smart agriculture is a transpire technology in which a framework is designed for investigating the status of fields with the assistance of sensors [2]. IoT promotes smart cultivation is profoundly productive while analyzing with the usual epistemology. Evolved horticulture applications assist smart and precision cultivation through IoT will empower operational proficiency, lower costs, diminish squander, and improve the nature of their yield. The three principle hindrances that the horticulture division faces in implementing IoT innovation. Poor internet connectivity in farms, High Hardware costs, Disrupted Connectivity to the cloud (Fig. 6.2).

The enhanced use of accessible resources is planned in the providence of IoT solutions. The horticulture field enthused with sensors is monitored perpetually for the collection of data and the optimal utilization of resources. The increased alertness of the methods can be achieved with the implementation of IoT in agriculture [2]. This helps the farmers to monitor the environmental conditions inclusive of weather, air, humidity and the gesture of animals may pulverize the crops are monitored. When the changes are detected with the proposed methods of IoT, the farmers are acquainted through mobile phones and the saving of crops can be improved higher [2]. Agriculture can constitute making more output products by the incorporation of data-driven methods of IoT. Smart Agriculture provides provisions for optimal irrigation as marginal and preeminent irrigation will deliberate on accrue. The farmer has control over the irrigation upon weather affairs, particulars, and strategies from the system. The proposed system assists in maintaining crops and to acquire finer yield.

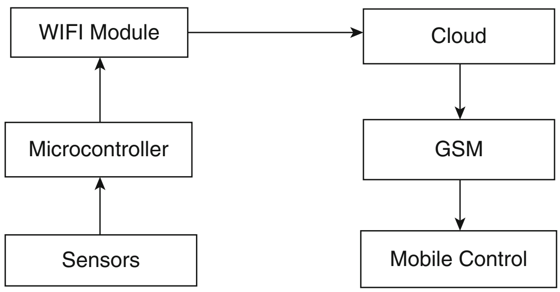


Fig. 6.2 Smart agriculture with IoT

6.6.3 Intelligent Irrigation

IoT is a versatile approach with an extensive ambit of application. IoT incorporates Modern methods of farming. Aside from epical methods of farming, contemporary farming proffer prime exertion of resources. IoT offers an intelligent irrigation system to irrigate crops devoid of personage intercession which requires manual irrigation of crops in a prevalent routine [3]. IoT assists in exterminating the desolation of water resources and in inclusion rescue time. Intelligent Irrigation system enforces sensors humidity sensors, soil moisture, temperature sensor to monitor the status of crops, field and resolve whether to irrigate based on the particulars gathered from sensors. The system imparts water resources when required as water is the prime source for all living entities [3]. The system prevents over watering and defective water furnish to crops as it results in drowns of plants and the cells of the plants will burst and the plant may perish. IoT offers comfort assists automation to have dominion over the gadget motor to control irrigation of farms, conveys a message to the mobile phone of the farmers exhaustively on the globe assists GSM module [3]. The proposed system assists in improving yield in agriculture (Fig. 6.3)

6.6.4 Automated Weather Report Causation for Smart Irrigation

The weather conditions have a preeminent influence on agriculture, human pursuit. The automated weather report causation system provides the weather outline provided by the meteorological services available to the farmers [4] so that they can take preventive measures to protect their crops from collapse. The system focuses on monitoring and reporting the weather outline incorporating the sensors like a rain sensor, dust sensor, gas sensor to measure the attribute of pollutants in the air,

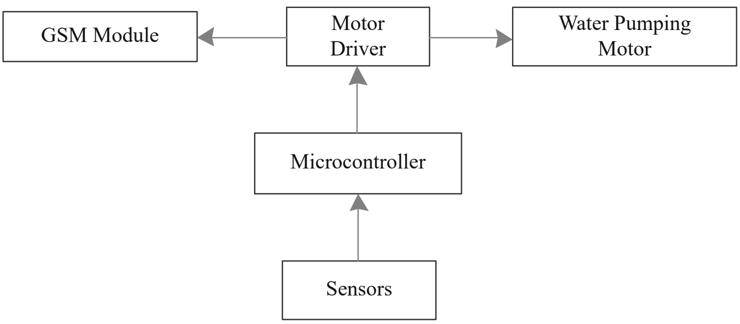


Fig. 6.3 Intelligent irrigation with IoT

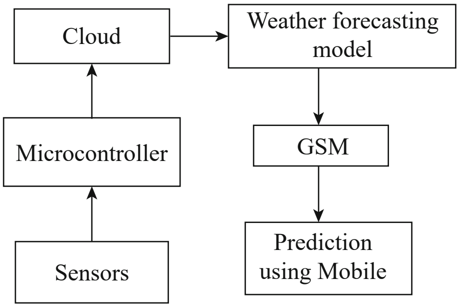


Fig. 6.4 Weather report causation for smart irrigation with IoT

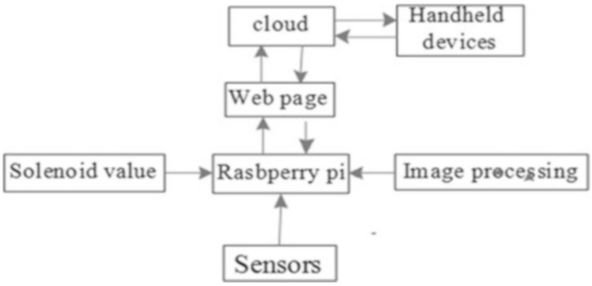


Fig. 6.5 Disease analysis in agriculture with IoT

temperature, humidity sensor, and assists the previous particulars to train the system and predict the weather beside the discernment with the current data [4] (Fig. 6.4).

6.6.5 IoT Based Disease Analysis in Agriculture

Agriculture is the vertebral column of our country. Our country has a profusion of sterile lands. IoT unveils modernization and assists in renovating hereditament. Agriculture is the Centre of vigorous refinement. Drastic accretion in population consequence in the expenditure of resources in an illicit manner as emanation there will be an insistence for food and water as further [5]. IoT assists in monitoring the status of crops whether it is afflicted by a grain of disease or it may deteriorate from insufficient afford of nutrients with the reinforcement of image processing techniques and IoT [5]. The system solicits two pertinent nutrients like nitrogen and magnesium as they are the major components for photosynthesis and to improve the yield of crops (Fig. 6.5).

The system also incorporates sensors like temperature sensors, humidity sensors, and solenoid values for intelligent irrigation in the inclusion of image processing techniques and the weather outline to the farmers so that they can take decisions of their own rather than the particulars obtained from the sensors [5]. IoT assists in making agriculture smarter and optimal utilization of resources and also contributes to the diagnosis of diseases so that the farmer can get better yield.

6.6.6 Flood Prevention Using IoT

India is the agriculture campaigner and the bulkiest promoter of agriculture outcomes. One-half of the country's work stead is implicated in agriculture. Unpredictable climatic conditions induce dissonant and inexorable conditions. The invariable climatic conditions have substantial supremacy on crop yield. The farmers were incompetent to manipulate the natural disasters like floods and drought escort ruin to crops and stiff deprivation to them [6]. The system assists in operating on the drought and flood conditions by the smart irrigation which draws out surfeit water in the course of flood conditions. The system in assistance maintains a database predicted on irrigation of fields, measurement of the amount of rainfall, amount of water surfeit on floods, humidity level of soil in the farm. The predictions from the database assist the farmers in restraining the crops from floods and furnish suggestions regarding the sort of the crop to emerge, instant to plow the crop, locale to cultivate [6]. The technique incorporates in preventing damage to crops and in inclusion, the farmers need no to worry about the unexpected rainfall or excessive floods. Advanced techniques such as aerial drown observing, farm mapping and incorporation of sensors helps the farmers with a better understanding of conditions and the quality of the crops. Because of the interconnected system, the improved nutritional value of the products can be achieved (Fig. 6.6).

The IoT agricultural utility is devising it attainable for glaziers, agriculturists to compile substantive particulars. The agriculturists requisite agonize the defensibility of IoT activity for horticulture by introducing brilliant advances to accumulate aggressiveness assists property in their products [6]. In inclusion of the exploded population, the request will be effectively comradely if the farmers, execute horticulture based IoT solutions in the best way. Consequently, the improvement of such areas as food and farming will consistently be a need. Hence IoT utilized in agribusiness has a hugely promising future as the main impetus of the productivity, Sustainability, and versatility in this industry.

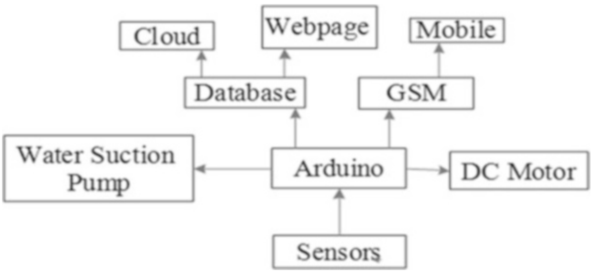


Fig. 6.6 Flood prevention using IoT

6.7 Healthcare Applications of IoT

6.7.1 IoT in Healthcare

The Transpiring tenor in cloud tallying and mobile applications, wearable devices technologies incorporating IoT accomplish healthcare smarter [7]. Smart healthcare is the solitary noticeable deployment of IoT. The expeditious enlargement of IoT reveals an indispensable role in health care province owing to its lesser expenditure and obvious convenience of the assistance. IoT with its rapid deployment in health applications tends to exaggerate communication to provide health aid to the person distressed (Fig. 6.7).

The system keeps tracking the person in requirement of health care assisting RFID tags which is extremely convenient by approaching doctor indulgence to patients [7]. Cloud tallying assists in cumulating and partaking particulars of patients.

IoT with the greatest advantages extends its applications in the field of healthcare devices [7]. The interconnection of healthcare devices will definitely support the medical system with automation and improved monitoring abilities.

6.7.2 Challenges in Health Care with IoT

Healthcare and medical egis depict sole of the greatest gorgeous solicitation sectors for life. Connected devices will make it easy for patients to track their health information. IoT fitness guidance provisions are more critical assignment to redeem long suffering consequence, and besides hold not many of the burdens of fitness practitioners. The Internet of Things was comprehensively instantiated as a latent infusion to meliorate the suction on attention substructure and it has been the engrossment of untold emerging investigation. Clinical IoT gadgets are equipped for interpreting the data and sharing them with specialists for real-time monitoring of patients. This live tracking is made possible with mobile apps and location finders. The paper [8] survey advances in IoT based healthcare technologies and reviews the state of the art network, applications, and industry trends in IoT based healthcare solutions. Further, the paper [8] proposes a bright assets simulation to deflate hedge

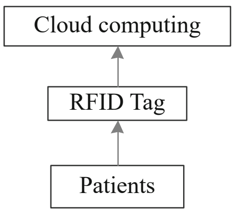


Fig. 6.7 Health care with IoT

speculative and provides some avenues for future research on IoT based on a set of open issues and challenges. The survey of IoT based healthcare systems presents the new healthcare network architecture along with the implementation platforms. It also facilitates medical data transmission and reception.

Challenges such as security and low power operations are considered during the design of IoT centered health care systems. This paper proposes an incomparable miniature for inevitable IoT based rehabilitate providence routine that will be appealed to habitual approach, and the technique that supervise especial co-ordinations. The advancement of techniques is the changes in the existing systems to provide a solution to the technological problem. This paper [8] also presents a buttoned up assist organized abridgement of the outlook of craft employs related to without exponent ingredient of the proffer miniature.

Several wearables, non-invasive sensors are granted and deliberated, inclusive of distinct essence on mentioned supervising viral cryptographs, haemoglobin stress, and haemoglobin its respiratory distribution. Miniature expanse and extended expanse conveying convictions were then contrasted in span of appropriacy for fitness supervision strategies. For the identification of the best industry-oriented enabled technology, the integration of gadgets, sensors with the technologies creates affordable healthcare devices along with the health services to limitlessly expand the potential of IoT-based healthcare services for further developments.

Contemporary province employ cloud equipments for particulars repository are granted and displayed that the cloud is the finest expedient for stowing and contriving enormous detail in fitness custody. In inclusion it is demonstrated by numerous entirety that superior particular concocting in the cloud can be easy than to persist executed in serviceable gadgets assists their restricted assets [8]. The peak crucial downside of adopting the cloud exhibits several hazards and so this paper presents several works on improving such risks and improves the security in the cloud. The technique estimates numerous defence requests and experiments and discloses a variety of research problems to propose a model that can mitigate associated security risks.

The e-Health along with IoT policies has been proposed for the benefit of various stakeholders interested in accessing IoT based healthcare technologies. It was inaugurate that ingress dominion strategies and secret writing can appreciably magnify guarding, yet that none avowed conventional is appropriate for expeditious administration into a serviceable, IoT premised robustness supervision system [8]. In inclusion, the outcomes of this inspection are anticipated to be convenient for academics, engineers, fitness proficient, and legislators operating in the sector of IoT and fitness supervision community (Fig. 6.8).

6.7.3 Multidisciplinary Health Care System

IoT is an auspicious technology. It desegregates the wireless sensor networks with sensors like infrared, magnetic sensors, microcontrollers to adjoin the obligations

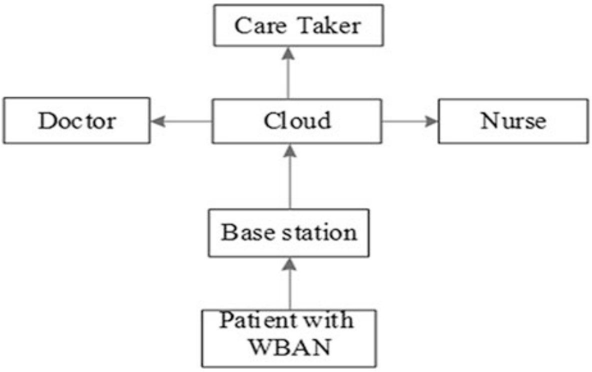


Fig. 6.8 Challenges in health care with IoT

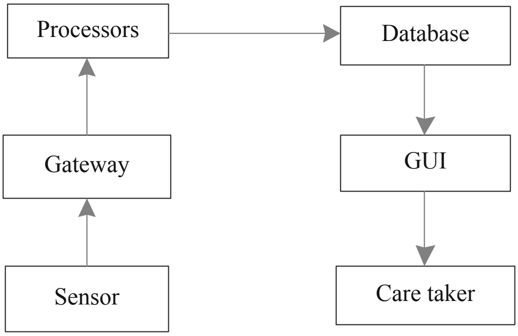


Fig. 6.9 Multidisciplinary health care system

of applications, protocols, hardware, databases [9]. WSN has two nodes interlinked by the gateway. The particulars from the sensor node are transferred to sink mode for further process of reserve and reporting. The nodes gather particulars from the patients and through gateway pass over the particulars to cloud database [9]. To upload evidence to the internet requires processors. The details of the patient in the database are available for the doctors, physician with the assistance of Graphic User Interface (GUI) applications (Fig. 6.9).

6.7.4 Survey on Internet of Things Based on Health Care

Health care monitoring provides online health care services to the oldster people progression of IoT revamps Medicaid assists precise and concerned protrusion. The system diversifies upgrades in IoT implanted health care strategies in inclusion contests the IoT protection and its requirements from health care ascertain [10]. The system debates the supremacy of big data and wearable devices in the fitness supervision techniques. It also reveals the contribution of IoT in assisting e-health intention, providence, and commonality for defensible habitat.

IoT assists in catena ting people by accrediting health and accession smarter through wearable widgets. The deployment of wireless sensor networks has a huge influence on the Internet of Things. It deals with unusual patients, monitors them, and provides health care measures to the patients in a hastened manner. The determinations from the professionals in the strategy of the discrepancy are offered to the patients through wearable widgets which are attached to the patients and it reports the anomalous status to the individual entrusted [10]. The system attains the sensor particulars, dissects the details, and furnishes counsel to the sufferers upon the parameters stated. The parameters like EEG, ECG, and Heart stature are deliberated assists wearable widgets to predict abnormal heart rate. The gadgets attached to the patients reinforce mobile phone to report the status to the doctors and the cloud. The wearable gadgets can accommodate sensors inclusive of temperature, capacitive sensors, accelerometer sensors, motion sensors to detect the temperature, motion of the patients. Mobile acts as a gateway between the widgets and the cloud [10]. The intercourse amid the gadget mobile through Bluetooth and mobile to thing speak via mobile internet and thing speak to IFTTT (If This Then That) through web reforms. The system continuously monitors the status of the patients and provides feasibility to the bargainers, assists in providing smart health care to the patients, the system averts unsought conveying, and dissent requires any labor (Fig. 6.10).

6.7.5 IoT Incorporate Attention Monitoring to Intercept Incursion

The deployment of IoT inclusive of electronic devices not to mention sensors paved the way for the huge stationing of wireless communication. Wireless Sensor Networks (WSN) assists in gathering patient status and to detect the disease [11]. The sensors like respiration sensor to detect the breathing rate, ring sensor to measure the heart rate and oxygen diffusion, collects details from the patients like

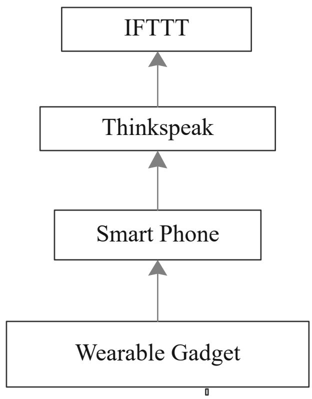


Fig. 6.10 Survey on the internet of things based on health care

temperature, pressure, heartbeat rate, temperature sensor, heartbeat sensor, ECG sensor to detect the muscular functions of the heart, blood pressure sensor, GSR sensor to measure the human emotion, stress by the conductivity of the skin, Graphene vapor sensor to measure the chemicals evolve from the skin, optical biosensor, health patch sensor it reports ECG, heart rate, breathing rate, temperature. TQM sensor a wearable widget to detect the conductivity of skin and temperature, oximetry sensor to report oxygen saturation, airflow sensor to detect the diseases like pneumonia, asthma, etc. these sensors incorporates in detecting the disease and cater beneficial commendation from the trained [11]. The system argues in reverse the SDN architecture converges sensor particulars of the patients from the cloud and proffer details of the disease to the patients and the doctors assist gadgets to alert. SDN architecture adopts MQTT (Message Queuing Telemetry Protocol) for effective communication. The system in inclusion clarifies about the cloud services available like Thing speak, IoT in inclusion affords IFTTT services which assists in conveying particulars to patients, doctors regarding the patients status according to their availability [11] in Facebook or WhatsApp referred to as SDN architecture for gathering particulars from the sensors, monitoring the details, siren to patients, doctors. The SDN architecture upon gathering the details from the cloud assists in diagnosing the disease and afford extensive security and flexibility in proffering particulars to the personage perturbed (Fig. 6.11).

6.7.6 IoT Based Healthcare with Body Sensor Network (BSN)

Body Sensor Network comprises of divergent sensors grated inwards or outwards in the human body system affords stupendous extensibility and marginal cost to the patients and the health care scholars despite its tremendous amenities [12]. The system assists in a smart healthcare monitoring system and monitors the patient guide subordinate sensors like temperature sensor, haemoglobin stress, and beating measure sensor to measure disparate parameters. The system endlessly

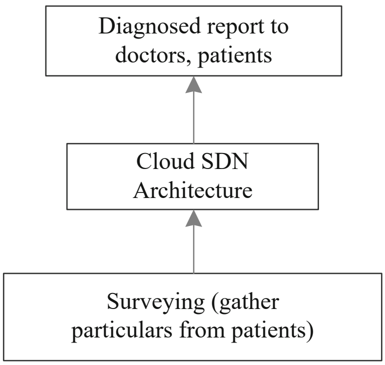


Fig. 6.11 Survey on the internet of things based on health care

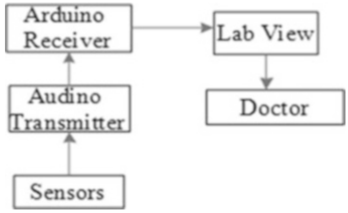


Fig. 6.12 IoT based healthcare with body sensor network

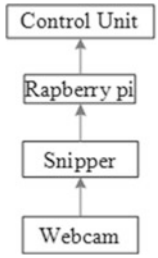
accumulates the particulars from the sensors with the assistance of a microcontroller to the Arduino transmitter, the measured are analyzed regarded to threshold values assisting VISA (Virtual Instrumentation software Architecture) in the Arduino receiver following the personal computer, allocate details with the personage accompanied through LabVIEW applications and repost it the statistics and resolve the report [12]. The system was devoid of the requirements of human competency for particulars access. The specialist requires only internet access to monitor the patient report (Fig. 6.12).

6.8 IoT in Military

6.8.1 Smart Sniper with IoT

Soldiers are the patrol of the constituency. Soldiers defend the nation from terrorist intervention and auxiliary aggression. Soldier's preservation is superfluity anxious for the development of a country. The nation is unable to absolutely reinstate soldiers, by in gather surrogate. Soldiers can be assisted through the imitation of automation, intelligent retrieval, and endure monitoring gadgets affords soldiers in their regular usual. Wireless sensor networks can predict the access of aspirant contingent [13]. The smart sniper gleaned from IoT techniques incorporates two perception constituents, the first perception component comprises of firing module and is accommodated in the warfare locale and the second component is the control unit lay down in the command center [13]. The system will is coherent over 200 m affords assurance to the health conditions of the soldiers following IoT. The enemies are recognized and monitored, knockdown perpetually proffers camcorder ascend on sniper shifts in all directed towards the target, confined by eminently assured GUI web page and the sensors throughout the occasion of warfare. The system safeguards the life of profusion of soldiers, in inclusion offers immense snug and only the authorized personage can access [13]. The snipers can be confined competently with the assistance of motion sensors the same technique can be incorporated in drones (Fig. 6.13).

Fig. 6.13 Smart sniper with IoT



6.8.2 *Military Applications in Smart City with IoT*

The consequential contrivance in the enclosure of military application is the contingent attention the system previously in acquaintance comprises the implementation of an extensive span of sensors and self-executing airborne vehicles. The system utilizes intercontinental potency to proffer relief to the people in a city troubled by disaster [14]. The system tends to upsurge the knowledge provenance like sensors to measure pollution and weather conditions to gather the particulars and to route the details for effectual governance. Many techniques are suggested for the automatic health monitoring of soldiers. The soldiers are furnished with sensors to monitor health conditions and gadgets monitoring [14]. The system consists of deliberate wear incorporate with a medical sensor to detect the heartbeat rate and muscular activities. The deliberate dress is also accumulated with a water level sensor to predict the quantity of water available for soldiers, an RFID tracking system to predict the equipage accessibility inclusive of the magazine, firearm with the soldiers. The sensors are connected to the Arduino microcontroller assists Bluetooth module. The system endlessly monitors the status of the soldiers by tracking and clarifies whether the person and the equipment offered are sufficient to complete the mission the particulars are conveyed to the leader through the MANET web work. The method depicted duplicating warfare in [14]. Argue an assumption in which an astute city is struck by the disaster because of the alliance attack. A multinational force is installed to proffer comfort. The initiator's precedence is to reform, to accept factual instance stipulation accusation, to supervise the attention assists intelligent IoT sensors. The attack in alliance nations and the system of protecting the nation was highlighted with the IoT techniques. The system in inclusive convey the strategies to the health care monitoring and disaster management team to do the destitute to rescue the nation in disaster, assists soldiers in knowledge provenance and offer assurance to the safety of soldiers by monitoring their equipment's status, obligation, forthright soldiers, communication with them with Mobile Adhoc Network. In the event of discrepancies, the status report to the health care monitoring system proffers assistance and the disaster management take responsibilities. The system affords safeguards the resistance to the disaster in an effectual manner. The issue of confidentiality and integrity was identified in [14]. The proposed object-level protection with IoT is by giving Cryptographic access. IoT gadgets inclusive of Malicious menace which will transform and adjusts the particulars [14]. The objective proposed can be implemented with the attestation mechanism. Imperfection patience is separate semblance of IoT military deliberation. To address these objectives, experiments assist the enforcement of the protection mechanism. Earlier reviews of application IoT is in the contacts of defend and public safety. Elaborate surveys of shelter stimulation with IoT systems are being procurable, inclusive of machine unfavorable system. Incorporation of inferior IoT's assists machine evaluative system is debated (Fig. 6.14).

6.8.3 IoT Based Military Federation

The redemption of the nation supremely, solely depends on the military federation and soldiers. The requirement of enhanced military confederation is indispensable to safeguard the nation. The system investigates the mystery of the military federation, suggests and implements the techniques to prevail over the riddle [15]. The system executes the four overlay architecture diagnosing, conveyance, refining, and a package of the network. In the first tier, the particulars are accumulated from the sensors, RFID tags, and accomplish the preliminary detection. The convey tier is inclusive of numerous networks like fiber-optics, sensor networks, Adhoc networks to convey details of the diagnosing tier to the refining, package tier. The refining tier process the particulars appraise the enforcement. Disparate techniques are attainable to perform data analysis, to extract resolution on the particulars. Wearable device configuration incorporated with sensors to predict the metrological provisions, the health status of soldiers. Dispersion of cartridges is extensively immense throughout warfare conditions [15]. The incorporation of sensors was found important in these applications like wear sensors to deal with the injury, sensors incorporate in weapons to predict the locale, alive status of the equipment, global positioning system to track the locale of military wagons. The particulars from the sensors are transferred to a direct platform. The platform can have access to control, operate the equipment, connected to the server to share the particulars over the internet. The sensors include temperature, humidity, smoke, and toxic gas along with Zigbee was proposed to

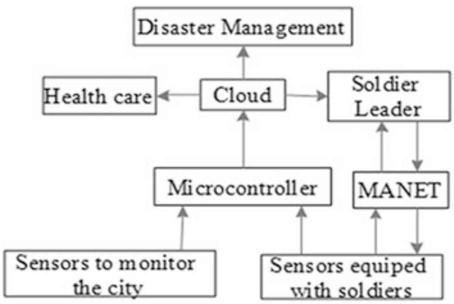


Fig. 6.14 Military applications in smart city with IoT

improve the protection mechanism and transportation. IoT based system for logistic support was proposed in [15] where an Integral part of IoT is its protocol. Wireless protocols have a high dependence on IoT. MQTT, RFID, BLUETOOTH, WI-FI. Lora Wide Area Network based IoT was designed which is used in sensors and microcontrollers. The range of LoRa is about 10+ Kilometers of communications, the effective range being tested with the appropriate result. RFID and BLUETOOTH are for smaller range applications. In dealing with IoT devices the most observed thing it does not ask for a strong password to communicate. So this demands security in military IoT implementation.

6.8.4 Fault Tolerant Techniques on the Internet of Military Things

The fault tolerance mechanism for military applications based on IoT was proposed in [16]. An important aspect of the military operation in wars and during peacetime is proper situational awareness. Due to the increase in citified region military operations will conduct to an immense bound. Different types of sensors and unmanned vehicles already in a wider range of applications for gathering intelligence. The system utilizes the five-tier architecture of the Internet of Military Things inclusive of diagnosis tier, refining tier, conveyance layer, assistance tier, package tier. The diagnosing tier incorporates procurement and wireless communication assisting sensors, RFID. The refining tier processes the particulars and conveys details with other nodes through the radio interface. The conveyance tier incorporates various networks to transmit the details assembled. The service tier is to save particulars, compute, search the particulars. The system is ablest to detect the misconduct, desperate individual misconduct from the performing system prevents misconduct from spread out. The system in inclusion narrates the misconduct diagnosis techniques. In this paper [16] the common contest assists IoT is neither a communal format of broadly acquired criteria for conveying, particulars dissemination, and assisting elaboration. The substructure for astute cities was acquired from the system, to put forward an intersect stair head substructure, particulars superintendence for conveying details intermediate disparate scheme. The experiment focused on the current IoT approaches, eminent exercises employed sustain for Helsinki formulations assisting sensors. The astute city relies on establishing acceptable automation assists to reduce the prevailing troubles. The mountain of unprocessed details from IoT gadgets, rigorous assets, instance restriction of military rescue activity, requires a solution, processing, and dissemination. The system postulates soldiery confine grade particulars from sensors employed on broad extend of stair head [16]. Sensation prediction, locale prediction, gesture prediction, and distant pile up by sensor platforms through a diffused form.

6.8.5 IoT Based Military Applications

IoT is the hasty flourishing automation that incorporates superior dissemination. IoT reveals a cardinal position in military applications. It is obligatory to rescue subsists of fighters as they are the safe guarders of the nation. Commanding the equipment utilized in the military is an auspicious part of military applications [17]. The system elaborates on the protocols and the techniques required to be implemented in the military federation. Automation paved the way to rescue fighters. Wireless sensor networks assist in predicting the locale of enemies and desolate them automatically. War is not the only reason beyond losing warfighters yet ecological too leads fighters to struggle [17]. The effective system is in devoir of techniques to rescue soldiers in all circumstances. The soldiers are provided with wearable gadgets and RFID tags to monitors them individually. The particulars regarding the soldiers are conveyed to the leader of the military federation in the headquarters. Equipment employed are stopple to fighters upon detection of their requirements [17]. The system in inclusion afford measures to rescue from disaster, promotes intercommunication interpolate soldiers. The system offers immense security.

6.9 IoT in Railways

The capability of transferring data along with a network without human intervention is made possible with the designed IoT devices. A system integrated with communication, control, and information processing devices can be used with the transportation systems along with improvised IoT Techniques. Railways have been playing a vigorous role in public as well as commercial transportation since the nineteenth century. But unfortunately, railways have been facing severe problems in terms of maintenance.

Condition-based maintenance (CBM) uses its own concept combined with the concept of IoT. To implement the concept of IoT, we need a physical base infrastructure that is provided by a railway communication system. Technically speaking, IoT consists of phases inclusive of recognizing, admittance, and refining. Here we analyze whether IoT has its business by transferring it into narration its propriety to the railway sustainment and also its compatibility with CBM and Radio Access Technologies (RATs). The overall aim is to keep the railway system in good condition during its lifetime [18]. The first step includes the inspection of the target based on which its status is decided and maintenance actions are prioritized. The consequences of a high budget can be reduced by increasing efficiency and reducing the cost. Based on a survey it has been concluded that three targets namely track, bridge, and tunnels require major maintenance. Physical inspection of these targets takes most of the allocated budget. One of the methods to improve the efficiency of inspection can be done by the usage of IoT. Various types of sensors are employed in the terminals of our IoT solution. Extremity is pre-owned to dominion and supervises the sensors. The sensors are placed such that it covers a wide area by which the unit cost of terminals can be reduced from the capital expenditure (CAPEX). A railway device is usually replaced every 5–10 years. Reliability and power consumption are two aspects considered along with the operational time. The reliability is articulated in terms of MTBF (mean time between failures) which has to be at least 50,000–100,000 h. In terms of battery, the power supply is not available everywhere. So, the power consumption by the terminals should be reduced such that the battery life is for more than 3 years. The information regarding various maintenance targets is needed by various data consumers. Therefore these data should be processed, accessed, and collected at the proper time. IoT also promises to deliver these data at right time. Our IoT solution consists of a device platform, gateway, IoT Network, and platform server [19]. Our device platform consists of hardware functionality board sensor HAL, sensing controller, communication controller, and service convergence. The sensor information from the field is transferred to the trackside (through small distance) and the railway network (through long-distance) and finally to the data center. The condition information from the maintenance target is efficiently collected and said to a central node called the platform server [18]. The control of traffic density was made possible with the IoT devices.

Considering the current status of the railway operators, there are two potential candidates for the IoT networks namely LTE and LoRa. LTE has been evolved from GSM which is already in use while LoRa is a specialized low-power IoT device in a wide area. On conducting a performance evaluation through a field test, it is identified that the maximal transmit power LoRa is smaller than LTE. In terms of area coverage, LTE covers a slightly wider area (about 15%). In terms of error, the LTE packet error is more frequent. But it compensates for the error quickly by HARQ. About the power efficiency, LoRa is more efficient than LTE. Another possible alternative is that using Narrow Band IoT (NB-IoT). NB-IoT has a compromised performance between LTE and LoRa. A major difference is that in LoRa only the terminal side can trigger a connection while it can be done by both terminals and base station in NB-IoT. Lora is more efficient with the best power consumption while NB-IoT has its advantage in data latency [18].

In paper [19] the major problems and opportunities associated with smart railway infrastructure have been discussed. IoT being considered in our solution, it is ready to be applied in the field considering the practical issues. The evolution of IoT technology will be path changing and will continue to create a new innovative world.

6.10 Smart Train Detector Using IoT Approach

Railways are the most important mode of transportation used by people. Misuse of technology against passengers has been increasing lately. It is significant to ensure the safety of the passengers. Various authors have proposed various models in their literary works previously. The current scenario of train identification and traffic signaling is a bit flawed [19]. To overcome this a system comprising safety monitor, early warning system needs to be developed.

A load cell is a sensor that is used to measure the weight quantity of the object placed by converting the force being measured into the electric signal. There are several categories of load cells namely single point, bending point, compressive, and tensile [19]. It possesses various drawbacks such as overload, wiring issues, etc. Metallic sensors (proximity sensors) sense metallic objects without any physical contact with the target. The proposed device consists of a load cell and a metallic cell. The objective of our cell is to incorporate several signaling strategies to ensure safety by detecting the arrival of the train between a pair of railway blocks. The device is fitted on the railway track waiting for the train to arrive [20]. When the signal is sent to the metallic sensor upon arrival is transmitted to the load cell and the arrival of the train is verified, if not the loop is continued. The device is tested for various test cases and outcomes have been obtained.

The proposed device – The smart train detector, uses one of the recent technologies, the Internet of Things (IoT). But considering the external factors, the implementation may encounter some changes. Thus, it is required to test the device for various teat conditions post-implementation so that it may be more efficient and beneficial [19, 20].

6.11 IoT in Smart Cities

IoT is an intelligent system for providing smart and widespread applications that are being one of the maximum interesting future trends. From rural areas to urban areas, modernization has been an integral part of shaping the lifestyle of the people. Hence, in the communication sector, it helps one to communicate with another user with the help of the internet, as the internet has become more immersive nowadays. It is designed to allow cities to utilize urban networks and hence released a concept of "Smart City" [21]. Synchronization of small mechanizations can lead to much larger accomplishments as individual automation can lead to the formation of a smart city that is being automated in the future. Its main aim is to make better use of public resources that are being offered to the citizens. This can be attained by the development of urban IoT [21].

Some of the services that can be enabled by this plan are to check the mechanical health of buildings by combining vibration and seismic readings, waste management by using intelligent waste containers, checking the quality of air (in crowded areas, parks, trails, etc.), monitoring of noise with sound detectors, traffic congestion by installing GPS on modern vehicles, smart parking by using Radio Frequency Identifiers (RFID), smart lightning of street lights according to weather conditions and automation of public buildings [21].

Sensors can be developed at different locations for collecting and analyzing data to improve usage. Some of the future applications of IoT for smart cities are Smart homes -sensors to detect the pollution limit, Smart parking lots – to track the number of vehicles being parked, weather and water systems that can utilize some sensors to provide accurate information on temperature, rain, and pressure. Nowadays, Security is the most important factor hence analyzing data and detecting crimes are many challenging ideas. Internet of things in which the gadgets gather particulars from sensors, communicate with one another**.** The system affords to convey particulars effectively.

The application of IoT deals with the typical challenges that raised in smart cities like Security and privacy [22] – there is a chance of vulnerability as all the data are collected and analyzed in a common IoT platform, Heterogeneity – as every component are being placed in a particular application context to determine the required computing hardware and software and then integrating is the biggest challenge, Reliability – due to the presence of numerous smart devices, Large scale of information requires storage and computational capability, Data is a big deal as it consists of about 50 billion devices and it is necessary to pay attention of transferring, storing and recalling of data and many more challenges yet to be faced [22].

In the world of rapidly growing urban areas, it is difficult for one to survive without water. This water demand is due to massive wastage of water, pipeline leakage even till date. Monitoring of water resources can lead to the prevention of water theft and the use of PLC can control the supply of water [19]. At present, the water distribution is dependent on manpower which leads to wastage of resources as the time required for job completion leads to water theft because of increased usage of water. In the automated system, pumping stations are controlled by IoT enabled PLC equipment which is hydraulic and electrical. In case of a low water level detection, the sensor will start the motor of the pump station [19] (Fig. 6.15).

A change from the rural city into an urban city than to a metropolitan city but the problem of road traffic has been a big problem that is being faced by every people in their life. Sensors in the street cameras will send information to the operation Centre. The operation Centre then sends relevant instructions to IoT-imbibed traffic lights to change the direction to clear out congestion. Another problem is with the emergency vehicles carrying a patient being congested with the traffic. To overcome this,

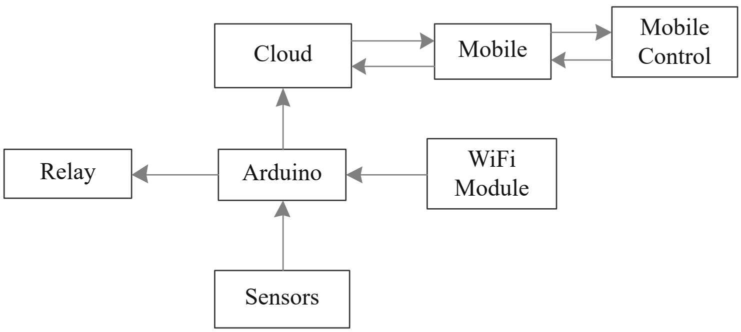


Fig. 6.15 IoT in smart cities

marking the emergency vehicles with infrared red beamers will give out infrared signals. Also, the thought of self-driving cars will reduce accidents and put down congestion.

Hence, the utilization of intelligent systems and sensors will lead to the smart city with advanced digital technology and different electronic devices on the origin of IoT, therefore, becoming smarter than before.

6.12 Smart Home

A smart home is fashioned out of the devices aforesaid is connected to the whole lot and the internet with the assistance of a wireless forum. Smart home particulars include IoT devices like sensors to measure temperature, humidity, the gathered particulars are reported to cloud from controller assists gateways. Protocols assure security for the particulars revolved midst smart devices.

Smart homes impart superlative gradation of affability and avert energy provisions in a provocative fashion. Home automation is a transpiring deployment of IoT, IoT exercises numerous application like mobile phones, internet integration, wireless sensor networks, and mesh stationed applications to have access over the home gadgets. The personage can access the gadgets from whatever locus on the globe. The proposed system focuses mainly on integrating gadgets over the internet and to access them from wherever required [23]. Home automation in inclusion ensures the optimal utilization of energy resources. Affords flexibility to the dotage personages. Numerous sensors, camcorders are incorporated in home automation, controllers to gather particulars from the sensors and to take necessary measures to access the home gadgets assisting vintage of equipment through the internet. Home automation automatically turns on and off the electrical appliances once it detects the personage, intimate them regarding the concerned pursuit adopting sensors like temperature sensor, PIR sensor, current sensors, gas sensor, relays, camcorder, biometric approaches to affords huge security [23]. The system requires internet connectivity to access the gadgets and only the authorized personage can access the gadgets. The end-user can have access over home gadgets assisting net stationed benefit, google assurance with IoT established with adafruit, IFTTT (Fig. 6.16).

6.12.1 Energy Competent Home Automation Using IoT

India is one fourth the bulkiest purchaser of energy owing to its utmost population. To come out of the energy requirements, the resources should be utilized at its precise level. Effective utilization of resources assists in handling energy deficits. Home automation assists in managing energy resources and affords security [24]. Home automation is the assimilation of gadgets and interrelation between them.

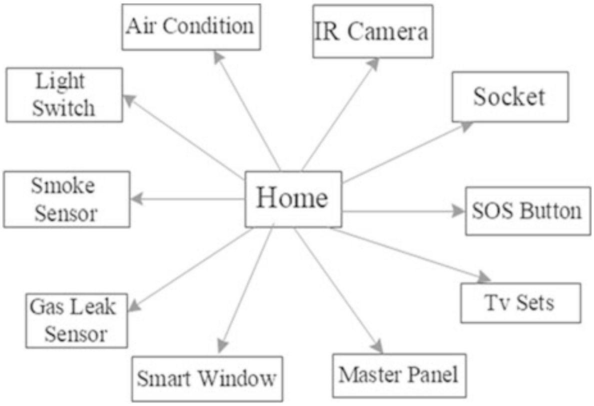


Fig. 6.16 sensors in IoT

Intelligent home automation reinforces dealing with the troubles in previously mentioned techniques through sensors, gadgets, applications, particulars transferring network [24]. Home automation furnishes Wi-Fi components, relay to have control over the home gadgets, cloud configuration, REST protocol to convey from mobile to Wi-Fi, and user access to gadgets. The system in inclusion elaborates protocols and their utilities [24].

6.12.2 *Home Gadgets Control with IoT*

Home gadgets are the active participants in home automation as they communicate, share details regarding the particulars gathered with one another assisting network articulation. The system responds automatically to the actuality globe refinement assists sensors like temperature, humidity, level sensor, and personage arbitration occasionally [25]. The system assures optimal exertion of energy resources by message through mobile phones, proffer flexibility, security by the anticipation of particulars, have access over gadgets from whatever locus on the globe, rectifies and treat the troubles occurred by conveying the trouble to the service persons and the proprietor [25]. The system grants end-users to access gadgets like a fan, TV in their home by the smart mobiles, personal computer from whatever locus on the globe through remote, assists an internet association. In inclusion, the system predicts trouble and provides notifications to the user [25]. Initially, sensor particulars are measured and analyzed assisting microcontroller and access through mobile or pc combined to the system which utilizes Naive Bayes classifier algorithm for particulars moaning.

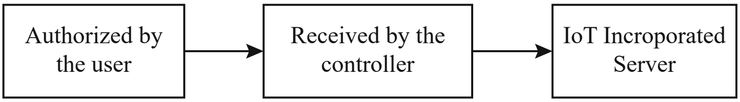
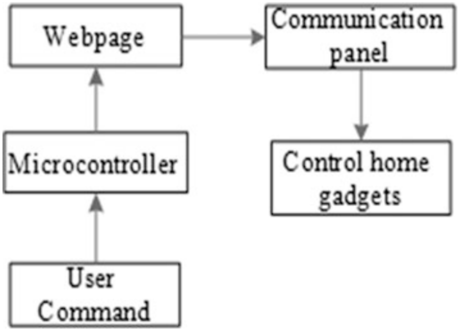


Fig. 6.17 Wireless smart home automation with IoT

Fig. 6.18 Home automation with IoT



6.12.3 Performance Analysis on Wireless Smart Home Automation

Home automation is the adorable deployment of the Internet of Things. Home automation assists in monitoring and controlling home gadgets with IoT distantly, whatever locus on the globe. Mobile phones or computers are employed to access the home gadgets assisting web page with internet interference [26] (Fig. 6.17).

The system offers contingency to the end-users. System contrive on three main approaches first authorized by the user like turn aside fan or TV ensue by the reception of dictate from the customer to the controller pursue by conveying it through IoT incorporated server to controller specified Smart.

Home automation actualizes the web folio locale from where the gadgets are accessed provided with Wi-Fi intermediary to have dominion over eight diversified gadgets. The system disregards personage interference and enhances the endowment of existence [26]. The system is proffered with a communication panel connected to a hotspot, Arduino panel which is to access the communication panel provided with a default Wi-Fi connection. The communication panel begins muster grant from the user through the web page after verifying internet connectivity. The system access the home gadgets according to the user grant (Fig. 6.18).

6.13 Industrial IoT

Industrial IoT application incorporates smart sensors, equipment, operating system platforms, cloud framework, and applications. Deployment of sensors contributes towards the deployment of all fields' assists automation. The sensors collectively form the sensor network to convey particulars to the IoT portal Which is the center of communication among the IoT gadgets and the cloud assists in transmission, reception of particulars to the cloud for further clarifications. Experienced administration streams are progressed to manage huge particulars inward of a steady network through mobile applications.

6.13.1 The Internet of Robotic Things

The Internet of Robotic Things is a transpiring procedure to accomplish prevalent sensors and commodities that assist automation with robots. Internet of Things assistance Robotics technologies leads to the deployment of robotics system and Internet of things correspondingly. The association of robotics with IoT empowers the conception of advanced, probably troublesome indulgence.

Cloud computing and the IoT are desperate fields from robotic facilitators, they assist in enabling disseminated roaming approaches. Upon requirement, cloud computing affords online network admittance to the hardware gadgets for transferring particulars to the cloud for the aspiration of a stockpile.

IoT commodity assists cloud computing to establish flexible IoT forum exertion to administrate accession to sensor particulars. The cloud prototype was preferred by the robotics commodity designated as cloud robotics for delegating assets comprehensive obligations, reroute to the broadcasting of particulars from the sensor and comprehension among robots, for a constellation of robots consecutive application reserve model.

6.14 Recognition Proficiency

The sensor particulars analyzation systematizations of IoT afford robots augmented perspective contrasted to convenient accessible diagnosing, in obedience to the grading of the manifest. Regardless, mounting sensors on mobile robots permits to locale those in an adaptable, energetic manner, permits enlightened exertive recognition intention. The cardinal requirement of robots' recognition proficiency is acquiring apprehension of the locale of themselves, in inclusion the proficiency to formulate else rejuvenate standards. Even though robotics has huge achievements, automation in the detection of their locale is a rigorous province in congested, Global Positioning System (GPS)- disclaimed interior habitats, Radio frequency identification (RFID)- IoT rudiments assists in proffers trustworthy locale particulars to accustomed robots.

6.15 Fluctuation Proficiency

The proficiency to fluctuate is the indispensable superfluous benefit of robotic systems. In inclusion streamlined pattern is the prime ingredient to evaluate the inherent effectuality of robot fluctuation, IoT technology contributes to mobile robots by assisting robots to access doors through automation, elevators. IoT, machine to machine communication in association with consorting protocols capable of assisting the progression of dispensed robot access architectures in exhaustive applications, inclusive of delicacy agriculture, health care, smart city, smart military monitoring. The mandatory applications like rescue the soldiers, personage from disaster, in which debate framework competes for a preeminent part even in the absence of conveying framework deficit, mobile robots assist in framing conveying framework, mobile ad hoc network to act as supporting hosts for effective communication.

6.16 Conclusion

IoT based systems are inevitable in the current era. Quality of life is enriched with IoT. The framework decides the technical realization of IoT based systems. Challenges exist and to be solved with the hardware implementation of IoT systems. With this rapid deployment of IoT, In the future Billions of devices are going to be connected through IoT. Device to device communication is the major achievement of IoT which reduces human intervention.

References

1. G. Carrión, M. Huerta, B. Barzallo, Monitoring and irrigation of an urban garden using IoT, in 2018 IEEE Colombian Conference on Communications and Computing (COLCOM), Medellin, 2018, pp. 1–6, https://doi.org/10.1109/ColComCon.2018.8466722
2. G. Sushanth, S. Sujatha, IOT based smart agriculture system, in 2018 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), Chennai, 2018, pp. 1–4, https://doi.org/10.1109/WiSPNET.2018.8538702
3. M.N. Rajkumar, S. Abinaya, V.V. Kumar, Intelligent irrigation system – an IOT based approach, in 2017 International Conference on Innovations in Green Energy and Healthcare Technologies (IGEHT), Coimbatore, 2017, pp. 1–5, https://doi.org/10.1109/IGEHT.2017.8094057
4. A.J. Rau, J. Sankar, A.R. Mohan, D. Das Krishna, J. Mathew, IoT based smart irrigation system and nutrient detection with disease analysis, in 2017 IEEE Region 10 Symposium (TENSYMP), Cochin, 2017, pp. 1–4, https://doi.org/10.1109/TENCONSpring.2017.8070100
5. A. Parashar, IoT based automated weather report generation and prediction using machine learning, in 2019 2nd International Conference on Intelligent Communication and Computational Techniques (ICCT), Jaipur, India, 2019, pp. 339–344, https://doi.org/10.1109/ICCT46177.2019.8968782

6. S. Gupta, V. Malhotra, V. Vashisht, Water irrigation and flood prevention using IoT, in 2020 10th International Conference on Cloud Computing, Data Science & Engineering (Confluence), Noida, India, 2020, pp. 260–65, https://doi.org/10.1109/Confluence47617.2020.9057842
7. N. Ahmad, R. P. George, R. Jahan, Emerging trends in IoT for categorized health care, in 2019 2nd International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT), Kannur, Kerala, India, 2019, pp. 1438–1441, https://doi.org/10.1109/ICICICT46008.2019.8993208
8. S.B. Baker, W. Xiang, I. Atkinson, Internet of things for smart healthcare: Technologies, challenges, and opportunities. IEEE Access **5**, 26521–26544 (2017). https://doi.org/10.1109/ACCESS.2017.2775180
9. J. V. Alamelu, A. Mythili, Design of IoT based generic health care system, in 2017 International Conference on Microelectronic Devices, Circuits and Systems (ICMDCS), Vellore, 2017, pp. 1–4, https://doi.org/10.1109/ICMDCS.2017.8211698
10. S. Ananth, P. Sathya, P. Madhan Mohan, Smart health monitoring system through IoT, in 2019 International Conference on Communication and Signal Processing (ICCSP), Chennai, India, 2019, pp. 0968–0970, https://doi.org/10.1109/ICCSP.2019.8697921
11. A. Srilakshmi, P. Mohanapriya, D. Harini, K. Geetha, IoT based smart health care system to prevent security attacks in SDN, in 2019 Fifth International Conference on Electrical Energy Systems (ICEES), Chennai, India, 2019, pp. 1–7, https://doi.org/10.1109/ICEES.2019.8719236
12. V. Vippalapalli, S. Ananthula, Internet of things (IoT) based smart health care system, in 2016 International Conference on Signal Processing, Communication, Power and Embedded System (SCOPES), Paralakhemundi, 2016, pp. 1229–1233, https://doi.org/10.1109/SCOPES.2016.7955637
13. B. Bumble, S. Katkar, D. There, G. Arage, S. Bagwan, M. Jadhav, IoT based smart sniper, in 2017 International Conference on I-SMAC (IoT in Social, Mobile, Analytics, and Cloud) (I-SMAC), Palladam, 2017, pp. 557–561, https://doi.org/10.1109/I-SMAC.2017.8058241
14. F. T. Johnsen et al., Application of IoT in military operations in a smart city, in 2018 International Conference on Military Communications and Information Systems (ICMCIS), Warsaw, 2018, pp. 1–8, https://doi.org/10.1109/ICMCIS.2018.8398690
15. J. Wang, L. Cao, Y. Shen, G. Zheng, Research on design of military logistics support system based on IoT, in 2018 Prognostics and System Health Management Conference (PHM-Chongqing), Chongqing, 2018, pp. 829–832, https://doi.org/10.1109/PHM-Chongqing.2018.00148
16. J. Chudzikiewicz, J. Furtak, Z. Zielinski, Fault-tolerant techniques for the Internet of Military Things, in 2015 IEEE 2nd World Forum on Internet of Things (WF-IoT), Milan, 2015, pp. 496–501, https://doi.org/10.1109/WF-IoT.2015.7389104
17. J. Furtak, Z. Zieliński, J. Chudzikiewicz, Security techniques for the WSN link layer within military IoT, in 2016 IEEE 3rd World Forum on Internet of Things (WF-IoT), Reston, VA, 2016, pp. 233–238, https://doi.org/10.1109/WF-IoT.2016.7845508
18. Ohyun Jo, Yong-Kyu Kim, Internet of things for smart railway: Feasibility and applications. IEEE Internet Things J.. https://doi.org/10.1109/JIOT.2017.2749401
19. Himadri Nath Saha, Supratim Auddy, IoT solutions for smart cities, in 2017 8th Annual Industrial Automation and Electromechanical Engineering Conference (IEMECON), https://doi.org/10.1109/IEMECON.2017.8079565
20. P. Srivastava, R. Majumdar, et al., Smart Train Detector using IoT Approach, 978–1- 5386-5933-5/19/$31.00_c 2019 IEEE
21. A. Zanella, N. Bui, A. Castellani, Internet of things for smart cities. IEEE Internet Things J.. https://doi.org/10.1109/JIOT.2014.2306328
22. H. Arasteh, V. Hosseinnezhad, Iot-based smart cities: a survey, in 2016 IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC), https://doi.org/10.1109/EEEIC.2016.7555867

23. S.K. Vishwakarma, P. Upadhyaya, B. Kumari, A. K. Mishra, Smart energy efficient home automation system using IoT, in 2019 4th International Conference on the Internet of Things: Smart Innovation and Usages (IoT-SIU), Ghaziabad, India, 2019, pp. 1–4, https://doi.org/10.1109/IoT-SIU.2019.8777607
24. P.A. Dhobi, N. Tevar, IoT based home appliances control, in 2017 International Conference on Computing Methodologies and Communication (ICCMC), Erode, 2017, pp. 648–651, https://doi.org/10.1109/ICCMC.2017.8282546
25. K. Agarwal, A. Agarwal, G. Misra, Review and performance analysis on wireless smart home and home automation using IoT, in 2019 Third International conference on I-SMAC (IoT in Social, Mobile, Analytics, and Cloud) (I-SMAC), Palladam, India, 2019, pp. 629–633, https://doi.org/10.1109/I-SMAC47947.2019.9032629
26. H.K. Singh, S. Verma, S. Pal, K. Pandey, A step towards home automation using IOT, in 2019 Twelfth International Conference on Contemporary Computing (IC3), Noida, India, 2019, pp. 1–5, https://doi.org/10.1109/IC3.2019.8844945

Chapter 7
Simplify the Difficult: Artificial Intelligence and Cloud Computing in Healthcare

Sargam Yadav, Abhishek Kaushik, and Shubham Sharma

7.1 Introduction

The world is witnessing a recent upsurge in the terminology associated with Artificial Intelligence such as machine learning [1], deep learning, and neural networks. As to what Artificial Intelligence encompasses, there is much left to debate. Artificial Intelligence is a broad sub-field of computer science, generally characterized by machines performing intelligent tasks. Machine learning is a subset of artificial intelligence which uses algorithms to enable machines to perform predictive and classification tasks. Deep learning, on the other hand, focuses on neural networks. A neural network is an artificial simulation of a neuron of the human brain. Deep learning usually calculates parameters automatically, making it highly efficient. Artificial Intelligence holds tremendous potential to revolutionize healthcare. Recent developments in the application of deep learning and block chain systems in image processing and electronic health care records have provided magnificent outcomes [2]. Human limitations such as memory restriction can be potentially eliminated with the use of computer models to supplement diagnosis and treatment implementation.

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Deep convolutional neural networks (DCNN) have been employed to detect diabetic retinopathy through image classification performed on fundus images, as the authors Gulshan et al. [3] demonstrate in their study. As demonstrated by the authors Poplin et al. [4], retinal fundus images have also used for the early diagnosis of cardiovascular diseases. The authors Hamet and Tremblay [5] outline a targeted drug delivery system through nanobots. Several other types of cancers can be detected through the use of deep learning models performed on diagnostic scans. This is demonstrated in the study by Harmon et al. [6], where in deep learning models were applied to biopsy samples to detect prostate cancer. In another study done by Iqbal et al. [7], DCNN were applied to MRIs to perform tumor segmentation that aided with the detection of brain tumors. There are other applications in the detection of diseases affecting the nervous system, for instance the study done by Wang et al. [8] which employed computer vision in the detection of multiple sclerosis through MRIs.

It is challenging to develop tools that can be clinically adopted in mental healthcare. This is because unlike most other medical fields, mental healthcare requires a careful comprehension of the disease. In the paper by Clark et al. [9], Tweets regarding breast cancer were analyzed to determine the issues faced by patients and survivors. Sentiment Analysis is a study to analyze the text such as comment, blogs, tweet and automate the polarity detection process which can help the end-user to understand the insights in the text in an effective way [10, 11]. Sentiment analysis is performed to determine the satisfaction of patients with the available healthcare. The analysis of other social media websites such as Instagram by the authors Reece and Danforth [12] has uncovered markers of depression through machine learning tools. Similarly, in the paper by the author Weiderhold [13], analysis of Facebook posts for suicidal behavior has been performed. Figure 7.1 summarizes the application of artificial intelligence models in the performance of various functions in the medical

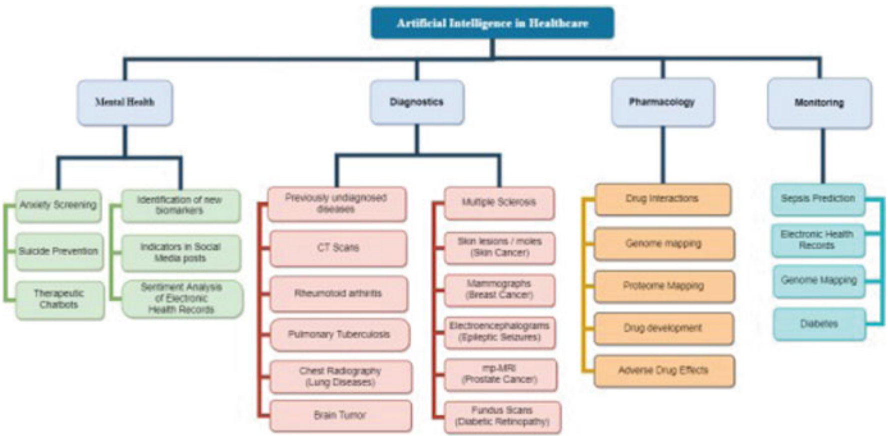

Fig. 7.1 Application of artificial intelligence in various medical processes

field. The four main application areas have been divided as follows: mental health applications, applications in diagnosis of diseases, pharmacology development and testing, and monitoring symptoms for diseases.

Any use of algorithms for determining diagnosis, prognosis or treatment options can be considered within the purview of artificial intelligence. The availability of large amounts of data enables the effective use of deep learning models, which has led to the rapid advancement of these models in various fields. The availability and quality of the healthcare provided to patients can also be greatly improved upon by using AI. AI models have shown to improve the accuracy of diagnosing diseases, which can free up a pathologist to focus more high-level and human-centric tasks. There have been several advancements made in diagnosis through the use of convolutional neural networks. Certain types of skin cancers can be detected by simply taking a picture of the affected area and uploading it on an application. The clinical deployment of these models is still facing certain issues. The concerns about the replacement of physicians with AI tools are severely misplaced. Medicine is an inherently human enterprise which requires human interaction. With the current upsurge of applications in radiology, it is crucial to keep in mind that AI is aimed at automating tedious and time-consuming tasks and it cannot replicate the comprehensive tasks of radiologists.

Significant amounts of electronic health data already exist and more will be created. This data needs to be digitized. Most of this EHR remains under-utilized and siloed. There is a great challenge in multidisciplinary inter-operability. The largest drivers are new drugs, therapeutic treatments, cost reduction, and availability worldwide. Cloud technologies can help us turn petabytes of healthcare genomic imaging clinical and claims data to provide streamlined care. They can also help to translate rich datasets into helpful developments. AI and cloud supported insights and workflows will help provide clinicians with more time to engage with patients. It can also accelerate biomedical research discovery and resolve the problem of scarce resources. There is a critical need for security and privacy protections. The concerns with streamlining health data need to be addressed with careful data stewardship and patient privacy.

There is enormous potential for improvement in the field of pathology. With the widespread adoption of clinical tools, there may be some resolution achieved in healthcare disparities. Assistive technologies could be especially beneficial in primary and in-house patient care. There exist significant barriers in the clinical deployment of AI tools. Significant training of practitioners and advanced infrastructure required to house clinical tools are crucial in the seamless incorporation into the existing workflow. Also, before implementing the tools the practitioners need to have an understanding of the basic concepts of machine learning, data science, and informatics. The rest of the article is divided into the following sections: motivation for the review article, various AI and cloud computing tools used, application areas for AI and cloud systems in medicine, current limitations of AI applications in healthcare, and the future prospects of AI applications in healthcare. Figure 7.1 shows the application of Artificial Intelligence divide into categories.

7.2 Motivation

Availability of multimodal data has proven to be transformational in the use of data-driven computational tools which can implement and improve clinical diagnoses. Machines have performed as well and even exceeded the accuracy of pathologists in diagnosing cancer with the use of genome mapping. AI has found substantial and encouraging applications in Medicine. Many clinical decision support systems have been developed to assist practitioners. With the use of deep learning models, there has been great success in interpreting electrocardiograms, diagnostic processes, treatment options, and interpretations and review of clinical reasoning regarding a disease.

This is mainly because there has been a shift from the rule-based and rigid "coding" approach that was common-place the 1970s, towards a more "adapt as you learn" method of machine learning. Machine learning models can learn from data without being explicitly programmed, which provides a considerable advantage over the initial programming approach that required explicit expressions of decision and constant updates. It was nearly impossible to encode higher-order interactions, such as the difference in opinion between practitioners. Machine learning methods can deal with these complex interactions, identify patterns from the data, discover previously unrecognized patterns without any specific decision rules, as outlined by the authors Shortliffe and Sepulveda [14]. The AI tools have proven to be of great pertinence to healthcare facilities. This paper attempts to portray and appeal for bridging the gap between existing healthcare facilities and available computing tools.

7.3 Cloud Computing

Cloud computing is a paradigm that allows on-demand network access to shared computing resources. It is a model for managing, storing, and processing data online over a network. It is an on-demand service, which takes advantage of shared resources and provides scalability by makes resources elastic. The delivery models for cloud computing are as follows:

7.3.1 Software as a Service (SaaS)

SaaS is an on-demand service in which users pay per use of application software to users, as the authors Dubey and Wagle [15] highlight in their paper. It provides an independent platform which does not require any installation. SaaS runs a single instance of the software and is available for multiple end users. Cloud computing services are generally cheaper for the end users, as the computing resources are managed by the vendor. It is universally accessible via a web browser or a lightweight client application. It eliminates the need to commute and is excellent for collaborative working. It is beneficial for vendors as it allows multi-tenancy. SaaS may fall short if the internet performance of the user device is not up to the mark. There may also be compliance restrictions, portability, and browser issues. Examples of SaaS include the Google ecosystem (Gmail), Office 365.

7.3.2 Platform as a Service (PaaS)

PaaS encapsulates the environment where users can build, compile, and run their program without being concerned with the underlying infrastructure, as the authors Boniface et al. [16] explain in their paper. It is made up of a programming language execution environment, an operating system, a web server, and a database. In the PaaS model, the data and the applications are managed by the user, and all other resources are managed by the vendor. It is a cost effective and rapid development process. The main users of this model are developers as it provides an easy deployment of web applications. Migration to other platforms may be considered as an issue with PaaS. Developers are also limited to the languages and tools provided, and vendor lock-in may result in the loss of progress.

7.3.3 Infrastructure as a Service (IaaS)

IaaS offers an architecture and computing resources in a virtual environment so that multiple users can access them. As the authors Bhardwaj et al. [17] highlight in their paper, the main components of an IaaS architecture are data storage systems, virtualization, servers, and networking. Runtime and middleware are for the users to handle. The primary user-base of IaaS is Sysadmins. The cloud provides the Infrastructure which enables enhanced scalability. IaaS is flexible and supports dynamic workloads.

Examples of commonly used cloud computing services are Amazon web services (AWS) which provides a complete suite including Beanstalk, EC2, RDS, etc. iCloud is a cloud system by apple which allows the backup and storage of multimedia and other files online. This content can then be seamlessly integrated across all apple devices. Other examples are Microsoft Azure, Google Cloud Platform, and IBM Smart Cloud.

7.3.4 Internet of Things (IoT)

IoT is a system of interrelated computing machines, objects, and agents with unique identifiers. It is characterized by the ability to transfer data over a network without human intervention. A thing in IoT can be any intelligent agent with an IP address which can transfer information over a network. Any device in an IoT system is web-enabled and human intervention is not always necessary. Applications of IoT include the improvement of customer service, decision-making, and increase business value.

7.4 Artificial Intelligence Tools

A brief overview of the main concepts and tools have been provided below. These include concepts from both the medical field and artificial intelligence. The most commonly used algorithms have been explained in detail.

7.4.1 Neuron

An artificial neural network is inspired by a biological neuron, though it functions based on mathematical models. Figure 7.2 shows the structure of a biological neuron in comparison to an artificial neuron as shown in Fig. 7.3. A biological neuron consists of a cell body, where the nucleus is located. The axon of a nucleus transmits signals from the cell body to the axon terminal. Communication between different neurons takes place with the help of synapses, which are electrical currents passed from the dendrites of one neuron to another. An artificial neuron, in a similar manner, takes the inputs x_1, x_2, x_n and multiplies the inputs by their respective weights w_1, w_2, w_n. These inputs are then summed up and a bias is added to them. An activation function is applied to the summed inputs, which provides the output y [20]. Although an artificial neuron derives inspiration from a biological neuron, they have very little in common. Artificial neurons function on mathematical models unlike biological neurons.

7.4.2 Neural Networks

Neural networks function as a computational analogy of the human brain. Each neuron is connected to several other neurons through synapses. The communication between neurons is done with the help of neurotransmitters. Similarly, in an artificial neural network, various units communicate through activation functions, which

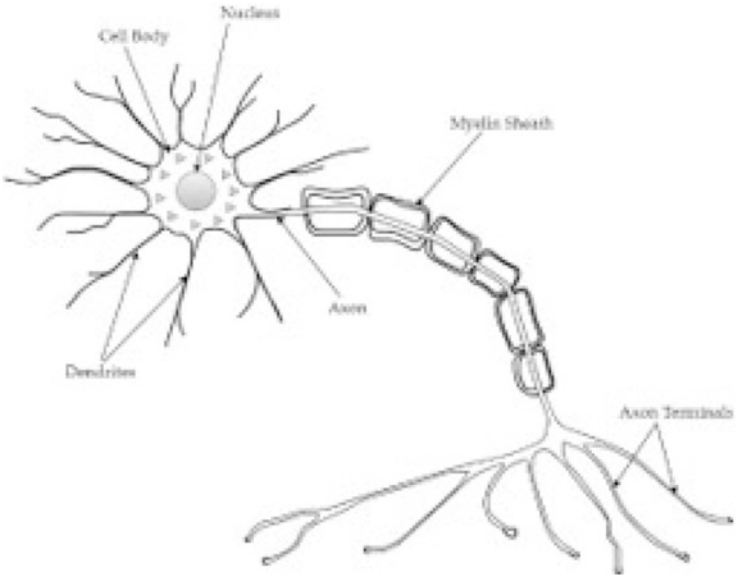

Fig. 7.2 Structure of a biological neuron [18]

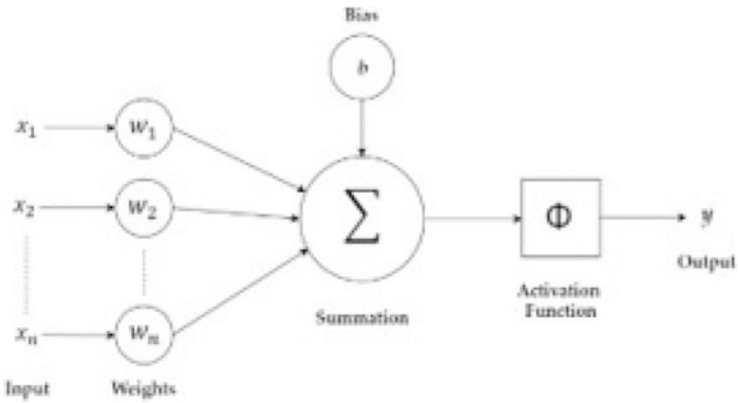

Fig. 7.3 Artificial neuron [19]

guides them on the activity to be performed. Neural Networks are explained by the authors Goodfellow et al., in Deep Learning [21].

7.4.2.1 Deep Neural Network

A multi-layer perceptron with several hidden layers is considered a deep neural network, as covered by the authors Goodfellow et al. [21]. The neural network takes in the inputs x_1, x_2, *and* x_3 in the input layer. The hidden layers consist of neurons with weights shown inside the circles. The output layer consists of outputs y_1, y_2, *and* y_3, which may correspond to three different class labels. Deep neural networks have shown potential in the diagnosis and treatment of various diseases such as Rheumatoid arthritis [22], Diabetes [23], Cardiovascular diseases [24], etc.

7.4.2.2 Natural Language Processing

Natural language processing(NLP) helps machine learning models to analyze and interpret natural human languages. It is crucial in the analysis of Electronic health records [25].

7.4.2.3 Recurrent Neural Networks (RNN)

A recurrent neural network deals with sequential data, such as audio and text, for predictions. It is a suitable model for sequential memory data, as explained by the authors Goodfellow et al. [21] in their book. The RNN output is fed into a feed-forward neural network, with the hidden state initialized. One key drawback of RNNs is the vanishing gradient problem. The gradient is calculated as a function of the gradient of the previous layer, which eventually causes the gradient to shrink. Earlier layers suffer due to this. This means that the network has trouble retaining information from previous states, due to back-propagation algorithm. The back-propagation algorithm is the adjustment made to the weights of the neurons in an ANN which allows it to learn better.

7.4.2.4 Convolutional Neural Network (CNN)

CNNs are inspired by the visual cortex of the human eye. Hidden layers try to learn the higher-level representation of the input data. CNN is the process of taking a dataset, reducing it down to base components through various processing algorithms and attempting to find common results by cross referencing them against each other for a computer to be able to identify other instances. The authors Goodfellow et al. [21] cover CNN in detail. Figure 7.4 shows a Convolutional Neural Network which takes a retinal scan as an input and provides the severity of the diabetic retinopathy as the output label. The input is passed through convolution and pooling layers which extract certain features from the image [21].

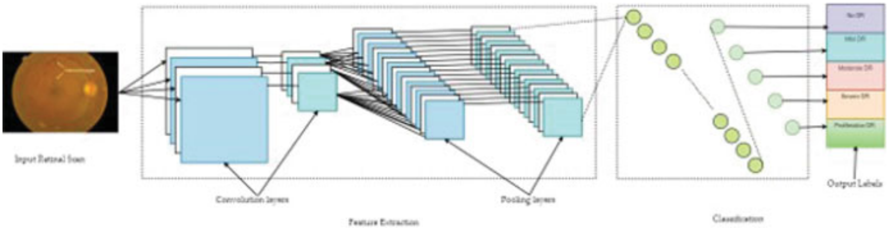

Fig. 7.4 A convolutional neural network to diagnose diabetic retinopathy [21]

7.5 Application Areas

Application areas for Artificial Intelligence that could be divided into four main categories: providing information tools to healthcare facilities, performing pathological diagnosis, disease management and performing preemptive measures to maintain the health of the person.

7.5.1 Information Tools

7.5.1.1 Applications in Health Care Administration

Cloud computing, IoT, and AI can serve to form the basis for providing administrative systems for health care management. Figure 7.5 illustrates the pipeline for cloud systems for health care management. Five major areas of application within the entire health sector are highlighted below:

1. Improving clinical care: Tools can be used to extract measurements from patients and to predict outcomes given some input data. Baseline diagnosis and prognosis can be provided on the basis of the collected data. Reactions to the prescribed medication can be observed and an appropriate intervention response can be planned.
2. Clinical efficiency: The time-consuming and labor-intensive tasks can be automated. Tools can help in data preparation, quantification, prioritization, and integration.
3. Clinical auditing: A continuous assessment of the quality of care can be provided with proper data analysis. This can help the health facility to constantly achieve health standard and performance targets.
4. Operational efficiency: The clinical data collected can be used to inform administrative decisions, optimize bed utilization in facilities, update cost codes periodically, and keep track of patient samples collected for testing.

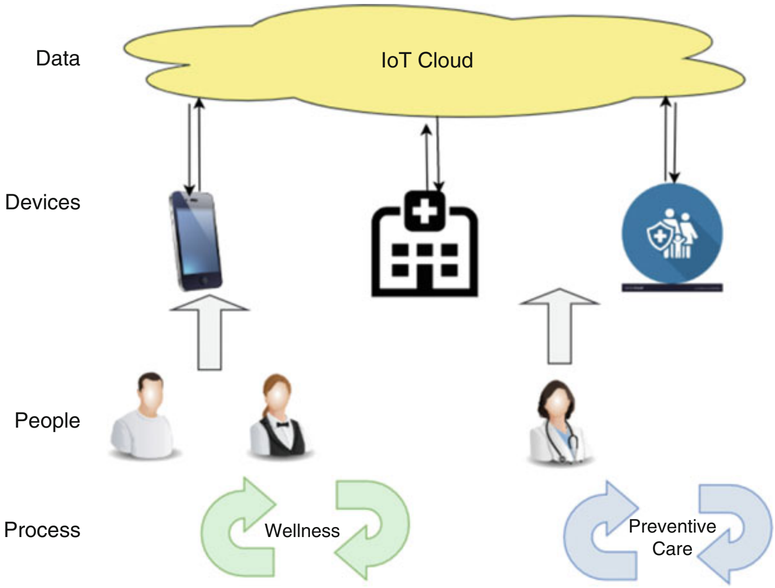

Fig. 7.5 Health care management through cloud systems [26]

5. Value-based care: Cloud systems can be used to optimize the value, which is indicative of the outcome and cost of the full care pipeline. For individual establishments, hospital-specific care pathways can be optimized.

7.5.1.2 Cloud Computing Systems for Healthcare Management

Cloud systems have a myriad of applications in the healthcare sector. With the use of cloud systems to store patient data, multiple devices can be connected through multiple vendors to provide an interoperable healthcare platform. The need to perform fresh diagnostic tests every time a patient gets transferred can be eliminated, saving time and costs for both the patient and practitioners. Furthermore, enhancing the diagnostic results may provide greater insight into the disease. Image processing may directly be able to provide post-processed imaging, inbuilt with visualization and collaboration tools. There have been health clouds set up by companies which store patient health data and provide health care services to patients. As mentioned in the paper by the author Sultan [27], one such initiative has been taken by GE Healthcare in collaboration with Med Cloud. The Centricity Practice is a cloud-based SaaS system which provides a Patient Self-Service Portal where patients can securely communicate with healthcare providers regarding their appointments and also safely access their clinical data.

Another initiative to develop a clinical information management system was taken up by IBM and ActiveHealth Management. "Collaborative Care Solution" is a cloud system architecture which aims to consolidate data from a lot of sources such as EHRs, claims, medication history, and diagnostic data. It also provides a progress report of the response of a patient to the treatment and find patterns in the response. The cloud system can be equipped with analytic tools to compare the performance of a particular unit to a standard. The model can be used to monitor patient response to a certain drug regime and automatically keep track of the appointments and due prescriptions. Another initiative was taken up by Practice Fusion and Dell to develop an electronic medical record SaaS system for medical enterprises.

The advantage of using cloud systems for healthcare management is that there is no need to provide a fixed architecture and the associated investment upfront. The cloud architecture is developed as the requirements increase, and the costs incurred are directly proportional to the usage. Privacy concern is a barrier to the widespread adoption of the cloud systems. Despite the amount of useful data being generated on a daily basis, most of it remains unconsolidated and thus unusable. As mentioned in the paper by the authors Ali et al. [28], approximately 30% of the healthcare sector already employs cloud computing to some extent, and the percentage will increase drastically in the next 5 years. Likely the most pertinent use of cloud technology in healthcare is for the processing of data across multiple devices. Also, the need of widespread availability of patient monitoring tools cannot be overstated.

7.5.1.3 Health Monitoring with IoT

Internet of things provides interconnectivity of devices over a network, which can prove beneficial in tracking and monitoring patient data and treatment history. It can also be extended into existing infrastructure and used to provide remote healthcare services to elderly patients and patients of chronic diseases. As explained by the authors Maksimovi et al. [26], a cross-organization integration of IoT information services can be used to develop a system of e-health logistics. The authors explain the use of a DIY (Do it yourself) self-monitoring device, which is a body sensor network used for continuous health monitoring and logging patient vitals. This type of network can be used for both physiological and physical conditions. The health data from the network can then be transmitted to a centralized location where it is analyzed by a trained professional. The paper proposes a small computer board called the Raspberry Pi (RPi), which contains a large number of input and output peripherals and the ability to interface with many platforms.

7.5.2 Disease Management

7.5.2.1 Diabetes Management Through Artificial Intelligence

Deep learning can increase both availability and accuracy in healthcare. The open-source standard for machine learning makes it readily available everywhere. Verily, which was formerly known as Google life sciences, aims to utilize the health data and is a multidisciplinary collaboration consisting of computer scientists, doctors, engineers, clinical researchers, etc., as mentioned by the authors Dorsey and Marks [29]. An individual possesses several gigabytes of health data (molecular technologies, etc. provide huge sums of data). Diabetes is an urgent health issue. Side effects are peripheral neuropathy. Two potential inhibitors in the advancement of machine learning tools in healthcare are the information gap that exists due to sparse data and the decision gap that occurs due to infrequent health check-ups. A lot of crucial data is missed out on, which leads to practitioners overlooking valuable insights. The actual biology is happening all the time, and this needs to be monitored. Vitals need to be monitored in real-time. A viable approach to close the information gap is to shift from episodic and reactive care to a more proactive care. Focus is also to be directed towards collecting the right data through continuous glucose monitoring. The data also needs to be formatted into form that can be used by the algorithm. Extremely small, bio-compatible electronics can be implemented to collect health data from an individual. Devices can be integrated seamlessly, allowing diabetic data can be monitored in a more continuous fashion. This approach simplifies diabetes management at a personal level, so that the patients can be the center of their healthcare decisions. The next goal is to try to find a pattern in the impact of food intake and physical activity on glucose levels.

7.5.2.2 Monitoring Mental Health Through IoT

Smartphones and other hand-held devices generate a significant amount of data which can be used for monitoring an individual's mental health as well. The data regarding a person's phone battery level can also serve as an indicator of their mental health, as is the case of individuals suffering from depression. The paper by the authors Hayati and Suryanegara [30] highlight how health data for can be monitoring to indicate the well-being of an individual. Connected healthcare is a prime goal that could be strived for through the use of various AI tools and IoT. Networked sensors that are also present in everyday hand-held devices can collect information rich data that could be indicative of physical and mental health. Posts made by individuals on social media platform are also serve to provide with psychological and behavioral data, as highlighted by the authors Yang et al. [31] in their paper. Wearable sensors can detect social cues provided by an individual and keep track of health. A study was conducted to highlight and address the privacy concerns about the use of personal data. Audio data and data from questionnaires was collected from volunteers but altered and not used in a raw form.

7.5.3 *Preemptive Measures*

7.5.3.1 Early Detection Through Biomarkers

A biomarker, the portmanteau of "Biological marker," is a quantifiable indicator of the severity or presence of some ailment. It can be seen as an objective characteristic of a biological or pathogenic process. It also includes pharmacological responses to drugs and treatments, as explained in the article by the authors Strimbu and Tavel [32]. Such a quantifiable approach can provide an upper hand while designing datasets to build models.

7.5.3.2 Diagnosis Through Image Recognition

Deep learning has shown substantial potential and improvements in image classification. In recent years, image-based diagnosis has proven to be a highly efficient. Convolutional neural networks have been useful for extracting spatial or temporal reactions in the field of radiodiagnosis. Also, millions of broken bone and skin lesion images can be generated by deep neural networks to serve as sample control set for diagnosis. A few examples in which CNN models have been implemented in diagnostics with surprising ease and accuracy are the study of chest radiography for lung diseases, mammography scans to detect breast cancer, retinal scans to detect diabetic retinopathy, magnetic resource imaging, and more. In recent studies, these tools have reached expert level diagnostic accuracy.

In the paper by the authors Yang et al. [33], a recurrent neural network uses circular connections to model temporal event and have been useful in the early detection of Adverse drug effects (ADEs) through accessing several Electronic health records. The importance of domain knowledge while designing these applications cannot be stressed enough. The diagnostic and treatment tools desired out of machine learning models should be fed consistent and thoroughly reviewed data. Automated medical-image diagnosis had proven to be successful in recent years, with applications extending in the field of radiology, ophthalmology, dermatology, and pathology.

7.5.4 *Pathological Diagnosis*

7.5.4.1 Rheumatoid Arthritis

Rheumatoid arthritis is a chronic inflammatory disorder that causes pain and swelling in the joints. It is more common among women and is most common among ages 40–70. The common treatments for RA include Nonsteroidal anti-inflammatory drugs, Disease-modifying antirheumatic drugs, etc. The authors Chocholova et al. [22] conducted a study in which hundred patient serum samples from healthy and people suffering from rheumatoid arthritis were collected. Key

RA markers were identified using glycan analysis through an artificial neural network. When compared to people who did not possess these RA markers, and discrimination accuracy of 92.5% was achieved. Author Stoel [34] proposed the development of a software for automatic quantification of bone marrow edema with the use of atlas-based segmentation and fuzzy clustering. The early detection of RA can be done by looking for inflammatory signs in MRIs of wrists and feet.

7.5.4.2 Epileptic Seizures

Seizures are a common symptom of Epilepsy. Seizures affect patients in different ways, depending of the area of the brain affected. In a study conducted by the authors Daoud and Bayoumi [35], four deep learning models are used to predict seizures in patients who suffered from epilepsy. The diagnosis of an epileptic seizure was done with the use of Electroencephalograms. Early prediction greatly improves patient's quality of life. Deep learning models are applied to Electroencephalogram recordings to detect real-time preictal brain state. Convolutional neural networks are trained to extract the significant spatial features from different scalp positions. A recurrent neural network is then utilized to predict the incidence of a seizure. A semi-supervised approach is used for optimization.

Channel selection algorithm is applied for selection of most relevant EEG channels. The predictive accuracy of the four models was compared. The highest accuracy reached was 99.6% and a false alarm rate of 0.004 h (inverse). Multi-layer perceptron has the worst performance among the four proposed models. This is because no features are extracted from the input data and the number of parameters is very large (9 million). Training time of SVM is moderate due to network simplicity. Seizure prediction is patient specific. Support Vector Machine has proven to be extremely specific and sensitive in previous studies of epileptic detection in several previous studies. The main challenge is to determine the most discriminative features that best represent each class. A multi-layer perceptron is applied to raw EEG recordings. A deep convolutional neural network is used to learn the discriminative spatial features between interictal and preictal states. Another proposed model is the concatenation of Bi-LSTM RNN to DCNN for the classification.

7.5.4.3 Alzheimer's Disease

Alzheimer's is neurodegenerative disease which accounts for over 80% of cases of dementia. There are currently at least 50 million people worldwide suffering from Alzheimer's. There is no cure as of now, with only disease management being an option when the patient is diagnosed. In a paper by Liu et al. [36], multimodal imaging data was used to perform diagnostics. The mild cognitive impairment (MCI) stage is crucial for providing early diagnosis according to the NIA AA criteria, which make use of biomarkers, multi-modality imaging-based diagnosis such as MRI,FDG PET, amyloid PET, and the recent tau PET. This data can be used for both classification and prediction. AD is the main cause of dementia, incurs severe health costs, and is fatal. Very few FDA approved drugs exist for treatment, and there is no cure. The best possible treatment is to try to slow down the disease at the MCI or preclinical stage. Various statistical and machine learning models have been developed to provide diagnosis and prognosis. In preclinical AD, the criteria for clinical AD are not met yet, but signs of early pathological changes are evident. The imaging modalities are classified as follows: imaging for identifying amyloid positivity or for identifying neuronal injury.

7.5.4.4 Diabetic Retinopathy

Around 285 million people worldwide suffer from diabetes, about a third of which are prone to Diabetic Retinopathy. Diabetic Retinopathy has been a key area of application recently, demonstrating the usefulness of AI in healthcare screening. It is the fastest growing cause of blindness and is also completely preventable. All diabetics are at risk if developing DR. 45% of patients suffer some degree of vision loss before the disease is even detected. The screening process involves taking a picture of the back of the eye using a digital retinal camera. DR is diagnosed by obtaining a retinal scan. These scans reveal retinal fundus which are outpouchings in the blood vessels of the eye. The scan reveals to what extent is the diabetes is affecting your vision by grading it on a scale.

In a study conducted by author Gulshan et al. [3], a labeling tool is developed based on the Fundus scans, starting from (1) moderate or worse diabetic retinopathy, (2) severe or worse diabetic retinopathy, (3) referable diabetic macular edema, or (4) fully gradable. Convolutional Neural Network is used to detect microaneurysms in fundus images. Machine learning can significantly help doctors with ‘housekeeping predictions’, for instance, predicting whether the scan is of the left or the right eye. The F-score of the model and an average ophthalmologist was compared: 0.95 vs. 0.91. Evaluation measures were as follows: Sensitivity (percentage of the time that the patient had the disease the model correctly predicted it- True Positives) and Specificity (Percentage of the time that the model predicted accurately that the patient did not have the disease). High values of both are desirable.

In another study conducted by Sayres et al. [37], the author employed deep learning models which provided improved accuracy on detecting DR. The new model brought the machine accuracy to pair with Retinal Specialists. The model tends to make more accurate predictions when the specialists cross-validate the diagnosis among themselves as well and feed that data to the model. The weighted kappa shows the agreement that the specialists had on the five-class diagnosis tool. There have also been successful attempts at showing how the model predicted a certain positive diagnosis. The so-called black-box limitation of a deep learning model was overcome using the “show me where” technique in a study done by

Mehta and Schwab [38]. A heat map is generated indicating the relevant pixels in a retinal scan which contribute to a positive diagnosis. Very mild cases of DR would require a highly trained specialists to detect “microaneurysms.” Moderate DR tends to have some bleeding and the diagnosis becomes a little easier.

7.5.4.5 Breast Cancer

Studies done by Vestjens et al. [39] and Bejnordi et al. [40] demonstrate how deep learning diagnostic tools have also been used to detect Breast Cancer and metastases in Lymph nodes. Screening Lymph nodes for signs of metastasis is not an easy task. 24% of biopsies showed a change in the nodal status in an additional review, which changes from false positives to false negatives and vice versa). A pathologist without time constraints and access to relevant data can accurately detect tumors at 94% accuracy. Time constrains tend to make pathologists overlook data which indicate metastases. It is akin to looking for a needle in the haystack. Machine learning models can easily take on this daunting and time-consuming task.

7.5.4.6 Obstructive Lung Disease

Obstructive lung diseases are caused due to blockages or obstructions in the airways. They include chronic obstructive pulmonary disease (COPD), cystic fibrosis, asthma, etc. Obstructive lung diseases are currently the third major cause of mortality worldwide, with approximately 328 million patients worldwide in 2017 [41]. Smoking is a major cause in the development of obstructive lung diseases, with most of the diagnoses occurring after age 40. COPDs are likely to become the leading cause of death worldwide in 15 years. In the paper by author Das et al. [42], several methods are compared for the detection of lung diseases. Textural analysis through machine learning algorithms was applied on computed tomography scans. A region of interest is selected, and feature extraction algorithms are applied based on structural, statistical, and binary patterns. A supervised classification algorithm is then applied to categorize the texture. Breath analysis provides very useful data as it contains volatile organic compounds originating from the respiratory tract itself. This can be crucial in developing biomarkers for phenotyping biomarkers for obstructive lung diseases. Algorithms can also be applied to forced oscillation tests to detect chronic obstructive pulmonary diseases (COPD). Clinical decision support systems have also been developed for COPDs, as discussed by the authors Anakal and Sandhya [43]. Electronic health records (EHRs) have been integrated to provide better clinical workflow improvements in the diagnosis and treatment of COPD. The tool is proposed to help physicians diagnose the severity of the disease efficiently. It can also monitor the drug reactions and associated comorbidities.

7.5.4.7 Cardiovascular Diseases (CVDs)

Cardiovascular diseases are related to diseases of the heart and blood vessels. The blood flow in the body is hampered. This could be because of a blood clot (thrombosis), or fatty deposits in an artery (atherosclerosis). CVDs are one of the primary causes of death worldwide, with an estimated 18 million deaths per year [44]. Deep learning can also be used to train highly accurate models that can help in detection of diseases which do not solely rely on image-based diagnoses. In the paper by the authors Poplin et al. [4], convolutional neural networks have been applied to retinal fundus images to predict cardiovascular risk factors. These risk factors generally include age, gender, smoking habits, blood pressure, and more. The model proved successful in predicting not only these risk factors but also the likelihood of a cardiac event in the next 5 years. This work is in its infancy but still provides an AUC of 0.7. This is very phenomenal considering the fact that doctors can provide this prediction at an accuracy of 50%, and because this procedure of prediction is completely non-invasive.

7.5.5 Applications in Mental Healthcare

Clinical Psychiatry is being continually updated with new cases being discovered every day that do not traditionally align with the rigid diagnoses outlined in DSM-5 (Diagnostic Statistical Manual of Mental Disorders 5). Formal diagnosis in Psychiatry relies very heavily on the DSM-V manual, which proves to be detrimental to the field as patients usually display correlated symptoms. The idea is to identify and cluster the underlying biomarkers which are indicative of an underlying brain disorder. The paper by author Fleming [45] is aimed at identifying information rich biomarkers from mentally healthy participants, cross-validating the current possible diagnosis according to the DSM-5 and evaluating the hypothesis that individuals with a formal psychiatric diagnosis tend to fall into clusters based on these biomarkers. Data was collected on a suite neurocognitive tasks from individuals diagnosed with 50 individuals with Schizophrenia, 49 individuals with Bipolar disorder, and 43 individuals with attention deficit hyperactivity disorder. A control group of 130 mentally healthy individuals was used. The outputs were the set of the latent features describing the subjects in a reduced feature space and a clustering based on these features. In the paper by author D'Alfonso et al. [46], the potential of AI in mental healthcare is discussed. Mental health concerns greatly an affected individual's life in several aspects. AI has a high potential of applications in mental healthcare, with some unique advantages and limitations as compared to other fields, such as oncology and ophthalmology. It can be used for predicting an individual's disposition to mental illness before the onset of the condition, monitoring the symptoms regularly, providing personalized healthcare, provide a prognosis and even monitor the probability of a relapse. It may help in preventing clinical syptomps altogether in certain cases.

7.5.5.1 Mental Health Detection Through Sentimental Analysis on Tweets

Twitter provides a useful political outlet for patient populations. Social media has the advantage that the invisible patient reported outcomes (iPROs) are self-generated and provide a better picture of the life-indicators such as diagnosis, treatment experience, coverage options, etc. Plenty of tweets about people's experiences with cancer have been compiled and analyzed. Twitter's public streaming API can be used potentially for monitoring public health trends. Twitter and other social media can likewise fill in as an educational and support tool for spreading awareness about cancer. Successful supportive organizations use social media sites for communicating with patients. They also play a role in educating the public and extending successful donor outreach programs. The challenge in applying sentiment analysis to social media is filtering through irrelevant tweets, which is a time-consuming task and has to be done manually to some extent. Noise may be added if automated and spam accounts are not removed. The spam tweets can severely distort the sentiment analysis. Hyperlinks also need to be removed, as they will add more irrelevant data to the set. This may have the side effect of information loss.

The 9-point scale ranges from keywords expressing negative sentiments ("emergency," "hate," "die") to keywords expressing positive sentiments ("laughter," "love," "healthy"). The labeled tweets provided a self-reported medical decision-making process. Identify tweets pertaining to patient's experience served as an additional informative tool for monitoring public health.

Spritzer Feed is the free Twitter API that was used in the study to mine for targeted keywords, shifting through up to 1% of Twitter's full content volume. Numeric account ID can be used to pinpoint tweeting entities that tend to tweet more frequently, hence contributing more to the relevant dataset. Retweets were removed as they introduce redundancy in data. Tweets were pre-processed by lowering and removing punctuation. Only tweets in English were analyzed, diminishing the reach and relevance of the study with respect to other communities. The happiness scores were added and normalized by their frequency. "Peaks and dips" in the data can be used to identify unpopular but relevant themes that may be overlooked in the frequency distribution. Logistic regression content relevance classifier with maximum entropy was used to obtain sentiment relevant classifier. A natural language processing classifier operates by converting sentences to word vectors. It then identifies key characteristics, such as the vocabulary of the classifier.

7.5.5.2 Suicide Prevention

In the paper, the author Wiederhold [13] has explored the question of using AI for suicide prevention. A lot of at risk young people divulge suicidal thoughts either online or to chatbots. They are not comfortable discussing these matters with their professional therapists, especially if they are considering suicide. The Ada Health online chatbot service with around 130,000 people expressing suicidal tendencies. Machine learning algorithms were able to predict suicidal risk from health records successfully with an accuracy of almost 90%. A study at Carnegie Mellon University, conducted by cognitive neuroscientist Marcus Just, showed patterns in a patients MRI, mapping out a road map of suicidal thoughts. With a combined effort from psychologists at Harvard University, machine learning models were combined with neural imaging and word association to get a suicidal accuracy of over 50%. People who suffer from depression and substance abuse are at a higher risk of developing suicidal tendencies.

Facebook has been criticized for using algorithms to detect suicidal behavior in user posts. Although the employees called for medical assistance of behalf of the high-risk users almost 3500 times, the criticism stems from the fact that this data can also be used to develop profit-driven models. Social media use has a positive correlation with the increase in depression, which is a leading cause of suicide. Teenagers may suffer from cyber-bullying while using social media. The major concern is that though artificial intelligence may be good at narrowing down users with suicidal tendencies on a social media platform, the final call for assistance has to be made by employees. The authors McGinnis et al. [47] conducted clinical trials where a 90-minute mood induction task was conducted with a wearable sensor. The resulting accuracy was 80%, with a specificity of 88% and a sensitivity of 67%. Depression and anxiety disorders usually have unobservable symptoms, thus making it hard for the patient to get the appropriate treatment. This is a breakthrough in diagnosing and treating internalizing disorders, which significantly affect an individual's quality of life. The comparison with the control group of parents who reported their child's symptoms was promising. This will help in screening.

7.6 Current Limitations

Despite all the significant achievements in the previous decade, the application of artificial intelligence in healthcare is still experiencing genuine impediments. The fact that machine learning algorithms are data-driven can also work to their detriment. The data may not be representative of the population that needs to be studied for the disease. Inappropriate data from electronic health records may exacerbate the bias problem in recommended treatments. Furthermore, artificial intelligence applies a very mechanistic approach in calculating risk factors. These models, when applied by insurance companies and the likes, may assign weightage to factors survival rate, race, gender, age, and so on. There are obvious privacy concerns regarding the use of health data to build deep learning models, especially if cloud computing services are involved as well. The public is concerned with targeted marketing and public health companies contacting them based on their data, but not so much the data being used to further research in the field.

The major dilemma here is that commercial companies have contractual contract to data, health services have legal right to data. but researchers do not have any right to the data whatsoever. Another problem is that machine learning models that will be integrated into clinics will not easily accessible due to the computational costs.

Table 7.1 Application areas of deep learning models with the best results

Disease	Data input	Diagnosis	Result
Rheumatoid arthritis [22]	Serum samples, biomarkers. Dataset of 2000 data points.	ANN	Discrimination accuracy of 92.5% from RA markers and glycan analysis
Epileptic seizures [35]	EEG recordings of preictal state from CHB-MIT EEG dataset	Semi-supervised, CNN, Channel selection, RNN, SVM, DCAE.	99.6% accuracy in seizure prediction
Diabetic retinopathy [3]	Fundus images. The EyePACS-1 dataset consisted of 9963 images from 4997 patients. The Messidor-2 dataset had 1748 images from 874 patients	CNN	AUROC: 0.95 for detecting DR. Specificity: 98%, Sensitivity: 87–90.3%.
Prostate cancer [6]	Biopsies of prostate glands. Tissue micro-array data.	mp-MRI	92% accuracy in cancer detection. 79% accuracy in classification of low and high-grade prostate cancer.
Breast cancer [39, 40]	2186 whole-slide images from the Cancer Genome Atlas.	Computer-aided detection DCNN. Automated classifier algorithms.	AUC: 0.994 vs. AUC: 0.810 of prediction accuracy of 11 pathologists.
Diabetes [23]	Digital phenotyping. PubMed database.	Sentiment analysis, deep learning models.	Diabetes and blood glucose management.
Mental Health [46]	Therapeutic chatbot data, User usage data	NLP	Personalized mental health management
Skin cancer [48]	Images of skin lesions. 129,450 clinical images, consisting of 2032 different diseases.	CNN	AUC of 91% vs. dermatologists.
Cardiovascular diseases [24, 49]	Electrocardiograms. Dataset of about 30,000 unique patients who have used the Zio Patch monitor. Risk factors, Fundus images.	34- layer CNN +ECG ANN, SVM	Precision: 0.80 vs 0.723 (cardiologist). Sensitivity: 0.784 vs. 0.724(cardiologists).
Multiple Sclerosis [8]	MRI, 676 MR slices containing plaques from 38 MR patients, 880 MR slices from 34 healthy controls.	Biorthogonal wavelet transform, RBF Kernel PCA, logistic regression.	Accuracy: 97.76% (approx). Sensitivity: 97.12% (approx). Specificity: 98.25% (approx).
Brain tumors [7]	Multi-spectral MRI. BRATS segmentation challenge dataset	DCNN + MRI	Proposed (SENet): 0.88, Proposed (IntNet): 0.90, Proposed (SkipNet): 0.87
Alzheimer's disease [36]	MRI, FDG-PET, and florbetapir-PET	Logistic regression, PLS (Partial least square regression).	Accuracy: 0.86, Sensitivity = 0.81, Specificity = 0.90.

In health care, features such as race and ancestry play a role in the predisposition to certain ailments, and thus, cannot be edited out of the model. A model that is not build by a fair representation of the concerned demographic will not be affective. This, however, may again be a double-edged sword in providing health care regardless of ethno-geographical considerations. Deep learning models that are typically used in providing clinical decision support tend to be black-box systems, which is not acceptable in medicine. The doctor and the patient both need to have a clear understanding of the type and intensity of the treatment procedure. The procedure of designing a decision tool for clinics may take a lot of time in the data preparation stage. Also, the interface should be simple and quick to use as to not take up too much time and effort on the practitioners' part. It should also provide intuitive features and patterns that may help in further improvement. Medical science is not very definitive. There are several gray areas in the diagnosis and treatment procedure (Table 7.1).

7.7 Conclusions and Future Prospects

Despite many concerns regarding the competence of artificial intelligence and the privacy issues associated with it, there have been several promising developments in the medical field. Convolutional Neural Networks are already being used in diagnostics with very promising results. In time, integrated clinical systems could provide doctors with the tools necessary to treat patients more efficiently. Artificial intelligence in medicine is being used as a factor for determining medical treatment decisions, and breakthroughs in AI research have caused them to become a more powerful and flexible tool. AI systems can be trained with data (such as MRI images) to generate their own datasets on ailments, instead of older systems which required a high amount of overhead with manual updates that required input from medical professionals.

Convolutional Neural Networks (CNNs) are able to perform complex processing of datasets for this purpose; and combined with modern processors means they can analyze large amounts of input data faster and cheaper than they could before. This has also been helped by medical data becoming readily available from many studies for training AIs because the more datasets the AI has to work from, the more accurate the results will be. Radiology, dermatology, and pathology are great examples of this. Genome interpretation is very data intensive so AI can make comparisons a lot easier than a human can. Advances in wearable monitoring devices have meant that AI systems can analyze patients in their day to day lives and provide recommendations or warnings. However, while robotics controlled by AI system are prevalent in manufacturing industries there is still a lot of work left to be done to integrate them into surgeries—especially true autonomous ones, even though tests have shown them to be more reliable than human hands. AI applications in the medical field, however, still have a lot of technical challenges.

Integrating datasets from different AIs may cause issues where their training can lead them to ignore patient data from different ethnic backgrounds or introduce bias. Another setback is that while AIs can produce results from highly detailed analysis it does not necessarily translate into a result that a human can interpret without aid or cause over reliance on their result by a medical professional which can lead to a bad diagnosis. Datasets can also be too limiting for properly providing diagnoses because outside factors may be impacting the patients' health. Apart from these issues, malpractice suits will also need clarification of the ultimate responsibility for bad diagnostics, should AI systems become more integrated into medical fields. This is especially the case if they render personnel obsolete, leading to more reliance on them. Overall, AI has enhanced the accuracy of clinical diagnosis, driven the cost down in analyzing patient medical data and depending on how it is integrated into practical applications will continue to change how medical professionals treat their patients—even possibly changing their primary roles.

References

1. A. Kaushik, S. Naithani, A comprehensive study of text mining approach. Int. J. Comput. Sci. Netw. Secur. **16**(2), 69 (2016)
2. D. Saxena, J.K. Verma, Blockchain for public health: technology, applications, and a case study, in *Computational Intelligence and Its Applications in Healthcare* (Elsevier, New York, 2020), pp. 53–61
3. V. Gulshan, L. Peng, M. Coram, M.C. Stumpe, D. Wu, A. Narayanaswamy, S. Venugopalan, K. Widner, T. Madams, J. Cuadros et al., Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs. J. Am. Med. Assoc. **316**(22), 2402–2410 (2016)
4. R. Poplin, A.V. Varadarajan, K. Blumer, Y. Liu, M.V. McConnell, G.S. Corrado, L. Peng, D.R. Webster, Prediction of cardiovascular risk factors from retinal fundus photographs via deep learning. Nat. Biomed. Eng. **2**(3), 158 (2018)
5. P. Hamet, J. Tremblay, Artificial intelligence in medicine. Metabolism **69**, S36–S40 (2017)
6. S.A. Harmon, S. Tuncer, T. Sanford, P.L. Choyke, B. Türkbey, Artificial intelligence at the intersection of pathology and radiology in prostate cancer. Diagnost. Intervent. Radiol. **25**(3), 183 (2019)
7. S. Iqbal, M.U. Ghani, T. Saba, A. Rehman, Brain tumor segmentation in multi-spectral MRI using convolutional neural networks (CNN). Microsc. Res. Tech. **81**(4), 419–427 (2018)
8. S.-H. Wang, T.-M. Zhan, Y. Chen, Y. Zhang, M. Yang, H.-M. Lu, H.-N. Wang, B. Liu, P. Phillips, Multiple sclerosis detection based on biorthogonal wavelet transform, RBF kernel principal component analysis, and logistic regression. IEEE Access **4**, 7567–7576 (2016)
9. E.M. Clark, J.R. Williams, C.A. Jones, R.A. Galbraith, C.M. Danforth, P.S. Dodds, Sifting robotic from organic text: a natural language approach for detecting automation on twitter. J. Comput. Sci. **16**, 1–7 (2016)
10. S.R. Shah, A. Kaushik, Sentiment analysis on Indian indigenous languages: a review on multilingual opinion mining (2019). Preprint. arXiv:1911.12848
11. G. Kaur, A. Kaushik, S. Sharma, Cooking is creating emotion: a study on Hinglish sentiments of YouTube cookery channels using semi-supervised approach. Big Data Cogn. Comput. **3**(3), 37 (2019)
12. A.G. Reece, C.M. Danforth, Instagram photos reveal predictive markers of depression. EPJ Data Sci. **6**(1), 1–12 (2017)

13. B.K. Wiederhold, Artificial intelligence and suicide: where artificial intelligence stops and humans join in **22**(6), 363–364 (2019)
14. E.H. Shortliffe, M.J. Sepúlveda, Clinical decision support in the era of artificial intelligence. JAMA **320**(21), 2199–2200 (2018)
15. A. Dubey, D. Wagle, Delivering software as a service. McKinsey Quart. **6**, 1–12 (2007)
16. M. Boniface, B. Nasser, J. Papay, S.C. Phillips, A. Servin, X. Yang, Z. Zlatev, S.V. Gogouvitis, G. Katsaros, K. Konstanteli et al., Platform-as-a-service architecture for real-time quality of service management in clouds, in *2010 Fifth International Conference on Internet and Web Applications and Services* (IEEE, New York, 2010), pp. 155–160
17. S. Bhardwaj, L. Jain, S. Jain, Cloud computing: a study of infrastructure as a service (IAAS). Int. J. Eng. Inf. Technol. **2**(1), 60–63 (2010)
18. N.T. Carnevale, M.L. Hines, *The NEURON Book* (Cambridge University Press, Cambridge, 2006)
19. M. Minsky, S.A. Papert, *Perceptrons: An Introduction to Computational Geometry* (MIT Press, Cambridge, 2017)
20. Y. LeCun, Y. Bengio, G. Hinton, Deep learning. Nature **521**(7553), 436–444 (2015)
21. I. Goodfellow, Y. Bengio, A. Courville, *Deep Learning* (MIT Press, Cambridge, 2016)
22. E. Chocholova, T. Bertok, E. Jane, L. Lorencova, A. Holazova, L. Belicka, S. Belicky, D. Mislovicova, A. Vikartovska, R. Imrich et al., Glycomics meets artificial intelligence–potential of glycan analysis for identification of seropositive and seronegative rheumatoid arthritis patients revealed. Clin. Chim. Acta **481**, 49–55 (2018)
23. I. Contreras, J. Vehi, Artificial intelligence for diabetes management and decision support: literature review. J. Med. Internet Res. **20**(5), e10775 (2018)
24. P. Rajpurkar, A.Y. Hannun, M. Haghpanahi, C. Bourn, A.Y. Ng, Cardiologist-level arrhythmia detection with convolutional neural networks (2017). Preprint. arXiv: 1707.01836
25. S. Bird, E. Klein, E. Loper, *Natural Language Processing with Python: Analyzing Text with the Natural Language Toolkit* (O'Reilly Media, Inc., Sebastopol, 2009)
26. M. Maksimović, V. Vujović, B. Perišić, A custom internet of things healthcare system, in *2015 10th Iberian Conference on Information Systems and Technologies (CISTI)* (IEEE, New York, 2015), pp. 1–6
27. N. Sultan, Making use of cloud computing for healthcare provision: Opportunities and challenges. Int. J. Inf. Manage. **34**(2), 177–184 (2014)
28. O. Ali, A. Shrestha, J. Soar, S.F. Wamba, Cloud computing-enabled healthcare opportunities, issues, and applications: a systematic review. Int. J. Inf. Manage. **43**, 146–158 (2018)
29. E.R. Dorsey, W.J. Marks Jr., Verily and its approach to digital biomarkers. Digit. Biomark. **1**(1), 96–99 (2017)
30. N. Hayati, M. Suryanegara, The IoT LoRa system design for tracking and monitoring patient with mental disorder, in *2017 IEEE International Conference on Communication, Networks and Satellite (Comnetsat)* (IEEE, New York, 2017), pp. 135–139
31. S. Yang, B. Gao, L. Jiang, J. Jin, Z. Gao, X. Ma, W.L. Woo, IoT structured long-term wearable social sensing for mental wellbeing. IEEE Internet Things J. **6**(2), 3652–3662 (2018)
32. K. Strimbu, J.A. Tavel, What are biomarkers? Curr. Opin. HIV AIDS **5**(6), 463 (2010)
33. X. Yang, J. Bian, Y. Wu, Detecting medications and adverse drug events in clinical notes using recurrent neural networks, in *International Workshop on Medication and Adverse Drug Event Detection*, 2018, pp. 1–6
34. B.C. Stoel, Artificial intelligence in detecting early RA, in *Seminars in Arthritis and Rheumatism*, vol. 49 (Elsevier, New York, 2019), pp. S25–S28
35. H. Daoud, M.A. Bayoumi, Efficient epileptic seizure prediction based on deep learning. IEEE Trans. Biomed. Circ. Syst. **13**(5), 804–813 (2019)
36. X. Liu, K. Chen, T. Wu, D. Weidman, F. Lure, J. Li, Use of multimodality imaging and artificial intelligence for diagnosis and prognosis of early stages of Alzheimer's disease. Transl. Res. **194**, 56–67 (2018)

37. R. Sayres, A. Taly, E. Rahimy, K. Blumer, D. Coz, N. Hammel, J. Krause, A. Narayanaswamy, Z. Rastegar, D. Wu et al., Using a deep learning algorithm and integrated gradients explanation to assist grading for diabetic retinopathy. Ophthalmology **126**(4), 552–564 (2019)
38. P. Mehta, D.J. Schwab, An exact mapping between the variational renormalization group and deep learning (2014). Preprint. arXiv: 1410.3831
39. J.H.M.J. Vestjens, M.J. Pepels, M. de Boer, G.F. Borm, C.H.M. van Deurzen, P.J. van Diest, J.A.A.M. Van Dijck, E.M.M. Adang, J.W.R. Nortier, E.J.Th. Rutgers et al., Relevant impact of central pathology review on nodal classification in individual breast cancer patients. Ann. Oncol. **23**(10), 2561–2566 (2012)
40. B.E. Bejnordi, M. Veta, P.J. Van Diest, B. Van Ginneken, N. Karssemeijer, G. Litjens, J.A.W.M. Van Der Laak, M. Hermsen, Q.F. Manson, M. Balkenhol et al., Diagnostic assessment of deep learning algorithms for detection of lymph node metastases in women with breast cancer. J. Am. Med. Assoc. **318**(22), 2199–2210 (2017)
41. S.A. Quaderi, J.R. Hurst, The unmet global burden of COPD. Global Health Epidemiol. Genom. **3**, e4 (2018)
42. N. Das, M. Topalovic, W. Janssens, Artificial intelligence in diagnosis of obstructive lung disease: current status and future potential. Curr. Opin. Pulmon. Med. **24**(2), 117–123 (2018)
43. S. Anakal, P. Sandhya, Clinical decision support system for chronic obstructive pulmonary disease using machine learning techniques, in *2017 International Conference on Electrical, Electronics, Communication, Computer, and Optimization Techniques (ICEECCOT)* (IEEE, New York, 2017), pp. 1–5
44. P. Lakhani, B. Sundaram, Deep learning at chest radiography: automated classification of pulmonary tuberculosis by using convolutional neural networks. Radiology **284**(2), 574–582 (2017)
45. S.L. Fleming, Characterizing data-driven phenotypes of schizophrenia, bipolar, and attention deficit/hyperactivity disorder. published in stanford university website http://cs229.stanford.edu/proj2017/final-reports/5246443.pdf
46. S. D'alfonso, O. Santesteban-Echarri, S. Rice, G. Wadley, R. Lederman, C. Miles, J. Gleeson, M. Alvarez-Jimenez, Artificial intelligence-assisted online social therapy for youth mental health. Front. Psychol. **8**, 796 (2017)
47. R.S. McGinnis, E.W. McGinnis, J. Hruschak, N.L. Lopez-Duran, K. Fitzgerald, K.L. Rosenblum, M. Muzik, Rapid detection of internalizing diagnosis in young children enabled by wearable sensors and machine learning. PLoS One **14**(1), e0210267 (2019)
48. A. Esteva, B. Kuprel, R.A. Novoa, J. Ko, S.M. Swetter, H.M. Blau, S. Thrun, Dermatologist-level classification of skin cancer with deep neural networks. Nature **542**(7639), 115–118 (2017)
49. C. Krittanawong, H. Zhang, Z. Wang, M. Aydar, T. Kitai, Artificial intelligence in precision cardiovascular medicine. J. Am. Coll. Cardiol. **69**(21), 2657–2664 (2017)

Chapter 8
NOS Personal Assistant to Engage Elderly People with Smart Home

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8.1 Introduction

The Internet of Things (IoT) has increased exponentially in the last years, especially among residential consumers due to the benefits of connected products to the Internet. Moreover, the main drivers for the growth of smart home market will be video doorbells, voice assistant technologies (e.g. Alexa and Google Home), and surveillance systems due to the growing increase in consumer demand.

Meanwhile, the world is aging rapidly. Approximately, 12.3% of the global population is aged 60 and older, and this figure is expected to increase to almost 22% by 2050. It is well known that these people want to live healthy and active

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in their homes; however, it is also well known that this type of population presents key challenges with technology, especially with smart homes. Furthermore, most of the smart things and systems targeting elderly population are more focused on improving the Quality of Life (QoL) and health monitoring (falls detections and preventions, health parameters, etc) rather than providing a seamless and learning ecosystem for old population break their fears with advanced technology and understand how it works. Also, most of the published research on smart homes for old people is only using mobile phones, forgetting the fact that this population has preference for television.

In this chapter, we described a personal assistant that allows the users to learn how to work with smart sensors, giving them different contexts to test, use, learn, and at the same time to keep active and update regarding the next generation of homes.

This personal assistant will promote voice interface between the user and the smart thing in the following contexts:

(1) Voice Interaction with television: In this use case, the user will ask the NOS Assistant to change the channel, to tune his/her favourite channel, etc.
(2) Voice Interaction to control lights.
(3) Voice Interaction to care his/her plants.

We are still in the user research process following some co-creation guidelines. Therefore, we believe that the presented approach is the missing trigger in the blue ocean for AAL market and may have the potential to start the discussions and the birth of new end-user and business's opportunities to involve more and more elderly people with technology, contributing to the inclusive technology and keep a healthy digital world transformation targeting most of the user groups.

8.2 Background

8.2.1 Internet of Things

The Internet of Things (IoT) has enlarged exponentially within the last years, particularly among residential shoppers thanks to the advantages of connected products to the net. Moreover, the main drivers for the growth of sensible home market will be video doorbells, voice-assisted technologies, surveillance systems, and police work systems due to the growing increase in consumer demand.

However, and in opposite approach, the market is turning into even additional fragmented, concentrating around few key suppliers. In 2017, the highest ten of the 450 suppliers in 2017 controlled a quarter of the market share in step with IoT Analytics estimates. In 2019, the highest ten of the 620 suppliers controlled 58% of the market share. Cloud firms AWS and Microsoft stand out significantly. Each company have superimposed tremendous capabilities to their IoT platform offerings since 2017. Each firm ranks okay within the list of high 10 IoT Platforms by revenue and that they conjointly dominate end-user satisfaction of IoT platforms.

5G has been seen as a key player in IoT market. Its enlarged speed can change connected environments to additional or less run on their own as well as to be ready to share knowledge mistreatment machine learning tools to be told and improve. As a consequence of the enlarged speed, additional devices are accessible and interconnected which implies additional business opportunities. The key to 5G is knowledge. The necessity for intelligent knowledge is the reason for edge computing rise in 5G stream as a key part within the way forward for IoT domain. Edge computing can permit investment time period datasets instead of making an attempt to dins what is going to be like in an exceedingly more centralized cloud.

The connected home has been a commercially accessible thought for over 25 years; however it has not continually lived up to its packaging. This is often ever-changing. In step with Mckinsey, "Alexa and Google Assistant have achieved crucial mass, and, despite some security and privacy issues, square measure progressively integrated into however we have a tendency to operate things in our homes. each square measure establishing a foothold because the "control point" for the house, wherever previous tries, by comparison, were too pricy, too difficult, and fewer future-proof. Consumers, particularly younger ones, use these devices to initiate searching, management diversion, change the thermostat and lighting, and even build occasional. This has vital implications for IoT strategy as makers and retailers position their product and services to integrate with connected homes." In support of this premise, NOS Inovação is exploring these IoT-related technologies to supply new services to residential customers, with a special concentration on older individuals. NOS aims the inclusion of this populations who has been discriminated by technologies; however, individuals are aware that technology oughts to be a part of their lives.

8.2.2 Ambient Assisted Living Market

Ambient Assisted Living (AAL) and smart homes provide a comfortable standard of living. AAL refers to support from technology, electronic systems, products and services that guide and improve the quality of individuals' daily lives and help stay healthy. On the other hand, smart homes consider the automation of homes that are equipped with information and computing technology (ICT) devices, which respond to users' requirements efficiently. For example, smart homes control and monitor air conditioning, heating and security systems, lighting, and appliances such as ovens, dryers, refrigerators, ventilation (e.g. windows) through the Internet of things. The global AAL and smart home market are fragmented with numerous large- and medium-scale companies operating applications and services that are integrated and presented in a user-centred/controlled fashion [1].

From 2017 to 2027, the global AAL market is expected to grow with 19% Compound Annual Growth Rate (CAGR) [2], which means that a market value of € 11 billion by 2027 is anticipated to be achieved. A main drive for the AAL market is the advances in smart technologies, covering smart homes and connected space. Furthermore, the growing demand for handling with care in old age is also leading this market. Governments are also collaborating with AAL's activities and initiatives, with the aim of reducing costs both directly associated with elderly care and indirectly through other healthcare events (e.g. reducing slips, trips and falls or social isolation, which is associated with increased risk of cardiovascular disease and dementia).

The market for AAL is staged to evolve in three-generation stages: (1) wearable devices including emergency response systems and user-initiated alarms, (2) home sensors and automatic response systems and (3) automated systems that have to be available on the market or are still in development (e.g. domestic robots). Taking into account the adoption rate of smart homes, the global household market share increased from 8 to 9% between 2016 and 2017 [3]. Products used in smart homes include wearable devices (e.g. smartwatches), home automation (e.g. smart lights), devices for well-being (e.g. heart rate sensors, blood volume pressure sensors), fitness (mobile apps to track records and progress), media and entertainment, home (e.g. smart televisions, virtual assistants using voice) and personal security (e.g. cameras, doors sensors) and smart energy (smart thermostats). The highest market share of approximately 5% was seen in the United States during 2017. However, the UK is close with an adoption rate of 3%. AAL can be considered as a piece of smart homes and, consequently, higher smart home adoption rates will grow the AAL market too. Although the market caters mostly for the needs of older people, smart homes offer better resources for managing energy, resources, processes, and connectivity [4].

People with disabilities are considered the main domain in which the traditional assistive technologies were applied in the beginnings of AAL.

The EU AAL market is characterized by being a niche for the private sector and too expensive to public healthcare. The main concern is how to make this high-cost and unique EU AAL market economically available to the ageing society: there is no doubt that governments want to access innovative and state-of-the-art solutions, but it is a constant struggle trying to balance public funds versus social and healthcare application, and at the same time, deal with an Eurozone economy that is slowly evolving.

The rapid evolution of mobile technologies and IoT services have expanded other boundaries: from the use of wearables that become "daily partners" like Apple watch for activity and sleep monitoring, to entering in new worlds and ways of working with virtual/augmented reality (like Microsoft Hololens or Google Glasses), and tracking devices that are now naturally embedded in consumer commuting or professional services.

The adoption of smart devices in personal routines and houses, the increased demand on home care medical services combined with the agility of crowdsourcing and the launch of open data platforms related to health, social and elderly care create the right conditions to develop more and new solutions in the AAL market.

These components that largely contribute to the technological radar mainly consist in:

- Wearable sensors, whether it is smartwatches or even clothing
- Smart home device that can go from smart speakers like Alexa or Google Assistant devices, light bulbs or gateways like Philips or IKEA, that provide connectivity to other health, home, and social ecosystems
- Tracking and geolocations services that can be used indoors and/or outdoors

IoT-based solutions have become one of the great drivers in the development and growth of the AAL market: its evolution will also depend on the application of machine-to-machine (M2M) communications, supported by advanced networks and cloud computing, as also seen in 5G. In line with the International Data Corporation (IDC), IoT is "a network connecting (wired or wireless) devices or things, characterized by autonomous provisioning, management, and monitoring." It also states that "the emergence of new IoT-based digital ecosystems to be one of the most relevant innovation trends over the next 5-10 years, with potential impacts ranging from incremental to disruptive innovation for most vertical markets."

For the next 5 years and further, IoT technology is expected to evolve in a way that will provide the emergence of new innovative solutions that will have impact across several markets.

8.2.3 Natural Interfaces Landscape

The most natural, efficient and flexible means to communicate is using the natural language. A lot of research has been made in the integration of natural language in the human-to-machine domain.

The aim of building dialogue systems based on natural language is to give users access and manage information through natural language systems. These systems are increasingly omnipresent in our lives, as a result of fast progress in terms of performance and lower costs.

The performance of dialogue systems based on natural language has improved significantly over time, with a general increase in applications based on these systems. In the beginning, natural language-based dialogue systems were limited to certain domains, such as telephone weather information systems (JUPITER) [5] and travel planning (DARPA communicator) [6]. Subsequently, the developed systems were integrated into domains with navigation, entertainment and communications [7, 8]. In this domain, it is possible to highlight the strong contribution of the European project TALK (http://www.talk-project.org), which has developed innovative technologies to adapt dialogue systems using voice, graphics or the combination of both in a car. Another example is ALICE (http://www.alicebot.org/), a project that triggers the development of chatbots applied in entertainment and education applications.

However, the language processing is a complex system, which involves not only to control the language, but also to learn several domains in the same conversation. This last one is one of the big challenges for dialogue systems, since it implies to become the machine able to control multi-domain and be prepared for real situations. Such systems are currently available for services such as telematics, smart home or smart robots; however, they still have several issues in dealing with multi-context. Although there has been some progress in multi-tasking and accessing information from different sources, the creation of a perfect dialog management system is still an oasis. One of the issues is the correct identification of the domain that the user wants and to switch between domains in a smooth way. While this problem is not solved, the use of natural language systems will still have critical weaknesses in terms of user experience and user usability. Dialogue systems must be able to adapt and transport to new domains [9–13]

The first dialogue systems such as SUNDIAL [14] and ARISE [15] were built by developers, who have an exclusive knowledge domain. These systems were generally limited to highly structured tasks for which the expected language is restricted and regularized. This technique commonly uses automations for a finite state that mostly involves "artisanal" rules. These rules are established through knowledge of the application and the continuous experiences of users. Still, this approach was used for rapid prototyping of dialogue systems for standard interactions with undoubtedly well-defined structures and objectives [16]. However, the complexity of creating manual rules in advance is high. In addition, there is little domain capacity, meaning that the entire design and develop process has to be restarted whenever a new application for a different domain is developed.

In order to overcome the problem of low domain portability, several research groups [17–20] applied different methods to simplify the representation, by breaking it down to smaller tasks and schedules.

Nevertheless, since most of the tasks are usually developed by human experts, it is still revealed to be a very lingering and expensive design process.

In the last years, the dialogue management experts have begun to investigate data-driven approaches for automatic speech recognition (ASR) and natural language understanding (NLP). In these first systems, even though the data-driven approach took time to record the data, training is done automatically and requires little human supervision. Moreover, these new systems can be developed only at the cost of acquiring new data to move to a new domain. This approach requires less time and effort when compared to the knowledge-based approach. These advantages have thus led to a stochastic development of dialogue models using reinforcement learning (RL) based on Markov's decision processes [21–22]. These frameworks apply statistical models to the data collected and theoretical principles for modelling the dialogue so that they are able to dynamically change the dialogue strategy, due to the optimization of some reward or cost functions, considering the current state of the dialogue. However, the practice of RL in dialogue systems encountered several obstacles [23], such as the optimization policy that can eliminate developers' control. Furthermore, optimizing the control of the dialogue is complex, being that in cases of multi-domain the correct identification of the domain as well as switching between domains remains a difficulty.

Processing and understanding of natural language involves data processing to extract valid information from natural language. Language comprehension is a key component in human-machine interactions, especially in scenarios where the user talks to the system and expects an answer, such as checking flights, restaurants, weather, etc.

Natural Language Processing (NLP) is defined as a channel for computers to understand, analyse and derive meaning from human language in a smart and useful way. NLP can be subdivided into other areas, including Natural Language Understanding (NLU) and Natural Language Generation (NLG). NLU is based on text analytics and facilitates the understanding of sentence structure and meaning, sentiment and intent through statistical and ML methods, especially deep learning architectures. On the other hand, NLG relates to generating natural text (that can be turned to speech in later steps), from computer data.

NLP systems have a higher performance when they know what is the subject for which the interaction should be processed. For example, the ASR of NLP module can use several models (linguistic or acoustic models) to determine the content of the user's interaction, as well as their intention. The ASR module can thus use specific models for that subject, also known as a domain, as long as the system knows that domain. Other modules of an NLP system such as the NLU can also interpret the user's words, received through the ASR to determine what action the user would like to initiate, also known as an intention (user's intent). The NLU model can be configured to interpret the user's words in actions within a particular domain. However, if the user's words are not interpreted within a specific domain for which the NLU is not configured, the processing of the NLU module will be inefficient, inconsistent and error-generating.

Some NLP systems are configured to process user intentions within one of the different domains. These systems choose a domain in which the user's intention should be processed. For example, the system may be waiting for an intention related to a currently active domain and, as such, will only process the user's intentions in that specific domain. However, the user may want to initiate an action to obtain certain directions, but in the middle of the interaction process the user may decide to want to listen to music. However, the NLP system is still in the domain of getting directions and may not be able to interpret the last command (listening to music).

In the last years, one particularly growing NLP application are the so-called *bots*, or *chatbots*. Although initial versions were not very capable in user engagement, recent ones are rendering user interfaces more natural, intuitive, turning an interaction seamless, based solely on text or voice. These *bots* are usually focused in single domains, for better results, although the concept of Digital Personal Assistant has risen, popularized by examples including Cortana, Siri, Alexa, or Google Assistant. These can automate simple tasks based on voice commands or text inputs and are equipped with capabilities of forecasting, inferencing and recommendation.

8.3 NOS Technology

8.3.1 The Challenges of NOS Personal Assistant

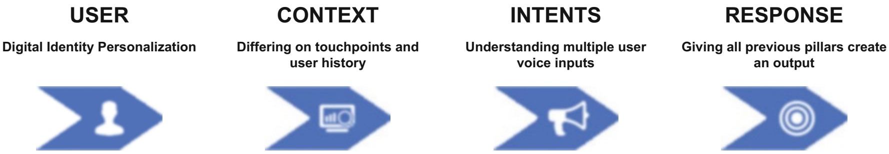
NOS Personal Assistant aims at enhancing the customer experience on several interaction channels, such as STB devices, OTT, web portals and IVR, and third parties. The ultimate goal is to provide the customer with a coherent and more helpful feature at home in order to:

a. Control his/her Internet
b. Control his/her television
c. Ask assistant for NOS services, and to receive immediately feedback or support
d. Control all devices connect to his/her WiFi network

To achieve those goals, product principles were designed and defined following the below user experience requests:

a. Easy Interaction – Helpful: creating a problem-free environment. An easier discovery interaction with technological devices.Informative: good information framework for providing contextual and relevant suggestions.Friendly: The User Interface (UI) or voice response must be user-friendly, intuitive and always accessible.
b. Understanding – Scalability: always learning, always improving.

The feature framework is, consequently, designed by the following flow:



Each step of this flow presents some product and architectural challenges, which are not resolved by state of the art yet. To know:

1. User: digital identity personalisation.

Beyond all RGPD requirements to be compliant, this step brings the following challenges:

a. How to teach user about personalisation?
b. How to develop a customise engine?
c. How to do the user's voice recognition?

2. Context/Domain: different on touchpoints and user history.

The challenge in this step is not to discover the domain/context of the conversation but manage and integrate several contexts through different interactions and devices without blocking the Personal Assistant. To explain the context to user and teach him this tool is a big challenge.

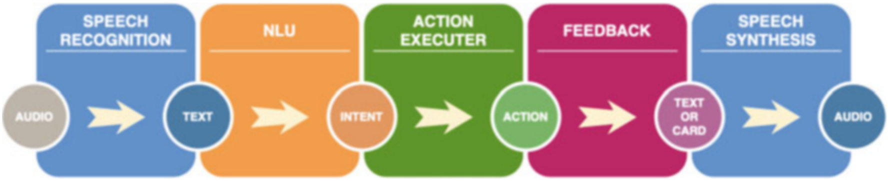


Fig. 8.1 NOS personal assistant flow

3. Intents: understanding multiple users, multiple voice inputs.

Once within a specific domain, the user will have a myriad of intents. We cannot guess what the user is thinking, but we can learn with him/her. In this way, a flexible and easy integration should be assured, and new and evolved intents must be integrated: metadata catalogues, search, among others.

4. Response: giving all previous steps, to create an output.

The main challenge of this step is to provide the user with an accurate response, meaning that consistent responses across touchpoints should be assured. For that, we believe that the usage of analytics tools should be integrated since they are the key for the responses, and they will be used to train and learn the algorithms for better actions.

8.3.2 The Overall Solution

NOS Personal Assistant was designed as a solution with the following two steps:

1. Understand: It uses the Natural Language Process (NLP) to extract meaning of phrases (entities and parameters) that can be mapped to a single Terminal Actions.
2. Conversation: It receives as input the entity and the context, implements a functional workflow (skill or capability) per knowledge domain and outputs Intermediary Action or Terminal Actions. This is the brain of the Assistant.

Taking into account the aforementioned challenges and steps, NOS Personal assistant is designed with the following full flow, as represented in the Fig. 8.1. This full flow represents the three main layers that compose the NOS Personal Assistant architecture, as shown in Fig. 8.2. The client layer is related to the channels themselves, external to the core framework. This layer will allow the seamless integration with all mainstream voice assistant channels (such as Cortana, Google Assistant, Alexa) and the input channels for NOS (such as NOS Remote App, UMA STB, NOS TV).

Fig. 8.2 General overview about the architecture for NOS personal assistant

The FE layer concerns the conversational layer responsible for all the common logic and intelligence of understanding context/domain of the input to figure out which intent should handle this input.

When the system knows the context/domains, BE layer is responsible to leverage skill-specific Natural Language Understanding Models to extract the intent itself from the input as well as all the relevant entities from the input from the JSON response from the NLU model's API Contract. This implementation is provider independent for the NLU API, so it translates the JSON from any of the supported NLU APIs to an internal Entity Model common to these responses. Finally, each skill may have dependent APIs that perform actions or provide skill-specific data or context that are external to the core platform. For other external domains, the architecture has included the webhook feature, which allows the communication with third-party apps, especially the ones integrated into Dialogflow.

8.3.3 A Bottom-Up Approach

One important issue regarding technology and elderly people is how to engage this type of population with advanced technology and how to have their acceptance. This is especially critical not only for the usage of smartphones but also to educate elderly people in using it and to leverage its advantages in their own lives.

Several initiatives are trying to push or stress elderly people in this domain, but in fact few progresses has been made in this area. On the other hand, we are witnessing an exponential growth of voice personal assistants, which may have a huge potential to several domains and also may be the open door to engage people with technology in a smooth and seamless approach. With this in mind, NOS Innovation team is looking to voice personal assistants as a driver not only for IoT and smart homes, but also as a technological teacher for elderly people.

Taking this into account, we have designed and implemented a bottom-up approach, testing three different use cases from the simplest one to the most complex. Those use cases have considered the main technological touchpoints of elderly people: television and mobile phones.

In 2016, NOS was the first Portugal telco to launch a set-top box with voice interaction: its TV remote has a push-to-talk button that allows the user to send voice commands to the set-top box.

Currently, this feature of addressing voice commands to the set-top box has also evolved into a digital app, which also allows the user to use a smartphone (android or iOS), as it emulates the physical remote.

Since television is the main preference of elderly people, we have started their engagement through our TV remote that is connected to our STB. Afterwards, we replicated the same flow in mobile phones, that is, we have developed a digital app remote, where the user can control STB from mobile phone using voice feature. When quite familiar with these technologies, we evolved to an intermediate level, keeping the user in the mobile phone environment but using a non-NOS framework. The user started using Google Action to interact with smart lights. We consider this level very important because the user starts learning how to use common technology (the voice) in different domains (television and home automation). The third use case combines both environments (television and mobile phones) and both frameworks (NOS and Google frameworks), promoting the sense of care using a third-party application to manage their own plants at home. This third use case has been developed under a European funding project, the Turntable [24].

At the end, all three use cases were integrated in NOS voice architecture, which is agnostic to ASR and NLP providers.

Use Cases

As referred in the aforementioned section, three use cases were designed and implemented using different touchpoints with increasing complexity.

First Use Case: Control your TV and Router by Voice

Voice interaction with television: in this use case, the user will ask NOS Assistant to

- Change channel by name or number.
- Change profile.
- Search for contents.
- Launch apps.

These voice commands are configured to be simple commands.

For example, by saying "change to channel 1" or "BBC News", the NLU identifies that it is a channel entity. When a certain voice command is not understood, either by noise or the whole audio sentence was not caught by the ASR, there is a message feedback saying it did not understand the intention and it also shows on the screen examples of what one person can ask. This feedback and information are relevant not only to understand how to interact with the devices but also how to provide a better and successful experience.

These sentences or voice commands need to be simple in order to provide an easy-to-use experience to the end user of any age. The following figures illustrate the NOS remote control experience as well as some tasks that the user can do and the feedback that is provided (Figs. 8.3, 8.4, and 8.5).

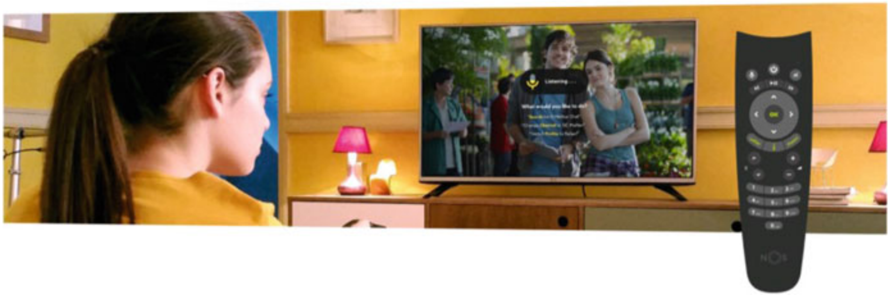


Fig. 8.3 NOS – TV remote control experience

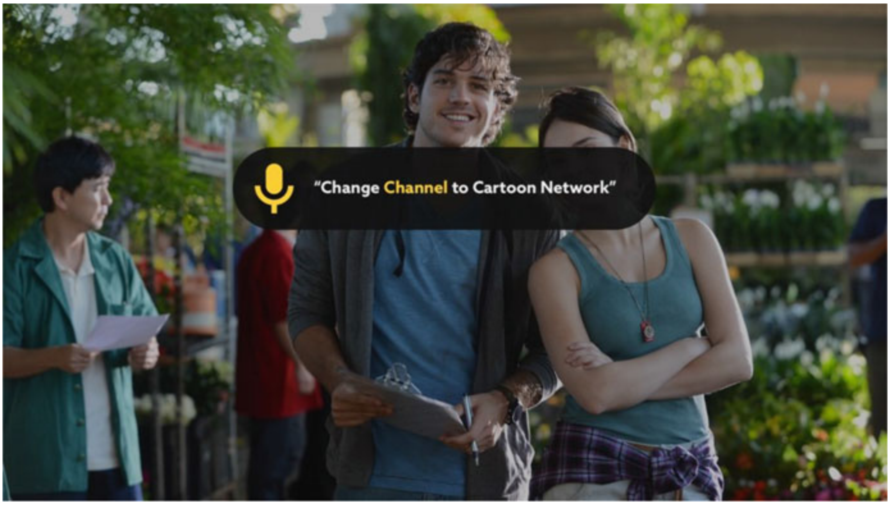


Fig. 8.4 NOS – TV Remote – voice command example: change channel intent

To extend in some way the user knowledge with come advanced features, like profile, we have also developed a feature to personalize the TV experience by providing User Profiles: whoever is watching can choose to create a profile, kids or adult, in order to have tailored contents or continue watching programmes.

Through voice commands, the user can quickly change the profile on the set-top box, as illustrated in the following Fig. 8.6.

Second Use Case: Control Your TV and Lights by Voice Using Your Mobile Phone

In NOS ecosystem, it is possible to interact with other NOS devices, TV, or set-top box through voice commands, such as the router Internet: this enables the user to know the network name or status or even to share his Wi-Fi with other guests. This feature is useful when you have a lot of IoT devices connected to the home/house Internet, and it does not require technical help or the need to get

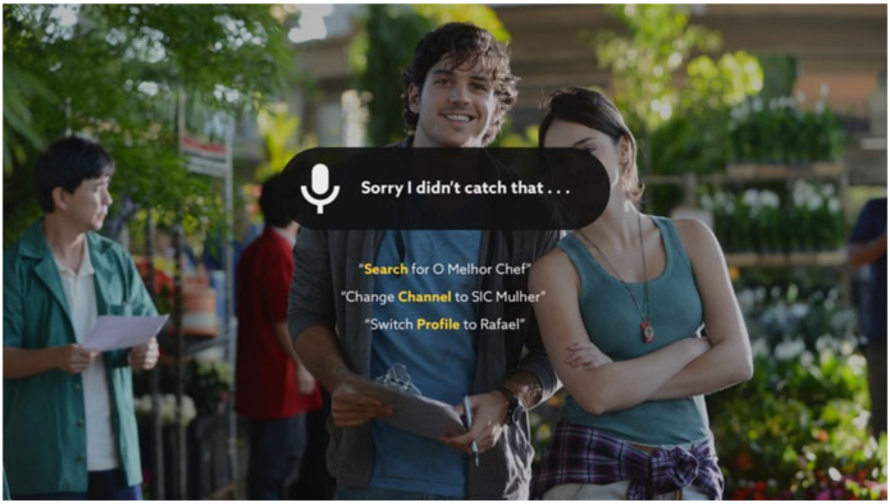


Fig. 8.5 NOS – TV Remote – Message feedback example and suggestion menu

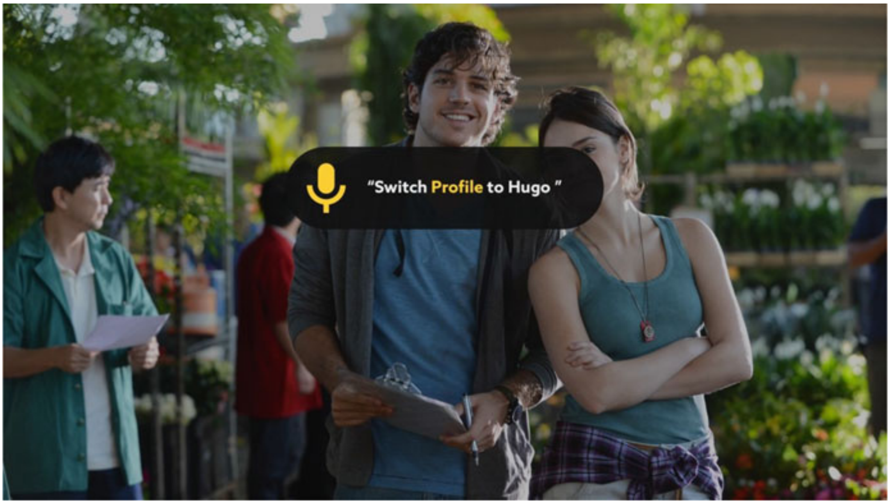


Fig. 8.6 NOS – TV Remote – voice command example: Change profile

other more complexed devices, in order to know the status of your home network connection.

In order to make a smooth transition from television to mobile phone environment, we have developed the digital TV remote control. This mobile application allows the same interaction with STB using voice. Some examples are shown in the Figs. 8.7 and 8.8.

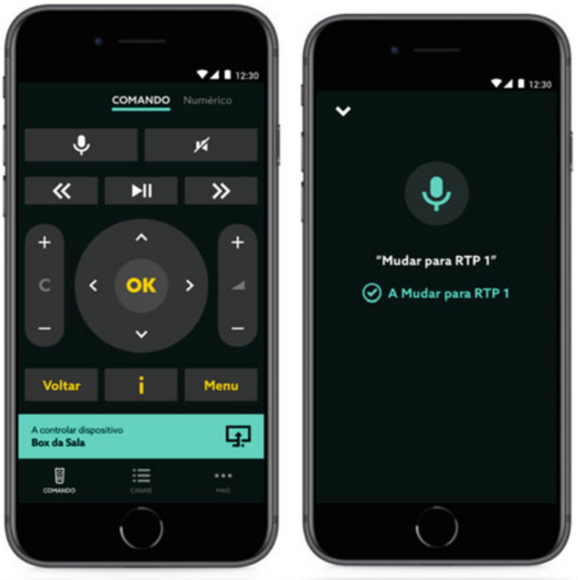


Fig. 8.7 App NOS TV remote control – remote emulator UI and voice interaction

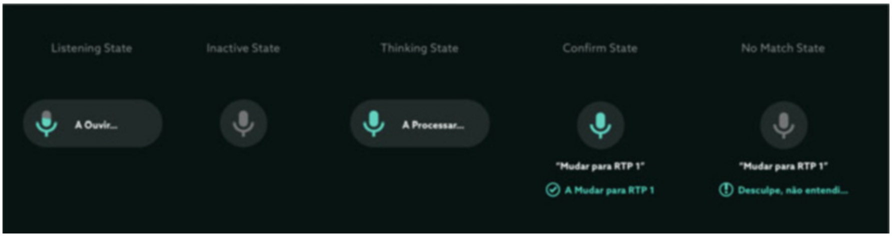


Fig. 8.8 App NOS TV remote control – voice states

This approach allows the user to be more familiar with mobile phones, learn how to install mobile applications and how use it. To go to a different context, Google Assistant can be used; however, the user will still be in NOS ecossystem thanks to the transversal NOS's architecture, which allows the integration of third-party devices in the same system of STB.

This way, one useful interaction through voice is the remote control of house lighting: the inability of reaching switches to turn on or off lamps or lights, or even energy economization, voice interaction has become a major feature in controlling house lights. Many third-party assistants allow to easily integrate light solutions, like Philips Hue with Google Assistant Smart Home and Amazon Alexa, along with other IoT devices like network routers and set-top boxes. Thus, we have launched a way to learn how to use smart sensors, through smart lights, but always to keep a way to leave the user back to NOS core services, selecting NOS devices as illustrated in the following Fig. 8.9.

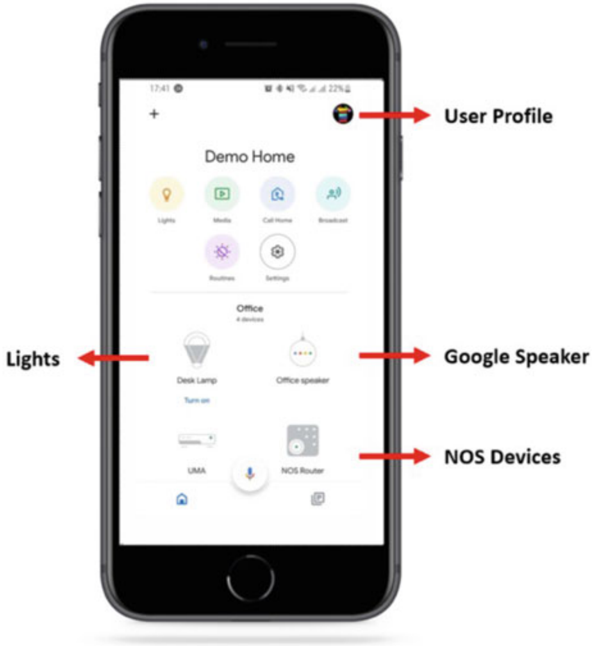


Fig. 8.9 Google Home App with lights, NOS network router and STB, with voice integration

Third Use Case: Build Your Smart Garden at Home Using NOS Personal Assistant

In order to promote the sense of care and independent living, we have created a use case to manage plants at home, supported by NOS Personal Assistant. This use case combines several technologies in NOS ecosystem, aiming to show the elderly people how all things might be connected and how voice interaction can help.

For this third use case, NOS Inovação started the integration of plant sensors with NOS Personal Assistant. This integration was seen as an external third party and, consequently, as an external domain. However, this domain is connected to our ecosystem as described in the Section 3.2.

The integration was performed based on a button-up approach, meaning that we have started the implementation of this use case from the simplest use case and we are improving the complexity based on the outcomes achieved. This use case was named *Build your Smart Garden at Home,* and it has involved several tasks following an agile approach. In this use case, we have developed an external Proxy API to translate raw sensor data from sensors into parsed responses on thresholds. Example:

From this:

Your plant has 27 °C, 20% humidity and 8000 lux of light

To this:

Your plant is hotter than it should, lacks water and could have some shade

This NOS Plants proxy API aims at delivering processed information, so that client platforms – STBs, OTT Apps, Assistants may in turn present the information according to the specific plant type in question.

Using the NOS Plants Proxy API resource, plant/device sensor data was available; we have queried data using Voice Interaction. The intended use case was:

> Question: *Is Plant name/id/etc thirsty?* Answer: *Yes, please water it / No, it is fine at the moment.*

To do this simple use case, we have implemented the following:

(1) What are my plant stats?

(raw data values) – > proxy server getRawData API Request.
request response example:
{*luminosity: <> lumen.*
humidity: <> %.
temperature: <> °C.
battery: <> %.
}

(2) How is my plant doing?

(treated values) – > proxy server getHealthData API Request
request response example:
{*luminosityLevel: Full Shade / Sunlight / Sunburn*
humidityLevel: Drawning / Watered / Dry
temperatureLevel: Cold / Mild / Hot
batteryLevel: Low / Intermediate / High
}

(2.1) If battery below <> %, add message queue saying "Battery is low".

For implementing the voice interaction, we have created a project into Dialogflow with:

- 3 entities
  - @Plant-HealthData (humidity, temperature and luminosity)
  - @Plant-Level (High, Low and Medium)
  - @Plant-type (Rose, Cactus, Dracaena)
- 1 intent
  - Plant-HealthData

We developed our own webhook into the Dialogflow and we have integrated into our voice architecture in order to send messages and receive feedback in two touchpoints: NOS STB and Google Assistant in mobile phones. The following user scenarios (Table 8.1) were designed and implemented for this first version.

The following Fig. 8.10 and 8.11 present some examples of the outcomes.

Table 8.1 Some examples of user scenarios

Humidity/luminosity	Normal	High	Low
Normal	"Hello! Today I feel good!"	"Hello! Wow ... so much light! Can you lower the blinds, please?	"Hello! It's dark! Can you turn on the light a little, please?"
High	"Hello! Today I'm a little bit soaked / wet! Can I borrow an umbrella?"	"Hello . . . Today I feel a little sick . . . ."	"Hello! Today I'm a little bit soaked / wet! A little light would also be good."
Low	"Hello! Today I am thirsty / dehydrated. Can you give me a glass of water, please?"	"Hello! Today I'm thirsty / dehydrated. Can you give me some water, please? And if possible, dim the light."	"Hello . . . Today I feel a little sick . . . ."

Fig. 8.10 The outcome in NOS TV STB results from voice interaction and interconnected with sensors

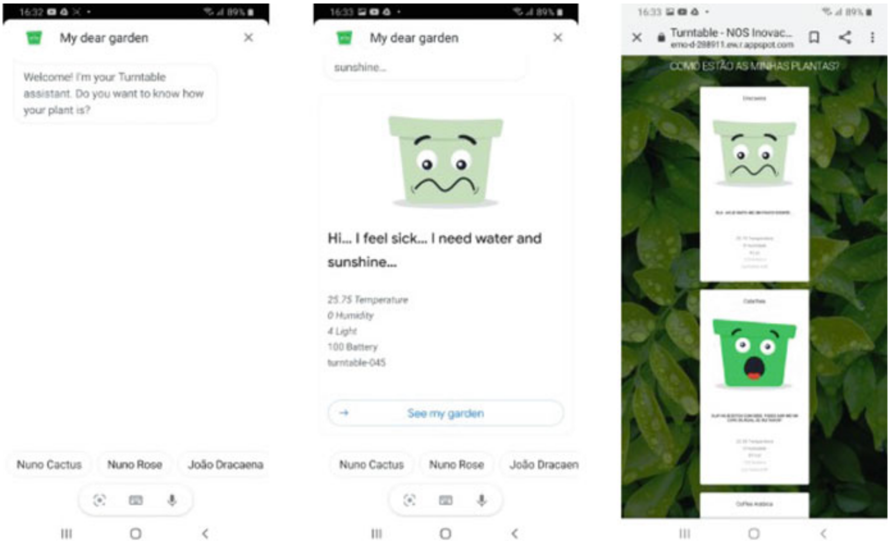


Fig. 8.11 The outcome in Google Assistant results from voice interaction and interconnected with sensors

8.4 Future Research and Innovation Directions

Several initiatives in this implementation are still in progress for both TV and mobile phone environment. The main aspect that we have always in mind is to first put in television and then replicated it in mobile phones and other voice touchpoints.

Those new features with NOS devices that are also being developed on the TV ecosystem are:

- UI visualization: play, pause, programme info, show live TV, restart programme
- TV control: turn on/off set-top box, volume up/down, mute/unmute
- UI shortcuts: Open Recordings, Open VOD/Store
- Advanced Search: show action movies from the 1980s

Furthermore, we are also design a new use case: to introduce voice recognition as a feature to recognize who is the end user that is currently interacting with the device, so that it can change to the correct profile just by saying a word, and thus automatically change the contents that are being presented in the UI.

8.5 Conclusion

The Internet of Things has increased among residential consumers. The main drivers for the growth of smart home market will be video doorbells, voice-assisted technologies, and surveillance systems due to the growing increase in consumer demand.

Meanwhile, the world is aging rapidly. Elderly people want to live healthy and active in their homes; however, this population presents key challenges with smart homes. Most of the smart things targeting the elderly population are focused on improving the Quality of Life rather than providing a seamless and learning ecosystem for breaking their fears with technology.

We described a personal assistant that allows the user to learn how to work with smart sensors, giving them different contexts to test, use, learn and at the same time to keep active and update regarding the next generation of homes. This personal assistant will promote voice interface and learning in the following contexts: to control television and router; to control lights; and to care for their plants. With this new concept in mind and considering the current NOS voice architecture, we have implemented a bottom-up approach to design and test three different use cases to help elderly people use advanced technology based on the main touchpoints.

Since television is the main preference of elderly people, we have started their engagement through our TV remote that is connected to our STB. Afterward, we have replicated the same flow in the mobile phone. When quite familiar with these technologies, we evolved to an intermediate level, keeping the user in the mobile phone environment but using a non-NOS framework. The user started using Google Assistant to interact with smart lights. We consider this level very important because the user starts learning how to use common technology (the voice) in different domains (television and home automation). The third use case combines both environments (television and mobile phones) and both frameworks (NOS and Google frameworks), promoting the sense of care using a third-party application to manage their own plants at home.

We are still in the user research process following some co-creation guidelines. Even so, we believe that this approach is the missing trigger in the blue ocean for AAL market and may have the potential to start the discussions and the birth of new end-user and business's opportunities to involve more and more elderly people with technology, contributing to the inclusive technology and keep a healthy digital world transformation targeting most of the user groups.

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References

1. M. M. Cruz-Cunha (Ed.), Handbook of Research on ICTs for Human-Centered Healthcare and Social Care Services. IGI Global (2013)
2. Global Ambient Assisted Living Market Research Report, by System (Entertainment, Communication, Medical Assistance, Transportation), Sensor (Temperature, Occupancy), Service (Installation & Repair) – Forecast till 2027
3. Geriatric Care Services Market Size By Service (Home Care, Adult Day Care, Institutional Care [Nursing Homes, Hospitals, Assisted Living, Independent Senior Living]), By Service Provider (Public, Private), By Payment Source (Public Insurance, Private Insurance, Out-of-pocket), By Age Group (65-70 years, 71-75 years, 76-80 years, 81-85 years, 86-90 years, Above 91 years) Industry Analysis Report, Regional Outlook, Application Potential, Price Trends, Competitive Market Share & Forecast, 2018–2024
4. Smart Home Healthcare Market by Technology – Global Market Size, Share, Development, Growth and Demand Forecast, 2013-2023. Global Ambient Assisted Living Market
5. V. Zue, S. Seneff, J.R. Glass, J. Polifroni, C. Pao, T.J. Hazen, L. Hetherington, JUPlTER: A telephone-based conversational interface for weather information. IEEE Trans. Speech Audio Process. **8**(1), 85–96 (2000)
6. M. Walker, R.J. Passonneau, J.E. Boland, Quantitative and qualitative evaluation of Darpa communicator spoken dialogue systems, in Proceedings of the 39th Annual Meeting of the Association for Computational Linguistics, pp. 515–522 (July 2001)
7. L. Dybkjaer, N.O. Bernsen, W. Minker, Evaluation and usability of multimodal spoken language dialogue systems. Speech Comm. **43**(1–2), 33–54 (2004)
8. O. Lemon, X. Liu, D. Shapiro, C. Tollander, Hierarchical Reinforcement Learning of Dialogue Policies in a development environment for dialogue systems: REALL-DUDE, in BRANDIAL'06, Proceedings of the 10th Workshop on the Semantics and Pragmatics of Dialogue, pp. 185–186 (September 2006)
9. J. Allen, D. Byron, M. Dzikovska, G. Ferguson, L. Galescu, A. Stent, An architecture for a generic dialogue shell. Nat. Lang. Eng. **6**(3), 1–16 (2000)
10. S. Larsson, S. Ericsson, GoDiS – issue-based dialogue management in a multi-domain, multi-language dialogue system, in Demo Abstract in the Association of Computational Linguistics, pp. 104–105 (2002)
11. O. Lemon, A. Gruenstein, S. Peters, Multi-tasking and collaborative activities in dialogue systems, in Proceedings of the 3rd SIGDIAL Workshop on Discourse and Dialogue, pp. 113–124 (2002)
12. Pakucs, B.: Towards dynamic multi-domain dialogue processing, in Proceedings of the European Conference on Speech, Communication and Technology, pp. 741–744 (2003)
13. K. Komatani, N. Kanda, M. Nakano, K. Nakadai, H. Tsujino, T. Ogata, H.G. Okuno, Multi-domain spoken dialogue system with extensibility and robustness against speech recognition errors, in Proceedings of the 7th SIGDIAL Workshop on Discourse and Dialogue, pp. 9–17 (2006)
14. J. Peckham, A new generation of spoken dialogue systems: Results and lessons from the SUNDIAL project, in Third European Conference on Speech Communication and Technology (1993)
15. P. Van Houtte, L. Delannay, I. Samajdar, Quantitative prediction of cold rolling textures in low-carbon steel by means of the LAMEL model. Texture Stress Microstruct. **31**(3), 109–149 (1999)
16. M. McTear, G. Kouroupetroglou, Emerging multidisciplinary educational issues in the area of spoken dialogue communication, in Proceedings of the International Conference: "The Future of the Humanities in the Digital Age", Bergen, Norway (September, 1998)
17. C. Rich, C.L. Sidner, COLLAGEN: A collaboration manager for software interface agents, in *Computational Models of Mixed-Initiative Interaction*, (Springer, Dordrecht, 1998), pp. 149–184

18. D. Bohus, A.I. Rudnicky, Ravenclaw: Dialog management using hierarchical task decomposition and an expectation agenda, in Eighth European Conference on Speech Communication and Technology (2003)
19. A.A. Bui, R.K. Taira, S. El-Saden, A. Dordoni, D.R. Aberle, Automated medical problem list generation: Towards a patient timeline. Medinfo **11**(Pt 1), 587–591 (2004)
20. S. Larsson, D.R. Traum, Information state and dialogue management in the TRINDI dialogue move engine toolkit. Nat. Lang. Eng. **6**, 323–340 (2006)
21. C. Monson, A.F. Llitjós, R. Aranovich, L. Levin, R. Brown, E. Peterson, ... & A. Lavie, Building NLP systems for two resource-scarce indigenous languages: Mapudungun and Quechua. Strategies for developing machine translation for minority languages, 15 (2006)
22. J.D. Williams, Multi-domain learning and generalization in dialog state tracking, in Proceedings of the SIGDIAL 2013 Conference, pp. 433–441 (August 2013)
23. T. Paek, Reinforcement learning for spoken dialogue systems: comparing strengths and weaknesses for practical deployment, in Proceedings of the Workshop on Dialogues, International Conference of Spoken Language Processing (2006)
24. TURNTABLE Homepage., https://www.aalturntable.eu, last accessed 2020/11/14

Chapter 9
Digital Technologies Changing the Landscape of Corporate Learning and Development

Neha Verma

9.1 Introduction

9.1.1 Rise of Digital Learning

Technology is transforming the landscape of jobs and skills faster than any organization could adapt. Across the world, business leaders are finding it challenging to keep their workforce relevant and up to date [1]. A report from IBM Institute for Business Value suggests that 60% of business leaders globally are struggling to keep their workforce relevant [4]. The World Economic Forum has identified three key reasons that have contributed to an inefficient labor market. First, our current learning and employment system are set on the premise of linear careers that follow a traditional framework of "learn, work, retire." This outdated model is based on the assumption that learners prepare for employment by gaining formal qualifications, and once employed follow a linear career progression until retirement. Thus, in this traditional model, job fit is primarily identified based on formal qualifications. Second, the fourth industrial revolution (4IR) has brought fresh challenges to a system where employers were already struggling to identify the right candidate for the job. Research by the World Economic Forum suggests that by 2022 the core skills required to perform most roles will change by 42% on average. A linear career is an artefact of the past and, to remain employable, employees need to update their skillsets. Third, in many countries, socioeconomic inequalities are exacerbated by the current system of determining job fit. Largely, the educational background of one's family works as a predictor of the educational outcomes of future generations.

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For establishing a fairer base for social mobility and cohesion, rewiring the skills ecosystem is imperative [20].

In today's labor markets, in the midst of the 4IR, there is an urgent demand for both digital and "human" skills. Career paths today are rarely linear, and this will become even more prominent in the future. Therefore, shifting to a skills-based system will be one of the key solutions. Continuous learning infused with upskilling and reskilling has to be embedded into the DNA of organizations for addressing the demand of emerging skills and empowering employees to learn new skills. In addition to the lurking global skills crisis, most of the organizations also recognize the fact that skills of the future may be entirely unknown to the organization. Thus, it is imperative to implement a learning ecosystem that is based on platform-model thinking and helps in embedding the culture of continuous learning [1, 20].

The past decade has witnessed a change in business education with digital learning leading the foray. LinkedIn Learning and other platforms such as Coursera and Udemy are revolutionizing corporate learning. MOOCs and Small Private Open Courses (SPOCs) have been the flag bearers of digital learning transforming higher and corporate education and servicing millions of learners worldwide. To manage, track and achieve learning goals, organizations are investing in cloud-based learning management systems (LMS). As the amount of digital learning content grows, cloud computing technologies and services have emerged as an effective solution for maintaining better access to learning content [6].

As learning delivery becomes increasingly digitized, it is vital to have a digital learning strategy and an ecosystem that acts as an enabler to create business impact. Establishing a digital learning strategy requires collaboration between the business and the learning team. A successful digital learning strategy should have three major characteristics of success. First, the learning strategy should be driven by the organization's current and future needs. Second, it should support learners' need for continuous learning and upskilling. Third, the overall digital learning strategy should be supported by insightful learning data and analysis of performance metrics. Having a clear digital learning strategy establishes a direction for the business and provides a rationale for the adoption or retirement of technologies. Successful implementation of a digital learning strategy not only helps in building an organization's capabilities but also drives digital transformation [14].

9.2 Digital Learning Framework

Technologies and learning theories have to be meaningfully interwoven to create an impactful and lasting learning experience. In essence, for digital learning to be effective, an array of elements needs to be deployed in parallel, and the learner's journey should be monitored and restructured through constant iterations. Thus, Learning & Development (L&D) professionals need to focus on creating engaging learning content and a performance support system to facilitate the transfer of learning into meaningful actions [11]. Figure 9.1 below captures a 6-step framework

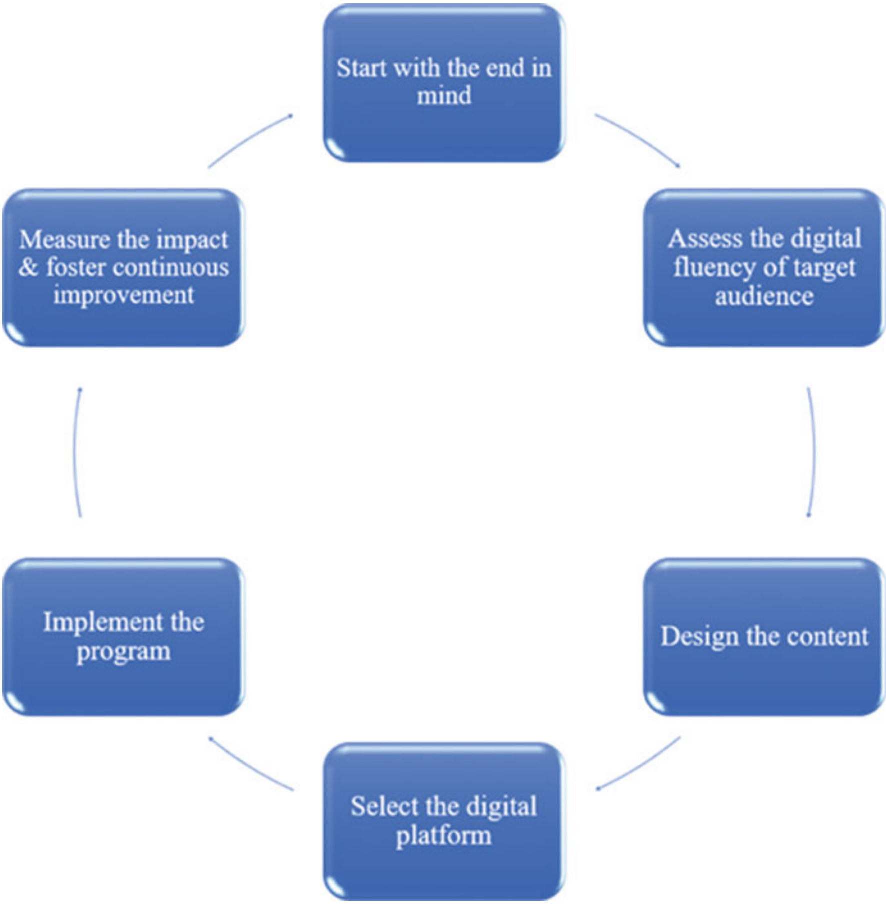

Fig. 9.1 6-step digital learning framework

for impactful digital learning [10, 18]. In addition to the 6-step digital learning framework, fostering a culture of learning and upskilling of learning professionals are equally important.

9.2.1 Start with the End in Mind

Starting with a clear understanding of the problem or current gap in skills will be instrumental in defining desired outcomes or goals and crafting methodologies to measure them. The L&D professionals need to act as strategic partners to the business, thus it is essential to understand what success looks like. Tying the learning outcomes to overarching business objectives is crucial for the success of a digital learning strategy [18]. Learning is an important constituent of the employee lifecycle. In order to create effective learning solutions, learning designers need to understand the "moments of need" that arise on the job for employees. "The 5 Moments of Need" is a framework designed by Gottfredson & Mosher that is based on the premise that employees require learning and performance support at certain moments of need [8]. These moments of need should be leveraged as an opportunity to upskill employees and improve performance by designing meaningful digital learning content.

New Employees are new in the role and should develop an understanding of the job, domain, people, and systems.

More As the employees mature in their current role, the need for expanding their knowledge about a particular skill or subject arises.

Apply Applying what has been learned is the essence of learning effectiveness. This moment of learning need pertains to planning, remembering, or adapting. Just-in-time and bite-sized learning content is the best way to address this need.

Solve Not all days are the same and many times employees come across scenarios for which immediate performance supports tool are needed. FAQs, online discussion forums, or live chat are a few spontaneous methods to make information available to the learners.

Change Things are moving at a much faster rate than ever before and the current pandemic has just accelerated the change. Learning needs and content are also changing at the same speed and it is challenging to cope with this pace of change. This volatile and ambiguous environment requires organizations to undergo a transformation and employees need to adopt new skills and knowledge. It requires learners to unlearn the old way of working and acquire new skills and knowledge.

By understanding these moments of learning needs, L&D professionals should design a learning experience that results in meeting the required business objective.

9.2.2 Assess the Digital Fluency of Your Target Audience

Managing the learning needs of multiple generations in the workforce is challenging. Customizing the learning content and reinforcing digital fluency are paramount for the success of digital learning solutions. Baby boomers in the workforce might have a preference for more face-to-face interaction over a digital discussion forum compared to millennials and gen Z who are considered digital natives. While being aware of learner's digital fluency, it is important to upskill the target audience in navigating new learning technologies [18]. Learner centricity is the key to designing a successful digital learning program. Covid-19 has accelerated the digital transformation, and major universities and corporate learnings have increased their online presence to meet the growing demand and maintain learning continuity. The digital platforms provide engagement by making it easier for learners to access the learning programs and permitting them to participate in the online discussion forums and mentoring plans based on their needs [10]. Technology is accepted widely as an enabler in facilitating learning programs and, thus, encouraging employees to become digital savvy is key to the adoption of digital learning.

9.2.3 Design the Content

The Internet is awash with learning content and today's L&D professionals depending upon the topic of interest can choose to either create or curate the content. Content is valuable in designing a meaningful learning journey. The instructional content falls under two broad categories: micro- and macro-learning [2].

a. Macro-learning is primarily used to develop an understanding of the job, domain, people, and the systems. Macro-learning content should be used when learners want to learn something new and need to dedicate several hours or days to comprehend the definitions, concepts, and practice. MOOCs are one of the most popular examples of macro-learning which are useful in acquiring new skills and knowledge. Digital learning platforms such as LinkedIn Learning, Udemy, and Coursera have pioneered in customizing the learning content based on the requirements of the learners. Content design and delivery are crucial in attaining defined learning outcomes. Macro-learning is particularly helpful in onboarding new employees and driving transformational change. It can be used efficiently to drive effective learning in the moments of learning need when learners want to learn something new or are considering to upskill themselves. However, macro-learning when blended with micro-learning would give superior results [2].
b. Micro-learning should be used to address just-in-time learning needs. As the employees mature in their current roles, the need for expanding their knowledge about a particular skill or subject arises. Such moments of learning need which are linked to applying, solving a problem, or expanding the knowledge should be addressed using digital micro-learning content. Short videos, blogs, or a set of FAQs are extremely helpful. The rise of social media and user-generated content in the past decade offer such learning content in a massive, curated stream. YouTube, Twitter, and Wikipedia are good sources of micro-learning [2].

Digital learning content should be designed and delivered according to the moments of learning need. The overall learning outcome and moments of learning need will require the learning designer to create or curate either macro- or micro-learning content. In today's digital learning environment, we must focus on creating learning journeys where content is easily accessible to learners depending upon their learning needs. A seamless and meaningful learning journey is not only memorable for the learners but also helps in driving organizational transformation.

Macro- and micro-learning work effectively in tandem. These two formats should be used together to meet the "5 moments of learning need." Employees would need macro-learning early in their role when they have to learn something new. As the learning journey progresses, employees need to continuously upskill themselves, thus new information can be dispersed via micro-learning format. In the course of their careers, employees reach a point of maturity where they need to learn new skills as a result of a promotion or to energize their careers. At that point, macro-learning intervention would take the learning curve upwards but failure to deliver a learning intervention when employees need them the most might lead to attrition [2, 8].

Digital learning bestows L&D professionals with an opportunity to create a learning journey personalized for each employee in every role and catalog content, so it can be used for all different purposes. Digitization of learning is one of the key enablers of continuous learning.

9.2.4 Select Appropriate Digital Learning Platforms and Tools

There is a plethora of digital learning platforms and tools in the market. To build a successful learning experience, L&D professionals need to design engaging content delivered on a platform that is intuitive, user-friendly, and simple [5]. Today's employees are overwhelmed, distracted, and constantly bombarded with numerous emails and meetings. The average US employee spends 25% of their time checking emails and they check their mobile phone almost 150 times a day. Thus, the average time spent by employees on learning is approximately 20 min a week [2]. So, it is understood that for upskilling employees gravitate to the learning platforms and content that work best for them. As employees are pressed for time, they have a low appetite for lengthy and linear content, which is also supported by the research in neuroscience that reveals that the human attention span is 20 min. The digital learning ecosystem incorporates spaced, personalized, and bite-sized learning powered by technologies such as artificial intelligence, mobile apps, and cloud computing. To bring learning to where employees are, in addition to LMS and content platforms, many organizations are now adding learning experience platforms such as Degreed, EdCast, Cornerstone, Fuse, etc., and content providers such as Coursera, Udemy, LinkedIn Learning, to name a few. To foster adaptive learning, organizations are relying on vendors such as Qstream, Grovo, and Axonify. These systems operate intelligently and arrange learner-centric content into micro-learning pathways to cater to the just-in-time need of employees. Augmented and virtual reality are being widely used in manufacturing to create memorable learning journeys. Many companies are using the amalgamation of different kinds of digital learning tools and platforms to create a learning journey for the employee lifecycle. The challenge, however, remains in selecting the right platform and tools for the deployment of engaging content to the employees. To manage corporate learning, organizations are investing in cloud computing services: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) [6]. MOOCs are hosted on cloud platforms and are capable of managing a large number of users [7]. LinkedIn Learning, Coursera, Udemy, and many other platforms based on modern cloud infrastructure have attracted millions of users worldwide. One of the major pharma companies has created a digital learning ecosystem where all the internal learning content is deployed using Cornerstone and Fuse, and for external learning content employees have been provided access to LinkedIn Learning and Coursera. It is indeed a good example of organizations leveraging modern cloud-based infrastructure and platforms to create valuable learning experiences.

9.2.5 Implement the Digital Learning Program

Before the full roll-out of any digital learning program, it is important to run a pilot to check the feasibility of full-scale implementation. Running a pilot benefits the learning team in assessing the design (duration, audience size, access of technology and content) and impact (learners as well as the stakeholders) of the program [8]. It is important to roll out the pilot program in the same environment as you would roll the full program to gauge the challenges and successes of the program. Any learning from the pilot programs should be incorporated into the revised program. A key ingredient of implementing successful digital learning is to create an implementation plan which includes all the stakeholders along with roles and responsibilities of the project team and milestones [8].

9.2.6 Measure the Impact and Foster Continuous Improvement

Peter Drucker famously said, "If you can't measure it, you can't prove it". The success of a digital learning strategy for any organization should be measured for its effectiveness. Key performance indicators (KPIs) of business should be achieved by the digital learning intervention and presented using a learning dashboard. L&D professionals should measure the impact of digital learning by measuring the difference between the KPI scores before and after learning intervention [4]. Keeping a pulse check on employees' engagement provides an early indication of the overall satisfaction level of the cohort and also gives an opportunity to L&D professionals to improve content delivery. Most of the content delivery platforms have integrated mechanisms to rate content delivery and satisfaction. Modern learning management systems have the functionality to measure key learning metrics such as learner performance, time and date of course completion, learner competency through assessment, and learner satisfaction. To measure the impact of digital learning programs, it important to foster a mindset of continuous improvement. The KPIs and feedback process for continuous improvement of digital programs should be defined at the start of the program while defining the end goal to meet business objectives [8]. Throughout the lifecycle of digital learning programs, performance should be measured by asking key questions [3]:

- What are the key areas of improvement?
- What is working as expected and what is not?
- What should have been done differently to create a better impact?
- What are the methods of data collecting and who should the data be shared with?
- What went well and what did not?

It is important to gather feedback and data around important metrics and share them with all the key stakeholders to validate the performance of the digital learning program. By collecting data in a timely manner, learning professionals can demonstrate the performance of the program and also troubleshoot and take corrective action if needed instead of waiting for the program to end. Measuring impact and fostering the mindset of continuous improvement are imperative for the success of digital learning programs, and it is not unknown that most learning teams struggle to show impact to their key stakeholders.

9.3 Creating the Culture of Learning

Hermann Ebbinghaus' forgetting curve emphasizes that 90% of learning is lost within a week [2]. Hence, learning cannot be treated as a one-time event, continuous learning and performance support are at the heart of an effective digital learning strategy. One of the major pharma companies is driving the learning culture by promoting curiosity across employees at all levels of the organization. A month was dedicated to celebrating curiosity by hosting and curating webinars on various topics. As the gatekeepers of knowledge, L&D professionals should embed continuous learning in organizational culture by delighting the employees with easy-to-use platforms and engaging content meeting the learners' need. A high-performing learning culture involves digital transformation as one of the priorities. Organizations supporting the culture of learning are open to new ideas, experiments, and errors. Employees actively participate in dialogue and decision-making; thus, a strong learning culture is a hallmark of successful and performance-driven organizations [17]. By driving a learning-oriented culture, many organizations have successfully embodied transformation. After Satya Nadella took the helm of Microsoft in 2014, he emphasized a dynamic culture of learning based on a growth mindset within Microsoft, encouraging employees to move from know-it-alls to learn-it-alls [12]. Leaders play an important role in driving the culture of learning and making it a part of strategic planning as they are responsible for providing the resources required to build and drive a learning culture [19]. Research has shown that digital learning programs act as a strategic enabler in upskilling employees and reducing employee turnover [9].

9.4 Upskilling L&D Personnel

One of the most crucial factors for success in the implementation of digital learning strategy is the skilled L&D professionals. With the changing landscape of technologies, L&D professionals should develop a solid foundation on the use of technology and its impact in creating a learning journey. The market is flooded with varied technologies and vendors; sometimes, it gets frustrating to choose the right tools and platforms that best support the organizational learning requirements. Learning professionals and trainers require significant training in new digital mediums and pedagogy so that they can effectively perform their tasks [9]. The pedagogy for digital learning depends upon the digital fluency of learners [13].

- For less independent learners with minimal digital literacy taking a digital learning program, trainers play a crucial role as a coach actively guiding and instructing the learners through their learning journey [13].
- For independent learners with high digital literacy, trainers play a less active role mostly acting as a mediator while learners navigate through the curriculum autonomously [13].

Thus, upskilling learning professionals and trainers on Information and Communications Technology (ICT) and evolving digital pedagogy are essential for any organization to create a robust digital learning strategy. L&D professionals should develop a deeper understanding of the technological advancements and apply criteria-based assessment while selecting or retiring a platform or tools for designing the digital learning ecosystem [14].

9.5 Conclusion

To achieve long-lasting impact with digital learning strategy, all the above-mentioned factors are important. Today's employees are self-directed, motivated, and aware of their learning needs. Weaving together the learning theories, neuroscience of learning and digital technologies to create a memorable learning journey is crucial for the success of learning organizations. L&D professionals have realized the importance of learners' involvement during the early development of learning programs. The learning systems thus far have given positive results in upskilling the workforce but in order to scale and meet the needs of the VUCA (Volatile, Uncertain, Complex and Ambiguous) environment focusing on digitization is required. Google has already stepped up to disrupt the college degree which will become the basis of hiring for most of the top-tier companies. The new certificate program launched by Google will take only 6 months to complete a catalog of professional programs that will teach the learner to perform jobs that are in demand [9]. The current Covid-19 pandemic has also accelerated the adoption of technologies in corporates and universities. Slack, Microsoft Teams, Zoom, Workplace have already become the favorite tools of engagement and sharing knowledge for most of the employees during the pandemic [2]. Due to access and ease of use, cloud-based learning platforms such as LinkedIn Learning, Udemy, and Coursera have successfully managed to gain millions of users worldwide [16]. Now, more than ever design thinking and prototyping are being used for the successful implementation of emerging technologies (social media, gamification, adaptive software platforms) and emerging practices (user design) in transforming corporate learning [21]. Technology will always act as an enabler, a solid understanding of the science of learning is equally important to create a lasting impact [15].

References

1. L. Belsky, Where online learning goes next. Harv. Bus. Rev. Digit. Articles, 2–5 (2019)
2. J. Bersin, *A New Paradigm for Corporate Training: Learning in The Flow of Work. Josh Bersin: Insights on Corporate Talent, Learning, and HR Technology* (2018)
3. Blended Learning Implementation Guide (2013). http://digitallearningnow.com/site/uploads/2013/02/DLNSmartSeries-BL-paper_2012-02-05a.pdf
4. J. Choi, How to craft a strategically aligned digital learning strategy. Train. Dev. (1839–8561) **47**(2), 10–14 (2020)
5. J. Cook, G. Miranda, Shriver, T., The Rise of the Digital Learning Ecosystem. IBM Institute for Business Value (2018). https://www.ibm.com/downloads/cas/O9ZJ2ZXB
6. F.H. El-Sofany, A. Al Tayeb, K. Alghatani, A.S. El-Seoud, The impact of cloud computing technologies in E-learning. Int. J. Emerg. Technol. **8**(1), 37–43 (2013)
7. A. Fernández, D. Peralta, M.J. Benítez, F. Herrera, An overview of E-learning in cloud computing, in *Workshop on Learning Technology for Education in Cloud (LTEC'12)*, (Springer, Berlin/Heidelberg, 2012), pp. 35–46
8. C. Gottfredson, B. Mosher, *Innovative Performance Support* (McGraw-Hill, New York, 2011)
9. Google Has a Plan to Disrupt the College Degree (2020). https://www.inc.com/justin-bariso/google-plan-disrupt-college-degree-university-higher-education-certificate-project-management-data-analyst.html
10. How to Design and Scale Digital and Blended Learning Programs to Improve Employment and Entrepreneurship Outcome (2015). https://www.accenture.com/t20160119T105855__w__/us-en/_acnmedia/PDF-5/Accenture-Digital-Learning-Report-and-How-To-Guide_Full.pdf
11. P. Hunter, Digital learning 2.0. Glob. Focus EFMD Bus. Mag. **11**(2), 26–29 (2017)
12. H. Ibarra, A. Rattan, A. Johnston, Microsoft: Instilling a growth mindset. Lond. Bus. Sch. Rev. **29**(3), 50–53 (2018)
13. M. Mentis, Navigating the E-learning terrain: Aligning technology, pedagogy and context. Electron. J. E-Learn. **6**(3), 217–226 (2008)
14. M. Murray, N.C. Nielsen, A strategic approach to digital learning. Chief Learn. Off. **18**(8), 54–65 (2019) https://www.chieflearningofficer.com/2019/11/13/a-strategic-approach-to-digital-learning/
15. D. Pontoppidan, D. Everhart, Digital learning: How to train for long term impact. Glob. Focus EFMD Bus. Mag. **12**(2), 40–43 (2018)
16. G. Riahi, E-learning systems based on cloud computing: A review. Procedia Comp. Sci. **62**, 353–359 (2015)
17. M. Santa, Learning organization review – A 'good' theory perspective. Learn. Organ. **22**(5), 242–270 (2015)

18. T. Sheehan, Designing digital learning strategies. Glob. Focus EFMD Bus. Mag. **10**(3), 10–13 (2016)
19. M. Srimannarayana, Creating a culture of learning in the workplace: An exploratory study. Indian J. Ind. Relat. **54**(4), 657–676 (2019)
20. Strategies for the New Economy Skills as the Currency of the Labor Market (2019). http://www3.weforum.org/docs/WEF_2019_Strategies_for_the_New_Economy_Skills.pdf
21. G. Veletsianos, *Emergence and Innovation in Digital Learning* (AU Press/Athabasca University, Edmonton, 2016)

Chapter 10
An Assessment of the Behavioral Intention of Generation Z Toward the Adoption of Digital Learning Applications

Raj Kumar Singh and Bijay Prasad Kushwaha

10.1 Introduction

In the era of digitalization and technological advancement, use of online teaching and learning platforms is increasing in the academia. In the COVID-19 pandemic, the use of learning and teaching platforms has increased dramatically wherein mobile applications are very common in facilitating the delivery of learning contents [61]. In the recent past, various online learning platforms and mobile applications have been introduced to simplify teaching and learning. These applications are commonly used by academia in the domain of computer science, social science, marketing, human resource, banking and finance, mathematics, etc. [5]. Nevertheless, the adoption of mobile applications by students is easily accepted due to their interactive interface and ability to perform several tasks starting from instructions, assessments, reports, and results [40]. Similarly, web portals are also being used especially for certificates, distance learning courses, and skills development programs [18, 48]. In the era of the Internet of things, information technology (IT), and communication, innovation and creativity have played a vital role in terms of user-friendliness, ease of use, and compatibility of such applications in budget smartphones [59]. The present digital society is moving ahead with the methodological change in digital or online learning in schooling and higher education. Schools and higher educational institutions are adopting teaching methods through e-learning applications [34]. A paradigm shift from physical teaching-learning has been supported through a transformation in adopting various communication devices like smartphones, tablets, laptops/desktop [8].

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Considering the time factor and its importance as a key salient element, e-learning has to boost up to enable skill development programs through certification and employability skills. Meanwhile, it should reduce study time, expenses, flexible time, and space [37]. A developing country like India was not very much into implementing online learning due to lack of essential resources like the Internet, awareness of courses among teachers and students, availability, and cost of services. Even the consideration of online certification was limited to some organization or industry. The performance-driven organizations are considering skills rather than just educational qualifications, giving more importance to skill-based programs. Considering the pandemic situation, schools, colleges, universities, and other institutions disseminating knowledge in the society have adopted online teaching methods and are determined to offer a wide range of teaching assistance. This method of e-teaching and e-learning method is promoting social distancing and reducing the widespread COVID-19. The future of students and academics lies in the hand of digital devices and the Internet. Generation Z is familiar with the new developments in the Internet of things, whereas the teachers are not much experienced in handling app and web technologies. Looking into the demand of the time and expectations of the industry, virtual teaching-learning is going to get attractive market shares of the education industry. On the other hand, the infrastructure such as network quality, Internet speed, device compatibility, content quality, location, lack of interaction, and personal data security is lacking in developing nations [56, 66]. Sidelining all challenges, the online mode of teaching has been adopted by several schools, colleges, and universities wherein students seem benefited, but in actual it is yet to be measured and addressed. Factors such as facilities for online teaching-learning process are important to consider for better output.

In the line with the above facts, this study attempt to investigate the factors that are important in shaping the behavioral intention of users to adopt digital learning applications. This study will also try to find out the solution to the following research questions:

1. How effective digital learning applications can be in the teaching-learning process?
2. What are the elements that influence the user's intention to adopt a digital learning platform?
3. What are the challenges faced by users while using digital platforms for learning?

This investigation will be carried out using technology acceptance model (TAM) to find out the adoption intention of the user of online learning. This investigation will provide an upgraded TAM model for digital learning apps wherein reflective constructs of perceived usefulness are utility and learning, student engagement, data security, feedback and rating, accessibility, and user interface. Similarly, reflective variables of perceived ease of use are accessibility, entertainment, and user interface. The existing constructs of the existing TAM model may not be suitable in diagnosing the intention and attitude of the user in accepting the digital learning applications. Therefore, researchers have used a new construct to investigate the research questions. This research paper contributes to both academics and industry to incorporate the relevant features in applications, which affects the online teaching-learning process the most. Similarly, it will also provide important features that are mostly considered by users in the selection of digital learning platforms.

The remaining paper is structured in different sections. After the introduction section, Sect. 2 explains the theoretical framework with the introduction of different applications used in the teaching-learning process and associated variables influencing the teaching-learning process. Section 3 explains the data collection process, analysis, and interpretation. Section 4 consists of practical and theoretical implications along with a conclusion.

10.2 Literature Review

Technology has introduced a paradigm shift in the service and manufacturing industries. Technology greatly influences and impacts people's behavior and formed behavioral intention toward a product or service. Several models have been used in this domain, but the TAM has been widely studied and has broad applications. TAM measures the effects of variables that are associated with perceived ease of use and perceived usefulness, assertiveness toward the adoption of technology, and changes in willingness to use. TAM is used to measure the effectiveness of IT in various areas of operations like email systems, Internet banking, C2C behavior, telecommunication, online games, social media, retail services, and distance learning [12]. Scholars have modified and expanded the TAM theory since its establishment. TAM prototype has been upgraded from TAM1, TAM2, to TAM3. The TAM3 model proposed by Agudo-Peregrina et al. [2] introduced two major variables, personal innovativeness and perception, which provide a deep insight concerning the influence of behavioral intention. TAM3 model has been applied in the adoption of information technology in SMEs, banking, and e-commerce, etc.

10.2.1 Digital Learning

The development of IT has played a significant role in the academics. Numerous learning platforms are being used to facilitate a wide range of students across the world [18]. Information technology along with communication has become one of the best mediums for constructive teaching and learning. Constructive learning enables the user or learner to be an agent of social and economic change. The use of communication technology has made learning more interactive and interesting which acts as a motivation factor for students [28]. Performance-driven organizations invest a huge amount of capital in human resource development and other resources, which directly greatly improve and affect their performance [46].

Mobile applications or technologies provide a variety of learning and teaching possibilities [31]. Digital learning provides a mechanism to access the online available or searchable content and eliminates the constraint of carrying, moving physically, and budget.

10.2.2 Internet of Things (IoT) and Cloud Computing

IoT is a global, dynamic, and self-configuring capable network infrastructure. IoT connects the world with the integration of smart objects like devices, software, and the web [7]. The majority of educational institutions (schools, colleges, and universities) are moving toward smart classrooms and digital learning to facilitate interactive and innovative teaching and learning methods because of improved Internet connectivity and easy access to it [41]. The IoT network connects almost all devices such as computers/laptops, smartphones, smart bands, TV [4], and even other devices used in different segments of the manufacturing and service industries [26]. Moreover, IoT is playing a significant role in academia for interactive teaching-learning modules [47].

Cloud computing has created a buzz with its plain feature especially in digital learning, both economically and efficiently [57]. Cloud computing is redefining and restructuring digital learning with its capabilities of storing and sharing, security, worldwide accessibility, and collaborative interaction with user-centricity. The data availability, transferability, accessibility, and agility have become more scalable and cost-effective [9]. Moreover, cloud computing provides ease of use in terms of records keeping, grading academic performances, and scientific research [39]. Furthermore, the availability of worldwide industrial/market data for forecasting and decision-making creates a sustainable environment in academics and digital learning at the personal and organizational level [20].

10.2.3 Digital Learning App

The advancement of electronic devices like smartphones, computers, tablets, etc., networks, motivation, attraction toward online teaching-learning, and COVID-19 pandemic encourage tutors and learners to use different applications for better teaching and learning. Interfaces like Microsoft Teams, Zoom, Google Classroom, LMS/Moodle, Google Meet, Google Hangout, and many more are being widely used for teaching and learning. Even many more learning applications like YouTube, Unacademy, TEDx, TED Talk, Byju, Diksha, and ePathshala are playing a prominent role in promoting learning at a global level. Considering the need and want of time and education system, many MOOC (massive open online courses) providers like edX, Khan Academy, Udemy, Coursera, Swayam, NPTEL, Edureka, Canvas, FutureLearn, Udacity, Simplilearn, Skillwise, Wizi, Alison, and many more also support and promote online learning and skill development programs.

10.2.4 Actual Use (AU)

Learning applications create an interactive and learner-centric environment and promote collaborative student learning [17]. Behavioral willingness to use the modern technology significantly influences and impacts the acceptance and actual use of IT [16]. The actual use of technology can be determined by the relevance of technology, relative advantages, playfulness, self-efficacy, and other important factors [1].

10.2.5 Behavioral Intention to Use (BITU)

User willingness to use any interface or application is influenced by many variables [35]. Major variables through which behavioral intention to use can be measured and determined are mainly concerned with the regularity of use, the total time spent on use, the actual frequency of use, and, finally, the diversity in usage [24]. A questionnaire that included 17 statements from TAM on behavioral components like attitude and beliefs was put forward to 45 teachers indicating a positive relationship between acceptance of technology and behavioral intention [28].

10.2.6 Attitude Toward Use (ATU)

User's learning attitude plays a vital role in adopting online resources for teaching and learning [19]. It has been reported that e-learning is affected by many external factors but is influenced by two major elements: first, perceived usefulness of learning platforms including utility and learning, student engagement, data security, feedback and result, content accessibility, entertainment, and user interface and second, perceived ease of use including accessibility, entertainment, and user interface [1].

10.2.7 Perceived Usefulness (PU)

It is the perceived faith of users about the benefits of using technology in terms of performance and output [43]. Technological resources have proved very useful and beneficial in teaching and learning. Various resources like audiovisual content, processed information, better connectivity in terms of covering long distances/places, and quick and timely access of service providers and service users improve perceived usefulness to a great extent [28]. E-learning system cannot be benefitted and maximized if either party does not use the application and its features [1]. Expansion in digital learning platforms provides useful insight in professional development using a different medium of teaching and learning like tutorials and/or social networks by reducing time usually consumed and the cost incurred to avail it [22]. In the case of government applications where accessibility of the content becomes mandatory up to some extent, is positively impacted by the perceived usefulness of the platform or application [13].

10.2.8 Perceived Ease of Use (PEOU)

Ease of use refers to applying technological resources effortlessly in the teaching and learning process, influencing user's attitudes and behavior toward using digital learning platforms [43]. Ease of use indicates the smoothness of the digital interface which generates interest in the teacher as well as the learner without facing any sort of difficulty/obstacle in learning [28]. Ease of use makes the user comfortable, indirectly helps in retaining the users, builds a learned community, and finally results in a deep knowledge pool [21]. Perceived ease of use usually influences user's behavior and leads to the intention to use that application regularly [6].

10.2.9 Utility, Learning, and Perceived Usefulness

Online learning (augmented reality apps) provides an interface which makes learning simple and attractive with the experience that student wants to have. These applications enrich technological capabilities and expertise and are found very cost-effective [54]. The usability attribute of digital learning platforms enhances willingness and promotes creativity among teachers and students and engages both parties [28]. Easy, approachable, thought-provoking language and student's proficiency in the language also support learning and hence support perceived usefulness [55]. Learning can be enhanced through the interactive interface of the applications among schoolchildren. Associated utility and features with the learning platform help in building communication and social network among students [53].

10.2.10 Student Engagement and Perceived Usefulness

Students' engagement is a crucial and integral part of the learning system [45]. The engaging student in a class or in online or distance learning is the real concerned area which directly impacts the perceived usefulness of the learning applications [10, 38, 49, 50]. Digital learning facilitates interactive platforms containing different types of study material like text content, pictures, audiovisuals, etc., which make the teachers or instructors more comfortable in disseminating information to learners [59]. Previously, many studies support student engagement in learning and also indicate a positive connection and relationship with online learning technologies and learning outcomes [36]. The free play in the application improves creativity and student engagement [53].

10.2.11 Data Security and Perceived Usefulness

E-learning is being adopted at a very fast pace, and due to rapid changes in the societal and academic environment, teachers and students are almost bound to use digital learning platforms/applications [33]. Adopting the e-learning platform has become the need of the time, but due to improper IT policies, cybersecurity, and adequate authentication, data security has become the most important factor for consideration [67]. The majority of the users are using unsecured applications or systems which are the easy targets for hacking the personal data as well as content/resources available. Confidentiality, integrity, and availability are the major requirements that protect personal and official data [38]. The decision of accessing any platform or application is influenced by perceived information security. Electronic data threat is being generated by unauthorized access to information [60].

10.2.12 Feedback and Rating and Perceived Usefulness

Feedback and rating features in an application or web portal can be teacher-centric or learner-centric or both [68]. The feedback and output facilitate levels of engagement, liking, room for doubt clearance, improvement, and learner's and teacher's achievement [27]. Student's feedback and teachers' feedback play a vital role in producing better output. Based on feedback and ratings, a comparative analysis can be done which provides insights about trends and performance of all students as well as trainer/instructor [29].

10.2.13 Accessibility and Perceived Usefulness

Accessibility features permit users to access the content or resources available on websites or in an application [44]. Many applications are restricted or partially accessible or can be accessed only after making a certain amount of payment [58]. Accessibility is not only concerned with applications but also the personal data of users or learners, which creates a sense of insecurity in the minds of users, finally leading to perceived usefulness [32].

10.2.14 User Interface and Perceived Usefulness

The user interface is a platform or space where human and machine interaction occurs. Hardware and software are the major elements that facilitate the user's interaction with the machine [53]. An interactive user interface facilitates teachers and learners to create and share content and receive feedback that leads to an improvement in the quality of results or outcomes [25]. A flexible and interactive interface provides ease of use and collaborative learning and retains users as well as service providers ([42]). Several studies have brought out that if the interface is not interactive and attractive, new users spend less time on it and never revisit. Due to a lack of flexibility, existing users feel the complexity and lookout for an alternative [30].

10.2.15 Entertainment and Perceived Ease of Use

Digital games associated with learning apps promote game-based learning and entertain the user or learner [62]. Game-based learning is usually characterized by involvement, interaction, use of multimedia, challenges, rewards, and social experience which influence instructor's and learner's behavior in such a way to become more involved in learning [23] and develop curiosity, creativity, observation, and experimentation [54]. The touch screen of the device also potentially supports entertainment and improves learning [25]. Perceived enjoyment and entertainment positively influence the use of technology leading to a change in attitude of use of technology.

10.2.16 Accessibility and Perceived Ease of Use

Accessibility is the degree of freedom to use or to access the interface or content of any online platform or application [44]. Accessibility inspired the users to achieve their full potential. Various researches depict that content accessibility improves the perceived ease of use in terms of frequent access to stored content [11]. Convenient accessibility of content saves time and promotes interest in learning [25].

10.2.17 User Interface and Perceived Ease of Use

The user interface increases the degree of interest and learnability of students and provides a sense of satisfaction [46]. It has been observed from the previous studies that user guidance positively influences ease of use [32]. Effectiveness and value proposition digital technology depend on the user's acceptability which is directly related to the application interface [37]. A user-friendly interface promotes and determines the perceived ease of use and promotes engagement [17].

10.2.18 Exiting TAM Models

Various models/theories on technology acceptance behavior were studied, and it was found that various external variables were widely allied with the apparent effectiveness of technology and support apparent ease of use. Theories like theory of reasoned action (TRA), recommended by Ajzen and Fishbein [3], portray that a user's conduct is a utility of his assertiveness toward the act and individual rules [37, 43]. Another TAM, proposed by Davis [15], is also TRA [35, 51]. TAM model explains the customer's attitude toward using a particular service and his behavioral intention in using new technology which results in actual use [14]. TAM2 was proposed by Venkatesh and Davis [64], and TAM3 was proposed by Venkatesh and Bala [63]. Unified theory of acceptance and use of technology (UTAUT) was proposed by Venkatesh [65]. Initially, the UTAUT model identified four major constructs: effort anticipation, community effect, performance anticipation, and easing situations; but later on, some more determinants like hedonic motivation, price value, and habits were also identified in the updated version of the model, UTAUT2, which determine the behavioral intention and usage behavior. Further, facilitating conditions and habits are found to have a direct impact on usage behavior [52]. Various models on behavioral willingness toward the use and acceptance of technology found out that the relationship of external variables with the perceived usefulness of online platforms and perceived ease of use creates interest in digital learning (Fig. 10.1).

10.3 Research Methodology

The survey was conducted with a structured questionnaire as an instrument of data collection for this study. The purposive sampling technique was applied to choose the 490 samples for this study. The sample of this study were existing users of the digital learning platform wherein the parents of the students have also joined in this study. The parent of kids are using the digital learning platform for their kids; therefore, their participation was important. Moreover, both learners and

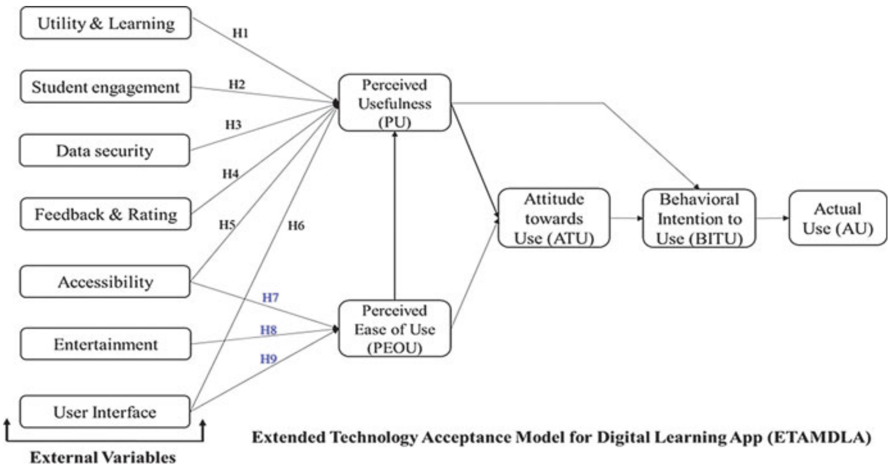

Fig. 10.1 Conceptual model of extended TAM for digital learning apps. (Source: Authors' Observations)

instructors are also important sides of teaching-learning technology. The attributes of behavioral aspects are taken from the reasoned-action theory which is similar to the existing technology acceptance model (TAM); however, the attributes of perceived usefulness and ease of use are taken from UTAUT and other similar models to prepare a hypothesized extended TAM model for digital learning applications. This study has been conducted in Delhi NCR from June 2020 to August 2020. The questionnaire was prepared on the Google form platform, and the link was circulated through emails and the WhatsApp chat application. The responses of respondents related to their demographic profiles were collected using the radio button to accept a single choice, and inquiries related to the behavioral aspects of technology acceptance were on a 5-point Likert scale. The structural model was analyzed by the partial least square method of structural equation modeling using Smart PLS 3.0 software. This software is very useful in analyzing the relationship impact among two or more variables.

10.4 Data Analysis and Interpretation

10.4.1 Sample Characteristics and Distributions (N = 490)

Table 10.1 indicates the sociodemographic profile of the sample wherein the highest representation is from female (51.84%), age below 20 years (56.94%), and undergraduate educational qualification (58.98%). Similarly, the highest proportion of respondents (i.e., 72.65%) have accessed two to five e-learning applications. The highest frequency of using such applications is three to five times a week by users.

Table 10.1 Descriptive statistics ($N = 490$)

Characteristics	Category	f	(%)
Gender	Male	236	48.16
	Female	254	51.84
Age group	Below 20 years	279	56.94
	20–25 years	160	32.65
	25–30 years	38	7.76
	Above 30 years	13	2.65
Education level	School	122	24.90
	Undergraduate	289	58.98
	Post-graduate	79	16.12
Number of application access for e-learning	≥2	91	18.57
	02–05	356	72.65
	05–10	43	8.78
Frequency of using mobile learning app	1–5 times/day	163	33.27
	6–10 times/day	48	9.80
	3–5 times/week	247	50.41
	6–10 times/week	23	4.69
	3–5 times/month	9	1.84
The time duration of using learning websites/day	<1 h	38	7.76
	1–2 h	193	39.39
	2–3 h	181	36.94
	3–4 h	49	10.00
	4 h <	29	5.92

The highest duration of spending time on e-learning platforms is 1–2 h per day. The above table also indicates a good composition of respondents that have participated in this study.

10.4.2 Measurement Model: Reliability and Validity

Table 10.2 represents the validity of the statement that was asked to the respondents during the survey. The statistics of the standardized outer loading of all the items are above 0.70 that meet the minimum threshold of retaining the items for further analysis. Therefore, all the items that were considered in this study were reserved. The mean and standard deviation values of all the items are in the range 3.55–4.14 and 0.702–9.46, respectively. This indicates a good range of mean and standard deviation results. The mean scores of statements relating to entertainment, utility and learning, and actual use are better than the other constructs (Table 10.3).

The correlation coefficient matrix and quality criteria (Table 10.2) indicate that correlations among the constructs are low, moderate, and high; however, the highest correlation coefficient values is less than 0.90 which ensures that the situation of

Table 10.2 Measurement model assessment

Latent variables	Manifest variables	Codes	Factor loading	Mean	SD
Accessibility	Before deciding on whether or not to adopt the digital application, I use the trial version	AC1	0.854	3.97	0.764
	Before deciding on whether or not to adopt the digital application, I try out it properly	AC2	0.834	3.96	0.768
	Before deciding on whether or not to adopt the digital application, I look for a longer open source app	AC3	0.913	3.92	0.753
Attitude	I like using digital learning applications	AT1	0.861	3.88	0.765
	The digital learning system is used as fun by me	AT2	0.878	4.01	0.770
	Digital learning system provides an interactive environment	AT3	0.846	3.98	0.778
Actual use	I propose to finally switch over to the digital learning	AU1	0.846	4.06	0.730
	Using digital apps systems improves my productivity	AU2	0.913	4.13	0.741
	Using systems enhances my effectiveness in grades	AU3	0.714	4.09	0.721
Behavioral intention	I intend to use the digital learning application on my device	BI1	0.789	4.14	0.746
	I intend to adopt digital application frequently on my device	BI2	0.879	4.09	0.702
	I think there is development happened during the pandemic which has brought advanced digital learning applications	BI3	0.890	4.11	0.707
Data security	I believe that my data is safe on digital platforms	DS1	0.861	3.62	0.813
	I believe that my academic info is safe on digital platforms	DS2	0.720	3.63	0.866
	I believe that my academic progress data is safe on digital platforms	DS3	0.869	3.55	0.890
User interface	It is stress-free to recall how to complete tasks	UI1	0.858	3.55	0.946
	I consider that it is a simple process to do what I want	UI2	0.853	3.57	0.923
	My interaction with the system is clear and understandable	UI3	0.851	3.62	0.863
Feedbacks and rating	I like to use such a platform that has a good rating	FR1	0.918	3.61	0.915
	I like to use such a platform that has good user reviews	FR2	0.756	3.59	0.880
	I like to use such a platform that has a positive word of mouth	FR3	0.922	3.65	0.919

(continued)

Table 10.2 (continued)

Latent variables	Manifest variables	Codes	Factor loading	Mean	SD
Perceived ease of use	Learning to operate the digital application is easy for me	PE1	0.806	3.63	0.826
	It is easy to be skilled by using a digital learning app	PE2	0.882	3.58	0.865
	It is easy to be skilled by using digital learning sources	PE3	0.880	3.63	0.864
Perceived usefulness	Using a digital application enhances productivity	PU1	0.880	3.96	0.711
	Using a digital application enhances the effectiveness	PU2	0.861	3.97	0.759
	Overall, I find the digital application useful for my learning	PU3	0.705	4.03	0.724
Student engagement	Information is well structured and presented	SE1	0.792	3.95	0.740
	I find the screen pleasant and engaging	SE2	0.914	4.00	0.757
	The information interface is efficient and attractive	SE3	0.818	4.01	0.728
Entertainment	I find the digital application on my digital device entertaining	EN1	0.894	4.00	0.772
	I find the digital application on my digital device pleasant	EN2	0.741	4.00	0.757
	I find the digital application on my digital device excited	EN3	0.854	3.96	0.709
Utility and learning	I like digital platforms that have more features available	UL1	0.799	4.00	0.770
	I like digital platforms that have an interactive learning system	UL2	0.822	4.00	0.729
	I like digital platforms that have learning features	UL3	0.849	3.95	0.712

multicollinearity does not exist. Similarly, the average variance extracted (AVE) values of all the constructs are above 0.50 which indicates more than 50% variance among the constructs there for the convergent validity of all the constructs are approved. Similarly, the shared variance of all constructs is more than the AVE; therefore, discriminant validity is also approved. The lowest values of convergent reliability of all the constructs are 0.71, and the highest is 0.90 that falls in between 0.70 and 0.95 which indicates a satisfactory to good range and also establishes the internal consistency reliability. Cronbach's alpha values of all the constructs are greater than 0.70; therefore the reliability check is also conceded and the dataset is eligible for structural model analysis.

Table 10.3 Correlation coefficient matrix and quality criteria

Latent Variables	Accessibility	Actual Use	Attitude	Beh_ Intention	Data Security	User Interface	Feedbacks & Rating	Per_Ease of Use	Per_Usefulness	Stud_ Engagement	Entertainment	Utility & Learn
Accessibility												
Actual Use	0.14											
Attitude	0.08	0.72										
Behavioural Intention	0.15	0.88	0.84									
Data Security	0.11	0.17	0.14	0.16								
User Interface	0.07	0.71	0.81	0.75	0.15							
Feedbacks & Rating	0.73	0.19	0.11	0.18	0.11	0.06						
Perceived Ease of Use	0.08	0.80	0.80	0.75	0.15	0.76	0.13					
Perceived Usefulness	0.13	0.69	0.77	0.72	0.18	0.80	0.15	0.74				
Entertainment	0.13	0.15	0.11	0.12	0.90	0.12	0.11	0.13	0.14			
User Interface	0.92	0.12	0.04	0.12	0.11	0.05	0.78	0.06	0.10	0.13		
Utility & Learning	0.11	0.25	0.20	0.19	0.21	0.17	0.14	0.15	0.21	0.20	0.13	
AVE	0.75	0.55	0.74	0.52	0.67	0.73	0.71	0.73	0.51	0.71	0.69	0.68
Composite Reliability	0.90	0.76	0.90	0.71	0.86	0.89	0.88	0.89	0.70	0.88	0.87	0.86
Cronbach's Alpha	0.84	0.58	0.83	0.45	0.78	0.81	0.82	0.82	0.43	0.82	0.79	0.76

10.4.3 Structural Equation Model

Figure 10.2 indicates the relation between endogenous and exogenous variables. It shows that the independent variables such as utility and learning, student engagement, data security, feedbacks and rating, accessibility, and user interface and entertainment have an important relationship with either dependent variables: perceived usefulness or perceived ease of use. Similarly, the variables such as perceived usefulness and attitude, perceived ease of use and attitude, attitude and behavioral intention, and behavioral intention and actual use have an important relationship with each other. Therefore, the structural model looks good and sound for understanding the digital learning technology adoption pattern.

Table 10.4 shows the outcomes of the bootstrapping procedure to test the hypotheses and relationships of variables by selecting (490 cases, 5000 subsamples,

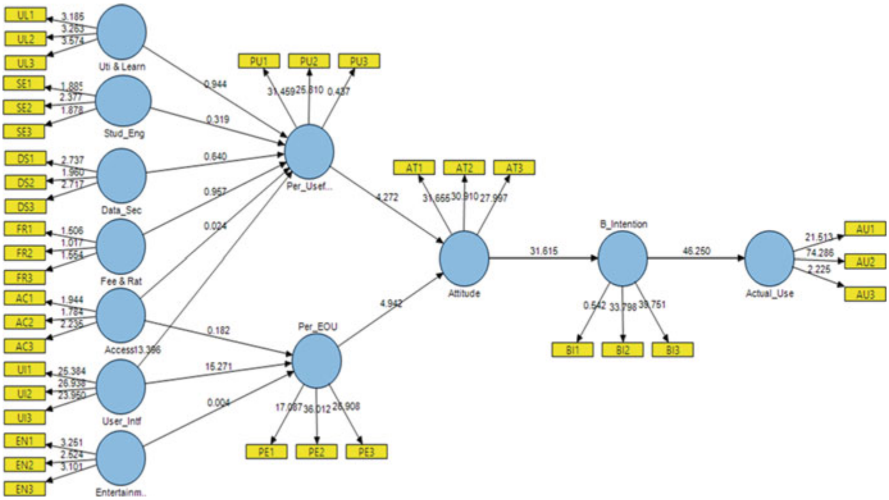

Fig. 10.2 Path diagram

and no significant change) the structural model. Out of the 13 hypotheses of the technology acceptance model of digital learning, 6 hypotheses have been accepted and 7 have been rejected. There is a significant impact of perceived usefulness ($\beta = 0.779$, $p \leq 0.01$) on attitude, perceived ease of use ($\beta = 0.761$, $p \leq 0.01$) on attitude, attitude ($\beta = 0.844$, $P \leq 0.01$) on behavioral intention, and behavioral intention ($\beta = 0.878$, $p \leq 0.01$) on actual use. Similarly, there is a significant impact of user interface on perceived ease of use ($\beta = 0.761$, $p \leq 0.01$) and perceived usefulness ($\beta = 0.779$, $p \leq 0.01$). Nevertheless, there is an insignificant impact of accessibility, data security, feedbacks and rating, student engagement, and utility and learning on perceived usefulness, and accessibility and entertainment on perceived ease of use.

10.5 Discussion

This study aims to provide a digital learning technology acceptance model to application developers and service providers of such platforms. The finding of this study suggests that users of digital learning application's perceived usefulness can be increased with the help of improvements in factors such as user interface. The user interface of digital learning applications is considered an important factor in deciding the digital learning platform. An interactive interface of the application makes a user-friendly application, and users find it easy in using the platform. Interactive and user-friendly digital learning applications will gain a favorable attitude of users. The factors such as accessibility, data security, feedbacks and rating, engagement, and utility of digital learning platforms have not much

Table 10.4 Structural model assessments

Hypotheses		Beta	*SM*	SD	SE	*T* Stat.	Decision
H7	Accessibility –> perceived ease of use	0.028	0.002	0.153	0.153	0.181	Rejected
H5	Accessibility –> perceived usefulness	−0.004	0.038	0.170	0.170	0.024	Rejected
H12	Attitude –> behavioral intention	0.844	0.844	0.026	0.026	32.00***	Accepted
H13	Behavioral intention –> actual use	0.878	0.879	0.020	0.020	45.10***	Accepted
H3	Data security –> perceived usefulness	0.074	0.058	0.118	0.118	0.632	Rejected
H8	User interface –> perceived ease of use	0.761	0.763	0.049	0.049	15.44***	Accepted
H6	User interface –> perceived usefulness	0.779	0.756	0.056	0.056	13.85***	Accepted
H4	Feedbacks and rating –> perceived usefulness	0.093	0.073	0.100	0.100	0.92	Rejected
H11	Perceived ease of use –> attitude	0.499	0.503	0.101	0.101	4.92***	Accepted
H10	Perceived usefulness –> attitude	0.401	0.399	0.093	0.093	4.30***	Accepted
H2	Student engagement –> perceived usefulness	−0.036	−0.006	0.112	0.112	0.31	Rejected
H9	Entertainment –> perceived ease of use	−0.001	0.026	0.161	0.161	0.00	Rejected
H1	Utility and learning –> perceived usefulness	0.059	0.064	0.061	0.061	0.97	Rejected

***$p \le 0.01$; **$p \le 0.05$; *$p \le 0.10$

importance in digital learning application adoption. However, these factors are very important for any digital learning application; therefore, the findings have shown that there is less role of application developers even though one should always keep these factors while developing digital learning platforms. The existing constructs of TAM models are also shown a significant relationship among them and their importance in new technology adoption.

10.6 Practical Implications

Digital learning, the Internet of things (IoT), and cloud computing have been witnessed as a necessity during this pandemic. The concept of learning through different digital platforms is satisfying the need and adding value to the education system through a world web connection. The study focuses on the factors determining the adoption of the digital learning platform, access to the Internet, and the importance of cloud computing. The study suggests that the factors which have a significant influence on the perceived usefulness of the application and ease of use will build a competitive advantage in the market. From the learner's point of view, the outcome of this study will be useful if the service providers and developers of digital learning platforms should incorporate all the suggestive features in the application/platform. The increase in access to the Internet will facilitate more learners to move to digital learning platforms. Implementing the findings will improve the learning process from the angles of both teachers and students. Factors that are making the learning platform user-friendly, easy access to the Internet and its improved speed, and interactive in terms of ease of use including playfulness will promote more usages among peer groups and industry. The study will help in gaining a competitive advantage in terms of market share and the number of users. Digital learning application developers can initially go for a free trial to attract the users, and thereafter they can go for commercialization. The suggested features are the expected features by the users and will encourage users and organizations to even pay for the application's commercial version. Consideration of the suggested changes will cater to the needs and expectations of the users and the application/platform developers, and finally, it will add value to society at large.

10.7 Theoretical Implications

Techno-savvy or technology-driven society has huge expectations in terms of ease of use and effectiveness of the applications. The majority of the factors studied earlier were relating to the overall technology acceptance aspects. In this paper, the significant focus is given to behavioral aspects of users and expected technological advancement in digital learning platforms only. Some of the factors are taken from existing literature on the UTAUT and TAM. To understand the behavioral aspects of users, we have applied the elements of the theory of reasoned action (TRA). Combining and correlating previous models with learners' needs and expectations has resulted in these new significant contributions in the existing literature. The findings of this research will add a new edge to the education sector and corporate sectors and will increase skills among the young generation.

10.8 Conclusion

Pandemic and revolutions in digital technology have created several opportunities for many businesses. There are many application and platforms that have been developed to grab the opportunities in this pandemic. The competition is also at its peak, and every developer is trying to provide a high level of features and experience to their users. The framework of this study has tried to provide a comprehensive structural model to understand the digital learning technology acceptance behavior of users. The users of the digital learning platforms give more priority to the interface of the application; therefore, developers should develop a user-friendly application that any layman can operate easily. There is a situation where parents are using these digital technologies for their students to set up and join online classes who may not have much experience of using it. Therefore, ease of use factor is the most important wherein easy-to-use tools and easy to join classes and complete assessment tasks are the most frequently used tools of digital learning platforms. Developers can also look into data security, feedbacks and rating, engagement tools, and entertainment in learning and utility which are also important factors that can be considered while designing such applications.

The future study in this area can be conducted in different locations such as rural and urban because the literacy levels of using a digital application of rural and urban users are significantly different. The only limitation of this study is the location, for example, Delhi NCR. The Delhi NCR is the capital of India where people from all Indian states are residing, and these users mostly possess better technical skills of using digital application; therefore, the findings of this study may be applicable for all urban locality of India and other Asian countries. The generalization of this study may not be possible from a global perspective because the participants of this study are urban users only.

References

1. F. Abdullah, R. Ward, Developing a general extended technology acceptance model for e-learning (GETAMEL) by analyzing commonly used external factors. Comput. Hum. Behav. **56**, 238–256 (2016). https://doi.org/10.1016/j.chb.2015.11.036
2. Á.F. Agudo-Peregrina, Á. Hernández-García, F.J. Pascual-Miguel, Behavioral intention, use behavior and the acceptance of electronic learning systems: Differences between higher education and lifelong learning. Comput. Human Behav. **34**, 301–314 (2014). https://doi.org/10.1016/j.chb.2013.10.035
3. I. Ajzen, M. Fishbein, A Bayesian analysis of attribution processes. Psychol. Bull. **82**(2), 261–277 (1975). https://doi.org/10.1037/h0076477
4. M. Al-Emran, S.I. Malik, M.N. Al-Kabi, A survey of the internet of things (IoT) in education: Opportunities and challenges, in *Studies in Computational Intelligence 846*, (Springer, 2020). https://doi.org/10.1007/978-3-030-24513-9_12
5. S.S. Al-Gahtani, Empirical investigation of e-learning acceptance and assimilation: A structural equation model. App. Comput. Informat. **12**(1), 27–50 (2016). https://doi.org/10.1016/j.aci.2014.09.001

6. A.-A. Amer, A.-A. Ahmad, S. Jo, Exploring students acceptance of e-learning using technology acceptance model in Jordanian Universities. Int. J. Educ. Dev. Using Inf. Commun. Technol. **9**(2), 4–18 (2013). http://ijedict.dec.uwi.edu/viewarticle.php?id=1617
7. T. Ane, M. Billah, T. Nepa, Performance of internet of things (IoT) potential applications in education. Bangladesh J. Multidiscip. Sci. Res. **2**(2), 10–16 (2020). https://doi.org/10.46281/bjmsr.v2i2.653
8. L. Anthonysamy, Digital literacy deficiencies in digital learning environment among university students, in *CoMDITE, 2017–2020*, (2019)
9. M. Bakhouya, M. Zbakh, M. Essaaidi, P. Manneback, Cloud computing, IoT, and big data: Technologies and applications. Concurr. Comput. **32**(17), 10–13 (2020). https://doi.org/10.1002/cpe.5896
10. M. Boekaerts, Engagement as an inherent aspect of the learning process. Learn. Instr. **43**, 76–83 (2016). https://doi.org/10.1016/j.learninstruc.2016.02.001
11. D. Carless, D. Boud, The development of student feedback literacy: Enabling uptake of feedback. Assess. Eval. High. Educ. **43**(8), 1315–1325 (2018). https://doi.org/10.1080/02602938.2018.1463354
12. J.K. Chen, The influence of behavioural intention on third-party e-commerce payment. S. Afr. J. Econ. Manag. Sci. **21**(1), 1–9 (2018). https://doi.org/10.4102/sajems.v21i1.2157
13. L. Chen, A.K. Aklikokou, Determinants of E-government adoption: Testing the mediating effects of perceived usefulness and perceived ease of use. Int. J. Public Adm. **43**(10), 850–865 (2020). https://doi.org/10.1080/01900692.2019.1660989
14. C.Y. Chiang, K. Boakye, X. Tang, The investigation of e-learning system design quality on usage intention. J. Comput. Inf. Syst. **59**(3), 256–265 (2019). https://doi.org/10.1080/08874417.2017.1342176
15. F. Davis, Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q. **13**(3), 319–340 (1989). https://doi.org/10.2307/249008
16. Y. Deshpande, S. Bhattacharya, P. Yammiyavar, A behavioral approach to modeling Indian children's ability of adopting to e-learning environment, in *4th International Conference on Intelligent Human Computer Interaction: Advancing Technology for Humanity, IHCI 2012*, (2012). https://doi.org/10.1109/IHCI.2012.6481776
17. K. Diliberto-Macaluso, A. Hughes, The use of mobile apps to enhance student learning in introduction to psychology. Teach. Psychol. **43**(1), 48–52 (2016). https://doi.org/10.1177/0098628315620880
18. R.J. Fang, C.L. Chang, H.L. Tsai, C.J. Lee, Explain the factors of primary school teachers choosing digitalized teaching materials with theory of planned behavior, in *Proceedings of the 10th WSEAS International Conference on Multimedia Systems and Signal Processing, MUSP*, vol. 10, (2010), pp. 77–83
19. R.J. Fang, H.L. Tsai, C.J. Lee, A.L. Chin, In the artificial society of choosing digitalized teaching materials with theory of planned behavior. Recent Researches in Artificial Intelligence, Knowledge Engineering and Data Bases – 10th WSEAS International Conference on Artificial Intelligence, Knowledge Engineering and Data Bases, AIKED. **11**, 354–358 (2011)
20. B.J. Faritha, R. Revathi, M. Suganya, M.N.R. Gladiss, IoT based cloud integrated smart classroom for smart and a sustainable campus. Procedia Comput. Sci. **172**, 77–81 (2020). https://doi.org/10.1016/j.procs.2020.05.012
21. M. González-Sanmamed, I. Estévez, A. Souto-Seijo, P.C. Muñoz-Carril, Digital learning ecologies and professional development of university professors. Comunicar **28**(62), 9–18 (2020). https://doi.org/10.3916/C62-2020-01
22. M. Gonzalez-Sanmamed, A. Sangrà, A. Souto-Seijo, I. Estévez, Learning ecologies in the digital era: Challenges for higher education. Publica **50**, 83–102 (2020). https://doi.org/10.30827/publicaciones.v50i1.15671
23. M. Görke, V. Bellmann, J. Busch, P. Nyhuis, Employee qualification by digital learning games. Procedia Manuf. **9**, 229–237 (2017). https://doi.org/10.1016/j.promfg.2017.04.040

24. S.F. Griffith, D.H. Arnold, Home learning in the new mobile age: Parent–child interactions during joint play with educational apps in the US. J. Child. Media **13**(1), 1–19 (2019). https://doi.org/10.1080/17482798.2018.1489866
25. S.F. Griffith, M.B. Hagan, P. Heymann, B.H. Heflin, D.M. Bagner, Apps as learning tools: A systematic review. Pediatrics **145**(1) (2020). https://doi.org/10.1542/peds.2019-1579
26. S. Gul, M. Asif, S. Ahmad, M. Yasir, M. Majid, M.S.A. Malik, A survey on role of internet of things in education. IJCSNS Int. J. Comput. Sci. Netw. Secur. **17**(5), 159–165 (2017)
27. J. Harland, M. Michel, T.A. Kampmann, J. Kierfeld, Event-chain Monte Carlo algorithms for three- and many-particle interactions. Europhys. Lett. **117**(3), 30001 (2017). https://doi.org/10.1209/0295-5075/117/30001
28. A.F. Hayati, Oknaryana, J.E. Marna, How is teachers' accept on digital learning? **124**, 430–434 (2020). https://doi.org/10.2991/aebmr.k.200305.100
29. A.M. Hughes, M.E. Gregory, D.L. Joseph, S.C. Sonesh, S.L. Marlow, C.N. Lacerenza, L.E. Benishek, H.B. King, E. Salas, Saving lives: A meta-analysis of team training in healthcare. J. Appl. Psychol. **101**(9), 1266–1304 (2016)
30. B.B.J. Joao, Assessment for learning with mobile apps: Exploring the potential of quizizz in the educational context. Int. J. Dev. Res. **10**(01), 33366–33371 (2020)
31. J.B.B. Junior, Assessment for learning with mobile apps: Exploring the potential of quizizz in the educational context. International Journal of Development Research **10**(01), 33366–33371 (2020)
32. L. Kenney, Elementary education, there's an app for that: Communication technology in the elementary school classroom. Elon J. Undergrad. Res. Commun. **2**(1), 67–75 (2011). http://www.elon.edu/docs/eweb/academics/communications/research/vol2no1/07kenney.pdf
33. D. Keržič, N. Tomaževič, A. Aristovnik, L. Umek, Exploring critical factors of the perceived usefulness of blended learning for higher education students. PLoS One **14**(11), 1–18 (2019). https://doi.org/10.1371/journal.pone.0223767
34. B. Klimova, Impact of mobile learning on students. Educ. Sci. **9**(2) (2019). https://doi.org/10.3390/educsci9020090
35. C.J.B. Landicho, Research attitudes, motivations, and challenges of STEM education researchers. Int. J. Technol. Des. Educ. **3**(1), 49 (2020). https://doi.org/10.46328/ijte.v3i1.21
36. M.H. Lin, H.C. Chen, K.S. Liu, A study of the effects of digital learning on learning motivation and learning outcome. Eurasia J. Math. Sci. Technol. Educ. **13**(7), 3553–3564 (2017). https://doi.org/10.12973/eurasia.2017.00744a
37. L. Liu, L. Zhang, P. Ye, Q. Liu, Influence factors of satisfaction with mobile learning APP: An empirical analysis of China. Int. J. Emerg. Technol. Learn. **13**(3), 87–99 (2018). https://doi.org/10.3991/ijet.v13i03.8381
38. D. Man, M.H. Chau, B. Kong, Promoting student engagement with teacher feedback through rebuttal writing. Educ. Psychol., 1–19 (2020). https://doi.org/10.1080/01443410.2020.1746238
39. A.K. Mani, S. Said, V. Gokilavani, K.N. Unnikrishnan, A review: IoT and cloud computing for future internet. Int. Res. J. Eng. Technol. **6**(May), 1098 (2019). www.irjet.net
40. I.J. Maria, D. Thirupathi, R. Rajendran, B. Velumani, Technologies, challenges and tools for digital learning. Proceedings – IEEE 10th International Conference on Technology for Education, T4E 201 (2019), pp. 268–269. https://doi.org/10.1109/T4E.2019.00068
41. A.C. Mary, P.J. Rose, The impact of graduate student's perceptions towards the usage of cloud computing in higher education sectors. Univ. J. Educ. Res. **8**(11), 5463–5478 (2020). https://doi.org/10.13189/ujer.2020.081150
42. A.V. Maschio, N.M.R. Correia, Digital learning object for audiovisual production. Int. J. Inf. Educ. Technol. **10**(3), 201–208 (2020)
43. M. Masrom, Technology acceptance model and E-learning. 12th International Conference on Education, May (2007), pp. 21–24
44. S. Nowakowski, G. Bernard, From digital humanities to a renewed approach to digital learning and teaching. J. Sib. Fed. Univ. Humanit. Soc. Sci. **12**(9), 1682–1693 (2019). https://doi.org/10.17516/1997-1370-0486

45. B. O'Donovan, C. Rust, M. Price, A scholarly approach to solving the feedback dilemma in practice. Assess. Eval. High. Educ. **41**(6), 938–949 (2016). https://doi.org/10.1080/02602938.2015.1052774
46. K. Okano, J.R. Kaczmarzyk, J.D.E. Gabrieli, Enhancing workplace digital learning by use of the science of learning. PLoS One **13**(10), 1–10 (2018). https://doi.org/10.1371/journal.pone.0206250
47. S.S. Pai, Vikhyath, Shivani, Sanket, Shruti, IOT application in education. Int. J. Adv. Res. Dev. **2**(6), 20–24 (2017). https://www.ijarnd.com/manuscript/iot-application-in-education/
48. S. Papadakis, M. Kalogiannakis, Mobile educational applications for children: What educators and parents need to know. Int. J. Mobile Learn. Org. **11**(3), 256–277 (2017). https://doi.org/10.1504/IJMLO.2017.085338
49. J. Philp, S. Duchesne, Exploring engagement in tasks in the language classroom. Annu. Rev. Appl. Linguist. **36**, 50–72 (2016). https://doi.org/10.1017/S0267190515000094
50. L. Phung, Task preference, affective response, and engagement in L2 use in a US university context. Lang. Teach. Res. **21**(6), 751–766 (2017). https://doi.org/10.1177/1362168816683561
51. C.R. Pitt, A. Bell, R. Strickman, K. Davis, Supporting learners' STEM-oriented career pathways with digital badges. Inf. Learn. Sci. **120**(1–2), 87–107 (2019). https://doi.org/10.1108/ILS-06-2018-0050
52. P. Ramírez-Correa, J. Arenas-Gaitán, F. Rondan-Cataluña, Gender and acceptance of E-learning: A multi-group analysis based on a structural equation model among college students in Chile and Spain. PLoS One. **10** (2015). https://doi.org/10.1371/journal.pone.0140460
53. M. Rich, Can smartphones make smart kids? Pediatrics **145**(1), 8–11 (2020). https://doi.org/10.1542/peds.2019-3503
54. A.H. Safar, A.A. Al-Jafar, Z.H. Al-Yousefi, The effectiveness of using augmented reality apps in teaching the English alphabet to kindergarten children: A case study in the state of Kuwait. Eurasia J. Math. Sci. Technol. Educ. **13**(2), 417–440 (2017). https://doi.org/10.12973/eurasia.2017.00624a
55. M. Sato, S. Loewen, Metacognitive instruction enhances the effectiveness of corrective feedback: Variable effects of feedback types and linguistic targets. Lang. Learn. **68**, 507–545 (2018). https://doi.org/10.1111/lang.12283
56. A.R. Sousa, *Learning Analytics in Higher Education* (Jossey-Bass, San Francisco, 2018), pp. 787–793. https://doi.org/10.4324/9780203731864
57. G. Suciu, G. Todoran, A. Vulpe, V. Suciu, C. Butca, R. Cheveresan, Cloud computing and validated learning for accelerating innovation in IoT. Proceedings of the International Conference on E-Learning 2015, E-LEARNING 2015 – Part of the Multi Conference on Computer Science and Information Systems (2015), pp. 178–182
58. H.L. Tay, S.W.K. Low, Digitalization of learning resources in a HEI – A lean management perspective. Int. J. Product. Perform. Manag. **66**(5), 680–694 (2017). https://doi.org/10.1108/IJPPM-09-2016-0193
59. A. Tick, Digital learning – Sunshine and shadow. INTED2020 Proceedings 1(March) (2020), pp. 6200–6209. https://doi.org/10.21125/inted.2020.1680
60. T. Tsiakis, Consumers' issues and concerns of perceived risk of information security in online framework. The Marketing Strategies. *Procedia - Soc. Behav. Sci.***62**, 1265–1270 (2012). https://doi.org/10.1016/j.sbspro.2012.09.216
61. N. Upmanyu, R. Chauhan, Assessing the moderating relationship for mobile learning apps: A study of students in college context. Prestige Int. J. Manag. IT – Sanchayan **06**(01), 116–124 (2017). https://doi.org/10.37922/pijmit.2017.v06i01.009
62. I. Vandangeon-Derumez, A. Djedidi, E. Szendy, An experiential approach to learning about change management. J. Manag. Dev. **38**(9), 708–718 (2019). https://doi.org/10.1108/JMD-03-2018-0110
63. V. Venkatesh, H. Bala, Technology acceptance model 3 and a research agenda on interventions. Decision Sciences, Decis. Sci. Inst. **39**(2), 273–315 (2008)

64. V. Venkatesh, F.D. Davis, A theoretical extension of the technology acceptance model: Four longitudinal field studies. Manag. Sci. **46**(2), 186–204 (2000)
65. V. Venkatesh, M. Morris, G. Davis, F. Davis, User Acceptance of Information Technology: Toward a Unified View. MIS Q. 27(3), 425–478 (2003). doi:https://doi.org/10.2307/30036540
66. J.K. Verma, C.P. Katti, View on security, privacy and trust issues in cloud computing environment. Int. J. Latest Trends Eng. Technol. **5**(3), 490–494 (2015)
67. F. Weng, R.J. Yang, H.J. Ho, H.M. Su, A TAM-based study of the attitude towards use intention of multimedia among school teachers. Appl. Syst. Innov. **1**(3), 36 (2018). https://doi.org/10.3390/asi1030036
68. N.E. Winstone, R.A. Nash, M. Parker, J. Rowntree, Supporting Learners' agentic engagement with feedback: A systematic review and a taxonomy of Recipience processes. Educ. Psychol. **52**(1), 17–37 (2017). https://doi.org/10.1080/00461520.2016.1207538

Chapter 11
A Literature Review on Lean Manufacturing in the Industry 4.0: From Integrated Systems to IoT and Smart Factories

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11.1 Introduction

In the manufacturing world, the trend of shortening the productive cycle and increasing the variety of products, trying to reduce the costs and decrease the wastes, is always more researched. Higher importance is therefore given to the ability in answering rapidly to change in customers' requests; for this reason, productive systems with higher flexibility and easiness of upgrade are gaining more and more importance in the market, avoiding a fast obsolescence, which is the investment's first enemy. An approach based on these paradigm is the lean manufacturing (LM), defined as the philosophy of always reducing wastes in every plant section and in every way, in order to decrease the productive times and costs (James P. Womack and Daniel T. Jones, "Lean Thinking" 1996"); this concept resumes the production technics developed by Toyota Production System in the middle of the 1990s, thanks to Taiichi Ohno. This is only one of the several LM definitions that all share the following aspects:

1. Strategy: It is necessary to implement LM as part of a business strategy and, subsequently, spread in the company with an adequate approach. This is a quite complex operation, also because it is linked to the concept of cultural change.

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2. Removal of the wastes: With a continuous research, the productive operations can be performed in the most efficient way and at minor costs; the efficiency has to be translated in the ability to adapt the business to client's needs. Wastes can be divided into seven categories:

   - Inventory: excess of products or materials not used yet in the productive processes
   - Waiting: time lost waiting the step-by-step process
   - Motion: not necessary movement of production personnel
   - Defects: wastes due to rework of products, scarps, and erroneous information
   - Transportation: unnecessary movement of products and materials
   - Overprocessing: work used to achieve a higher quality, not requested by the standards of the market
   - Overproduction: production of more products than what is necessary or production faster than what is necessary

3. Reduction of production times: It can be achieved with the elimination of all the activities without added value for the processes. Jointly with wastes' elimination, more efficient operation should be performed, increasing the profit margin and the product quality.

A term strictly related to LM is common sense, intended as a series of activities performed in the proper way and applied in the right production environment. These activities are defined as the 5S and are used frequently in the LM implementation. Some operations have a key role for a successful implementation and for obtaining the defined results: must be taught to all the employees the basic principles of improvement and how to identify a starting point for waste elimination.

A 5S system includes the following activities:

- Sort: tool sorting in relation to their utilities in the determined area and removal of useless tools
- Set in order: stabilize organization of useful tools in order to guarantee an easy and efficient access
- Shine: cleaning and maintenance of the optimal situation, in order to share the concept of a well-organized environment
- Standardize: diffusion of the guidelines in order to comply with the previous activities
- Sustain: educate workers, in order to make them follow the guidelines

The LM can be considered as the starting point for all the companies that are trying to optimize their productive methods. What this approach brings to the companies is to create a simplified and very organized productive environment that can be modified when needed by the company as reply to companies' or customers' needs. The gained flexibility moreover allows a fast change in productive processes, in order to exploit the personnel, the equipment, and the space and time available.

11.2 The Term Industry 4.0

The term "Industry 4.0," introduced for the first time by Siemens in the Hannover exhibition in 2011, refers to the fourth industrial revolution and represents today a phenomenon, continuously evolving, described as the process that will bring the manufacturing industries into a completely automatized and interconnected reality. Industry 4.0 is considered the last evolution of the industry from its birth:

- In the middle of 1700, the steam engine allows to implement new systems able to improve and mechanize the productivity of the common processes. This is the first industrial revolution.
- From 1870, thanks to an always more diffused utilization of the electricity, the concept of mass production is born. At the same time, the utilization of the combustion engine starts.
- In the years around 1970, the digital era took place. The goal is to increase the automatization level, toward the exploitation of information technology.
- The fourth and last industrial revolution is based on the technologies available today; it hasn't an official precise starting day, yet, because its development is still in progress.

The origins of this revolution must be searched in today's scenario, characterized by a growing use of information technologies that can radically change the approach toward innovation, reducing the time necessary to reach quality and performance goals. On top of that, the market is influenced by a strong competition, significantly increased in all the sectors, creating the right circumstances for a drop of prices and augmentation of quality. Another interesting phenomenon is related to the reduced lifecycle of the product, driven by the necessity to react quickly and respond rapidly to the market desires in order to keep the pace with competitors and avoid losses in market share. Obviously, the product design and manufacturing are changing along with it, giving importance not only to quality but also to flexibility, intended as ability to react, resilience, and customization of product [4, 5].

These new conditions obliged the main manufacturing countries to put in place an economy effort to support the national companies to develop renovation strategies. In particular Germany, in 2012, developed a governmental strategic initiative (Industrie 4.0) to establish the position of the country as a leading advanced manufacturing solutions provider in the market; subsequently the US government presented a partnership, called Manufacturing USA, with the main ICT companies for improving research project in the Smart Manufacturing Area; the same happened in France, with the "Industrie du Futur," China with "Made in China 2025," Japan with "Industrial Value chain Initiative," England, India, and others. Recently (2016) also Italy has prepared a set of Government investment to improve research and development, start-up creation and university competences [7].

Today we are at the beginning of the fourth industrial revolution that aims to put in relation the world of automatized production with the connectivity: this is achieved through the utilization of Internet of things (IoT), an environment where the machines are enabled to independently generate and transmit data to a server for operations such as backup, reports, diagnostics, comparative analysis, role assignment, and so on. Another important step is done with the technologies for system integration and the creation of the cyber physical system (CPS), identified as an interconnection of physical machine and its digital counterpart, where the operational activities can be run in parallel or in different time scale, providing crucial information about the behavior and the context (US National Science Foundation, cyber-physical systems); intelligent machines, logistic systems, and production plants can be considered CPS. All these tools can be used to develop the Industry 4.0 and integrate the automation with the connectivity in the manufacturing industry, in order to create a flexible and customized business.

11.3 From Integrated System to IoT

The information and communication technologies (ICT) have a main role in the implementation of these innovative solutions and technologies of the Industry 4.0: intelligent integrated systems and global networks are the engines for the technological progress and have a fundamental role in the equipment and products used in the everyday life, such as smartphone, ABS and ESP car systems, house's informatics systems, and so on. The integrated systems are the central control unit for the management of the operation in the modern technological devices and, generally, are designed for a specific operation and aren't reprogrammable for other scopes. These systems relate to the external world through a network and are able to cooperate and transmit information with other intelligent systems. The evolution of these technologies is still an interesting point in several areas, because further research can guarantee benefits at a different level, like finance and informatics.

Furthermore, more advantages and evolution can be obtained from CPSs than traditional ICT. The ability to interact with the external world and enlarge the possibilities with calculations, connection, and control has a crucial role in the development of future trends. CPSs are defined as key enabling technology (KET), technologies whose adoption can boost innovation for a variety of industrial environments. Those technologies can be essential for a change toward environment sustainability as well as modernization of industrial processes, key element for reshoring of production that is vital for Europe industrial policy; they are characterized by high knowledge intensity and rapid innovation's cycle, with necessity of high investment to provide high qualifying employment (European Commission, Growth and Industry). The interaction between high performances integrated systems and dedicated interface that communicates through digital networks enables a high variety of new functionalities: an example is given by the smartphone that today is providing functionalities, applications, and services exceeding the original purpose of the phone. Moreover, CPSs represent a step forward also in the business and marketing models, since they are adding new elements and applications to the value chain: these reasons are behind the progressive transformation of the industrial sectors and the increasing importance gained by security, efficiency, and convenience for humans. CPSs represent the next step in manufacturing evolution, following the integrated systems, because reaching the goal of integration through the cooperation of Internet and online services: one of the main goals is therefore the development of always more advanced, secure and autonomous system, with higher reliability, through the integration of scientific, engineering, and computational activities in order to develop a new science over CPSs and provide support to technology and knowledge.

CPSs are creating the basis for the development of IoT, which is, in itself, in direct relationship with data and services, in order to realize the Industry 4.0 project. The expression Internet of things describes the technological development path that from the Internet network empowers every object of an own digital identity. This concept is revised in industrial meaning and generates the industrial Internet of things (IoT) and the smart machines, i.e., machines with intelligence ability that uses M-2-M technology, so that the fourth industrial revolution will change the way of working in the plants. In order to equip a machine of "intelligence," in the meaning of an ability to give information at a higher level than standard communications (status identification), it is necessary to provide the machine with new elements for the communication and interaction: measurement sensors, dedicated control system for performance optimization, and storage ability for data about working performances. These elements entail the diffusion of the IoT environment that can be controlled and monitored by experts from a centralized position (Internet of People): all these factors result in economic benefits for the company, through the optimization of the production, and for the client; this phenomenon is described as Internet of Services.

Even if some technologies and application mentioned before have been developed recently, the idea of interconnection and dialogue between the different parts of a plant is an argument already known in the past decades: with less advanced technologies, the objective was to obtain a simplified dialogue, i.e., an information transmission to central points from measuring sensors, with reduced abilities of interface and connection with external world. Nevertheless, the original idea has been realized and extended, thanks to some factors:

- Contamination and transversality of innovation and attitudes: referred to the ICT, for the implementation in the industry, and to the industry for the adaption at the improvements provided by ICT, in an always higher convergence between the two sectors.
- Interconnection: its development and diffusion are related to the decrease of technologies' cost and increase in computational ability of the platform.
- Change in company attitudes: it starts with a preparation and approach change in the company, linked with the new business opportunities related to the social media in order to define production and diffusion strategy for a product.
- The interconnection and the adequate complexity level provide advantages:
  - Improvement of the plant management through the increase of productive efficiency, reduction of energetic costs, better organized maintenance, new

services creation, real-time interaction with information about production toward augmented reality devices.
- Improvement of product quality and customization: customer request and change are flexibly handled, using also the big data analysis.
- Distribution of intelligent products with information about their production, use, and disposal.

It will be possible to embrace new business opportunities, thanks to the big amount of data available from products and transmitted through industrial Internet, from which derive a higher productivity, reduction of costs and wastes, general improvement of quality, and fundamental concept that are at the basis of the lean manufacturing, the starting point of this revolution [1, 2, 11].

11.4 Smart Factory: Future of Automated Production

IoT is therefore the result of a progressive evolution of systems that starts from integrated systems and ends up with the internet connection and CPS creation. Consequently, IoT and the previous steps lead to the creation of smart factory (SF), one of the main objectives of Industry 4.0. In fact, smart machines constantly share information about stock, problems, failures to production line, orders' modifications: the union of these machines' necessities needs coordination, in order to improve efficiency and optimize time, product quality, consumption, and development. For these reasons, smart networks are developed, i.e., intelligent networks made up of several machines, cooperating with products and users along all the chain value; this is the basis of the SF. Products, resources, and processes are managed by CPSs, which provide significant advantages to the live quality analysis and reduction in time, costs, and resources compared with the standard productive system: the SF is more intelligent, flexible, and dynamic.

The smart factory is built for a customer service-oriented business: in order to reach these goals, it pushes on levels at high automation and independence, guaranteed by the interconnections of CPSs and the automated supervision of processes. This is a revolution in terms of innovation and money/time savings, and, at the same time, it results in creation of new market opportunities. It is necessary to keep and analyze data from smart machines and to manage in a correct and automated way the interconnected smart factory; in fact, every machine produces a high volume of data, which represents a further tool able to improve the productive system [8, 10, 12].

11.5 Industry 4.0 Characteristics

From the government plan of the different countries, mentioned before, and especially from report of research international group, the picture of Industry 4.0 is colorful, and different points of view and strategies are depicted in order to handle in the proper way the industrial revolution; but all of them have some common points that are here presented as the principal characteristics of the Industry 4.0, related with the quantity of work necessary for an improvement of the traditional production.

Vertical network of the intelligent productive system: CPSs are exploited in order to react rapidly to customer request change, stock level, production defects, and general problem. Smart factories are managed autonomously and generate a production adequate to the customer requests: this is possible only with a high integration and connection between all the smart tools. CPSs permit the autonomous organization of the production management and allow the maintenance management of different tools: resources and products are connected to the network system and can be identified in real time, while all the production phases show the undertaken operation, recording eventual problems or variations to the optimal situation. In this way, possible change to the work order or to the quality or machinery problems are dealt with rapidly.

Horizontal integration through new value chain network: they are like production system network and are connected in real time along all the chain value, providing transparency and flexibility. The production, therefore, can be adapted to the customers' needs, changing the development, planning, composition, and distribution of products; factors such as quality, times, and prices can be managed dynamically in real time for all the chain phases, creating new business and cooperation models between clients and smart factories.

Engineering coordination throughout the value chain: every new product needs customized manufacturing system for an integrated and coordinated production where the data and information are available at every phase of the product's lifecycle.

Exponential technologies' impact is bringing adequate flexibility to any solution, together with money savings in industrial processes. To start with, high automation solutions, e.g., the artificial intelligence (AI) and advanced robotic, are able to take decision autonomously and increase exponentially the tool autonomy, intelligence, and flexibility. AIs improve products and resource transfers in the production process, increase reliability in analyzing data directly from machines, and enhance a better man-machine cooperation. Additive manufacturing is an example of exponential technology because it ensures new functional solutions, more complexity, and no cost upraise. Between the exponential technologies available today, the augmented and virtual reality must be mentioned as well, with simulation ability, and cloud, with all the related situation, such as cloud computing and cybersecurity [3, 6, 9].

11.6 Enabling Technologies of Industry 4.0

The Industry 4.0 KETs are a list of innovative technologies that cover different aspects of industry disciplines but are all characterized by an enormous potential of innovation and change radically the methodologies used today to design, manufacture, and manage a product. The scope of Industry 4.0 is to create an intelligent factory based on the interconnection between the physical manufacturing assets and a digital system; this interconnection is indicated as CPS. The adoption of digital enablers can revolutionize the way the orders are sent to machines; can increase the number, type, and frequency of data stored; and can increase storage capacity and accessibility to information pickup. Obviously, the availability of data, intended as rapid access, when needed, of a various information related to machine performance, can transform the manufacturing processes increasing the convenience and the accuracy. On top of that, the data-driven approach applied also to market and customer analysis can lead to a strict link between production chain and customer/market needs. This topic is mainly related to Industry 4.0 intelligent factory and its management; on the other side also the manufacturing technologies can benefit from the KETs, in particular, considering the adoption of additive layer manufacturing (also known as 3D printing) or the HMI revolution with digital tools and equipment, such as augmented reality. As a general statement, the industry needs to develop a new and innovative approach toward technologies, model methods, and demands.

11.6.1 Big Data and Analytics

As presented in the previous paragraph, the introduction of Industry 4.0 KETs, CPSs in particular, can generate a new capability of creating and storing data, coming from every connected equipment of the production plant. Those data, due to their size, are known as big data and, due to their complexity and variety, need specific algorithm and rules to be analyzed in order to provide value-adding and usable information. Those information, extrapolated from big data, are crucial to empower the decision-making process, giving insight to actual status of the processes.

Big data can be used in three different ways: First of all, it can influence the company path, thanks to the analysis of customer dynamic data. Secondly, it can be used to monitor and predict the performance of the product and refine the after-sale response and product improvement capability. The third aspect is related to industrial big data and possibility to collect data related to machines and plant performances, quality issues, energy absorption, anomalies, and similar, providing the right tools for manufacturing process optimization, reduction of costs, and planning of maintenance activities. The last one, industrial big data, has an impact also in the optimization of the supply chain, particularly significant to optimize storage and distribution activities, saving costs.

Factories that adopt KETs and use big data are often called intelligent factories, because the big data management can contribute significantly to the awareness of the company about their current status and their weakness points; and this point is crucial for the survival of the industry inside this competitive and fast-paced market.

11.6.2 Industrial Cloud and Cloud Computing

Starting from the fact that our age is defined as the "information age," the fuel of this age is clearly the data. Every day, a huge amount of data is generated everywhere from all sort of devices and users.

As presented before, big data and its analytics are a key element for future success of industry, but those technologies need an investment in terms of storage and computing capacity. For this reason, we have to consider also the cloud computing: the possibility to operate simultaneously different steps of the same calculus on different computers, interconnected to the same web. This distributed architecture is essential because one computer only can't manage all the data, and the investment for large number of computers can't be competitive versus the flexibility of cloud computing. All those aspects carry new challenges for the next future: security and integrity of the data must be guaranteed even if the data is geographically dispersed.

Cloud computing is service-oriented and is characterized by versatility, scalability, and virtualization. Those characteristics will be essential in the acceleration of hardware's and software's upgrade and in the introduction of the technology inside the industrial chain. The versatility of cloud computing will enhance the possibility to differentiate appropriately and accurately the computing capacity in accordance with the requirements in order to handle the different problems in the best way. At the same time, by enlarging the data pool generated by industrial equipment, more and more time will be necessary to analyze the data and retrieve the key information, forcing the use of cloud computing for a faster and cheaper solution.

11.6.3 Internet of Things (IoT)

The interconnection between the physical and digital world, empowered by big data analytics and cloud computing, is the key point of Industry 4.0.

This interconnection is achievable with a wide adoption of sensors and network technology, in order to create what is known as Internet of things (IoT). The devices that we use every day contains embedded sensors and software used to collect and analyze data; and these technologies have raised enormously in the last decades. In the same way, those smart sensors and chips will be used in the manufacturing plants to track and compute information related to production processes. Differently than traditional embedded systems, IoT works on multiple levels, because not only it is able to receive and transmit real-time data, it is also able to provide an aggregated result derived from processing and analysis. This type of information is vital for the industrial infrastructure and is necessary to link all the steps of the production chain, in a scenario of auto-control of the system, that put in action defined countermeasures when specific target value of process parameters is hit. This concept of industry is revolutionary and can provide significant economic benefits to companies.

11.6.4 Augmented Reality

Augmented reality (AR) is defined as the enrichment of real world with information generated by computers and integrated in the same environment. The most common AR applications integrate the user's view with specific information retrieved by the computer and related to his surroundings. In this way it is possible to improve the efficiency of the user activities, providing him with specific information related to the task that is performing, avoiding loss of time and reducing the probability of errors.

AR systems are available since the 2000s but were characterized by several limits that reduced their application into industrial environment. Today, thanks to the technological advances and miniaturization of devices, AR is a usable and ergonomic tool ready to be used. With the spread and availability of information typical of Industry 4.0 smart factories environment, the use of AR of productivity applications can represent an additional step toward effectiveness and efficiency, resulting in a determinant for industrial development.

11.6.5 Simulation

The Industry 4.0 meaning of "simulation" is not related to the process of simulating product characteristics, loads situation, or fluid-dynamic aspects but is related to the simulation of industry behavior and plant operations management. This simulation will transport the real-time data of the industry into a virtual environment, which obviously includes equipment, production lines, and operators but enriched with the collected data and elaborated information. This allows the company management and manufacturing managers to test and optimize the overall functioning of the next product line, prior to its real starting and avoiding potential issues in the setup of machines or in startup phase. This is a powerful tool that can represent a revolution for the design and implementation of production plants and logistic centers, where investment and cost can be enormous and a proper cost/benefit analysis must be conducted.

In the virtual environment, various operations can be simulated: resource allocation, production rates, equipment selection, system delays, buffer size, and so on.

It is extremely advantageous to test extensively the industrial environment, without consequences in case of failures, before implementation in the real world. With simulations, the management can obtain confidence in the different scenarios and under various operative conditions, gaining experience for the time of deploy. In this way, the risks are reduced to the minimum, and the investments are placed only when the right confidence is reached, empowering once more the decision-making process. On top of that, there is also the benefit coming from the reduced time and cost in the real deployment phase, achievable because of the experience gained through the simulation.

Obviously, the results and benefits of the simulation are strictly inversely related to the grade of uncertainty of the data in input: good, reliable, and complete data are propaedeutic to achieve positive results. In this Industry 4.0 scenario, once more, the availability of data in huge quantity and variety, and the availability of tools to analyze and process them, is a key pillar also for simulation.

11.6.6 Autonomous Robot

Inside the modern manufacturing industry presented above, an important role can be played by autonomous robot, because in an Industry 4.0 factory, all the ingredients are available for a complete autonomy of specific work operations, and, on top of that, there is also the capability to track and evaluate remotely their performances. Since 2004, the number and type of robots developed by the companies are doubled, in order to cover all the aspects of an industrial manufacturing process. Today, a wide use of intelligent and collaborative autonomous robots in several manufacturing steps can represent an improvement of safety, flexibility, and versatility, without diminishing the importance of human work. In this way, the integration between human and machine operations can open up new applications in industries, reducing all the risky situations where human operators are implied. Autonomous robots can be used on a variety of tasks, not only strictly related to manufacturing processes but also logistic and office management; it is possible to control their operations remotely, with the use of mobile devices, linked to webcam or just enabled to receive data about robots' activities, with the option of giving instructions and orders to fix potential problems and avoid productions stops, guaranteeing the 24 h/day production.

11.6.7 Horizontal and Vertical Integration

Horizontal integration occurs when the technologies here presented are used to exchange relevant information related to a production process and its management. An example of this integration is the use of augmented reality devices for maintenance operations.

Vertical integration is intended at the various levels of hierarchy in an industry. The interaction between these levels is complex and involves different IT systems, and this is where CPS can result significantly in the integration of all the value chain of the product, starting from the design and development of the goods, passing from its manufacturing process, and ending to the customer management. All these steps, joint and correlated by the data connection, are the base of the product lifecycle management.

11.6.8 Additive Manufacturing

A key manufacturing characteristic of Industry 4.0 is the ability to make the products faster, with less steps and resources and without fixed constraints. Those goals are easily achievable with the adoption of additive layer manufacturing (ALM) technologies. With this term a vast type of technologies able to process metals, polymers, ceramic, and composites is indicated with a common characteristic: the component is realized layer by layer. The first 3D printer was invented in the early 1980s, and today on Amazon there are several home 3D printers for few hundred dollars.

Obviously, considering the technology at an industrial level, the investment is completely different, but the benefits that ALM can guarantee are disruptive: faster time to market, thanks to a reduced time between prototyping phase and production; free form and complex geometries impossible to realize with traditional manufacturing technologies; and flexibility of change and improvement available because there are no fixed tools or equipment for the production apart from the 3D printer itself.

The first and most accessible use of Additive Manufacturing technology is the rapid prototyping: application involving mainly polymers, where the goal is to manufacture a component that is similar in shape to the final one but is missing its properties. The fourth revolution has the challenge to enlarge the use of ALM at an industrially structured level, with the production of fully functional components, designed for the technology, able to bring flexibility inside the value chain.

11.6.9 Cybersecurity

The importance of data has been already presented in a different paragraph, and in parallel with the practical usefulness of data for industry improvement, it must be considered also the strategic importance of data related to key process parameters, customer's information, intellectual properties, and so on. On one hand the hyperconnectivity can increase significantly the efficiency and effectiveness of industries, but on the other side it is putting at risk the security of the data itself. Since we are at the beginning of this revolution, the expectation of results can overcome the caution, relying too much on old connectivity protocols not designed for this extended connectivity. For this reason, another challenge of this revolution is to prepare and give companies the right tools to manage the interconnectivity putting at first place the security of the data, online as well as offline.

11.7 Conclusions

The goal of this chapter has been to gather the state of the art related to lean manufacturing in industrial application of new technologies as cloud computing and IoT-based tools. As it has been commented, the new support technologies for productive processes, as the connectivity and the utilization of new data, are going to have a key role in the development phase. These elements bring to the big data, to the Internet of things, to the connection between machines, and to cloud computing all processes that allow to centralize and store data that, subsequently, are analyzed and interpreted, in order to obtain valuable results.

Another result depicted in this chapter has been the consideration of artificial intelligence. In this regard, between the processes used to convert the data into information, there are the data mining, as the computational process of discovering patterns in large datasets involving methods of statistics and database systems, and the machine learning, the machines' improvement obtained through algorithms able to learn the necessary modifications to implement from the data analyzed. High importance is given also to human-machine interface and the related change to the way of interacting with the manufacturing products, due to new technologies and competences, such as augmented and virtual reality, that apply what is computed and analyzed from the digital world to the real one; additive manufacturing is another important point in the industrial revolution because it can be exploited for cost reduction, waste minimization, and performance optimization.

The common thread through all the sections related to Industry 4.0 and lean manufacturing is the sustainable development. Lean manufacturing pillars, such as the waste reduction and sustained approach of workers, are clearly linked to a rational approach that aims to develop a sustainable industry that can reduce the impact and consequences on the environment. Regarding the Industry 4.0, same approach can be pursued with the implementation of technologies and processes that aim to reduce at the minimum the resources necessary to perform a task; examples of those are the simulation that minimizes errors and mistakes, the 3D printing that reduces raw material waste, and the big data and data analytics that monitor the energy consumption.

As a conclusion, the crucial challenge of the next future for the manufacturing industries is to exploit the innovative tools made available by LM and I4.0 to develop a sustainable approach with a special consideration to society and environment.

References

1. B. Bagheri, S. Yang, H. Kao, J. Lee, Cyber-physical Systems Architecture for Self-Aware Machines in Industry 4.0 Environment. 15th IFAC Symposium on Information Control in Manufacturing, 1667–1672, 2015. https://doi.org/10.1016/j.ifacol.2015.06.318
2. Deloitte, Industry 4.0. Challenges and solutions for the digital transformation and use of exponential technologies. Industry 4.0, 1–30 (2015)
3. A. Dujin, C. Geissler, D. Horstkötter, *Industry 4.0 The New Industrial Revolution How Europe Will Succeed* (Roland Berger Strategy Consultants, 2014), pp. 1–24. https://doi.org/10.1007/s00287-014-0809-1
4. M. Koç, J. Lee, J. Ni, P. Bandyopadhyay, *Introduction to e_Manufacturing* (2016), pp. 1–18
5. J. Lee, E. Lapira, S. Yang, A. Kao, Predictive manufacturing system – Trends of next-generation production systems. IFAC Proceedings Volumes (IFAC-PapersOnline, 2013), pp. 150–156. https://doi.org/10.3182/20130522-3-BR-4036.00107
6. McKinsey&Company, *Manufacturing's Next Act* (2015), pp. 1–9
7. Ministero dell'Economia dei Ministri, *Piano nazionale Industria 4.0 – investimenti, produttività e innovazione* (2016)
8. A. Radziwon, A. Bilberg, M. Bogers, E.S. Madsen, The smart factory: Exploring adaptive and flexible manufacturing solutions. Procedia Eng. **69**, 1184–1190 (2014). https://doi.org/10.1016/j.proeng.2014.03.108
9. M. Rüßmann, M. Lorenz, P. Gerbert, M. Waldner, J. Justus, P. Engel, M. Harnisch, *Industry 4.0. The Future of Productivity and Growth in Manufacturing* (Boston Consulting, 2015), pp. 1–5
10. Sales Webinar Atos, *Smart Factory* (2014), p. 43
11. A.W. Scheer, *Industrie 4.0. Germany Trade and Invest* (2013). https://doi.org/10.1007/978-3-642-36917-9
12. D. Zuehlke, SmartFactory-towards a factory-of-things. Annu. Rev. Control. **34**(1), 129–138 (2010). https://doi.org/10.1016/j.arcontrol.2010.02.008

Part III
Improving the Technology

Chapter 12
Multimodal Feature Analysis for Precise Human Hand Gesture Recognition

K. Sakthidasan Sankaran

12.1 Introduction and Background

Human gesture analysis is the visual module of hand, legs, facial expression, and vision-based gesture. The recognition of human gestures from the video or an image is a difficult process; it is rectified by using human-computer interaction (HCI) [1]. The feature extraction is done on many methods to obtain the necessary information from the image. Manual gestures are also used to convey the message through facial expressions. Facial gestures are used as an additional way for effective communication [2]. Vision-based gesture reorganization has some issues while capturing or segmenting the features. It is hard to find the gesture, but there are several successful methods to address. The analysis is done on two approaches one is sensor-based, and the other is image-based. In image-based gesture recognition is done on digital image processing using certain algorithms [3].

In digital image processing, human gesture analysis is done on multi-model feature extraction and recognition [4]. The input image is captured from the sensor which is placed in the body. The input image is segmented to obtain important features. The features are based on the edges, boundary, ridges, etc. The classification of gesture is done on a multiband raster image [5]. The classification algorithm is used to classify the features. The coinciding features are removed to obtain the correctness in extracted output (identification). Based on the coordinates, the gesture is extracted. The final step is to match the query image with the database which is ranked with the list of gestures [6].

Hand gesture analysis using the dataset is observed by Zhang et al. [7]. The aim of this gesture analysis is done in two ways. The classification and spotting are

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done on the recognition step. The adaptation is done by analyzing the in-depth hand gesture.

Gesture recognition done on the wrist-worn sensor is implemented by Liu et al. [8]. The author designed three-step processing such as data preprocessing stage, training stage, and recognition stage. The gesture input is processed in decision making.

Zhang et al. [9] proposed a sensing wearable computing for hand gesture. Long- and short-time memory approaches are used to learn and classify the gesture. It is obtained from the training set as IMU (inertial measurement unit), Electromyographic (EMG).

Deng [10] presented a multi-scale feature fusion (MSFF) of human gesture. In this work, the deep gesture extraction is done based on mapping the size on various layers. The strategy is to decrease the information loss and enhance the gesture features.

Supervised fusing shallow hand gesture is developed form the deep image characteristic Zhao et al. [11]. The gesture is used for ranking the image in semantic tags. The salient object is identified using CNN features. Next, they are sent to the multi-class SVM for classifying.

The recognition of hand gesture by matching the string is observed by Alonso et al. [12]. Approximate string matching (ASM) is used to classify the gesture. The feature is analyzed by the K-mean algorithm. The selection of gesture is done through the clustering coefficient.

Li and Fei et al. [13] introduced a gesture recognition algorithm named as multi-sensor information fusion (MSIF). It uses the membership degree function for the matching process of gesture. The sensor data are correlated with the fusion-based model.

Wu [14] proposed a double channel convolutional neural network for hand gesture recognition. The preliminary step is removing the noise, and the edges are selected from the image. The second step is to obtain the hand gesture done on the input channel of CNN.

12.2 Multimodal Feature Analysis for Gesture Recognition

The human gesture is having various visual components, which include facial expression, hand detection, and conveying the information. It is one of the communication media with human-computer interaction (HCI). This work aims to obtain the data from the sensor that is placed in the body of the human. By using the sensor, the data are obtained, and these data are having the image of the human gesture. Then, the feature classification is done for the input image. The proposed method is used to improve the accuracy by detecting the gesture and mapping the correct gesture by utilizing a database. The human gesture consists of two basic components such as the following:

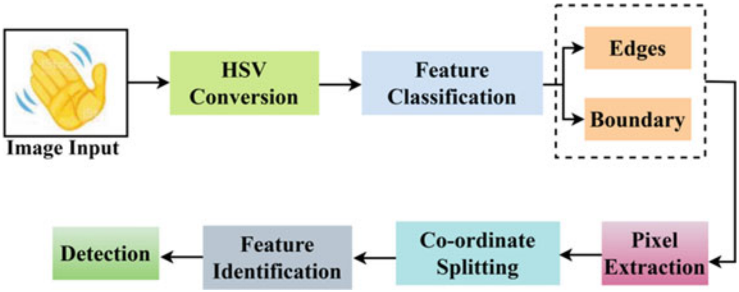

Fig. 12.1 MMFA process

Multi-model feature extraction
Multi-model feature recognition

In Fig. 12.1, the process flow of the proposed MMFA is illustrated.

In this work, both the feature extraction and recognition are done for the human gesture. The input image is initially segmented, and from that, the features are obtained for classification. The proposed method consists of five main elements as follows:

- Segmenting color space
- Feature classification of gesture
- Obtaining orientation of gesture
- Identification of gesture
- Matching process

Segmenting Color Space It is one of the important steps in image processing; the aim is to get the necessary information from the sensor image. They are acquiring the hue-saturation-value (HSV)-based color space which is based on RGB color. The color-based segmentation is used to define the skin color, and the following Eq. (12.1) is used to segment the HSV from RGB:

$$h = \frac{r\,(\max, \min)}{t_i} \tag{12.1}$$

From the above Eq. (12.1), the RGB to HSV conversion is done for the sensor data, h is HSV, and denoted r as RGB that ranges from 0–255. The RGB is having the value max or min. The total number is denoted as t, and i is the input image. The equation works to convert the RGB value which is either max or min. It is done for every sensor image to find the skin color as the luminance image which is easy to work with this information.

Feature Classification of Gesture After the image is converted as the segmentation to HSV, the classification is done on the image by separating the important feature for this work. This classification is done by mapping the gesture of the human here two sets of features are taken as edges and boundaries. The following Eq. (12.2) is used for the feature classification process:

$$f_c = (i + h) * \sum_{i=0}^{t} \frac{i_a^b}{e_o} \tag{12.2}$$

From Eq. (12.1) the segmentation is done from the RGB to HSV and obtains the luminance image. In the luminance image, the feature classification is done based on the edges and boundary which are denoted as *e and b*. The input image is represented as i and two coordinates are referred to as a, b. The classification is denoted as c, and feature classification is represented as f_c. The classification of feature denotes the gesture of the human on the way they include some gestures as writing, walking, raising the hand, etc. In this work, the multi-model features are extracted and recognized. After the classification, the multi-model extraction of gestures is preceded.

12.2.1 Multi-model Feature Extraction

The feature exaction is done on the edges and boundary of the image; the edge-based detection includes brightness of the pixel in the edge of the image. It identifies the object using HSV, which removes the artifacts in the sensor data. The boundary-based extraction is based on the decision classification that includes the edges and geometric features. The following Eq. (12.3) is used to calculating the feature extraction from the image:

$$f = i_a^b \left[\prod_{e=0}^{e} f_c + \prod_{o=0}^{0} f_c \right] * [i + e_o] \tag{12.3}$$

By using Eq. (12.2), feature classification is done on the image, and then the feature is extracted by deriving Eq. (12.3). In this Eq. (12.3), the feature of both edges and boundary is extracted. After the features are obtained, feature recognition is done as the next level for image processing.

Obtaining Orientation of Gesture The orientation is captured from the extracted features; the vector point is obtained from the pixel of features. To find the previous stage of the image and compare it with the orientation of the current image is done by using the following Eq. (12.4):

$$f\left(i_a^b\right) = p * g\,[a, b] \tag{12.4}$$

Equation (12.3) is used to acquire the multi-model feature, from the feature the orientation of gesture is calculated by using the gradient operator by using Eq. (12.4). In Eq. (12.4), from the input image feature extracted, it checks for the previous state of the image that is represented as p. The gradient g is denoted in the coordinates a, b. From this equation, the previous state of the image is processed by using the gradient value. From the gradient value, the orientation is calculated by using Eq. (12.5):

$$\alpha_a^b = \sin^{-1} \frac{i_a(x, y)}{i_b(x, y)} \tag{12.5}$$

From Eq. (12.4), the previous state of data is obtained in the coordinate, and then the obtained data are used to find the orientation which is formulated in the above Eq. (12.5). In Eq. (12.5), α represents the orientation of gesture, and $\sin^{-1}$ is used to find the two coordinate values in the pixel. The pixel coordinates are denoted as (x, y). The formula works from the feature of the historical data that is obtained by solving Eq. (12.4), and this could be able to find the orientation of the gesture by deriving the coordinates of the pixel point in the image.

Identification of Gesture The gesture is identified by knowing the action of the human that is the preliminary step in fetching inputs. The human action is observed from which sensor data the feature is segmented, and then the classification is performed. Using the history of human action, the gesture improves the reliability of detection served from the multimodal feature set.

12.2.2 Multi-model Feature Recognition

In this process, recognition is carried out from feature extraction represented in Eq. (12.3). From the various types of input data, the precise data are recognized. In this work, the gesture is identified from the collection of data from the sensor. The previous step is acquiring the extracted features like edges and boundaries. The aim is to analyze the gesture which is already stored in the database. The feature is matched with the database if it is having a similar feature else it is represented as the multi-model feature required for recognition.

From the pixel coordinate, the images acquire only the necessary information. In this way, the segmented image is obtained from the input image. The objective of this is to detect the image which leads to better accuracy, and also the detection should be mapped with the action (gesture) with the history of data in the database. It satisfies by applying the feature analysis method for the input image. The image is analyzed utilizing features from the pixel coordinate which is equated in the following Eq. (12.6) by considering Eqs. (12.4) and (12.5):

$$n_f = i_a^b * \begin{cases} \frac{i_a(x,y)}{i_b(x,y)} + p * g\,[a, b] = \alpha \\ \frac{i_a(x,y)}{i_b(x,y)} + p * g\,[a, b] \neq \alpha \end{cases} \tag{12.6}$$

In Eq. (12.5), the orientation is obtained for the gesture in motion from that the feature is recognized by formulating Eq. (12.6). In Eq. (12.6), n refers to the recognition of the feature. It consists of pixel coordinates and the previous state of data and analyzes it with the gradient value. The gradient is used for evaluation of α is the orientation of the gesture in which way the human is giving the gesture. The list of gesture is stored in the database that includes the human sitting, walking, writing, or any action performed. These actions are having some state of orientation; by knowing its orientation, only the recognition is observed.

Matching Process In this matching process, identified gesture is compared with the previous history of data. The k number of gesture is analyzed from the sensor data and compares it with the database. The data are having some identification of gesture, e.g., whether the human is raising his hand, based on the hand movement, the gesture is identified. Already the movement is stored, and if the human is eating, it means the action of eating is matched with the current scenario. It is calculated in the following Eq. (12.7):

$$s_u = f_c + e_o \left[\sum_{u=0}^{k} t_f \right] * \begin{cases} \frac{e_o}{c} + p < \beta \\ \frac{e_o}{c} + p > \beta \\ \frac{e_o}{c} + p = \beta \end{cases} \tag{12.7}$$

Equation (12.6) is used for recognition of gesture and form that Eq. (12.7) is derived for matching the current scenario with the previous history of data. By doing this matching process, the accuracy is detected properly. In this equation s is denoted as current sensor data, u represents the gesture, and β refers to the accuracy analysis. It consists of three conditions the first condition is $\frac{e_o}{c} + p < \beta$; it is derived by indicating the edges and boundary features of gesture. The features are compared with the previous state, and if it is lesser than the fixed accuracy, it means they are having the normal accuracy found.

The second condition is $\frac{e_o}{c} + p > \beta$; the previous feature is greater than the accuracy; in this case, it is not satisfied. The third condition is $\frac{e_o}{c} + p = \beta$;the feature data are equal to the accuracy in this case, and the accuracy level is maintained. Here the second condition is used for the improvement of accuracy in the feature data. After the feature accuracy is derived, the gesture is matched with the previous state perfectly. The mapping of gesture is done by considering Eq. (12.7) and derives Eq. (12.8).

$$w_u = \begin{cases} \frac{i_a(x,y)}{i_b(x,y)} + \frac{e_o}{c} = p \\ \frac{i_a(x,y)}{i_b(x,y)} + \frac{e_o}{c} \neq p \end{cases} \tag{12.8}$$

By evaluating Eq. (12.7), the accuracy level is enhanced in the second condition; the Eq. (12.8) is used to find the mapping of the gesture is denoted as w which satisfies the second objective of the proposed work. The first condition states, $\frac{i_a(x,y)}{i_b(x,y)} + \frac{e_o}{c} = p$; the pixel coordinates are extracted from the segmented gesture

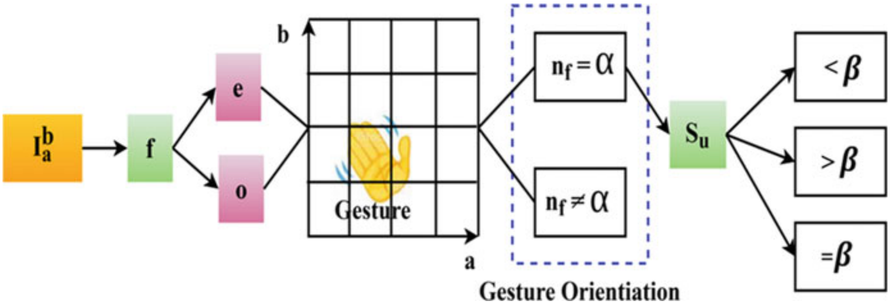

Fig. 12.2 Gesture recognition using MMFA

feature and adding with the classification of edges and boundary. The result is equal to that is the history of gesture which means the mapping of current and previous gesture is observed that it satisfies the mapping. The second condition is $\frac{i_a(x,y)}{i_b(x,y)} + \frac{e_o}{c} \neq p$ denoted as the previous history, and current gestures are not equal which does not satisfy. Figure 12.2 portrays the process of gesture recognition.

The proposed workflow is to observe the human gesture in multi-model feature extraction and recognition. By using Eq. (12.1), the initial step is to convert the RGB to HSV for better segmentation. Equation (12.2) is used for the classification of features form the segmented gesture of Eq. (12.1). Equation (12.3) is the main step for processing the features. The accuracy and mapping are done by Eqs. (12.7) and (12.8) that satisfy the objective of human gesture analysis in a reliable form.

12.3 Results and Discussion

This section describes the performance assessment of the proposed MMFA simulated using the OpenCV tool for a set of 12 inputs and a correlating database of 156 images. The images are analyzed using 20 classification instances for nearly 17 orientation observed. The number of epochs is 29 for which the varying interval for classification is 6–9 s. In this comparative analysis, the existing methods MSIF [13] and MSFF [10] are accounted for the metrics success ratio and recognition time. The comparative analysis is performed for the varying classification instances and inputs.

12.3.1 Success Ratio

In Fig. 12.3a and b, the comparative analysis of success ratio gesture recognition of varying inputs and classification instances is presented. In the proposed techniques, first, the extracted feature is assessed for its orientation after which s_u-based vali-

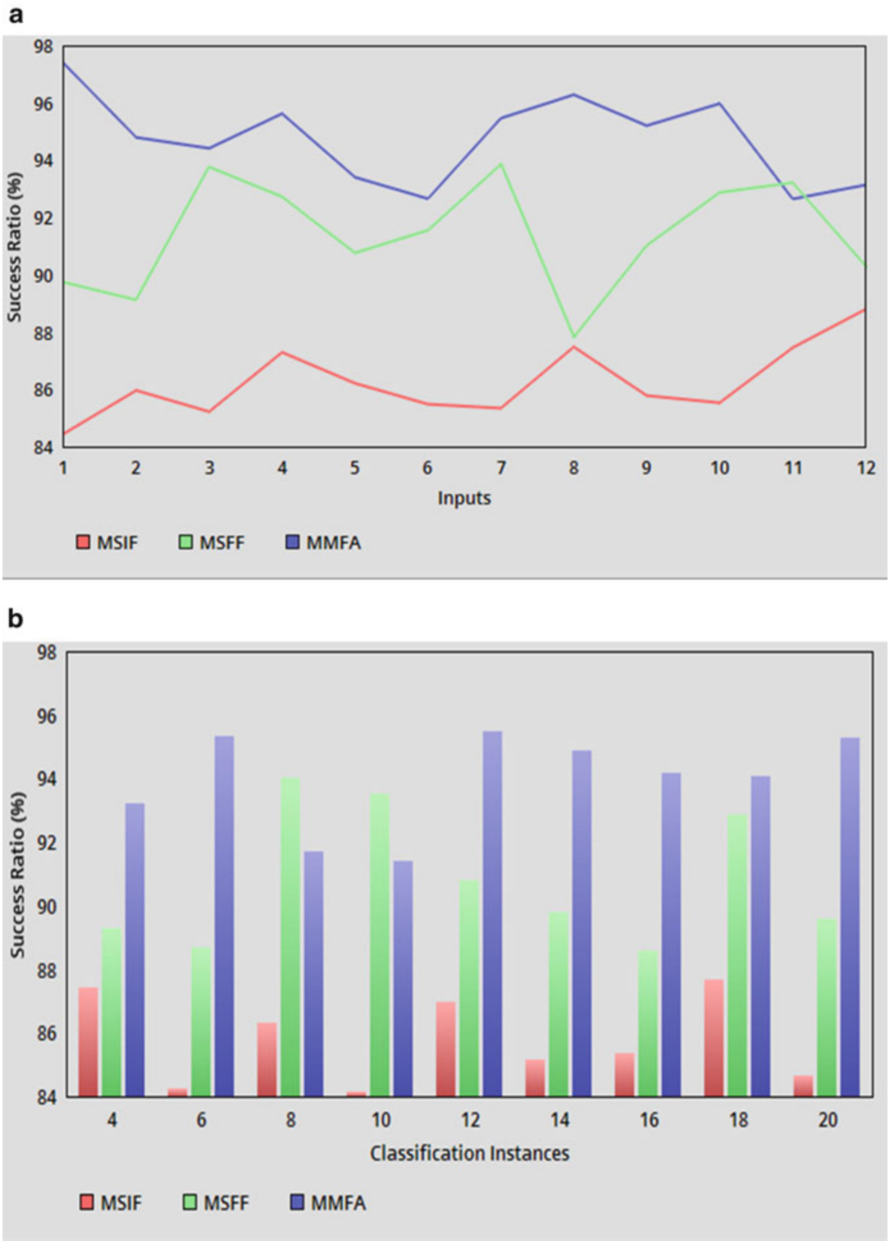

Fig. 12.3 (**a**) Success ratio vs inputs. (**b**) Success ratio vs classification instance

Table 12.1 Comparative analysis results

	Varying inputs			Varying classification instances		
Metrics	MSIF	MSFF	MMFA	MSIF	MSFF	MMFA
Success ratio	88.79	90.31	93.13	84.67	89.58	95.3
Recognition time (s)	18.46	13.6	10.8	16.63	14.15	12.53

dation is performed. This follows the mapping process from which the conditional β is assessed. Based on the conditions of β, the process of assigning features along with mapping instance is performed. This classification of the given input in each of the processing levels helps to reduce the errors in the detection and maximizing success ratio.

12.3.2 Recognition Time

The time for recognizing the gesture in the proposed MMFA is less compared to the other methods. The classification of "f" for its "o" and "e" helps to improve the detection based on orientation and mapping for which $\frac{e_0}{c} = p$ and $\frac{e_0}{c} \neq p$ are differentiated. This classification follows an independent mapping of w_u due to which the overall time required is less. Therefore the recognition follows either of w_u for the above condition depending on n_f. This helps to achieve less recognition time for different inputs and classification time. In Table 12.1, the results of the above comparisons are presented (Fig. 12.4).

12.4 Conclusion

This paper presents a multimodal feature analysis method for improving the recognition success rate of human hand gestures. The proposed analysis is performed using diverse feature classification and extraction based on the boundaries and edges. Followed by the pixel extraction-based coordinate splitting, the extracted features are identified and are correlated with the existing datasets to improve the detection accuracy. Besides, the varying and diverse classification instances help to reduce the recognition time though recurrent analysis and precise conditional validations. The experimental analysis proves the consistency of the proposed method by maximizing the success rate and reducing the recognition time for the varying inputs and classification instances.

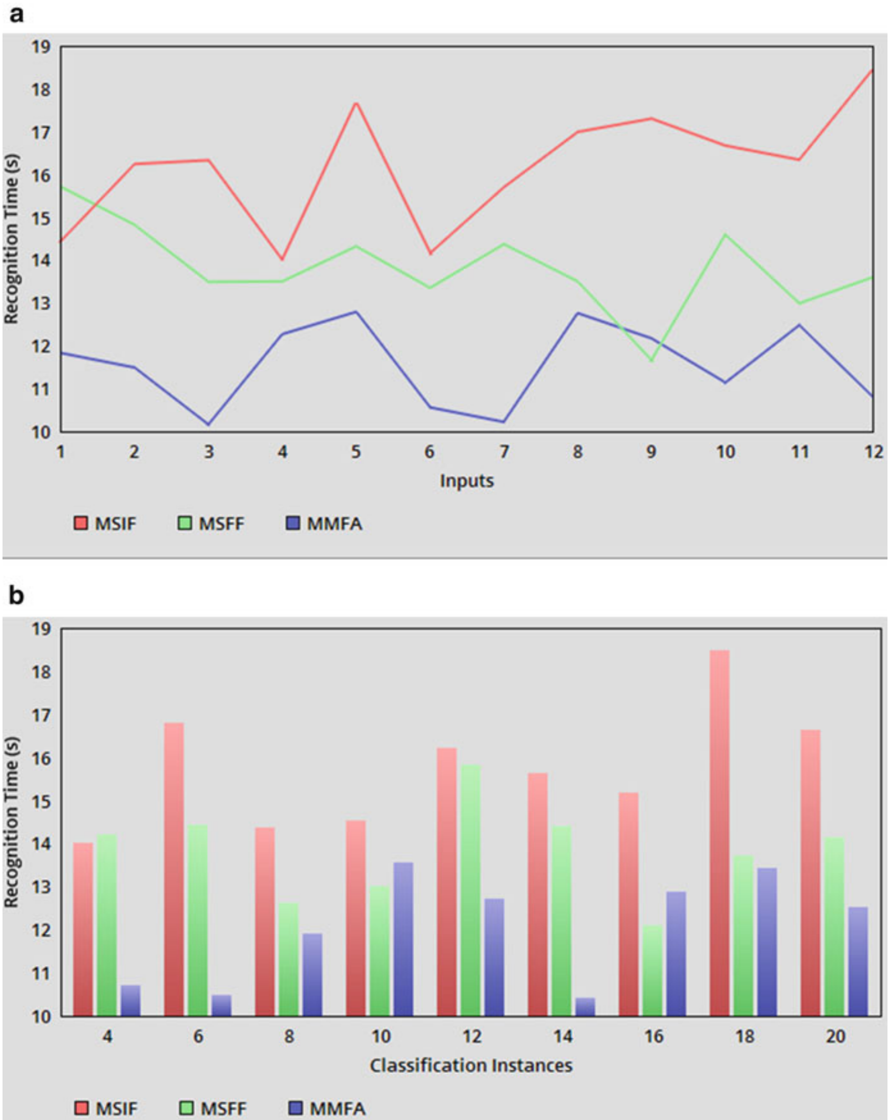

Fig. 12.4 (**a**) Recognition time vs inputs. (**b**) Recognition time vs classification instances

References

1. H.F.T. Ahmed, H. Ahmad, C.V. Aravind, Device free human gesture recognition using Wi-Fi CSI: A survey. Eng. Appl. Artif. Intel. **87**, 103281 (2020)
2. Y. Li, J. Huang, F. Tian, H.-A. Wang, G.-Z. Dai, Gesture interaction in virtual reality. Virt. Real. Intell. Hardw. **1**(1), 84–112 (2019)

3. C. Tan, Y. Sun, G. Li, G. Jiang, D. Chen, H. Liu, Research on gesture recognition of smart data fusion features in the IoT. Neural Comput. Applic. (2019)
4. Y. Wu, Z. Wu, C. Fu, Continuous arm gesture recognition based on natural features and logistic regression. IEEE Sensors J. **18**(19), 8143–8153 (Jan. 2018)
5. Y. Zhang, W. Zhou, Y. Wang, L. Xu, A real-time recognition method of static gesture based on DSSD. Multimed. Tools Appl. (2020)
6. K. Cheng, N. Ye, R. Malekian, R. Wang, In-air gesture interaction: Real time hand posture recognition using passive RFID tags. IEEE Access **7**, 94460–94472 (2019)
7. Y. Zhang, C. Cao, J. Cheng, H. Lu, EgoGesture: A new dataset and benchmark for egocentric hand gesture recognition. IEEE Trans. Multimedia **20**(5), 1038–1050 (2018)
8. Y.-T. Liu, Y.-A. Zhang, M. Zeng, Novel algorithm for hand gesture recognition utilizing a wrist-worn inertial sensor. IEEE Sensors J. **18**(24), 10085–10095 (2018)
9. X. Zhang, Z. Yang, T. Chen, D. Chen, M.-C. Huang, Cooperative sensing and wearable computing for sequential hand gesture recognition. IEEE Sensors J. **19**(14), 5775–5783 (2019)
10. M. Deng, Robust human gesture recognition by leveraging multi-scale feature fusion. Signal Process. Image Commun. **83**, 115768 (2020)
11. W. Zhao, Y. Bao, H. Qu, Hand gesture understanding by weakly-supervised fusing shallow/deep image attributes. Signal Process. Image Commun. **82**, 115760 (2020)
12. D.G. Alonso, A. Teyseyre, A. Soria, L. Berdun, Hand gesture recognition in real world scenarios using approximate string matching. Multimed. Tools Appl. (2020)
13. F. Li, J. Fei, Gesture recognition algorithm based on image information fusion in virtual reality. Pers. Ubiquit. Comput. **23**(3–4), 487–497 (Feb. 2019)
14. X.Y. Wu, A hand gesture recognition algorithm based on DC-CNN. Multimed. Tools Appl. **79**(13–14), 9193–9205 (2019)

Chapter 13
Calculating the Optimal Frequency of Maintenance for the Improvement of Risk Management: Plausible Models for the Integration of Cloud and IoT

E. Fuenmayor, C. Parra, Vicente González-Prida, A. Crespo, F. Kristjanpoller, and P. Viveros

13.1 Introduction

Best practices described in the standard ISO 55000 for asset management establish that every organization should take advantage of their assets' potential value during their asset lifetime. In this context, manufacturers or suppliers of equipment usually deliver a list of maintenance and inspection tasks, but the application frequency does not correspond to the current operational context, the life/age of the asset, and/or the failure consequences for the business. For this reason, it is recommended to design maintenance plans using methodologies from the early stage of the asset life cycle in order to adapt the asset care plan to the current context. On the other hand, it is important to define the optimum range of the maintenance frequency or periodicity for the replacement of components.

Maintenance is defined as the assurance that an installation, an equipment system, a fleet, or other physical assets continue to perform the functions for which

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they were designed [1, 2]. The proactive maintenance strategy is related to the set of planned activities that are executed before the function is lost, reducing or eliminating the potential consequences of the possible loss of function of the assets. Reactive maintenance activities are developed on the components of a piece of equipment or system, after the function has been unexpectedly lost (failure state) and its objective is to restore the function of the asset. In general terms, the process of preventing failures seeks:

– Prevent failure events and reduce their frequency
– Reduce the impact of failures on production and mitigate their consequences on the environment and safety
– Provide a period of time that allows planning and scheduling the preventive maintenance activity
– Help to optimize the total costs of maintenance execution

The effective application of proactive maintenance activities will help improve equipment availability and reliability processes. Availability can be understood as the probability that a system or component is available to operate in a time "*t*" under specific conditions. The reliability of an asset is defined as the probability that an equipment will not fail in a time "*t*" in a specific operational context [1].

In the life cycle of a physical asset, there are different stages where decisions would affect one way or another the performance and profitability of a production process. Decisions to carry out proactive and reactive maintenance activities, redesigns, etc., on a physical asset must be made throughout the entire life cycle, from the design phase, through the normal operation stage, to the final stage of disincorporation. The efficient estimation of total life cycle costs will depend on how all the activities mentioned above are selected and applied. All costs from the design, initial purchase, construction, installation, and commissioning are considered. These are the so-called CAPEX (capital expenditure), and the repairs, replacements, upgrades, movement to and from the repair facilities are the so-called OPEX (operating expenditure). The last stage corresponds to the stop of the service, disassembly, and removal [2, 3].

The ideal time to select the components of a system that will provide the best effectiveness in maintenance management is during the design phase, where much of the information required to make this type of decision depends directly on the manufacturer or the experience of some users of these components in real operating conditions. If an organization does not have an adequate procedure to evaluate aspects such as reliability, maintainability, availability, failure costs, etc., in the design phase, there is a very great possibility of selecting components that will negatively affect the technical and economic performance of equipment during its operational stage. A particularly good source of information on direct costs (labor, materials, and contracted service) and indirect costs is through a computerized maintenance management system (CMMS/EAM) such as SAP and MAXIMO, among others. It should be noted that the information extracted from a CMMS must be carefully analyzed before carrying out any reliability engineering study since these systems utilize the data that the user enters in them [4].

The process of decision-making in the maintenance management should integrate technical reliability and maintenance indicators with indicators of costs that include the consequences of failure events (risk analysis). This consideration will allow organizations to maximize the profitability of their assets together with an optimum level of safety and reliability. For example, in the case of an aircraft, it is simply intended to avoid the consequences of the decision, since its impact is catastrophic (in this case the analysis of reliability indicators and compliance with the maintenance program is a very rigorous process). However, in an industrial installation whose consequences for failures are fewer, the definition of maintenance policies should be oriented to minimize global costs associated, i.e., the occurrence of certain failures in the search for a balance between safety and cost of inefficiency can be accepted (in this case tracking and analysis of reliability indicators is much less rigorous). According to the above, the process of optimization of maintenance policies should ensure the operational continuity of the active (reliability, maintainability, and availability) at minimum global cost (considering the impact of costs for safety and environment, the costs of maintenance, and the costs of inefficiency and unavailability) [2, 3].

13.2 Variables Used in the Maintenance Frequency Optimization Process

13.2.1 Reliability and Risk

Reliability is defined as the probability that a system, equipment, or device fulfills its function(s) for which it was acquired for a period established under pre-established operational conditions such as temperature, pressure, flow, and pH among other variables of process in the defined operational context. The analysis of the failure behavior of a large population of components observed during long periods has shown a decreasing failure rate function in the first period. That first stage of observation (phenomenon known as infantile mortality) is followed by an approximately constant failure rate function (normal or random operation) and finally an increasing failure rate function during the last stage of the observation period (aging or wear). Through a Weibull analysis, these steps are determined through the form factor β, if $\beta < 1$; $\beta = 1$; $\beta > 1$, respectively (bath-tub curve) [3, 5].

If a significant number of units of the same component or equipment are available, and they are put into operation from an initial time $t0$, the behavior in the number of failures per unit of time could be observed and their particular curve of the bathtub. Typically a population of components or equipment in general has a high failure rate in the first period of life that decreases until it reaches a constant level for a period of time (known as random stage) and finally, due to the effect of characteristic aging or wear of the components, begins to increase again (wear). During the normal or random operation stage, several events can occur. When a failure occurs, it is necessary to decide whether a restoration task must be performed and return the asset to its infant mortality stage through the so-called reset of the clock or to perform an action (patch and continue) that allows the equipment to continue operating until it reaches its wear stage [4, 6].

13.2.2 Operational Costs

Operational costs tend to increase over time when the planned task is not carried out. These costs can be energy consumption, raw material consumption, consumable material, time spent by operators, and minor repairs, among others [2].

13.2.3 Loss of Performance

During the operation of an asset, it can deteriorate due to normal use, manifesting loss of performance, which must be considered when designing a preventive maintenance plan, since the task(s) must be oriented to control this performance pattern [2].

13.2.4 Extension of Equipment Life

The prolongation of life of an asset can be achieved through tasks that improve the condition of the asset over time. The most common task to prolong the life of an asset is the painting, but this activity must be subjected to two scenarios, i.e., the frequency to shorten a cost associated with the frequency or extend their respective cost. The tasks defined in the maintenance plans for life extension are generally for energy containment equipment (static assets) such as containers, tanks, pipes, furnaces, and reactors, among others. The following are examples in which the prolongation effects contribute to maintenance work [2, 7].

- Change air/oil filter: affects the life expectancy of gearbox, engines, etc.
- Paint: extends the life of steel structures, storage tanks, etc.
- Reverse extension: cleaning a boiler or pipe can reduce the life of the equipment.

13.3 Mathematical Models Used for Preventive Replacement

Before starting with the development of the mathematical models of preventive replacement considered for this article, the following points of attention are presented:

– The total costs generated by the failures must be higher than those generated by the preventive replacement activities (the costs for not preventing the failures must cause high economic impacts due to production losses, environmental penalties, and/or compensation to people for aspects of health).
– The failure rate of the components to be replaced must be increasing (taking the Weibull model as a reference, the factor β must be greater than 1 ($\beta > 1$)). When the failure rate is decreasing ($\beta < 1$), the preventive replacement of components is not the most recommended maintenance policy [7, 8].

13.3.1 Optimal Replacement Model with Use

When operating costs increase with use, some equipment operates with excellent efficiency when they are new, but over time, their performance deteriorates:

- $C(tr)$ = total cost in the interval (0, tr)/length of the interval
- Total cost in the interval = operating cost + replacement cost

13.3.2 Optimal Interval of Preventive Replacement

Taking as reference that industrial equipment is subject to failure, the proposed model considers that during the life cycle, in addition to scheduled replacement activities, failures will also occur despite performing preventive maintenance activities. The key aspects of this problem are being able to determine the most effective policy of maintenance costs for preventive replacement versus the costs of assuming the consequences of failures and determining the optimal frequency of preventive replacement for each maintainable component (when justified), helping to minimize the total cost of preventive replacement activities throughout the useful life cycle of the equipment under study [4].

- $C(tp)$ = total expected replacement cost per cycle/expected cycle length

If a preventive replacement occurs at time tp, then the average time to fail is the average of the shaded portion as shown in Figs. 13.1 and 13.2, because the unshaded area is an impossible region to fail.

Optimal interval of preventive replacement of equipment subject to failure has to take into account the time required to carry out preventive and failure replacements. This model refers to the replacement policy where preventive replacements are made once the item has reached a specific age, tp, plus replacements due to a failure when it occurs unexpectedly [4, 7, 9].

- $C(tp)$ = total expected replacement cost per cycle/expected cycle length

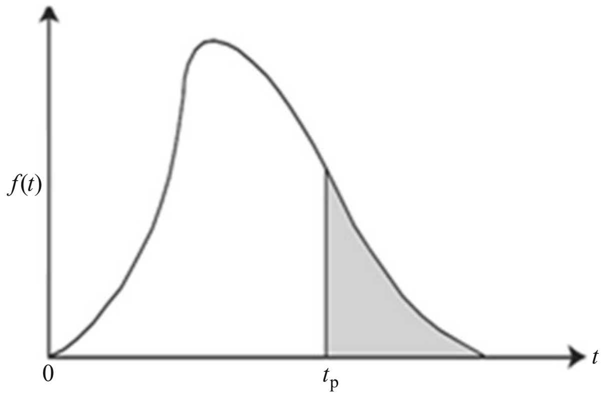
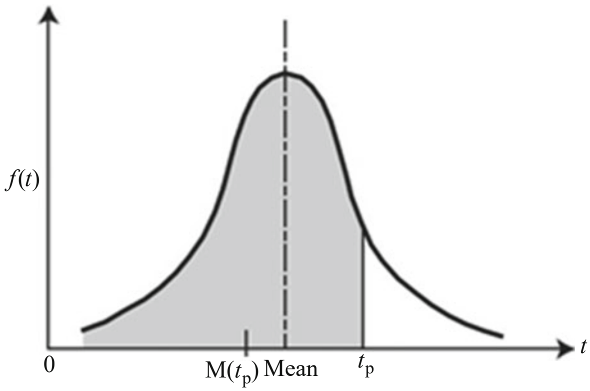


Fig. 13.1 Estimation of the average of the truncated distribution

Fig. 13.2 Estimation of the average of the truncated distribution



13.4 Case Study

In this case study, the analysis performed with a spreadsheet will be shown in graphics, considering all the variables described in the first paragraphs of this paper. Additionally, in order to validate the results obtained by the spreadsheet, the results obtained by a computer program with a wide global trajectory in asset management were used. The data is altered for confidentiality.

A steam turbine is installed in a continuous operation petrochemical plant. The reliability engineer assigned to the plant, after designing the maintenance plan based on reliability using the RCM methodology [10], is ready to optimize the maintenance frequency of planned tasks modeled at different frequencies. In order to carry out the maintenance action, failures would affect the reliability of the asset, the operational costs would increase, the performance of the asset would decrease, and this task would be applied to prolong the life of the physical asset (Figs. 13.3, 13.4, 13.5 and Tables 13.1, 13.2, 13.3, 13.4, 13.5) [16].

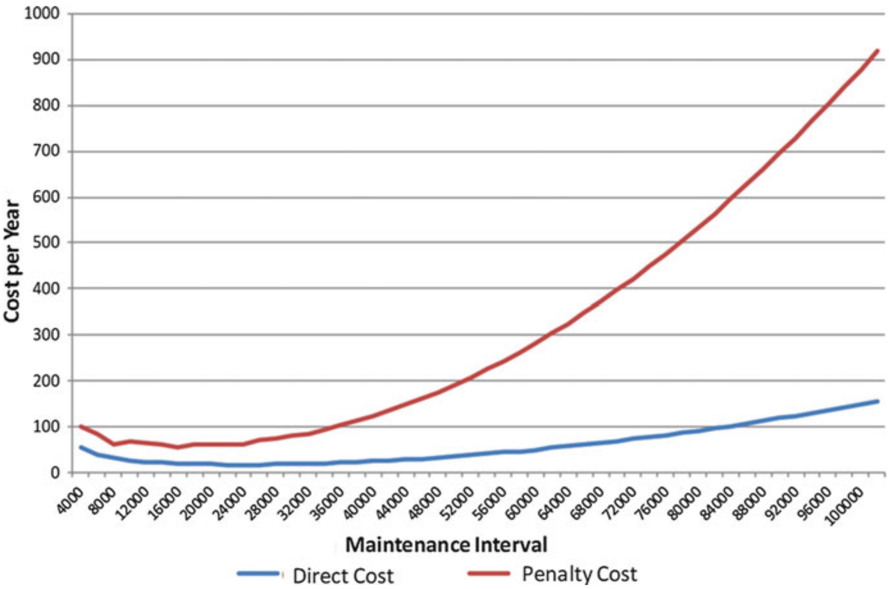


Fig. 13.3 Maintenance action cost

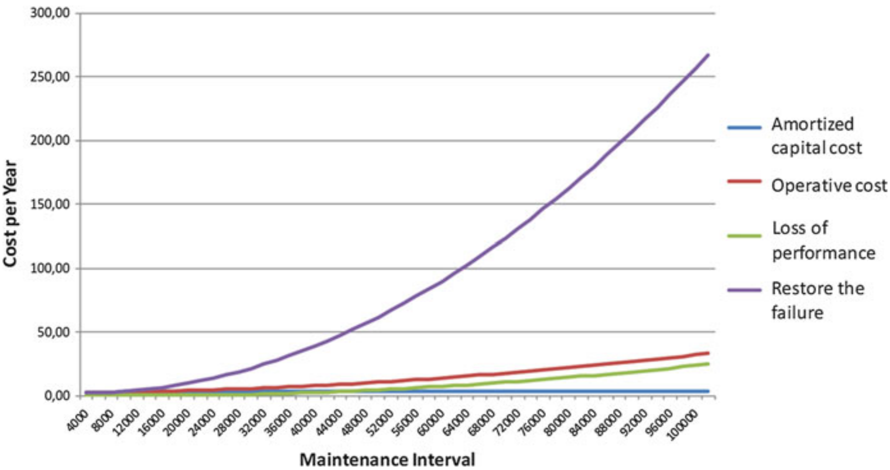


Fig. 13.4 Risk of no-maintenance action

The mathematical model shows that the optimum frequency to carry out the preventive maintenance action must be every 16,000 h (this result confirms that the maintenance frequency being carried out is the optimum). It should be noted that the results obtained by the spreadsheet were validated and are very close to those produced by a commercial computer program with application in several industrial sectors. The little difference is due to the accuracy or precision used in

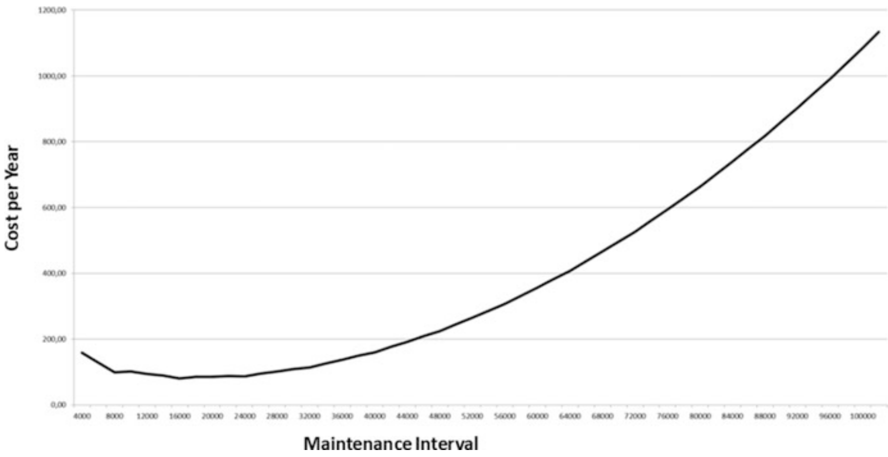


Fig. 13.5 Total impact to business

Table 13.1 Reliability profile (own source)

Time since last repair (h)	Failure amount (failures)	Equivalent rate (failures/h)
8000	1	0.000125
24,000	3	0.0001875
48,000	25	0.001041667

Table 13.2 Estimated operating costs profile (own source)

Time since last overhaul (h)	Operational costs (€/h)
0	2
8000	3
16,000	5

Table 13.3 Loss of performance profile (own source)

Time since last repair (h)	Loss of performance (%)	Efficiency (%)
2000	2	98
12,000	5	95

Table 13.4 Life extension profile (own source)

Overhaul interval (h)	Life extension (h)
2000	60,000
10,000	30,000

the commercial program model, which for reasons of confidentiality is not possible to know. The mathematics used in the spreadsheet has the necessary parameters and adjustments, which are defined in the standards and bibliographies consulted [11, 12].

Table 13.5 Results about the optimal frequency of maintenance or preventive replacement

Intervalo de Overhaul (Hora(s))	Costos Directos (Libras/Hora)	Costos de Penalización (Libras/Hora)	Restaurar la Falla (Libras/Hora)	Costo de Capital Amortizado (Libras/Hora)	Costos Operativos (Libras/Hora)	Pérdida de Desempeño (Libras/Hora)	Impacto Total al Negocio (Libras/Hora)
4000	54,58	100,00	0,00	1,90	2,19	0,17667	158,85
6000	39,39	84,25	0,00	2,22	2,34	0,23000	128,44
8000	31,55	62,44	0,00	2,67	2,51	0,26000	99,42
10000	26,72	68,68	0,00	3,33	2,69	0,26667	101,69
12000	23,48	64,42	0,00	3,33	2,89	0,25000	94,37
14000	21,22	61,69	0,00	3,33	3,10	0,21000	89,55
16000	19,62	54,02	0,00	3,33	3,34	0,14667	80,46
18000	18,52	60,03	0,00	3,33	3,60	0,06000	85,53
20000	17,81	60,89	0,00	3,33	3,88	0,05000	85,96
22000	17,44	62,81	0,00	3,33	4,17	0,18333	87,93
24000	17,35	61,58	0,00	3,33	4,49	0,34000	87,09
26000	17,51	69,69	0,00	3,33	4,83	0,52000	95,89
28000	17,91	74,62	0,00	3,33	5,19	0,72333	101,78
30000	18,53	80,52	0,00	3,33	5,57	0,95000	108,91
32000	19,36	84,27	0,00	3,33	5,97	1,20000	114,14
34000	20,39	95,22	0,00	3,33	6,40	1,47333	126,81
36000	21,60	104,00	0,00	3,33	6,84	1,77000	137,54
38000	23,01	113,72	0,00	3,33	7,30	2,09000	149,46
40000	24,59	121,89	0,00	3,33	7,79	2,43333	160,04

13.5 Conclusions

In summary, it is not enough to design a "perfect" maintenance plan considering all the failure modes that have occurred or those that may occur, through the different tools or methodologies that support the different answers. However, it should also be defined when to do the maintenance action in order to support decision-making in asset management [13–15]. Below some aspects are defined that should be considered by organizations when designing technical and economic indicators of maintenance aligned to a comprehensive risk management process [3]:

– Clearly define the objectives and the purpose of the process of calculation of the index (specify the use and the types of decisions to be optimized based on the analysis of maintenance indicators).
– Develop analysis of technical reliability indicators both at the level of design of an industrial facility (redundancy problems, selection of equipment, problems of waiting) and in the operation of a production unit (maintenance policies).
– Ensure the quality of the data (collection and verification procedures).
– Get feedback (feedback) of the processes of collection and analysis of data.
– Develop a process of reporting on the use of indices throughout the organization (implement training workshops that include practical exercises and actual cases analysis).
– Develop an effective process of follow-up of the recommendations based on the analysis of the indices.

When an organization within its maintenance management system can record, assess, and interpret in an orderly and objective manner information generated from core indicators such as time to failure, time to repair, availability, reliability, maintainability, cost for unavailability, etc., it may:

– Make more successful decision-making, with a lower level of uncertainty with respect to the various maintenance optimization processes.

– Maximize the effectiveness and efficiency of maintenance plans, integrating technical and economic aspects.
– Develop maintenance activities under an optimization approach: cost-risk-benefit.

Finally, for the improvement of risk management in the industrial organizations, the study of the optimal frequency of maintenance or preventive replacement should be calibrated or revised if the operational context where the asset is installed changes over time. Such changes may affect reliability and performance among other variables, due to the influence of the asset behavior to fulfill its function(s). Throughout the chapter, mathematical models are presented together with a case study, being visible the possibility to implement tools based on cloud and IoT technologies. As shown at the beginning of this paper, the asset reliability is affected as the equipment ages and as its failure rate increases. Therefore, it is recommended to adapt the maintenance plans to the age of the equipment, considering the costs in the life cycle in order to select tasks that are not only technically workable but economically profitable and budgetary viable.

References

1. E. Fuenmayor, Análisis de Reemplazo de un Activo Basado en Costos de Ciclo de Vida. Revista Confiabilidad Industrial N° 11. Venezuela (2011). www.confiabilidad.com.ve
2. J. Woodhouse, Asset Management Decision-Making: The SALVO Process, Strategic Assets: Life Cycle Value Optimization, United Kingdom, TWPL (2014)
3. Parra, C. y Crespo, A. (2015). Ingeniería de Mantenimiento y Fiabilidad aplicada en la Gestión de Activos. INGEMAN, Sevilla https://doi.org/10.13140/RG.2.2.29363.66083
4. A.K.S. Jardine, A.H.C. Tsang, *Maintenance, Replacement, and Reliability (Theory and Applications)*, 2nd edn. (CRC Press, 2014)
5. R. Gulati, *Maintenance and Reliability. Best Practices*, 2nd edn. (Industrial Press, 2013)
6. J.D. Campbell, J.V. Reyes-Picknell, *Uptime, Strategies for Excellence in Maintenance Management* (CRC Press, Toronto, 2016)
7. C. Labouchere, Use of a small computer to assist in making maintenance decisions. Proceedings of UK Maintenance Congress, London (1982)
8. D. Campbell, A.K.S. Jardine, J. McGlynn, *Asset Management Excellence: Optimizing Equipment Life-Cycle Decisions* (CRC Press, 2011)
9. T. Nilsen, T. Aven, Models and model uncertainty in the context of risk analysis. Reliab. Eng. Syst. Saf. **79**(309–317) (2003)
10. J. Moubray, *Reliability Centered Maintenance, RCM II*, 2nd edn. (Industrial Press, Inc., 1997)
11. A. Crespo, V. González-Prida, J. Gómez, (Eds.)., *Advanced Maintenance Modelling for Asset Management. Techniques and Methods for Complex Industrial Systems* (Springer, 2018) ISBN:978-3-319-58045-6

12. A. Crespo Márquez, M. Macchi, A. J. Parlikad (eds.), *Value Based and Intelligent Asset. Mastering the Asset Management Transformation in Industrial Plants and Infrastructures* (Springer, 2019) ISBN:978-3-030-20703-8
13. Asset Management – An Anatomy, Version 3, United Kingdom (2015). IAM
14. Macro Project EU 1488 (2008). www.macroproject.org
15. ISO – 55000 Asset Management – Overview, Principles and Terminology (2014)
16. Woodhouse, J. (1993). Managing Industrial Risk, Getting value for money in your business, London, Chapman & Hall.

Chapter 14
Interceptor Pattern-Based Middleware for IoT Protocol Interoperability

Alejandro Talaminos-Barroso, Javier Reina-Tosina, and Laura M. Roa

14.1 Introduction

The Internet of Things (IoT) is a concept that refers to the interconnection of objects that are able to collect and exchange data through the Internet [1]. These objects are physical elements with programming and communication capabilities, including mainly in this description, sensing devices, and actuators [2]. The transition to 5G and current technological trends on mobile and ubiquitous computing seem to acknowledge that these devices will have a greater impact in the near future due, among other reasons, to the increased miniaturization of electronic components, lower manufacturing and operational costs, and improved energy efficiency. The consequence of this technological progress is an ever more closely interconnected world [3]. Among the potential benefits of IoT systems is the generation of information, which provides citizens a better knowledge about their environment and eases the decision-making process [4, 5].

However, one of the main technological barriers to the massive deployment of IoT solutions is systems interoperability, which can be understood as the ability for devices from different vendors to communicate. In order to achieve full interoperability, a set of requirements organized at multiple levels of the communication process needs to be met. Starting from the top level of abstraction and then moving down to the lower levels, five levels of interoperability in IoT systems are usually defined: organizational, pragmatic, semantic, syntactic, and technical [6, 7]. In this sense, this work focuses on interoperability at the technical level because the objectives are closely aligned with the harmonization of communication between different IoT protocols.

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The technical level is defined by a set of protocols that aim at guaranteeing the delivery of data between IoT devices [8]. Among the requirements of these protocols are the low-resource consumption, energy efficiency, mobility, and scalability [9]. Therefore, these protocols are mainly intended for constrained devices and share technical characteristics such as communication paradigm, policy-based quality of service (QoS), acknowledge procedure, data containers, or specific aspects concerning communications security. In this sense, there is a wide range of studies focused on a general analysis of the most important IoT protocols [10], technically [11–13] and theoretically [14–16].

Despite the technological maturity and successful use cases of IoT protocols [17, 18], interoperability among them is not currently possible. Given the importance of IoT on 5G mobile systems, standardization efforts that provide reduced complexity and efficient communication protocols for all devices is unstoppable [19], becoming necessary an adaptation among IoT protocols [6, 7]. Other authors [14, 20] also mention the importance of investing efforts and resources in the design of brokers that serve as intermediaries for IoT protocols and select the appropriate ones according to the network characteristics and conditions.

In the literature, many works address interoperability in the context of IoT communications from a semantic perspective [21, 22]. In this context, semantic interoperability should be treated immediately after technical interoperability is accomplished, but not before. This has also been supported by other authors [6] indicating that interoperability among IoT protocols at the technical level is a current challenge within this ecosystem. This problem is magnified especially if the current wide diffusion of IoT platforms that already exist in the market is considered. While many manufacturers use proprietary and non-interoperable technologies, others prefer open and standardized protocols. Although the latter represents a significant advantage, open protocols are not always interoperable with each other; hence the problem remains unsolved. The migration of these IoT platforms to a common protocol is, in most cases, a costly process with a technological complexity that cannot always be addressed. In this sense, the variety of protocols may be beneficial given the wide spectrum of requirements that can be derived from different technological scenarios of IoT, such as those related to QoS, network performance, device limitations, and user needs. However, when there is no minimum interoperability (set of common functionalities) among the protocols, IoT systems remain isolated, regardless their inherent semantic characteristics.

In this context of technical interoperability, a benchmarking study for different types of IoT protocols was presented in a previous work by the authors [23]. The objective was to establish a guide to aid the choice of IoT technology. However, sometimes this choice of a protocol is not possible, and it is imposed by rigid requirements, non-modular software solutions, as well as other external factors that are beyond the designer's control. In this sense, the objective of the present work is the study, analysis, design, implementation, and validation of an IoT middleware that acts as an intermediary service in a communications ecosystem with devices using different protocols. The scope of the middleware covers a broader spectrum of operation due to integration with IoT protocols with different types of communication: device-to-device (D2D), device-to-cloud (D2C), and cloud-to-cloud (C2C).

The middleware is proposed as a technology-independent system and covers different technical requirements based on diverse needs that can be demanded by IoT systems. Its design is based on the interceptor pattern [24], i.e., the middleware has virtually no effect on the rest of the components involved (publishers, subscribers, and brokers). In this way, the middleware proposes a harmonization process at the level of data translation to ensure technical interoperability, with the possibility of providing more functionalities to lightweight IoT protocols through the extension of additional features available in other more advanced protocols. In general, the effort in terms of integration and adaptation of the different communication entities with the middleware is minimal and not mandatory due to the backward compatibility. Therefore, the proposed middleware is not a simple carrier of messages but a translation solution between IoT protocols that allows for extending the communication capabilities of the different nodes involved, regardless of the protocol used. Another significant advantage of the middleware is its ability to provide scalability in fast-growing IoT ecosystems with a large number of devices. Diverse healthcare applications toward digital health or integrated supply chains can take advantage of the benefits of the middleware presented in this paper to achieve IoT interoperability in the context of IoT for societal good.

The organization of the next sections is as follows. First, related works are presented; a comparison of the IoT protocols that have been studied and integrated in this work is described in Sect. 14.3. The description of the middleware is presented in Sect. 14.4, which details how the protocol integration analysis is materialized, including a brief introduction to the interceptor design pattern and how it has been integrated into the middleware design. Next, Section 14.5 describes a specific use case to validate the middleware, and Sect. 14.6 presents the results obtained, including comparison with works published by other authors. Finally, Section 14.7 draws the concluding remarks.

14.2 Related Works

A significant number of initiatives have focused on achieving interoperability in the context of IoT with the aim of integrating devices and applications of diverse nature. Most of these interoperability projects based on IoT are oriented to the definition of different ontologies involved with the semantics of the data.

For example, the Semantic Sensor Network (SSN) ontology [25] classifies sensors in terms of their functionalities, data, and types of deployments. Some authors have referred to its limitations with respect to real-time communication [26]. Other important semantic ontologies are oneM2M [27], IoTivity [28], IoT-Lite [22], and OpenIoT [29]. In general, these ontologies are incorporated into cloud services or platforms oriented to the deployment of IoT-based scenarios [10] with interoperability capabilities at the technical level.

Among these IoT platforms that offer interoperability between different IoT protocols is SensiNact [30], a unified framework for integrating and managing different IoT devices, collecting data, and simplifying the development of applications. SensiNact provides integrated access through different protocols and access interfaces to the environment, as well as tools for the management and deployment of IoT ecosystems. The platform is currently released under an Eclipse Public License 1.0, although the documentation is scarce and the details of the architecture are not entirely clear.

Another similar platform is Sofia2 [31], which includes a middleware to facilitate the interoperability of multiple systems and devices. It incorporates tools for integration with databases and bidirectional communications through Representational State Transfer (REST), Message Queue Telemetry Transport (MQTT), Java Message Service (JMS), or WebSockets, among other technologies and protocols. However, Sofia2 is a proprietary platform and it is deployed on a closed cloud.

In addition, large technology companies also provide their own cloud-based solutions for IoT, for example, IBM Watson Internet of Things [32], Samsung ARTIK [33], or Microsoft Azure IoT [34]. Typically, these platforms provide fully managed services in the context of a private cloud, with extensive connectivity and interoperability between different IoT protocols, real-time visualization of data, storage, and many additional functionalities.

Finally, FIWARE [35] stands out as an open-source initiative promoted in an EU Framework Programme for the development and deployment of future Internet applications. Technologically it provides public cloud with OpenStack [36], including open interfaces for integration, communication, and analysis of massive amounts of data in the context of IoT. An important innovation ecosystem is being created around this platform, formed by independent application developers, technology providers, and, in general, entities of all kinds that demand standardized IoT solutions [37].

In conclusion, it has been shown that there are many initiatives that try to achieve interoperability between IoT protocols, although sometimes these platforms or services may have limitations. For example, additional incorporated functionalities are not always necessary to cover the requirements of all IoT deployments. Other current drawbacks refer to the risk of obsolescence due to lack of software maintenance, the documentation is scarce, the implementation details are obscure, or the learning curve to understand the entire architecture, data model, or Application Programming Interface (API) provided by the manufacturer is hard. Additionally, dependence on a particular technology, protocol, or access interface can sometimes force the adaptation of IoT devices, and migration is not possible in all scenarios. Finally, although the compatibility between IoT protocols offered by these platforms is usually high, modularity is not always provided, and as is natural, some companies add bloat software to their solutions to increase the economic cost. Consequently, the computational and memory cost of deploying these services can also be increased. This can have a negative impact on deployments where the objective is to achieve a minimum technical interoperability between different IoT protocols considering a feasible migration and adaptation in economic and temporal terms.

Unlike other proposals discussed above, the middleware presented in this work does not define any API, and, therefore, the IoT developer does not need to adapt its applications to be integrated with the middleware. Consequently, the learning curve of the IoT developer to understand the behavior of the middleware is minimal. Since the design is based on the interceptor pattern, the IoT developer only has to worry about pointing their applications to the middleware location. On the other hand, economic, computational, and time costs derived from the deployment of middleware are also reduced. The middleware configuration and its modular design make it possible to establish which particular IoT protocols will be used and what exact amount of computational resources should be allocated. In this way, the middleware can be customized to ensure the highest possible performance to perform clearly defined operations considering computational needs and well-defined hardware capabilities.

14.3 Related Works

The selection of the IoT protocols studied in this work has been based on the following criteria: open standard-based protocols with open-source implementations, wide diffusion, successful use cases in different scenarios, and active development community. Based on these criteria, the selected IoT protocols are presented in Table 14.1, as well as the current version of the standard for the protocol and information related to the client and the broker used in this work.

Although the year of publication of some protocol standards is relatively old, this does not mean that the protocol is obsolete. For example, Extensible Messaging and Presence Protocol (XMPP) and Data Distribution Service (DDS) continuously receive security-focused extensions and specifications for integration with the web, or Constrained Application Protocol (CoAP) that has recently released extensions of the standard to support WebSocket compatibility. On the other hand, software architectural or protocols such as Java Message Service (JMS), Representational State Transfer (REST), and Text Oriented Message Protocol (STOMP) have not been included in this work since their characteristics are not aligned with the

Table 14.1 IoT protocols considered in this work

Protocol	Standard	Implementation of client	Implementation of broker
MQTT	ISO/IEC 20922:2016 (2016)	Eclipse Paho 1.4 (2018)	Mosquitto 1.4.14 (2017)
CoAP	IETF RFC 7967 (2016)	CoAPython 4.0.2 (2017)	Californium 1.0.4 (2017)
DDS	OMG DDS V1.4 (2015)	OpenDDS 3.13.1 (2019)	–
XMPP	IETF RFC 6120 (2011)	Smack 4.3.2 (2019)	Openfire 4.1.5 (2017)
AMQP	ISO/IEC 19464:2014 (2014)	amqp 2.4.1 (2019)	RabbitMQ 3.6.12 (2017)

requirements of IoT. In this sense, JMS was developed to be integrated with distributed enterprise applications and essentially uses heavy Java-based server implementations, what makes it difficult to build M2M communication [38]. On the other hand, REST provides client-server connections and presents disadvantages for asynchronous, loosely coupled, and publish/subscribe message exchanges [39]. Finally, STOMP is a protocol without much presence in the community, and the specification dates back almost 7 years [40].

The analysis of the characteristics of each IoT protocol included in this work is a laborious task given the variety of implementations and the continuous improvements of standards and their extensions (some of them currently in development). Hence, a summary of the most important features of each protocol considering the requirements of IoT devices is shown in Table 14.2. The information presented is based on the official standards released by the respective standard organization. In certain cases, protocol's functionalities are reported in the standard in an ambiguous way or are mentioned briefly without giving any implementation details. Sometimes standards are also extended with additional specifications to include new features. Finally, vendors sometimes release software extensions to provide additional functionalities to the protocol, via plugin or similar, usually at an additional cost. These vendor extensions are often incorporated into the official standard. All these extended or non-extended features are mentioned in Table 14.2 (principal characteristics) and Table 14.3 (technical characteristics and QoS) considering the implementations shown in Table 14.1.

Among the conclusions that can be drawn from Table 14.2 is the relationship between the standard and the technology for each of the protocols considered. In general, official extensions and standard documents associated with DDS and XMPP protocols exceed the functionalities currently supported by the implementations, while the opposite occurs in Advanced Message Queuing Protocol (AMQP). In contrast, MQTT and CoAP protocols maintain a parallelism between technology and standard.

The scope of action of IoT protocols is also a relevant factor. In this context, lightweight protocols such as MQTT and CoAP are mainly focused on D2C and D2D integrations, while all the other protocols have a broader spectrum of operation that also includes C2C environments.

With respect to the technological limitations of each protocol and considering heterogeneous communications in IoT systems, message queue paradigm is based on publisher/subscriber pattern in most protocols. Logical container of data is a common denominator of all protocols and conceptually represents the same, with different meanings (messages, topics, resources, containers, etc.).

An important issue of all IoT protocols is reliability, which is also closely linked to the orderly delivery of messages. Although most protocols provide mechanisms to ensure that the data are delivered in order and with no gaps, not all protocols guarantee the strict, orderly delivery with acknowledgment, so instability in a communications network can cause messages to reach the destination disorderly [41].

Table 14.2 IoT protocols comparison of principal characteristics

Characteristic	MQTT	CoAP	DDS	XMPP	AMQP
Architecture	Centralized multi-broker	Centralized multi-broker	Decentralized unbrokered	Centralized multi-broker	Centralized broker
Data model	Topic	Observable	Topic	Message	Message
Data structure	Without structure	Without structure	Specific dynamic data (DDS-Xtypes)	Without structure	Without structure
Transport	TCP	UDP	TCP and UDP	TCP	TCP
Publish/subscribe	Yes	Yes* (coap-pubsub) and partially (observers) too	Yes	Yes* (XEP-0060 and XEP-0163)	Yes
Point-to-point	No	No	Partially (partitions)	Yes	Yes** (direct exchange)
Request/reply	No	Yes	Yes (DDS-RPC)	Yes	Yes** (direct reply-to)
Multicast	Yes** (GNUnet)	Yes* (coap-multicast)	Partially (partitions)	Yes* (XEP-0033)	Yes** (direct exchange)
Peer-to-peer	No	Yes (RFC 7650)	Yes	Yes* (XEP-0166)	No
Scope	D2C	D2D	D2D, D2C, C2C	D2C, C2C	D2D, D2C, C2C

[a]In draft
[b]Supplied by vendor or community

Finally, among the remaining features of protocols, security of communications is one the main challenges in IoT and is often ignored in the deployment of these systems [42]. Most IoT protocols depend on the Transport Layer Security (TLS) and Datagram Transport Layer Security (DTLS) for encryption and data integrity, which are similar conceptually [43]. Access control is seldom considered, although the Simple Authentication and Security Layer (SASL) framework is sometimes used. In contrast, DDS provides an additional standard [44] that extends capabilities of access control, encryption, message authentication, and digital signature.

In summary, the selection of a protocol for an IoT environment with certain technical requirements depends on multiple factors involving devices, applications, networks, users, and context [14]. Therefore, the choice of an appropriate protocol is not a simple task and the design and development of a protocol translator becomes more justified.

Table 14.3 IoT protocols comparison of technical characteristics and QoS

Characteristic	MQTT	CoAP	DDS	XMPP	AMQP
Discover	Yes* (mqtt-spy)	Yes (RFC 6690)	Yes (DCPSTopic)	Yes (XEP-0030)	Yes** (amqp-discover)
Filter by content	Partially (wildcards)	No	Yes (content filtered topic)	Yes* (XEP-0062)	Yes** (filters)
Best effort delivery	Yes (QoS, 0)	Yes (non-confirmable)	Yes (ReliabilityQos)	Yes	Yes (at-most-once)
Reliable delivery	Yes (QoS, 1)	Yes (confirmable)	Yes (ReliabilityQos)	Yes* (XEP-0184)	Yes (at-least-once)
Delivery in order	Yes (QoS, 2)	No	Yes (PresentationQos)	Yes	Yes (exactly-once)
Durability	No	No	Yes (HistoryQos and DurabilityServiceQos)	Yes* (XEP-0045)	Yes** (queues)
Persistence	Yes (persistence)	No	Yes (DurabilityServiceQos)	Yes* (XEP-0136)	Yes** (persistent messages)
Meta-data	Yes (HTTP header)	No	Yes (UserData, TopicData and GroupData)	Yes* (XEP-0131)	Yes** (message attributes)
Priority	No	No	Yes (TransportPriorityQos)	Yes (RFC 3921)	Yes (message priority)
Maximum latency	No	No	Yes (LatencyBudgetQos)	Yes* (XEP-0079)	No
Deadline	No	No	Yes (DeadlineQos)	Yes (XEP-0149)	No
Lifespan	No	Yes (MSL)	Yes (LifespanQos)	Yes* (XEP-0079)	Yes** (TTL)
Flow control	No	No	Yes (TimeBasedFilterQos)	Partially* (XEP-0258)	Yes**
Control memory	No	No	Yes (ResourceLimitsQos)	No	Yes** (memory use)
Redundancy	No	No	Yes (OwnershipQos)	Yes* (XEP-0184)	No
Files transfer	No	Yes (RCF 7959)	No	Yes* (XEP-0234)	No
Encryption	Yes (SMQTT)	Yes** (DTLS-secured)	Yes (TLS, DTLS, and DDS security)	Yes (RFC 3923)	Yes** (TLS)
Authentication	Yes	Yes* (ace-oauth-authz)	Yes (DDS security)	Yes (SASL)	Yes** (SASL)
Access control	No	Yes* (ace-oauth-authz)	Yes (DDS security)	Yes (XEP-0356 and XEP-0074)	Yes**
Logic separation	Yes (wildcards)	No	Yes (partitions)	Yes* (XEP-0045)	No
High availability	Yes** (cluster)	No	Yes, decentralized	Yes** (cluster)	Yes** (cluster)
Websockets	Yes	Yes* (coap-websockets-00)	Yes** (web-enabled DDS)	Yes (RFC 7395)	Yes (WSB)
Constrained devices	Yes (MQTT-SN)	Yes	Yes* (DDS-XRCE)	No	No

[a]In draft
[b]Supplied by vendor or community

14.4 Related Works

In order to ensure interoperability between all the protocols considered in Sect. 14.4, a set of functionalities common to all of them has been identified. In this sense, all protocols are built upon TCP, UDP, or both and provide support for the publisher/subscriber paradigm through some type of data container (message, topic, or observable). At the QoS level, the most important functionality of these protocols is related to data acknowledgment. All protocols control this communication feature through the best effort QoS and reliable delivery QoS. All these common features were considered during the middleware design stage.

In this way, the middleware proposed in this paper ensures the interoperability of IoT protocols and acts as an intermediary agent between two communication entities with compatibility for some QoS common to all protocols. In this sense, reliability of the data is delivered (quality of service supported by all protocols) with two levels: guaranteed and not guaranteed. A classical publisher/subscriber communication model is used, also supported by all protocols, including CoAP via an observer. Therefore, the presence of at least one broker for each supported protocol is required. Finally, the effort of integrating the middleware with IoT devices is considered minimal.

From a software design perspective, five independent technology modules have been defined that are interconnected through a set of input and output interfaces. These modules are characterized by functionality and are classified as follows: filtering module, redirection module, duplication module, translation module, publication module, and storage module.

A simplified flowchart of the internal middleware structure is presented in Fig. 14.1. The initial step includes a data filtering to discard packets that are not supported by the middleware. After filtering, the data are processed and classified according to publications, subscriptions, and remaining traffic (establishment of connections, acknowledgments, security negotiations, communication releases, etc.). The data associated with subscriptions and remaining traffic are directly redirected to the broker protocol. Therefore, connection of the subscribers with the middleware is not required, and interoperability with other protocols is guaranteed even when subscribers are connected directly with the broker.

On the other hand, packets received from publishers are duplicated as many times as IoT protocols are supported by the middleware and redirected to the appropriate protocol translator. For example, two protocols are supported (red and blue triangles and circles), and data from other protocols are ignored (green circle) in Fig. 14.1. Afterward, if the sample does not require translation, it is then redirected directly to the broker protocol. Otherwise, the following header fields are extracted: logical container name, QoS configuration, publisher identification, and data. These fields are present in all the protocols that have been considered in this work. Finally, the middleware generates a publication entity corresponding to the protocol to be translated and is linked to the original publisher. This publication entity is

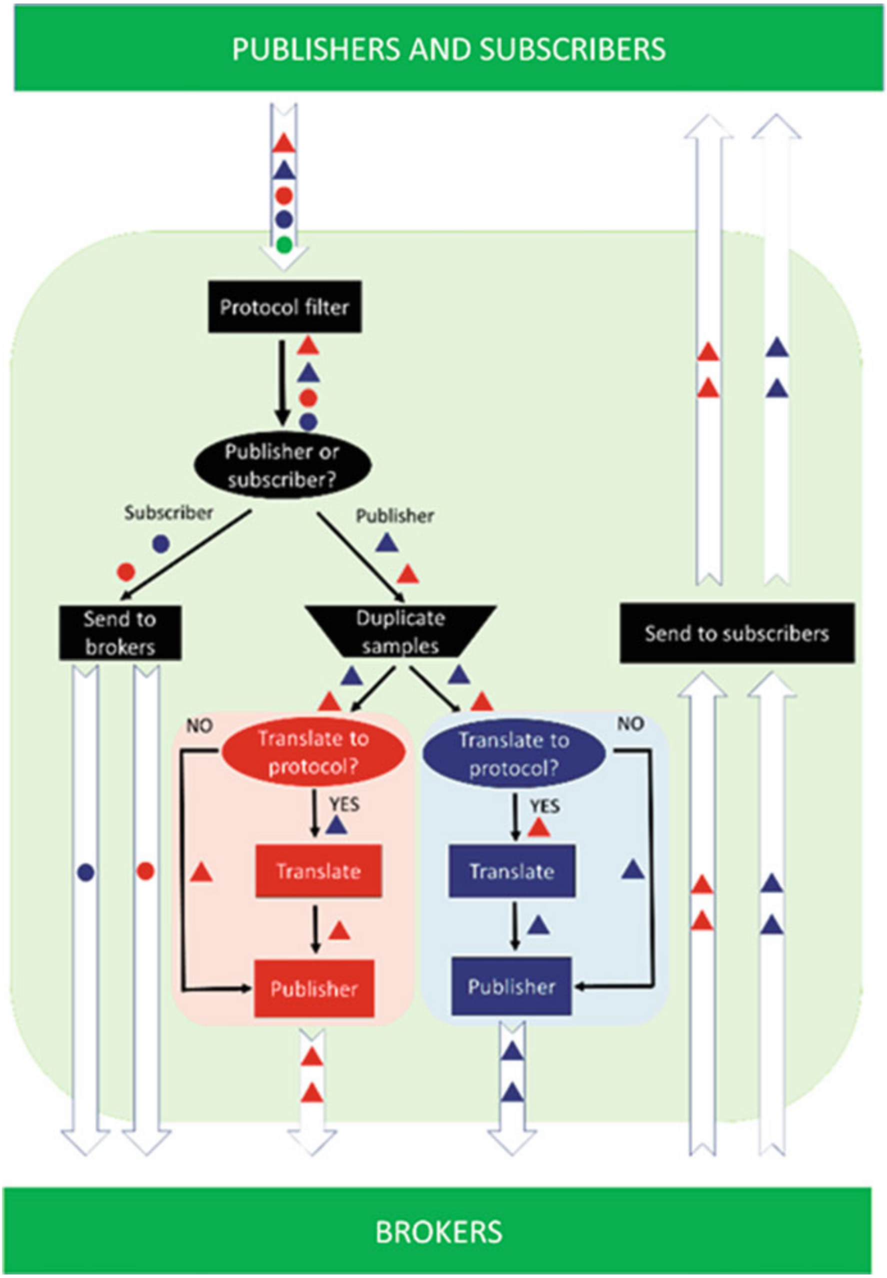

Fig. 14.1 The internal middleware structure. The triangles are data generated by publishers (blue is MQTT and red is CoAP), and circles are subscription requests (blue is MQTT and red is CoAP). The middleware understands the protocol packets, translates the data, adapts the QoS, and redirects both types of information considering the type of container (topic, message, observable, etc.) used by the IoT protocol

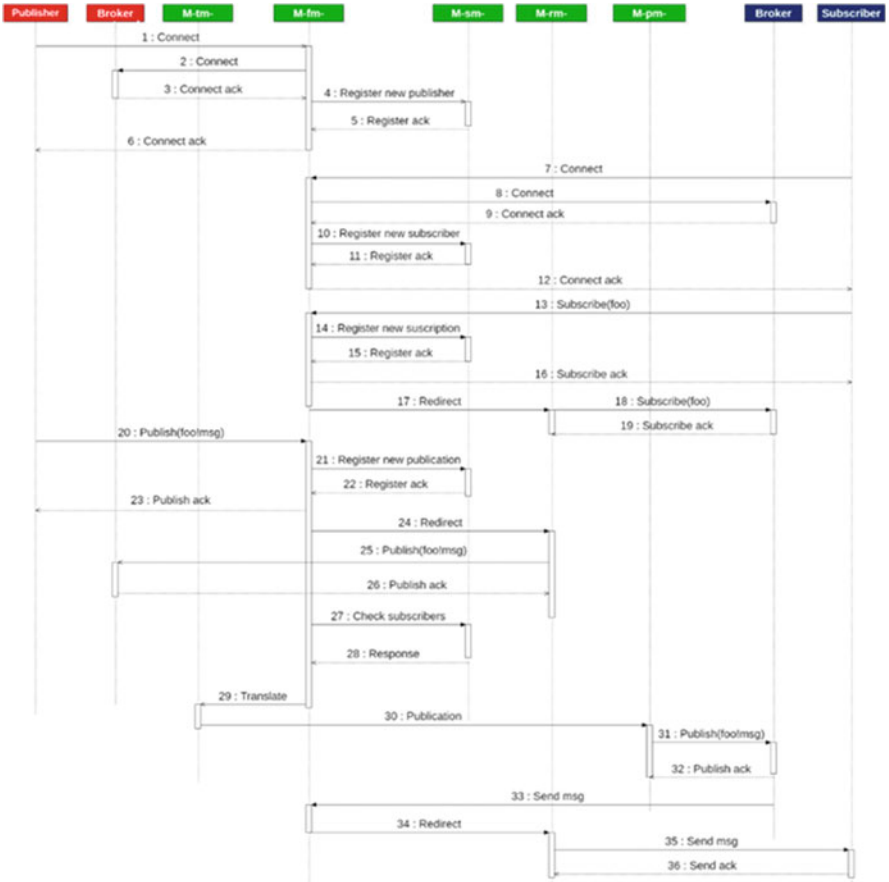

Fig. 14.2 Sequence diagram of the communication of a publisher and broker of a protocol (red), a subscriber and a protocol of other protocol (blue), and the different modules of the middleware (green)

maintained until the release of communication with the associated publisher, so it is invoked when new samples sent from the original publisher are received.

Figure 14.2 shows a simplified sequence diagram of the exchange of messages between the different elements involved in an IoT scenario with the presence of the middleware. The following elements have been considered: a publisher and a broker of a red protocol, a subscriber and a broker of a blue protocol, and the different modules of the middleware (green), with M-tm- (Middleware-translation module-), M-fm- (Middleware -filter module-), M-sm- (Middleware -storage module-), M-rm- (Middleware -redirection module-), and M-pm (Middleware -publication module-). As it can be seen, the middleware connects to the corresponding broker when it receives a connection request from the red subscriber and the blue publisher (1–12). In this process, both communication entities are registered in the M-sm- (4–5 and 10–11) waiting to interact with possible future subscriptions and publications. A subscription of the blue subscriber to the foo container reaches the M-fm- (13), is registered in the M-sm- (14–15) and redirected to the blue broker through the M-rm- (17–18). Registration of the subscription in the blue broker allows the blue subscriber to receive publications from blue publishers who are connected directly to the blue broker and not to the middleware. The red publisher then sends a message (msg) in the foo container by sending it to the M-fm- (20). The new publication is registered in the M-sm- (21–22), and it is sent directly to the red broker, in charge of sending to the red protocol subscribers who are not directly connected to the middleware (for the sake of simplicity, it has been omitted in the sequence diagram). At the same time, it is checked whether there are subscribers to the foo container considering other different protocols. As there is a red subscriber subscribed to the foo container, the translation is made to the red protocol (29) and published in the broker through the M-pm- (30–31). The blue broker sends the message to all blue subscribers who are connected to the middleware directly (it is omitted in the sequence diagram). As the middleware is subscribed to the foo container through the blue broker, it receives the message (33) and finally redirects the message to the blue subscriber (34–35).

At the implementation level, the middleware uses two sockets on two different ports at same time (Transmission Control Protocol and User Datagram Protocol), since it is common for some IoT protocols to support only one of these transport level protocols (see Table 14.2). Topologically, the middleware can be deployed in the same server of one of the broker protocols, or also in the location of the clients (publishers or subscribers), or even in some alternative location. Publishers (and optionally subscribers) are configured to point to the location of the middleware, as if it were a protocol broker.

The middleware design allows easy integration into IoT ecosystems characterized by a vast increase of devices, and its adaptation requires minimal technical effort. This is because the middleware is built upon the interceptor pattern, and, therefore, the IoT devices do not require any API or special requirement to interact with the middleware.

An interceptor pattern is a classic methodological tool in software engineering that allows for changing the processing cycle of an algorithm in a seamless way when a certain event occurs [45]. This software pattern is used in closed and unmodifiable systems that are intended to be extended with new services initially not considered and with minimum possible effort. The use of the interceptor pattern deals with the specification and exposure of one or more interceptor interfaces associated with one or more events that can be triggered by a closed system. Dispatchers are used for listening to events and triggering the callbacks associated with the interceptor or interceptors. The dispatcher defines methods to register or remove interceptors and events, following a philosophy also based on the publication/subscription paradigm. An important aspect is that the rest of the system does not need to know any of the implementation details to be able to act. In conclusion, its use is similar to a filtering process, and its application is widespread in web servers and Message-Oriented Middlewares (MOM).

In this way, IoT devices or applications only have to change the broker address, usually an Internet Protocol address (IPv4 or IPv6) or domain name, to the middleware address. At the implementation level, this implies only one line of programming code. On the other hand, integration is automatic considering decentralized standards such as DDS (without the presence of a broker), and no adaptation is necessary in this case. The middleware captures the packets from DDS publishers and subscribers and performs its expected function based on the established configuration.

From the network capability point of view, the middleware is also offered as a tool that provides horizontal scalability [46] with a low cost of adaptation. This is possible because the middleware works considering a stateless communication [47] and therefore does not need to be aware of the presence of other middleware instances. In this sense, the middleware can be deployed and replicated as many times as necessary without conflict. In extreme cases and it can be complemented with the addition of a load balancer when there is a high presence of publishers and subscribers. This prevents the middleware from acting as a single point of failure, adding redundancy and load distribution.

The middleware configuration allows enough flexibility to be adapted to the characteristics of any IoT ecosystem, considering the wide variability of possible scenarios, protocols, number of devices, type of data, and communication requirements. In this way, the middleware configuration allows to set a specific number of IoT protocols to be managed and ignore the rest of the network traffic. In addition, other configuration parameters can specify the amount of RAM memory, execution threads, and maximum bandwidth consumption to be used, in order to adapt the middleware capacities to the exact needs required.

Finally, the connection between publishers and subscribers with the middleware is performed without data security, because the middleware requires the analysis of the content of packets, and this is not possible if data are encrypted. To address this issue, tunnels can be used to protect traffic with TLS through the deployment of a secure communications channel for a data flow that is not protected. This type of software does not require any kind of modification in the middleware, publishers, and subscribers.

With the aim of highlighting the capacity and usefulness of the proposed middleware to translate different IoT protocols, in the next subsection, we present the description of a use case as the basis for middleware implementation.

14.5 Specific Use Case

For testing purposes, four virtual CPU machines with 4GB of RAM memory and Gigabit Ethernet network interfaces were used, and all machines were synchronized with the Network Time Protocol (NTP). Parallel computing was utilized to create publishers and subscriber entities on the same machine using processes and threads on both GNU/Linux and Windows operating systems.

From a physical point of view, machines are geographically dispersed and connected to a virtual private network (VPN) in the same network segment with broadcast enabled. The network traffic generator continuously transmits random packets, causing collisions and increasing latency. At the implementation level, the noise generator is a simple Python script that introduces Domain Name System (DNS) and Hypertext Transfer Protocol Secure (HTTPS) traffic with small random packets. The network traffic generator monitors the state of the network through a publication and a subscription to both brokers. This allows the noise generator to get the jitter value over time, and based on this, it generates random traffic following a dynamic distribution trying to keep this jitter value below a set threshold. This reproduces an IoT environment where network conditions change rapidly and unpredictably due to instability.

In a first approximation, only MQTT and CoAP have been considered, because of the importance of these protocols in the context of IoT systems [48, 49]. Topologically, this use case consists of the following actors: MQTT publishers, MQTT subscribers, CoAP publishers, CoAP subscribers, an MQTT broker, a CoAP broker, a relational object database, a network traffic generator, and the middleware that is described in this work. Figure 14.3 shows the logical infrastructure of the network with all the actors involved. For simplicity, the figure only illustrates a single MQTT publisher, MQTT subscriber, CoAP publisher, and CoAP subscriber; however, as described in the following subsection, the number of publishers and

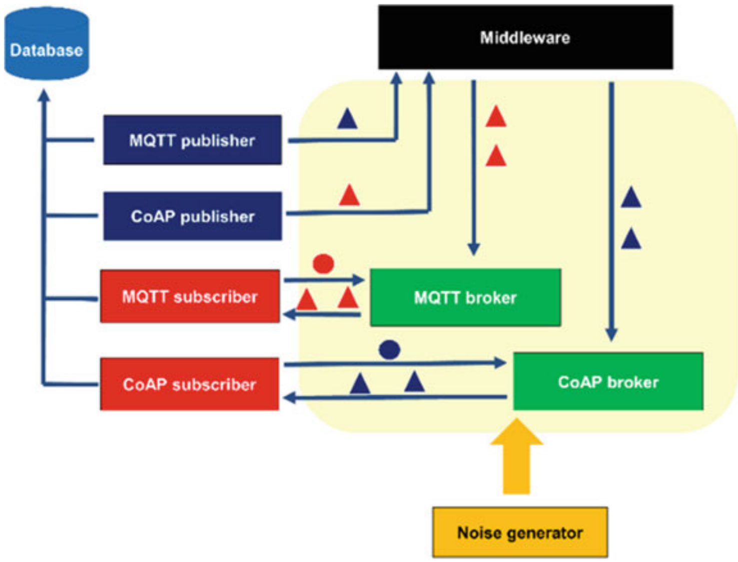

Fig. 14.3 Actors involved in the proposed case of use. The triangles are data generated by publishers (blue is MQTT and red is CoAP), and circles are subscription requests (blue is MQTT and red is CoAP). The middleware understands, translates, adapts, and redirects both types of information considering the type of container (topic, message, etc.) used by the IoT protocol

subscribers of each protocol will vary depending on the test performed. For this use case, publishers, subscribers, and middleware have been developed using the Python programming language considering the protocol implementations of Table 14.1. The database chosen for storing statistics was MySQL.

Subscribers are directly connected to brokers in order to reduce system overload, considering that packets from subscribers do not require any processing. In contrast, publishers do not establish a connection with the protocol broker but link directly to the middleware. This is the only modification necessary to achieve interoperability between protocols. As discussed above, this change generally involves only modifying a single line of programming code in publishers and subscribers.

On the other hand, an abstract container (topic or message) was defined as the minimum data structure employed by publishers and subscribers. This topic comprises information of the publisher's identifier, IP address, process identifier, protocol, number of samples, a timestamp, and a pseudo-random string that is obtained before the sample is sent. Therefore, the amount of bytes sent by publishers and received by subscribers is very small and practically negligible. This information is stored in publishers and subscribers until the end of the test so as not to interfere with the network. Finally, publishers and subscribers send all this information to the database. The performance indicators that are stored include latencies, bandwidth consumption, memory, CPU, and other metrics.

Subsequently, data are processed and quantitative measures of service quality are calculated such as latency, jitter, throughput, bandwidth used, and samples sent or lost. The results are presented considering data of publishers and subscribers of the two protocols either together and separately.

Finally, CoAP and MQTT protocols use a default configuration, except in acknowledgment tests where both protocols were parameterized accordingly with their respective QoS of reliability. In this sense, a publication interval of 50 milliseconds was considered for all publishers. This time interval is considered adequate based on similar studies about IoT protocols performance analysis [50–52].

14.6 Test Results and Discussion

From the implementation described in the case of use, it was observed that the communication between publishers and subscribers of different protocols was satisfactory. In this sense, any sample published by an MQTT publisher was received by an MQTT subscriber and also by a CoAP subscriber (the same for a CoAP publisher) without making any major changes to the publishers or subscribers. With this in mind, adding new protocols to the middleware only involves processing messages generated by the protocol.

Once the interoperability between different the protocols is achieved, the next step includes the analysis of network performance when the middleware system is present. The results can be compared with those obtained by other authors, since there are a significant number of studies that analyze the performance of MQTT and CoAP protocols [53–55].

Latency is the time elapsed since a sample is sent by a publisher until it is reached by a subscriber. When there are multiple subscribers, then latency is the average of latencies of all subscribers. As it is obvious, the theoretical latency with middleware will always be higher since it represents an additional intermediary element in the communications, and it contains a certain processing logic. Latency and increment of latency of the subscribers in each sample are shown in Fig. 14.4, considering the two protocols (MQTT and CoAP) and highlighting also the presence or not of the middleware.

In general, and as other authors also pointed out [14, 56], CoAP latency is slightly higher than in MQTT. However, a more detailed analysis indicates that latencies may be lower in CoAP protocol [20]. This is due to overload control on TCP header applied by MQTT with respect to UDP header of CoAP [57], which contains fewer bytes and consumes less network. However, due to the absence of TCP relay mechanisms, packet loss is more common in the CoAP protocol. Therefore, unstable conditions in network, heavy traffic, and collisions due to the presence of the noise generator network can cause more missed samples with the CoAP protocol than with MQTT. This has a great impact on the CoAP protocol when the QoS is configured to ensure reliability. Consequently, latency increases considerably with the number of CoAP publishers/subscribers, although MQTT generally generates more network traffic in the same circumstances, due to the use of TCP protocol and the additional traffic needed to ensure reliability. With the presence of the middleware, these effects are important and duplicated, due to the double connection, on the one hand, between publishers/subscribers with the middleware, and, on the other hand, between the middleware and brokers. There are no significant differences in latency with the middleware when the number of publishers and subscribers is low. Therefore, differences in latency with or without middleware are more relevant but still relatively low when the number of nodes increases.

The results shown previously can be complemented with the Round Trip Time (RTT) metric [58]. RTT is the time elapsed since a sample is sent from a transmitter to a receiver and back to the transmitter, including all the necessary processing that occurs in the receiver. In this use case, RTT is measured in the publishers, as opposed to the latency, that is measured in the subscribers. In this sense, it is necessary that publishers have subscription capacity and subscribers have publication capacity because publishers must receive information back from subscribers. Therefore, all communication entities are considered as publishers and subscribers at the same time. Figure 14.5 shows the RTT and increment of RTT for MQTT and CoAP publishers with and without middleware. In this way, it can be seen how RTT increases with respect to latency due to the increase of hops between publishers, subscribers, and return to publishers. This time is also strongly impacted by the use of the virtual private network that connects the nodes, the geographically dispersed location, and the presence of the random traffic generator.

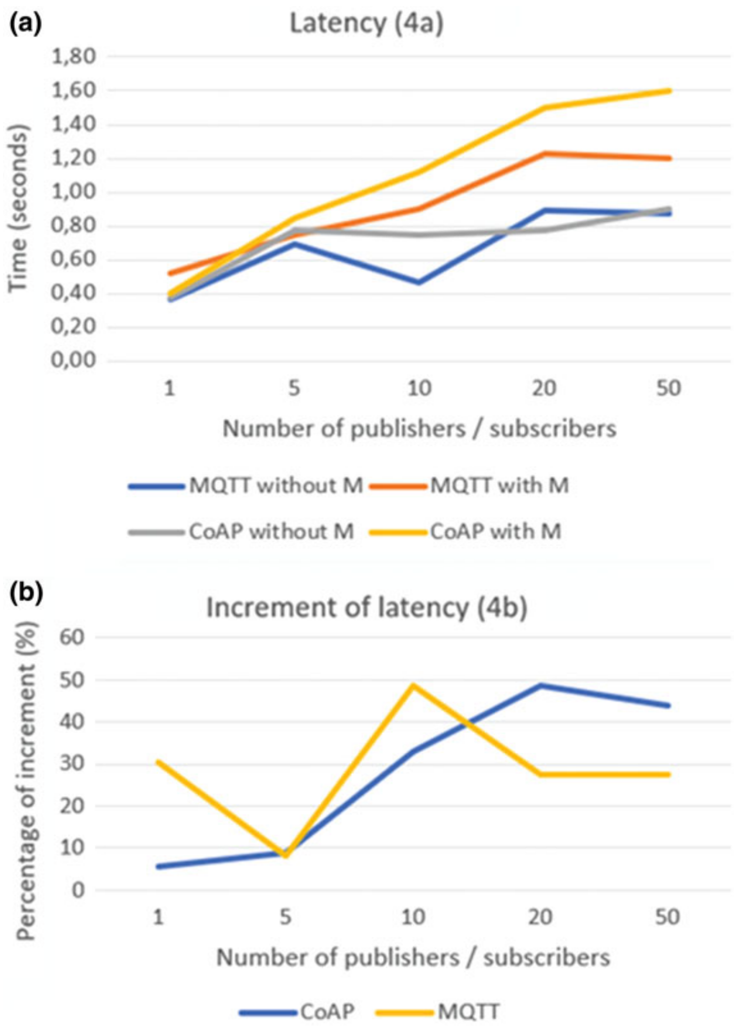

Fig. 14.4 Latency of the MQTT and CoAP subscribers with and without middleware (M) (4a) and increment of latency (4b)

However, the results presented are incomplete without being evaluated according to other additional network parameters such as jitter and missed messages. Jitter can be defined like the standard deviation of the latency. In this sense, jitter and increment of jitter results of the subscribers for the tests performed are presented in Fig. 14.6. As with latency, the time evolution of jitter practically remains similarly either with or without the presence of middleware when the number of publishers and subscribers is small. Beyond a certain threshold, differences are more pronounced, which may justify the use of a second middleware to distribute the load.

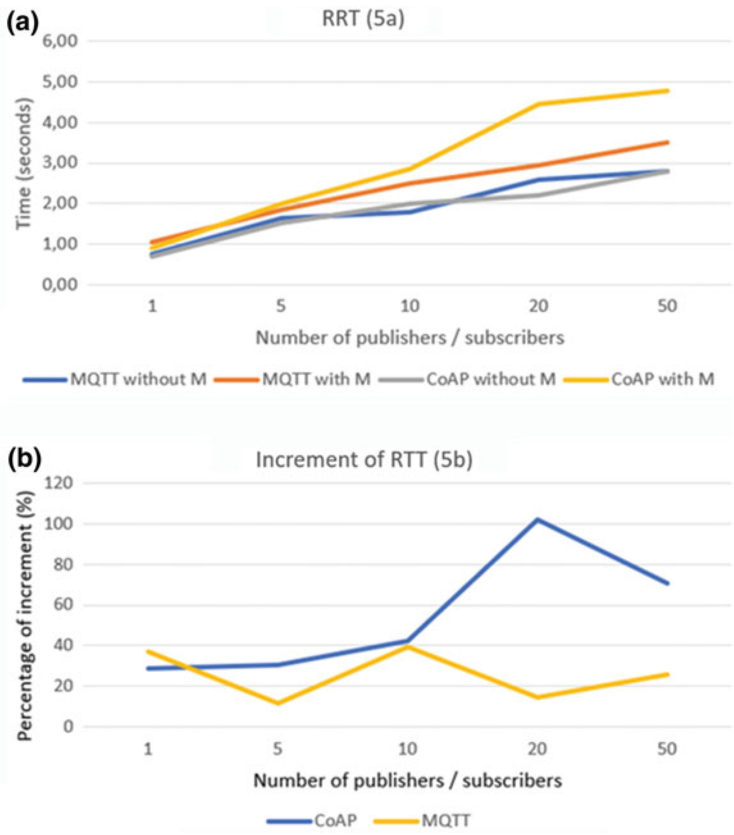

Fig. 14.5 RRT of the MQTT and CoAP publishers with and without middleware (M) (5a) and increment of latency (5b)

To analyze the number of samples lost with and without the presence of the middleware, QoS of publishers and subscribers were configured without reliability (QoS = 0 in MQTT and non-confirmable in CoAP). With higher QoS, the number of missed samples is non-existent, at the cost of increased traffic and also latency and RTT, as seen above. Figure 14.7 shows the percentage of missed samples with respect to the total transmitted by the CoAP and MQTT publishers. To measure the missed samples, each sample sent by a publisher carries a unique identification that is subsequently verified by the subscribers. The missed messages in MQTT was significantly lower than in CoAP, although with a high cost of increase of the traffic generated, an issue that is supported by other authors [19, 20]. There were no significant differences in this regard when the middleware was present. Obviously, these results may vary depending on network conditions.

On the other hand, it should also be noted that the length of the message may also have a strong impact on test results. Probability of sample missing in CoAP

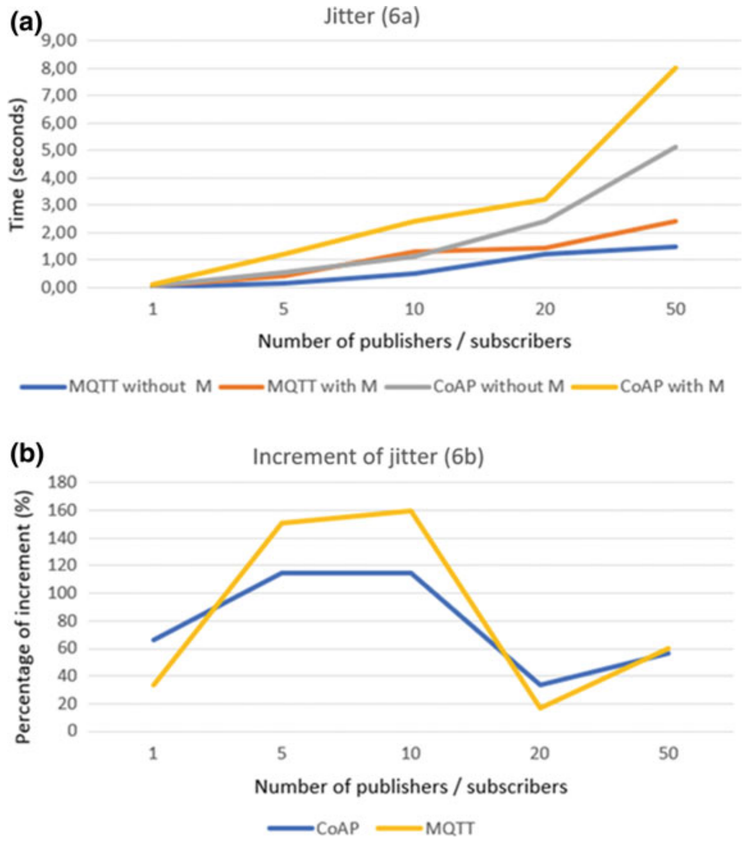

Fig. 14.6 Jitter of the MQTT and CoAP subscribers with and without middleware (M) (6a) and increment of jitter (6b)

protocol is higher than in MQTT with large sample sizes, because CoAP protocol uses UDP, and MQTT is based on TCP. This way, CoAP publishers retransmit the entire message more often than MQTT when the message is longer [20].

Finally, Table 14.4 shows CPU and memory usage for all entities involved in the test, where results for publishers, subscribers, brokers, and middleware are shown in averages for cases of 1, 5, 10, and 20 publishers/subscribers. The MQTT and CoAP brokers exhibit a higher CPU and memory consumption, at a similar middleware level. To reduce middleware memory usage, the source code was compiled into a binary before being executed.

The results presented in this paper and some more omitted due to space issues can be reproduced from the source code released in GitLab [59] for subscribers, publishers, middleware, network traffic generator, and data post-processing software.

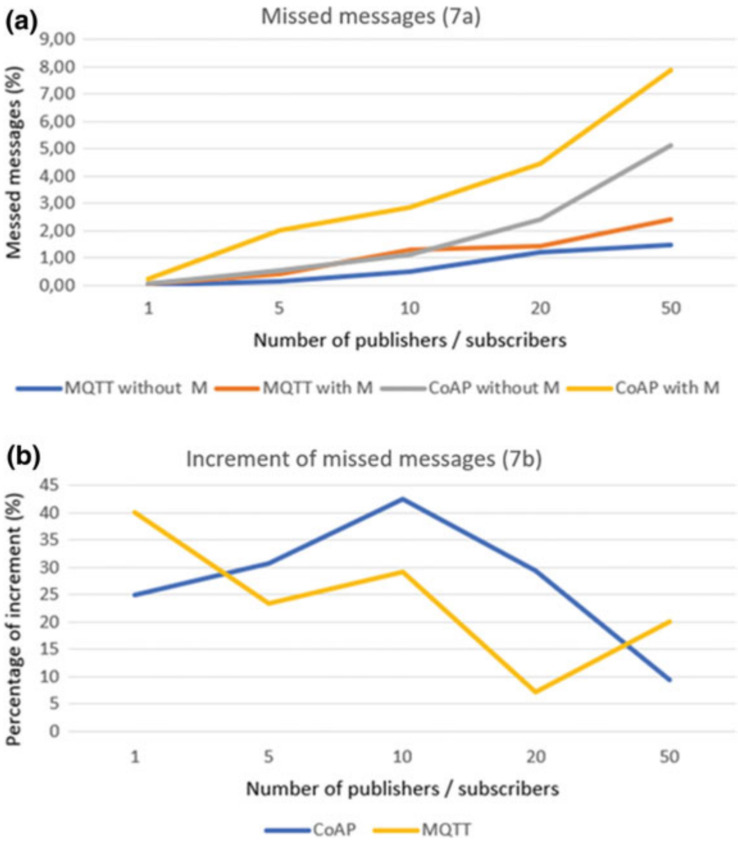

Fig. 14.7 Jitter of the MQTT and CoAP subscribers with and without middleware (M) (6a) and increment of jitter (6b)

Table 14.4 Usage of CPU and memory

Entity	Usage of CPU (%) - 1*	Usage of CPU (%) - 5*	Usage of CPU (%) - 10*	Usage of CPU (%) - 20*	Usage of memory (Kb)
MQTT Publisher	0,15	0,14	0,17	0,15	1130
MQTT subscriber	0,15	0,21	0,32	0,45	1129
CoAP Publisher	0,18	0,18	0,2	0,2	1530
CoAP subscriber	0,2	0,26	0,41	0,5	1530
MQTT broker	0,35	0,55	0,71	0,98	7531
CoAP broker	0,6	0,85	1,1	1,25	3213
Middleware	0,28	0,43	0,62	0,8	3206

[a]Number of publishers/subscribers

14.7 Conclusions

Interoperability among IoT protocols is one of the main challenges to be addressed in order to achieve success in this context. This paper presents a first approach to this problem, analyzing on the one hand the technical functionalities for each of the most important protocols of the IoT ecosystem, and then describing a middleware system that acts as a protocol translator. The middleware is based on a modular design, and its existence presents a minimum influence on the rest of the communication nodes, so that it can be integrated in IoT environments already deployed through a simple adaptation of publishers and subscribers. This way, the complexity of the technology can be isolated and the common functionalities that exist between protocols can be used to achieve full connectivity under satisfactory interoperability conditions within IoT ecosystem. The results showed that the addition of the middleware system does not have a significant negative impact on network degradation. It also demonstrated its adaptability and flexibility from the point of view of the scalability of an IoT system, considering the increase of publishers and subscribers.

The middleware has been presented as a stateless software tool, and, therefore, it is possible to deploy as many instances as necessary in a simple way in IoT scenarios with a large number of communication elements. This can decrease the computational load of the middlewares, obviously impacting on an improvement in latency, jitter, and missed messages. In extremes cases where the number of publications and subscribers is high, dynamic, unpredictable, phenomena such as hotspotting may appear in a particular middleware. To reduce the impact, a load balancer can be deployed to distribute the communication load equitably among a set of middlewares, for example, following a round-robin scheduling. These characteristics offered by the middleware can satisfy the needs of IoT environments with devices of very diverse nature. In this sense, interoperability at the communication level is an essential requirement to subsequently achieve interoperability at other higher levels of abstraction. The interoperability between computational devices with communication capabilities is a great challenge in a world that is increasingly interconnected, globalized, and more aware of the need to coordinate efforts toward the societal good.

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References

1. C.G. Garcıa, L. Zhao, V. García-Díaz, A user-oriented language for specifying interconnections between heterogeneous objects in the Internet of Things. IEEE Internet Things J. **1**, –1 (2019)
2. H.-J. Yim, D. Seo, H. Jung, M.-K. Back, I. Kim, K.-C. Lee, Description and classification for facilitating interoperability of heterogeneous data/events/services in the internet of things. Neurocomputing **256**, 13–22 (2017)
3. L. Vidyashree, M.A. Alworafi, S.A. El-Booz, Suresha: Survey of security mechanisms in Internet of Things, in *Recent Findings in Intelligent Computing Techniques*, ed. by P. K. Sa, S. Bakshi, I. K. Hatzilygeroudis, M. N. Sahoo, (Springer, Singapore, 2019), pp. 353–361
4. P.N. Howard, *Pax Technica: How the Internet of Things May Set Us Free or Lock Us Up* (Yale University Press, New Haven/London, 2015)
5. H. Mora, V. Gilart-Iglesias, R. Pérez-del Hoyo, M.D. Andújar-Montoya, A comprehensive system for monitoring urban accessibility in smart cities. Sensors **17**, 1834 (2017)
6. I. Yaqoob, E. Ahmed, I.A.T. Hashem, A.I.A. Ahmed, A. Gani, M. Imran, M. Guizani, Internet of things architecture: Recent advances, taxonomy, requirements, and open challenges. IEEE Wirel. Commun. **24**, 10–16 (2017)
7. M.I. Hussain, Internet of things: Challenges and research opportunities. CSI Trans. ICT. **5**, 87–95 (2017)
8. Zgheib, R., Conchon, E., Bastide, R.: Semantic middleware architectures for IoT healthcare applications. En: Ganchev, I., Garcia, N.M., Dobre, C., Mavromoustakis, C.X., y Goleva, R. (eds.) Enhanced Living Environments: Algorithms, Architectures, Platforms, and Systems. pp. 263–294. Springer, Cham (2019)
9. T. Watteyne, P. Tuset-Peiro, X. Vilajosana, S. Pollin, B. Krishnamachari, Teaching communication technologies and standards for the industrial IoT? Use 6TiSCH! IEEE Commun. Mag. **55**, 132–137 (2017)
10. J. Guth, U. Breitenbücher, M. Falkenthal, F. Leymann, L. Reinfurt, Comparison of IoT platform architectures: A field study based on a reference architecture, in *2016 Cloudification of the Internet of Things (CIoT)*, (2016), pp. 1–6
11. T. Yokotani, Y. Sasaki, Comparison with HTTP and MQTT on required network resources for IoT, in *2016 International Conference on Control, Electronics, Renewable Energy and Communications (ICCEREC)*, (2016), pp. 1–6
12. P. Kayal, H. Perros, A comparison of IoT application layer protocols through a smart parking implementation, in *2017 20th Conference on Innovations in Clouds, Internet and Networks (ICIN)*, (2017), pp. 331–336
13. T. Maksymyuk, M. Brych, S. Dumych, H. Al-Zayadi, Comparison of the IoT transport protocols performance over narrowband-IoT networks. Internet Things Ubiquitous Commun. **1**, 25–28 (2017)
14. V. Karagiannis, P. Chatzimisios, F. Vazquez-Gallego, J. Alonso-Zarate, A survey on application layer protocols for the internet of things. Trans. IoT Cloud Comput. **1** (2015)
15. J. Kaur, K. Kaur, Internet of things: A review on technologies, architecture, challenges, applications. Future Trends. Int. J. Comput. Netw. Inf. Secur. Hong Kong. **9** (2017)
16. T. Abels, R. Khanna, K. Midkiff, Future proof IoT: Composable semantics, security, QoS and reliability, in *2017 IEEE Topical Conference on Wireless Sensors and Sensor Networks (WiSNet)*, (2017), pp. 1–4
17. Y.D. Beyene, R. Jantti, O. Tirkkonen, K. Ruttik, S. Iraji, A. Larmo, T. Tirronen, A.J. Torsner, NB-IoT Technology Overview and Experience from Cloud-RAN Implementation. IEEE Wirel. Commun. **24**, 26–32 (2017)
18. H. Cai, B. Xu, L. Jiang, A.V. Vasilakos, IoT-based big data storage systems in cloud computing: Perspectives and challenges. IEEE Internet Things J. **4**, 75–87 (2017)
19. S. Mijovic, E. Shehu, C. Buratti, Comparing application layer protocols for the Internet of Things via experimentation, in *2016 IEEE 2nd International Forum on Research and Technologies for Society and Industry Leveraging a better tomorrow (RTSI)*, (2016), pp. 1–5

20. D. Thangavel, X. Ma, A. Valera, H.X. Tan, C.K.Y. Tan, Performance evaluation of MQTT and CoAP via a common middleware, in *2014 IEEE Ninth International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP)*, (2014), pp. 1–6
21. A. Mazayev, J.A. Martins, N. Correia, Interoperability in IoT through the semantic profiling of objects. IEEE Access, 1–1 (2017)
22. M. Bermudez-Edo, T. Elsaleh, P. Barnaghi, K. Taylor, IoT-Lite: A lightweight semantic model for the internet of things and its use with dynamic semantics. Pers. Ubiquitous Comput. **21**, 475–487 (2017)
23. A. Talaminos-Barroso, M.A. Estudillo-Valderrama, L.M. Roa, J. Reina-Tosina, F. Ortega-Ruiz, A machine-to-machine protocol benchmark for eHealth applications – Use case: Respiratory rehabilitation. Comput. Methods Prog. Biomed. **129**, 1–11 (2016)
24. E. Mezghani, E. Exposito, K. Drira, A model-driven methodology for the design of autonomic and cognitive IoT-based systems: application to healthcare. IEEE Trans. Emerg. Top. Comput. Intell. **1**, 224–234 (2017)
25. M. Compton, P. Barnaghi, L. Bermudez, R. García-Castro, O. Corcho, S. Cox, J. Graybeal, M. Hauswirth, C. Henson, A. Herzog, V. Huang, K. Janowicz, W.D. Kelsey, D. Le Phuoc, L. Lefort, M. Leggieri, H. Neuhaus, A. Nikolov, K. Page, A. Passant, A. Sheth, K. Taylor, The SSN ontology of the W3C semantic sensor network incubator group. J. Web Semant. **17**, 25–32 (2012)
26. I. Kalamaras, N. Kaklanis, K. Votis, D. Tzovaras, Towards Big Data Analytics in Large-Scale Federations of Semantically Heterogeneous IoT Platforms, in *Artificial Intelligence Applications and Innovations*, ed. by L. Iliadis, I. Maglogiannis, V. Plagianakos, (Springer, 2018), pp. 13–23
27. J. Swetina, G. Lu, P. Jacobs, F. Ennesser, J. Song, Toward a standardized common M2M service layer platform: Introduction to oneM2M. IEEE Wirel. Commun. **21**, 20–26 (2014)
28. T.-B. Dang, M.-H. Tran, D.-T. Le, H. Choo, On Evaluating IoTivity Cloud Platform, in *Computational Science and Its Applications – ICCSA 2017*, ed. by O. Gervasi, B. Murgante, S. Misra, G. Borruso, C. M. Torre, A. M. A. C. Rocha, D. Taniar, B. O. Apduhan, E. Stankova, A. Cuzzocrea, (Springer, 2017), pp. 137–147
29. J. Soldatos, N. Kefalakis, M. Hauswirth, M. Serrano, J.-P. Calbimonte, M. Riahi, K. Aberer, P.P. Jayaraman, A. Zaslavsky, I.P. Žarko, L. Skorin-Kapov, R. Herzog, OpenIoT: Open Source Internet-of-Things in the Cloud, in *Interoperability and Open-Source Solutions for the Internet of Things*, ed. by I. Podnar Žarko, K. Pripužić, M. Serrano, (Springer, 2015), pp. 13–25
30. L. Gürgen, C. Munilla, R. Druilhe, E. Gandrille, J.B. Nascimento, do: sensiNact IoT platform as a service, in *Enablers for Smart Cities*, (Wiley, 2016), pp. 127–147
31. Curado, M., Madeira, H., da Cunha, P.R., Cabral, B., Abreu, D.P., Barata, J., Roque, L., Immich, R.: Internet of things. En: Kott, A. y Linkov, I. (eds.) Cyber Resilience of Systems and Networks. pp. 381–401. Springer, Cham (2019)
32. A. Sheth, Internet of things to smart IoT through semantic, cognitive, and perceptual computing. IEEE Intell. Syst. **31**, 108–112 (2016)
33. C. Wootton, *Samsung ARTIK Reference: The Definitive Developers Guide* (Apress, 2016)
34. IoT Solutions in Microsoft's Azure IoT Suite - Data Acquisition and Analysis in the Real World | Scott Klein | Apress
35. M.A. Rodriguez, L. Cuenca, A. Ortiz, FIWARE open source standard platform in smart farming – A review, in *Collaborative Networks of Cognitive Systems*, ed. by L. M. Camarinha-Matos, H. Afsarmanesh, Y. Rezgui, (Springer, 2018), pp. 581–589
36. K. Jackson, C. Bunch, E. Sigler, *OpenStack Cloud Computing Cookbook* (Packt Publishing Ltd, 2015)
37. Limosani, R., Manzi, A., Fiorini, L., Dario, P., Cavallo, F.: Connecting ROS and FIWARE: Concepts and tutorial. En: Koubaa, A. (ed.) Robot Operating System (ROS): The Complete Reference (Volume 3). pp. 449–475. Springer, Cham (2019)
38. K. Främling, S. Kubler, A. Buda, Universal messaging standards for the IoT from a lifecycle management perspective. IEEE Internet Things J. **1**, 319–327 (2014)
39. V.K. Solanki, V.G. Díaz, J.P. Davim, *Handbook of IoT and Big Data* (CRC Press, 2019)

40. STOMP (The Simple Text Oriented Messaging Protocol) 1.2, https://stomp.github.io/
41. H.C. Hwang, J. Park, J.G. Shon, Design and implementation of a reliable message transmission system based on MQTT protocol in IoT. Wirel. Pers. Commun. **91**, 1765–1777 (2016)
42. S. Chaudhary, Privacy and security issues in internet of things. Int. Educ. Res. J. **3** (2017)
43. P.M. Kumar, U.D. Gandhi, Enhanced DTLS with CoAP-based authentication scheme for the internet of things in healthcare application. J. Supercomput, 1–21 (2017)
44. F. Martín, E. Soriano, J.M. Cañas, Quantitative analysis of security in distributed robotic frameworks. Robot. Auton. Syst. **100**, 95–107 (2018)
45. D. Schmidt, M. Stal, H. Rohnert, F. Buschmann, *Pattern-Oriented Software Architecture Volume 2: Patterns for Concurrent and Networked Objects* (Wiley, Chichester/New York, 2000)
46. Machiraju, S., Gaurav, S.: High availability, scalability, and disaster recovery. En: Machiraju, S. y Gaurav, S. (eds.) Hardening Azure Applications: Techniques and Principles for Building Large-Scale, Mission-Critical Applications. pp. 173–195. Apress, Berkeley (2019)
47. V. Manfredi, M. Crovella, J. Kurose, Understanding Stateful vs Stateless Communication Strategies for Ad Hoc Networks, in *Proceedings of the 17th Annual International Conference on Mobile Computing and Networking*, (ACM, New York, 2011), pp. 313–324
48. A.E. Khaled, S. Helal, Interoperable Communication Framework for Bridging RESTful and Topic-Based Communication in IoT. Future Gener. Comput. Syst (2018)
49. D. Serpanos, M. Wolf, IoT System Architectures, in *Internet-of-Things (IoT) Systems*, (Springer, Cham, 2018), pp. 7–15
50. H. Derhamy, J. Eliasson, J. Delsing, IoT interoperability—On-demand and low latency transparent multiprotocol translator. IEEE Internet Things J. **4**, 1754–1763 (2017)
51. C. Gündoğan, P. Kietzmann, M. Lenders, H. Petersen, T.C. Schmidt, M. Wählisch, NDN, CoAP, and MQTT: A Comparative Measurement Study in the IoT. ArXiv180601444 Cs (2018)
52. M.A. Prada, P. Reguera, S. Alonso, A. Morán, J.J. Fuertes, M. Domínguez, Communication with resource-constrained devices through MQTT for control education. IFAC-Pap. **49**, 150–155 (2016)
53. S. Bandyopadhyay, A. Bhattacharyya, Lightweight Internet protocols for web enablement of sensors using constrained gateway devices, in *2013 International Conference on Computing, Networking and Communications (ICNC)*, (2013), pp. 334–340
54. Y. Chen, T. Kunz, Performance evaluation of IoT protocols under a constrained wireless access network, in *2016 International Conference on Selected Topics in Mobile Wireless Networking (MoWNeT)*, (2016), pp. 1–7
55. M.H. Amaran, N.A.M. Noh, M.S. Rohmad, H. Hashim, A comparison of lightweight communication protocols in robotic applications. Procedia Comput. Sci. **76**, 400–405 (2015)
56. A. Pramanik, A.K. Luhach, I. Batra, U. Singh, A systematic survey on congestion mechanisms of CoAP based Internet of Things, in *Advanced Informatics for Computing Research*, (Springer, Singapore, 2017), pp. 306–317
57. N. Naik, Choice of effective messaging protocols for IoT systems: MQTT, CoAP, AMQP and HTTP, in *2017 IEEE International Systems Engineering Symposium (ISSE)*, (2017), pp. 1–7
58. P. Kumar, B. Dezfouli, Implementation and analysis of QUIC for MQTT. Comput. Netw. **150**, 28–45 (2019)
59. Middleware Based on Interceptor Pattern for Interoperability between IoT Protocols, https://gitlab.com/atalaminos/iot_middleware

Chapter 15
Mining Active Influential Nodes for Finding Information Diffusion in Social Networks

Ameya Mithagari and Radha Shankarmani

15.1 Introduction

In this advanced era, social networking communication is enormously evolving. The social networking sites have an extraordinary effect on more than 90% of young people worldwide and have a big market for innumerable startups. The impact of chat messages, posts, comments, etc., in social networks, tend to influence individuals' feelings, suppositions, and practices [1].

Particularly, recognizing influential users ends up as one of the fundamental issues in influence propagation. Rumor controlling, disease spreading, publicizing, etc. are some of the real-life applications of influence propagation. Thus, "recognizing the powerful nodes is of incredible significance." Influence maximization problem is formally defined by Kempe et al. [2] as the problem to identify such influential nodes.

There are two imperative qualities [3] found in social networks. One of them is that individuals in social networks can construct various trust relations with others setting aside geological positions. Another imperative quality is that the trust relationship is also built with someone who we may never have experienced each other face to face. Building such trust relations is a task of daily effort. This signifies the user must remain active to build good trust relation. The time of login and usage period is very sensitive information. Therefore, such data is hardly available for researchers.

In this chapter, a hybrid model named Active Influential Node Miner is proposed to identify active influential nodes in a temporal network. The activeness value of the node is inferred from the change of friends of that node over a time

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period. Such resource intensive task is accomplished using cloud computing. The discovered influential nodes can provide cost-effective marketing of several goods and products. The next section discusses various strategies to find influential nodes and research gap in models used for finding influential nodes. In Sect. 15.3, a hybrid model to identify active influential nodes is defined. Section 15.4 contains a discussion of Experimental results. Section 15.5 comprises conclusion.

15.2 Literature Review

15.2.1 Influential Nodes Identification in Static Network

A static network is a network graph which do not vary with time. Therefore, the nodes and edges in a static diagram stay consistent. In [4] various centralized algorithms are discussed Random walk, Page Rank algorithm, etc. In recent years many researchers have clubbed together these strategies to get efficient output. A matrix that is constructed in [5] consists of Page Rank, Geodesic Distance, Graph Density, Eigenvector Centrality, Degree Centrality, Closeness Centrality, Clustering Coefficient, and Betweenness Centrality.

The authors in [6] considered activeness based on the number of posts which flicker dataset provided and centrality algorithms to calculate the location-based influence measurements and clubbed them together to identify influential users. Algorithm proposed in [7] is useful in applications based on social networks with community structure. In [8] a framework to mine time-dependent users which are active for some time is developed.

15.2.2 Influential Nodes Identification in Dynamic/Temporal Networks

The network keeps changing at each time instance in any dynamic environment. Analyzing such dynamic network is not possible; therefore, a temporal graph is used to study the network behavior. A snapshot of a network at a specific time is called a temporal graph. The time period is monthly, quarterly, half-yearly, or yearly.

The concept of probing in dynamic networks was first introduced by Zhuang et al. [9] who studied the dynamic social network. The adaptive strategy discussed in [10] is to keep the previous seed set and replace a few influential nodes in a greedy manner. The most recent study on influence maximization is proposed by Weihua et al. [11]. This model is based on an algorithm consisting of stigmergy approach to finding influential nodes in a decentralized environment of social network.

15.2.3 Research Problem

In dynamic/temporal social network the links are created and destroyed which is defined as the change in the network. But for a particularly active user in the network, this change is inevitable, i.e., the increase and decrease in outgoing and incoming links. If the user is an influential user but is not active the information diffusion may not take place from that node. The above scenario is not considered by the algorithms discussed in the above sections because they focus on the complete dynamic network rather than each influential user. Thus finding such users and decreasing their priority to increase the accuracy of reality-based information diffusion is necessary.

15.3 Active Influential Node Miner (AINM)

The existing algorithms and models are based on theoretical study rather than a practical approach. An influential user is a node in the graph which has a strategic location in the network and strong connections with copious nodes in the network. In a real-life situation, if the user is not active for a certain period, the nodes connected to that node cannot be influenced. Hence finding activeness of a node is an important factor. Here, a hybrid model is proposed to identify the active and emerging set of influential nodes in a temporal environment. Figure 15.1 shows basic flow of data between components of AINM.
For applying the model following assumptions are considered:

1. The graphs are considered to be unweighted.
2. Vertex with no edges is the representation of deleted accounts.

The input to AINM are sets of temporal graphs exemplified as Graph G with V vertices and edges E classifies to $G(V, E)$, $G_1(V_1, E_1)$, $G_2(V_2, E_2)$ to $G_n(V_n, E_n)$. The time can vary between 1 and 6 months depending upon the social network. Thus a temporal environment is considered for our model.
Internal process of each component in AINM is detailed below:

15.3.1 Activeness Value Estimator

An algorithm to infer a node's activeness value derived from topological node behavior is defined. Previous snapshot graph $G_{i-1}(V_{i-1}, E_{i-1})$ and current snapshot graph $G_i(V_i, E_i)$ are the inputs to this component. These are snapshots of same graph taken at different time instance.

Algorithm 1 Algorithm to find activeness value

Input: $G_{i-1}(V_{i-1}, E_{i-1}), G_i(V_i, E_i)$
Output: Activeness
Initialization : Activeness Dictionary
for $\forall v_i \in V_i$ **do**
  $Glist = Neighbors\ of\ v_i\ in\ graph\ G_{i-1}$
  $Hlist = Neighbors\ of\ v_i\ in\ graph\ G_i$
  if G_list==H_list **then**
    value=0
  else if |G_list| == |H_list| **then**
    change_list= *set*(H_list)-*set*(G_list)
    value=|change_list|
  else if |G_list| < |H_list| **then**
    change_list= *set*(H_list)-*set*(G_list)
    value=|change_list|
  else
    change_list= *set*(G_list)-*set*(H_list)
    old_value=|change_list|
    if old_value $\geq AverageDegreeof\, G_i$ **then**
      value=old_value
    else
      value=0
    end if
  end if
  if $v_i \notin G_{i-1}$ **then**
    Activeness[v_i]= $\lceil value * 0.25 \rceil$
  else
    Activeness[v_i]= value
  end if
end for
return $Activeness$

The change of friends of user for that particular time instance is considered as activeness value for the user. The change can be negative or positive depending on the type of content that got posted by the user but the activeness shall only be considered as positive. If the change is positive, the amount of friends added to the node is the activeness value of that node. If the change is negative, the amount of friends the node has lost is the activeness value of that node provided the average degree of graph G_i is less than total friends lost, as the loss of friends may be due to other users. If there is no change of friends we consider that the node is inactive and assign its activeness value to 0. Whereas for new nodes 25% of activeness shall be considered because they are in the initial stage as well as they will not have set of friends in the previous snapshot of the graph. Therefore, the obtained activeness value is exaggerated as well as the trust value does not form at the beginning stage. But such nodes can become influential nodes in the future, therefore, to reduce the exaggerated activeness value of the node we consider only quarter part of its activeness value.

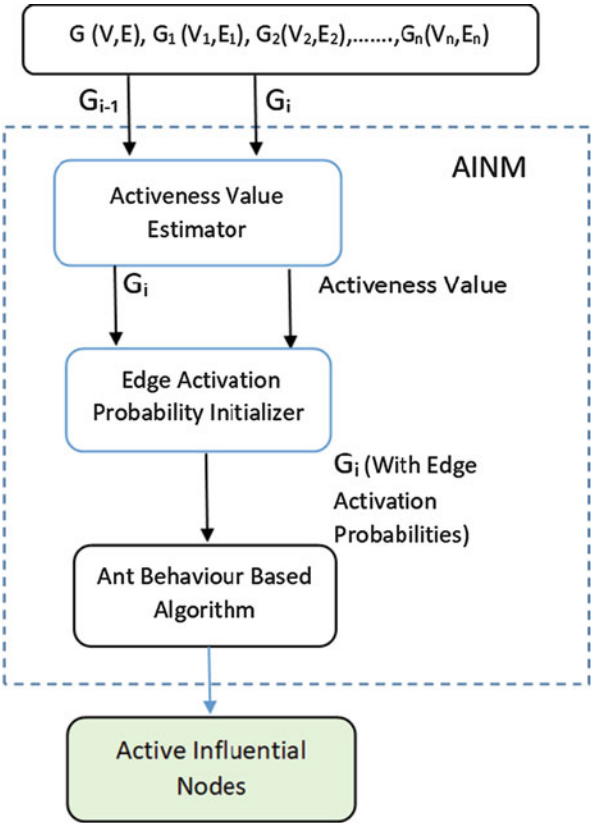

Fig. 15.1 Basic flow model of AINM

For every node x in the Graph G_i an activeness value A is obtained. The activeness value A of a node x ranges from 0 to $n - 1$ where n is number of nodes in the Graph G_i. According to the algorithm the obtained activeness value is always a whole number.

15.3.2 Edge Activation Probability Initializer

The Activeness value does not guarantee that the node is active, partially active or somewhat inactive. The Edge Activation Probability Initializer takes Graph G_i and activeness value as input. It assigns an activation probability ($w_{u,v}$) between node u and node v based on activeness values of both the nodes.

– If $(activeness[u] \vee activeness[v]) \leq 1$, then
  $w_{u,v}$=0.01, because it has a very low chance to propagate information to its neighbors.

– If $(activeness[u] \wedge activeness[v]) > 1$, then

$$w_{u,v} = \left(1 - \frac{1}{activeness[u]}\right) * \left(1 - \frac{1}{activeness[v]}\right) - \epsilon \quad (15.1)$$

where ϵ is an adjustment factor ranging from 0.20 to 0.23. We are de-escalating activation probability by subtracting ϵ because higher activation probabilities must be obtained only if both the nodes u and v are highly active.

This probability is incorporated to every edge in the Graph G_i. As the activeness value of a node is always a whole number; therefore, the minimum activation probability $(w_{u,v})$ obtained by Eq. (15.1) is when both nodes u and v have activeness value 2. The calculation is as follows: assuming $\epsilon = 0.23$, $(w_{u,v}) = (1 - \frac{1}{2}) * (1 - \frac{1}{2}) - 0.23 = 0.02$. Therefore, the minimum activation probability calculated in the second condition is greater than the activation probability assigned in the first condition.

15.3.3 Ant Behavior Based Algorithm

Ant Behavior based Algorithm [11] is based on stigmergy approach which is not a full ant colony optimization algorithm but a tweaked one for finding influence value of nodes in a network. The input to the algorithm is graph G_i with edge activation probabilities $w_{u,v}$.

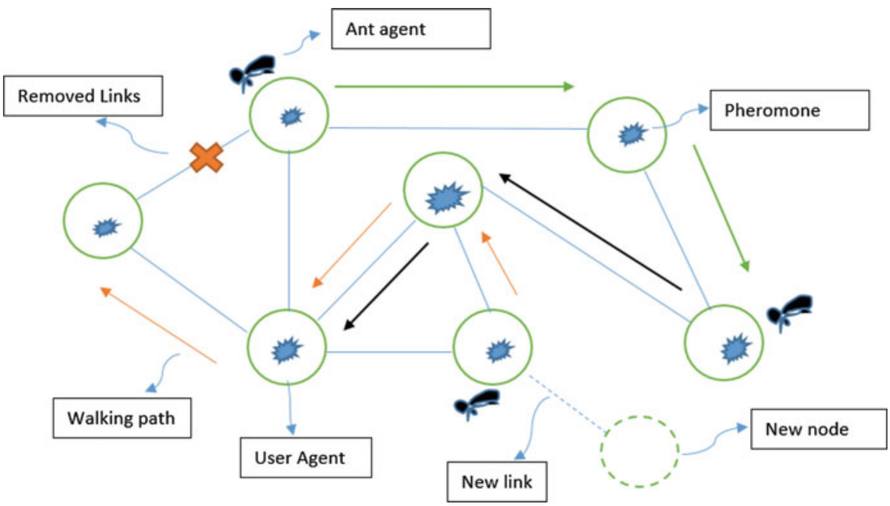

Fig. 15.2 Basic idea of ant behavior based algorithm

The basic idea of Ant Behavior based Algorithm is represented in Fig 15.2. The ant agent starts its tour from a random node v_s. The next node v_i to visit is selected from the list of neighbors of v_s based on pheromone value p_i of the node and edge activation probability $w_{s,i}$. Thus the ant agent visits the more previously influenced and recently active node. An ant agent can visit a node at the most once in its entire tour whereas A node visited by i_{th} ant agent can be visited by other ant agents. The ant agent deposits pheromone to every visited node. The amount of pheromone deposited on v_i depends upon the number of nodes the node(v_i) can directly influence. The tour of an ant agent stops when it has no further node to visit. After the completion of tours by all the ant agents, the list of nodes is sorted in decreasing order according to pheromone value. Top k nodes are selected as active influential nodes. The pheromone once deposited by Ant Behavior based Algorithm fades away with time. This is a global phenomenon affecting the entire network.

15.4 Experimental Results and Discussion

Facebook dataset archived in The Max Planck social computing research [12] is used to conduct experiment. Using the activities of a node specified in the dataset we developed graphs at an interval of every 3 months as shown in Table 15.1.

Using the algorithm defined in Sect. 15.3.1 we found the activeness value of each node. Then according to conditions defined in Sect. 15.3.2 edge activation probabilities are assigned to all the edges in the graph. Finally, we applied the ant behavior based algorithm [11] mentioned in Sect. 15.3.3 and obtained the pheromone value of each node. We arranged the nodes according to pheromone value. Table 15.2 shows ranks, node id, and its pheromone value for the top 10 nodes in the various snapshot of the graph.

For example, in Table 15.2, if we consider node 3703, it was an active influential node in all the snapshot of graphs but eventually in 22nd month snapshot it lost its position in top 10 active influential nodes. Hence when the network evolves the competition to obtain the rank becomes tough and both activeness and topological structure must be maintained to retain the position in the set of active influential nodes. Further, we observe that as the network evolves the pheromone deposition increases due to an increase in the relationship among the nodes.

For our experimentation, we test AINM with the following algorithms:

Random Walk A walker starts its tour from a source node and completes the tour at destination node depositing a unit point at each visited node. The selection of the node to be visited next is selected from the set of neighbors of the node uniformly at random.

Page Rank A node is deemed more important by the number of external nodes that links to it; similarly, a node is less important and, therefore, has a lower rank if less external nodes link to it.

Table 15.1 Number of nodes at different time intervals

Time interval	1st month	4th month	7th month	10th month	13th month	16th month	19th month	22nd month
Number of nodes	3672	9101	12,360	15,632	20,090	25,301	30,994	37,769

Table 15.2 Top 10 active influential nodes and its pheromone value

Node Id/pheromone value										
	RANKS									
Network snapshots	1	2	3	4	5	6	7	8	9	10
4th month	3703/6.21	7540/5.94	24,066/5.49	12,316/5.31	12,972/4.94	10,219/4.68	3725/4.59	22,613/4.23	9040/4.14	8695/4.05
7th month	24,066/9.60	10,219/9.00	3703/8.90	133/8.20	3725/8.20	12,316/8.10	8695/8.00	9660/7.90	2332/7.69	8850/7.59
10th month	8695/13.30	24,066/12.60	133/12.60	3703/11.99	10,219/11.10	2332/10.90	9660/10.70	12,316/10.50	8850/10.39	3579/10.29
13th month	8695/18.29	133/16.40	8850/13.80	24,066/13.70	3703/13.70	3943/13.40	3579/13.30	10,219/13.20	4374/13.00	2332/12.30
16th month	8695/22.10	133/20.59	2332/19.49	3703/15.10	8850/15.00	3579/14.80	10,219/14.60	24,066/14.60	12,316/14.00	9660/14.00
19th month	2332/26.70	133/23.29	8695/22.80	23/19.60	3703/16.09	8850/15.90	12,316/15.90	9660/15.60	10,219/15.50	5888/15.39
22th month	2332/36.59	23/31.09	133/30.00	8695/26.00	5888/24.40	1944/21.90	4374/20.50	451/19.60	3725/19.40	9660/19.30

Table 15.3 Information diffusion coverage using ICM

Network snapshots	Random walk	Degree-based	Page rank	AINM
4th month	5460	5443	5491	2348
7th month	8673	8787	8800	3745
10th month	11,741	11,852	11,726	4983
13th month	15,520	15,524	15,570	7066
16th month	19,359	19,309	19,223	7874
19th month	23,450	23,324	23,386	8719
22nd month	29,079	29,097	29,072	14316

Degree-Based How much connected an individual node belongs to the network is calculated by utilizing the number of immediate connections of that node.

The evaluation criteria for tests are ***Information Diffusion Coverage***. This refers to the number of nodes that shall accept an idea or the product propagated by the selected influential nodes. This is calculated using the Independent Cascade Model (ICM).

Independent Cascade Model (ICM) An idea or the product is accepted by the user at every cascade with activation probability $w_{u,v}$ each time one of the immediate connections accepts an idea or the product.

According to Uniform Activation all the edges in the graph are assigned with common activation probability. The node may not-spread/spread the information else it may be inactive/active regardless the activation probability allocated to all the edges is 0.5.

The comparison results are depicted in Table 15.3. It consists of the number of nodes that shall accept or idea or the product when the initial spread of information starts with the influential nodes are found using Random walk, Degree-based, Page Rank, and AINM.

The results obtained using Random walk, Page Rank, Degree-based indicates over-estimation of Information diffusion because they don't consider the node is active or not, it considers all nodes can propagate the information further, therefore the results obtained are non-realistic. Whereas results after applying AINM on a real-world network show significant and substantial information diffusion. Because the propagation of information from that node is based on the activeness of that node.

15.5 Conclusion and Future Work

Mining of influential nodes is of utmost importance to efficiently market the product or an idea through the social network. However, the models to identify influential users do not consider the behavior of the node. This issue is solved using the proposed Active Influential Node Miner which infers the node's activeness value derived from its topological behavior in a specific period. Thereby, finding locally active as well as influential nodes. The generated results using AINM through cloud computing tends towards the reality of the social network. Therefore, a meaningful information diffusion is obtained using AINM which is not the case when other algorithms are used. The way forward is to find the certainty estimation of the inferred activeness of the node.

References

1. J. Guo, P. Zhang, C. Zhou, Y. Cao, L. Guo, Item-based top-k influential user discovery in social networks, in *2013 IEEE 13th International Conference on Data Mining Workshops* (IEEE, Dallas, TX, 2013)
2. D. Kempe, J. Kleinberg, E. Tardos, Maximizing the spread of influence through a social network, in *Proceeding of the ACM International Conference on Knowledge Discovery and Data Mining* (ACM, New York, NY, 2003)
3. L. Kao, Y. Huang, Mining influential users in social network, in *2015 IEEE International Conference on Systems, Man, and Cybernetics* (IEEE, Kowloon, 2015), pp. 1209–1214
4. S. Singh, N. Mishra, S. Sharma, Survey of various techniques for determining influential users in social networks, in *2013 IEEE International Conference on Emerging Trends in Computing, Communication and Nanotechnology (ICECCN)* (IEEE, Tirunelveli, 2013), pp. 398–403
5. A. Farooq, G. Joyia, M. Uzair, U. Akram, Detection of influential nodes using social networks analysis based on network metrics, in *2018 International Conference on Computing, Mathematics and Engineering Technologies (iCoMET)* (IEEE, Sukkur, 2018), pp. 1–6
6. K. Almgren, J. Lee, A hybrid framework to predict influential users on social networks, in *2015 Tenth International Conference on Digital Information Management (ICDIM)* (IEEE, Jeju, 2015), pp. 103–108
7. Y. Zhao, S. Li, F. Jin, Identification of influential nodes in social networks with community structure based on label propagation. Neurocomputing **210**, 34–44 (2016)
8. L. Kao, Y. Huang, F. Sandnes, Mining time-dependent influential users in Facebook fans group, in *2016 IEEE International Conference on Systems, Man, and Cybernetics (SMC)* (IEEE, Budapest, 2016), pp. 718–723
9. H. Zhuang, Y. Sun, J. Tang, J. Zhang, X. Sun, Influence maximization in dynamic social networks, in *2013 IEEE 13th International Conference on Data Mining* (IEEE, Dallas, TX, 2013), pp. 1313–1318
10. G. Song, Y. Li, X. Chen, X. He, J. Tang, Influential node tracking on dynamic social network: an interchange greedy approach. IEEE Trans. Knowl. Data Eng. **29**(2), 359–372 (2017)
11. W. Li, Q. Bai, M. Zhang, SIMiner: a stigmergy-based model for mining influential nodes in dynamic social networks. IEEE Trans. Big Data **5**(2), 223–237 (2018)
12. Social Computing Research Homepage. http://socialnetworks.mpi-sws.org. Last accessed 13 April 2019

Part IV
Security and Privacy

Chapter 16
Enhancing Security in IoT Instruments Using Artificial Intelligence

N. Ambika

16.1 Introduction

IoT [1, 2] is an enormous assembly of instruments comprising detector [3] or mechanism related together over wired or on the other hand remote systems. IoT has been rapidly turning out to be over the earlier decade. During the turn of events, security has been perceived as perhaps the most vulnerable locale in IoT. IoT instruments are isolated into deuce basic social occasions: border instrumentation and entrance instrumentation. A border instrumentation is a reduced-control, reduced-assets instrument incorporate sensing element just as actuators. The border instrumentation normally aims in accomplishing some tasks, for instance, gathering weather collection and itemizing it to an entry. Entryway gadgets typically have more resources that appeared differently concerning border instruments. An entryway instrumentation is accountable to pair the border instruments to the cyberspace and conglomerating collection from border instruments. With the wide measure of instruments, the proportion of collection of developments among the instruments, and the impact these instruments will have on our ordinary routine presence, precaution [4] is a need.

IoT sensors will permit the assortment of an enormous measure of information, while AI can help determine insight for formulating more astute applications for a more intelligent world. IoT-AI upgrades problematic advancements in wearable and implantable biomedical gadgets for medical services checking, keen reconnaissance and observing applications, for example, the utilization of a self-governing robot for fiasco the board and salvage activities. It impacts all businesses going from assembling, retail, medical care, media transmission, transportation, and so forth.

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The work [5] uses artificial intelligence embedded in the instrument assist for the safety of the structure. Computer-based intelligence is a geographic area of imitative cognition in which PC program is engaged to pick up, in actuality, frameworks and correspondents. As learning occurs, the capacities inside the program become continuously sharp, and the program ends up fit for settling on taught decisions. Deuce of the most acclaimed strategies are artificial neural frameworks (ANNs) and inherited computations. They imitate the somatic cell and synapses inside the psyche to trade collection for agreement, realizing, besides, essential leadership. They are in use inside IoT arrangement to screen the domain of IoT instruments and to settle on instructed conclusions. The authors have suggested the use of ANN to get acquainted with the sound state of a system and related contraptions.

The contribution generates hash code for the vectors of the sample. The spotting has varying shapes and sizes; the vector is subdivided into three subsets. The system, after analyzing sample with regard to its characteristics like length and area, generates a hash code to them. Three parameters used include area, thickness, and length. Hence security is increased using the proposal by 4.17%. It increases reliability by 9.5%. The background is explained in Sect. 16.2. Literature survey is detailed in Sect. 16.3. The proposed work is described in Sect. 16.4. The fifth section examines the activity. The work is concluded in Sect 16.6.

16.2 Background

Fingerprints [6] are impressions left on surfaces by the grating borders on the finger of a human. The three essential illustrations of specific impression borders are the curvature, round, and curlicue:

- Curve: The boundary enters from one side of the finger, ascends in the inside framing a bend, and afterward leaves the opposite side of the finger.
- Clique: The borders come in from unit part of a finger, structure a twist, and later outlet on the equivalent side.
- Curl: Elevation structure round about a primary content on the finger.

Highlights of unique finger impression borders, called details, include as follows:

- Border finishing is the sudden finish of a border.
- Bifurcation is a solitary border partitioning in two.
- Short or autonomous border is a border that starts, ventures a little separation, and afterward closes.
- Island or speck is a lonely small border interior a short border or border completion that isn't associated with all other borders.
- Border fenced-in domain is a solitary border. It fornicates and unifies in the blink of an eye a short time later to proceed as remote border.
- Spike is a bifurcation with a short border fanning out a more extended border.

- Extension or hybrid is a short border that runs between two equal borders.
- Delta is a Y-formed border.
- Center is a hover in the border design.

16.3 Literature Survey

The proposal [7] utilizes the depletion strategy. The creators think about the measure of plausibility of weariness technique. The method can send the neural systems to multiple layered IoT designs without knowing the subtleties inside the system. This issue is putting n layers of the neural structure into m various gadgets and permitting void gadgets. The instruments are in a fixed request. The m squares of the systems are taken care of in m gadgets. It intends to embed m − 1 sheet in the n − 1 hole between n organize layers. At the point when given the layers number n and the gadgets number m, the measure of probability is found. The plan is a calculation to make the ideal system utilizing dynamic programming with the rule of limiting framework reaction time.

The proposed engineering [8] fall into four categories. It contains cloud knowledge, mist knowledge, border insight, and gadget insight. The instrument perception shows the procedure to join chain and intelligence to accomplish the objective of enormous information examination, precaution, and integration problems of the utilization, for example, savvy medicinal services, a keen city, and brilliant transportation. The gadget insight comprises of different IoT gadgets with intelligence and chain utilization. It creates an enormous measure of information, which moves to the border knowledge. Along these lines, the border insight comprises of AI-empowered base stations associated with the technology at the border of the system. The AI-empowered instrument (at the perimeter) associates with detecting gadgets. It dissects the traffic information from the instrument. The procedure information from border knowledge accounts for the mist insight, which is a blend of a few AI-empowered mist hubs with chain technology. Every artificial intelligence-empowered mist hub with chain is related with the making out of AI-empowered sink nodes at the border insight and mindful for handling information to the storage knowledge. At long last, cloud insight comprises AI-empowered server farms that are associated with the chain to give localized and assured enormous information of IoT applications, for example, smart social insurance, keen transportation, etc. Besides, every server farm announces the yields of its information preparation to the cloud insight for controlling a lot of information investigation to settle low precision, inertness, and protection issues for IoT.

The chain incorporated into IoRT [9] permits imitation-based border and storage insight answers for mechanical belongings, utilizing assured degraded inactivity correspondence innovation. It authorizes to prepare a machine to AI individually as well as prepare numerous automated instruments by holding a border and storage knowledge that modify progressively in the discipline the mechanical things with as good as ever aptitudes. The all-encompassing abilities can utilize computer-generated reality and increased reality for secure preparation. The base information assortment layer incorporates any sensor or equipment associated with the cyberspace accepting and transmitting the information. It implements in gadgets, cell language unit, modulations, independent conveyances, 3D peripherals, increased and augmented reality receivers, and associated national apparatuses. The information is taken care of into the information board level, along the job to deal with the collection gathered. It has various segments of a decentralized design. The particular items move in and out, utilizing a record framework and capacity segment, a preparing and collection base segment, and a recorded segment. These segments are a piece of individual stage or first-of-breed for all. The information computerization layer utilizes the information to robotize commercial activity. The motorization will originate from brilliant agreements using other information legitimately from the record or savvy contracts utilizing prophet's collection from outside of the framework. Counterfeit thin insight coordinates into the shrewd accord. The advanced level is the hierarchical construction that coordinates the action in the underneath levels. The entire stack administers by a decentralized self-sufficient association constrained by human onscreen characters. The whole doings can be overseen by an AI DAO, which might establish a counterfeit general knowledge.

The work [10] uses cautious alignment by the three primary elements of culture, digestion, and governance. The model guarantees cultural saving by empowering the quest for innovative information. A remarkable component in the proposed structure is that it doesn't provide food for innovation as its measurement. The creators suggest that invention is to be a preliminary center of astute metropolis where large collection can develop using IoT in different areas. Imitation ability is a hidden element which can summon, break down, and decipher the produced information. It guarantees that the consideration of large collection and imitation ability is equipping toward hominy livability.

In the proposed snarl-up framework for the acute metropolis [11], objects on the environments, for example, trade signs, electric posts, trade flags, etc., are outfitted with the appliance assemblage trade-related collection for quantities of vehicles leaving through that environment, the measurement of trade clogs, typical velocity, abnormality in the haste time period snarl-up illustration and being of the emergency conveyance, flame machine, or any other jurisprudence-requirement conveyance. These collections are then investigated and used for fetching conniving selection using imitative ability that clutches the computing. When a blockage is detected, the framework makes utilized computation to recourse the vehicles in a fair manner to take the traffic back to ordinary. The IoT gadgets communicate with our frame using different remote correspondence frameworks with help of Wi-Fi. Because of the ebb and flow traffic clog situation, the calculation computes the best elective course and trains the drivers likewise to clear the blockages.

The proposal is a wise exemplary control approach [12] for the payment of variable assaults on non-one-dimensional CPSs. It is the nonlinear CPS that encounters digital assaults in forwarding connection. The planned control framework incorporates a nonlinear controller dependent on the uncertain construction strategy and a Gaussian radial footing intent somatic cell system as an acute calculator for assault impact approximation. The power strategy is a powerful command method. It includes deuce primary track that is choosing a suitable exchanging surface and building up a hearty control input. The reckoned does the online approximation of potential assaults and the versatile neural VS controller that intends to reimburse the impacts of those assaults on the concrete framework and to master the presentation for guidelines and the following points. The adjustment jurisprudence for the keen reckoned uses a Lyapunov dependability investigation. Hence, the frame is asymptotically steady using this hypothesis.

The proposed model [13] comprises information pre-production and examination and includes choice, use of characterization, and grouping calculation dependent on AI. The approval measure is to execute for each progression to check the adequacy of the projected money-related misrepresentation location model. In the handling process, there are information connection investigation and information cleaning process that cleans the clamor collection performance. Additionally, the system keeps the collection information change decreased. The accompanying procedure is the examining procedure that assesses collection set with different proportions for confirmation through irregular oversampling and under the testing strategy. The highlight determination process has a performance by the channel-based technique. After the element determination process, the grouping procedure with the planned calculation performs, and this outcome employs as a preparation set in the order procedure. The administered computation to the past consequence infers in the grouping procedure beforehand accomplishing the higher expectation. The model approval process performs with accuracy and review rate through F-measure. The examination produces different collection sets utilizing the man-made nonage sample distribution method and ergo under inspecting.

The proposal [14] builds up a fire dynamic departure way illuminating the model by using the brainpower innovation. As per a designing case of a shopping center, a matrix domain model and the best departure course arrangement examine three distinct phases of fire with improved insect settlement calculation. The fire advancement process partitions into three phases containing beginning, development, and spread-stage phases. The medium path range describes the mediocre measure of all ants' routes, while the lowest track distance denotes the magnitude of the lowest trail. The results obtained may approve the choice made. It can help virtual penetration and crisis salvage of urban calamity rapidly and productively. It provides a valuable reference to improve the calamity of the executive's arrangement of open instances and hazardous arrange of serious debacles in China.

To create a savvy ecological house while keeping up low costs, the authors propose a GUI-based test system [15]. It permits composed fashioners to structure a house utilizing a UI. For simple control, the fashioner organizes house segments, and sensors use a mouse, virtual sensors like genuine sensors when identifying reproduction collection. The sensor initiates an unusual admonition message accounting to the eyewitness. In the framework, they apply rare hues to the location territories of the animated sensors. Likewise, we make a self-ruling operator furnished with reasoning to acknowledge the programmed situation age. Like people, these consciousness specialist plans are conducted dependent on natural inspiration. The work applies an inspiration-driven conduct arranging framework. The virtual condition editorial manager includes the shrewd house module and reenactment condition parts. The test system furnishes fashioners with various fundamental gadget models, including house parts, furniture, and sensors. Reenactment condition parts record collection from the house during the reproduction, for example, spatial and sensor collection. The self-ruling operator generator consequently produces a recreation situation dependent on the character inspiration and collection gathered by the various sensors. Situation age is actualized utilizing a reenactment center. The test system has two kinds of yields. Savvy house stockpiling incorporates spatial collection concerning the dividers, entryways, windows, and furniture, alongside different sensor spatial collections. The client can spare a keen house record from the structured model and burden it into a 3D state. The detected collection is a document that records the activity of different sensors, including actuation states, values, and the activity time estimated during specialist collaboration.

The contribution [16] is a brilliant unstaffed retail shop conspire dependent on fake insight and the web of belongings, targeting investigating the attainability of actualizing the unstaffed selling purchasing mode. It is embraced to automatically distinguish the area of the items. It has four levels: the foremost-end level, the foundation performance level, the host and assistance level, and the collection base layer. The front end accommodates video equipment, insightful unnerved retail holder, and IoT controller, which straightforwardly cooperates with purchasers, acquires, and move information. Cameras predominantly incorporate observation made by the video equipment, surface acknowledgment camera, and the fisheye camera. They actualize various capacities. The shrewd retail compartments stores and retail merchandise let customers pick products. They interconnect with host using the IoT power component part. It request and executes the executives. It installs and administers. Outsider assistance associates with this level. The server and administration layer comprised of the calculation servo-system middleware and the Apache server. The Apache server attempts the fundamental HTTP administration. The collection base layer consists of MySQL collection base and document stockpiling administrations, used to store essential information, picture records, and the computations, for example, facial recognition, SKU amount measurements, and item acknowledgment.

A progressive fundamental impulsive and accessible conceptualization [17] expands the artillery lifespan and spares the force in intelligence-based border processing stages for mechanical usage. Likewise, the transmission power control and obligation series substances of the IoT-supported convenient gadgets are enhanced by appropriately following vital impartial activity during detecting, handling, and transmitting mechanical information. It is a quality framework for the intelligencebased modern applications over crossed transmission, power control and obligation organize. In these systems, acceptable sign capability indication and packet loss ratio are the primary execution markers for analyzing the whole framework. Both levels are taken at the physical level, while the obligation cycle is at the MAC layer. TPC varies in the remote channel. It impacts a great deal on the RSSI plane, PLR, and the unwavering quality.

The SDN comptroller, whose capacity is to guarantee the top-grade QoS, is the focal hub in the system. It can settle on choices to interconnect the diverse IoT systems. The two systems [18] join the communication system chief to each IoT organization. It is an uncommon hub that deals with the IoT arrangement correspondence and sends the information through the SDN organizes. Besides, it utilizes the OpenFlow modular to speak with the comptroller and direct its measurements about the utilization of the system. The calculation of the system the board is more straightforward than the one utilized by the intelligence ability. The controller instates the AI module. Its fundamental errand is to use the modular OpenFlow content to accumulate measurements. The calculation organizes the executives and utilizes the AI module to distinguish primary traffic streams sent through the system. AI module identifies mixed media traffic. It appraises the assets required and the best activity to act to give a worthy degree of QoE. Contingent on the assets is expected to provide QoE in the transmission.

Telegram messenger [19] has numerous applications created through its API by using a BOT message. The ESP8266 is modified to be associated with a passageway in the workspace condition. Testing is finished by the client sending messages to the wire bot utilizing a cell phone. The client sends the order/message accurately and erroneously. At any point in time, the system ensures to avail workspace and the notice to the client.

The proposal [20] comprises two primary parts. The division is the information lifecycle inside the SSA engineering and information process area. The procurement and catching of information embrace at the layer containing sensors and actuators. The information passes through the application layer for business rationale and control. The collection for security issues examination is followed by information investigation and handling. It trails by information grouping, and changes the necessary ones. It handles information before it moves to information understanding and subsequent structure choices. The last stage is to store the information for future recovery.

Advanced metering infrastructures (AMI) [21] are frameworks that measure, gather, and examine utilities dissemination and utilization and speak with metering gadgets either on a timetable or on-demand. A savvy metering framework permits the water, electric, and gas utilities a constant perusing and recording in time stretch or, at any rate, every day detailing, checking, and charging. Shrewd meters empower both correspondences between the meter and the utility focal framework. It permits accumulation of stretch information, time-sensitive information, collapses the board, administration interference, administration reclamation, nature of administration checking, appropriation organize investigation, conveyance arranging, top interest, request decrease, client charging, and work of the executives. It permits request reaction of the executives, empowering clients to settle on educated choices and utilization forecast. AMI frameworks incorporate sensors, equipment, programming, correspondences, utilization presentations and controllers, client frameworks, information mining programming, meter information on the board programming, and business frameworks. They give two-way interchanges of the meter: permitting sending orders from the usefulness to the brilliant measuring instrument for various intentions and permitting screening continuous qualities and change of the recurrence of readings amidst others. The system between the meters and the utility community permits assortment and conveyance of collection to clients, providers, service organizations, and specialist organizations.

The plan is a savvy farming IoT framework of four layers [22] containing the rural information assortment layer, border processing layer, information transmission layer, and distributed computing layer. As a critical segment, profound fortification learning is conveyed in the cloud layer for settling on quick shrewd choices. The creators present a few agents like DRL models that have the potential to be utilized in building savvy horticulture frameworks. This work is relied upon to advance the improvement of smart farming and add to expanding food creation.

The proposal is a discard mixture model [23] supported to consume existing messages in the desert container. The message obtained through sensing element is sent over the cyberspace to a server for capable and ready components. It checks the everyday choice of waste receptacles, in light of which it courses to pick a few of the waste receptacles from various areas. Consistently, the workman gets the reinvigorated flowing route in their guidance appliance. It intends to update from its experience. It chooses to squander level status and foresee approaching province-related elements like traffic clog in a geographical area. It tends to anticipate earlier the deluge of waste occurring in the squander receptacles arranged in a particular field. Dependant on financial necessities determined at opening stage, the enhanced determination of barren receptacles to be collected is required to improve assortment proficiency.

IoT arrangement [24] has a functional use in a solanaceous vegetable nursery in Michurinsk. A definitive objective of the framework is to make sure about the nursery computerization and offer help to the workforce as the all-out region of the organization. Regarding creation, the objective is to screen and control the development pace of green groceries, which is fundamental for arranging and coordinating intent. Fortify getting the hang of having an operator with potentially zero information about the structure the person can prepare to perform ideal activities given the circumstance. Each venture is compensating for some worth. The operator learns the conduct by preliminary ones. This measure gives a increase in growth. For plant development, beneficial prizes are acknowledged for acceptable development revenue enhancement and last harvest production, while antagonistic premium is for the assets utilization.

The proposed approach [25] is the preparation period of the IoT framework and a period of typical use. The client can conclude either to prepare the IoT framework to be appropriately tweaked or to utilize some pre-stacked information from a collection base. The introduced human-centric intelligence approach proposes to use the model for preparing the IoT framework with back-propagation, which is a typical acquisition calculation for this sort of NN. For the preparation, the collection sources are the detected collection from the detector of the framework, and the yields for these information sources ought to be doled out by a hominy dependent on a known truth. The outcome can be either mark in grouping issues or numeral qualities in relapse issues. IoT frameworks undergo identification with the estimation of the client's states. After MODEL preparation, the scholarly model can appraise the yield, for example, the client's government for recent IoT sensing element stimulation. The educated framework is part of the information loads of every somatic cell. The output is gotten by ascertaining every somatic cell's yield from the weighted sources of info and applying a sigmoid capacity, every somatic cell layer after the previous one beginning from the MODEL contribution until the MODEL gives a yield. The initial two proposed HAI methods break down the MODEL learned for clarifying its most significant highlights, directly after the preparation stage. These methods depend on the investigation of loads of counterfeit somatic cell inputs. The tertiary projected HAI strategy clarifies the MODEL approximation for each information case dependent on the examination of preparing event.

It is a novel unique finger impression assault recognition [26]. It is dependent on another catch gadget ready to get pictures inside the shortwave infrared (SWIR) range and a top to bottom investigation of a few conditions of the art procedures dependent on both high-quality and profound learning highlights. The methodology is assessed on a collection base including more than 4700 examples, coming from 562 distinct subjects and 35 various introduction assault device kind. The finger SWIR catch gadget is inside the BATL venture in participation with our task accomplices. The camera and focal point set inside a shut box remember an open space for the top, around 30 cm aside from the photographic equipment. The encompassing light is blocked, and the ideal frequencies are considered. The outcomes show the adequacy of the projected conceptualization with a discovery equivalent mistake pace as low as 1.35%.

The work [27] presents an examination of the security quality of step biometric, especially its power against mirroring or imitating attacks. The MEMS gadget used to gather stride information takes after a memory stick gadget. It has the following principal highlights: stockpiling limit (64–256 + MB), SB, and remote Bluetooth interfaces for information movement and three speeding-up sensors. It records quickening at the pace of around 100 examples for each second. The yield of gadget quickening signaling in trio structure includes perpendicular X, in reverse for Y, and sidewise Z. Rather than investigating the crude increase in speed flags (important to gadget's position and direction), the creator's blend them resulting in the signal.

It is a multiple-passage Whirl neuronal system-based methodology [28] for introduction assault identification (PAD). They demonstrate that the freshly broad multiple passage introduction operation collection base for face PAD incorporates a broad mixture of 2D and 3D debut conflict for playing and muddle attack. It utilizes a face acknowledgment sub-network, to be specific Light CNN, devising the system reclaimable for PAD and look acknowledgment. The origin coding system prepares the model for accessible permitting to replicate the findings. Once the container is acquired, discovery acts in the identified bouncing box utilizing the supervised descent method (SDM). The arrangement practices changes pictures, with the end goal where the optic communities and oral cavity focus are adjusted to predefined facilitates. The regulated face pictures are changed over to grayscale and re-sized to 128 × 128 pixels. Collection from assorted transmission, for instance, tint conclusiveness and close infrared, is accessible to propel the exploration in look PAD. The processing phase for non-RGB transmission needs the pictures from assorted transmission to be adjusted both spatially and transiently with the shading channel. For these transmissions, the surface milestones recognized in the shading channel are reused in a comparable arrangement method. A standardization utilizing mean absolute deviation (MAD) changes over the scope of non-RGB facial pictures to an eight-piece format. The proposed strategy is a recovery scheme to execute an ACER of 0.3% on the bestowed collection.

The sigma-lognormal model [29] synthesizes the new online signature to acquire an improved impersonation. The improved fabrications deliver by supplanting their speed profile with others, more like a certified mark. It fits a whole of log normal to the direction and re-sampling with the new manufactured speed profile. The tests plan to refute that the credence magnitude relation declines with the biologically assured SONOFF open online mark collection base. In deuce stages, the initial adds the direction at 200 Hz utilizing cuboid strip. The subsequent uses a devalued running channel. They use the FIR channel with edged recurrence at 16 Hz. This smoothing likewise makes a difference to preserve an important spacing from a bogus point.

The proposition is of a factual assault against the fuzzy commitment scheme (FCS) [30]. The regular use of biometric FCSs successively substitutes pieces of picked cryptographic keys by relating blunder rectification code word. The subsequent groupings of code word are then bound to biometric formats to produce duties. The binomial appropriations of different scores yield higher fluctuation inside twofold pieces of biometric layouts. The framework is fruitful remedy unraveling with increments for impostor endeavors. As a result, measurable assaulting of FCSs gets practical if biometric includes vectors that don't display enough entropy. The proposed assault applies to various iris-biometric FCSs. By leading insights about decoded code word, little arrangements of impostor formats accomplish fruitful key recovery uncovering submitted layouts.

[31] is an original procedure that depends on photographic equipment-based biological science estimations to identify and upset such biometric introduction assaults. It utilizes a photoplethysmogram (PPG). It is a gauge of essential gestural with little shading alteration in the visual communication seen. It is insignificant pulsatile varieties in the measure of bloodline streaming to the face. They show that the worldly recurrence spectra of the assessed PPG signaling for genuine unrecorded people are particularly unique concerning those of introduction assaults and endeavor of these distinctions to distinguish introduction assaults. To extricate the PPG signals from the visual communication of a surface skin district, they changed over the RGB video to the green channel. They chose two 50 × 50 pixels areas out of sight, one to one side of the face and one to the other side. They take away the average and band-pass channel the PPG flags in [0.5 Hz, 5 Hz] extend, which relates to the physiological scope of PPG signaling. The greatness

of the Fourier range of each separated PPG communication turns into otherworldly components.

The work is a wolf assault likelihood [32] of the wolf assault with one wolf test. It is the upper bound of the achievement likelihood of assaults completed without information on a casualty's biometric test. Subsequently, it is in use as a safety effort to assess the decrease limit of a safety layer in a single biometric validation framework. A finger venous blood vessel design is a picture of 240 × 180 pixels. It is removed from an infrared picture of the finger. In producing an info incentive to the coordinating calculation from the picture, spatial decrease and description of picture elements are performed. The picture partitions into 4, 800 windows of 3 × 3 pixels, and a mean of the grayscale of every window is determined. The grayscale of every picture element in the decreased picture is allowed with the average.

Eye development chronicles are gathered from two disjoint subject pools [33]. The high-goal eye global positioning framework looks like the best in class in the current eye following innovation. The low-goal eye frame applies video oculography procedures and takes after equipment found in iris acknowledgment gadgets. The gathered eye development collection is accessible as aspects of the EMDB collection. The high-goal accounts lead (regarding a pool of 32 members) with historic periods running from 18–40. Twenty-nine of the subjects execute 4 accounts each, and 3 of them performed 2 chronicles each, producing an aggregate of 122 one of a kind eye development accounts. Low-goal directs (regarding a pool of 173 members) with ages extending from 18 to 49. One hundred and seventy of the subjects performed 2 accounts each, and 3 of them execute 1 chronicle each, producing a sum of 343 remarkable eye development accounts. Note that the last six members, every one of which performed two accounts, were prohibited from the complex caricaturing approach because of planning troubles.

The work [34] is a test study to assess the power of such frameworks against a voice transformation mask. They utilize the Gaussian blend framework-based SID frameworks, GMM with a general foundation exemplary-based SV frameworks, and GMM super vector with help vector device-based SV frameworks for this. The whole procedure isolates into deuce components: the preparation and the testing component. During the preparation procedure, the change work that represents the sound qualities of the host to the objective verbalize is found out from the put-away taped expressions of the two verbalizes in the collection. In the testing procedure, the picked-up planning capacity utilizes to change the info source verbalize discourse. Voice transformation directs by using three unique strategies: GMM-based VC strategy, weighted recurrence twisting (WFW)-based change technique, and its variety, where vitality remedy is incapacitated (WFW−). Assessment finishes by utilizing intra-sexual orientation and cross-sex voice changes between 50 male and 50 female verbalizes taken from the TIMIT collection. The outcome shows by debasement in the level of distinguishing proof (POC) score in SID frameworks and corruption in equivalent mistake rate (EER) in all SV frameworks. Exploratory outcomes show that the frameworks are against vocalization change caricaturing assaults than frameworks, and all SID and SV frameworks are generally defenseless toward GMM-based transformation than WFW and WFW− based transform. This work stretched out the investigation to discover the connection between VC target score and SV framework execution in CMU ARCTIC collection equals corpus. The aftereffects of this investigation show a methodology on measuring the target score of voice change identified with the capacity to mimic an SV framework.

Non-reference picture quality measures separate legitimate biometric information from information as utilized in introduction/sensor ridiculing assaults. A test study [35] shows that dependent on a lot of six such measures, the order of genuine versus counterfeit iris, unique mark, and face information is plausible with a precision of 90% by and large. The ATVS-Flr collection comprises of phony and genuine iris tests of according to 50 subjects and supplements the authentic information of the biologically secure collection. Tetrad examples of every iris are in two securing meetings with the LG Iris Approach EOU3000. In this manner, the collection holds 800 authentic picture tests (100 irises × 4 examples × 2 meetings). The phony is with the LG Iris Access EOU3000 from top-notch written pictures of the first example. As the artifact is equivalent to for the genuine copies, the collection contains 800 phony picture tests.

In the new mixed replacement [36], the client and assailant's information consolidates in remote layout. On the off chance, they mix utilizing mystery. A diversified format permits either the client or the aggressor to confirm against a similar record. In the conventional replacement case, the assailant can confirm all the while producing a forswearing of administration to the first client, which expands the opportunity of discovery. In the new mixed replacement, the aggressor can utilize the records at the same time with the client. They have presented three new classes of assaults against biometric vaults and biometric encryption (BE): record variety (ARM), secret key reversal (SKI) assault, and mixed replacement assaults. BFVs are undetermined by each of the three assaults. Biometric encryption is affected by SKI employing improved slope climbing and undermined by the ARM and replacement assaults.

The work [37] has different kinds of changes that apply to various biometric confirmation frameworks, particularly biometric portable applications. This assault is applicable to diverse modalities, making it dangerous on account of versatile applications dependent on unique finger impression or facial validation and in iris- and voice-based portable applications. The adjusted adaptation of the client picture recuperates from biometrics following utilizing, for instance, the client's image or hints of the unique finger impression left on a contacted surface. The impostor can use this picture as a solicitation to increase the unapproved or to get some collection about the client (that influences the client's protection). Six classes include alteration dependent on brightness, obscure, noise, part of the client's picture, mosaic picture, and negative picture.

The creators propose a novel replay identification approach [38] by exploiting commotion remaining highlights to distinguish if the information is antagonistically altered and produced by including clamors onto legitimate brain print format. It comprises of deuce phase. The character acknowledgment stage utilizes the convectional nervous system to characterize the info brainwaves. They confirm the personality of the client and the repeat location phase using the troupe classification to distinguish if the brain-generated wave signs are undermined and controlled by utilizing commotion remaining highlights. The crude EEG information gathered from 33 grown-up members with 30 anodes set uses the 26 geodesically masterminded locales. After information assortment is re-mentioned to the normal of the first mention and the correct mastoid. 1.1 seconds of EEG signals inspected at 500 Hz records for the introduction of each picture improvement. Exploratory outcomes show that the projected procedure can viably distinguish the replay assaults to the brain print biometric frameworks while keeping up an elevated level of client recognizable proof precision.

The plan [39] utilizes versatile and quantized surface patters acquired from nearby micro-features and worldwide spatial highlights for various shading diverts in a picture. Further, the surface descriptors gain proficiency with a frightfully relapsed discriminant classifier to order the ordinary visual images against the antique visual ones. The proposed conspire used to perform broad investigations on five openly accessible visual collections incorporating two collections procured in NIR space. Two collections utilize cell phones alongside a collection obtained using a camera. Noticeable spectrum iris artifact (VSIA) collection comprises visual pictures captured by a top-notch Canon DSLR camera and contains visual images obtained from 110 subjects with 5 examples. VSIA collection has the bona fide introduction pictures that use high goal cameras and the ancient rarities using a similar camera. VSIA collection has pentad distinctive sorts of assaults that incorporate both electronic screen assaults and top-notch print assaults which add to the different idea of antiques. There is a sum of 3300 visual pictures obtained from 110 topics and pentad distinct assault mechanisms. The tests directed on all the collection have reliably demonstrated the exhibition against assaults by appearing an ordering blunder of 0%.

16.4 Proposed Work

The work [5] uses artificial intelligence embedded in the instrument assist in safety of the structure. Computer-based intelligence is a geographic area of imitative cognition in which PC program is engaged to pick up, in actuality, frameworks and correspondence. As learning occurs, the capacities inside the program become continuously sharp, and the program ends up fit for settling on taught decisions. Deuce of the most acclaimed strategies are artificial neural frameworks (ANNs) and inherited computations. They imitate the somatic cell and synapses inside the psyche to trade collection for agreement, realizing, besides, essential leadership. They are in use inside IoT arrangement to screen the domain of IoT instruments and to settle on instructed conclusions. The authors have suggested the use of ANN to get acquainted with the sound state of a system and related contraptions. The creators made Gaussian models (GM) of the biometric collection. It duplicates the collection. Various features can be isolated from the biometric collection and consolidated to shape into a vector. Mean estimation and likelihood thickness limit

Table 16.1 Algorithm used to generate the hash code

Each parameter is assigned 16 bits each.
Number of parameters considered = 3
Total number of bits = 48 bits
Step 1: Divide the bits into two sets based on their position (even and odd position)
Step 2: for i = 1 to 24 do
Step 2.1: Xor the respective bits of the two sets to obtain 24 bits
Step 3: Left circular shift the bits for two position
Step 4: Divide this into two sets (i.e first 12 bits as set 1 and second 12 bits as set 2)
Step 5: both the bits are added to obtain 13 bits (if the addition of last bits does not result in carry, zero is considered as carry)
Step 6: resultant is equated to the obtained 13 bits

of multivariate Gaussian scattering are found. The absolute circulation work is also found.

The previous contribution considers all the biometric identification as a vector. As the spotting has varying shapes and sizes, the vector is subdivided into three subsets. Notation (16.1), (16.2), and (16.3) represent the vectors of the curve, clique, and whorl:

$$\text{Curve subset vector C} = \{C_1, C_2, C_3, \ldots\ldots\ldots\ldots\} \tag{16.1}$$

$$\text{Clique subset vector L} = \{L_1, L_2, \ldots\ldots\ldots\ldots\} \tag{16.2}$$

$$\text{Whorl subset vector W} = \{W_1, W_2, \ldots\ldots\ldots\ldots\ldots\} \tag{16.3}$$

The system, after analyzing sample with regard to its characteristics like length and area, generates a hash code to them. Three parameters used include area, thickness, and length. The algorithm generated by the hash cypher is described in Table 16.1.

Mean estimation and likelihood thickness limit of multivariate Gaussian scattering are found using the hash value. The absolute circulation work is also found.

16.5 Analysis of the Work

The work [5] uses artificial intelligence embedded in the instrument assist in safety of the structure. Computer-based intelligence is a geographic area of imitative cognition in which PC program is engaged to pick up, in actuality, frameworks and correspondence. As learning occurs, the capacities inside the program become continuously sharp, and the program ends up fit for settling on taught decisions. Deuce of the most acclaimed strategies are artificial neural frameworks (ANNs) and inherited computations. They imitate the somatic cell and synapses inside the psyche to trade collection for agreement, realizing, besides, essential leadership.

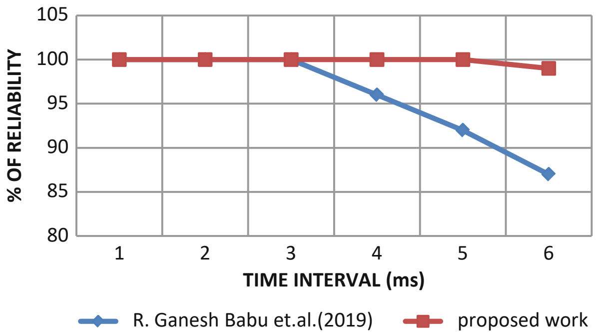
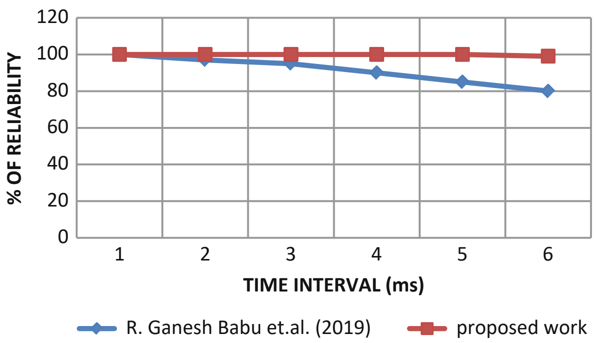


Fig. 16.1 Comparison of security

Fig. 16.2 Comparison of the two contributions with regard to reliability



They are in use inside IoT arrangement to screen the domain of IoT instruments and to settle on instructed conclusions. The authors have suggested the use of ANN to get acquainted with the sound state of a system and related contraptions. The creators made Gaussian models (GM) of the biometric collection. It duplicates the collection. Various features can be isolated from the biometric collection and consolidated to shape into a vector. Mean estimation and likelihood thickness limit of multivariate Gaussian scattering are found. The absolute circulation work is also found.

The previous contribution considers all the biometric identification as a vector. As the spotting has varying shapes and sizes, the vector is subdivided into three subsets. The system, after analyzing sample with regard to its characteristics like length and area, generates a hash code to them. Three parameters used include area, thickness, and length. Mean estimation and likelihood thickness limit of multivariate Gaussian scattering are found using the hash value. The absolute circulation work is found. Hence security is increased using the proposal by 4.17%. The same is represented in Fig. 16.1.

Reliability is increased by 9.5% compared to [5]. The same is represented in Fig. 16.2.

16.6 Conclusion

IoT is the amalgamation of sensor and actuators monitoring to accomplish a task. These instruments with different capabilities communicate over a common platform. IoT with AI aids the machines to learn and incorporate the methodology in many samples. The combined technology is used in medical services and industry. They aid in surveillance, processing collection, and transmission of collection. The proposal divides the biometric identifications into subsets. The system, after analyzing sample with regard to its characteristics like length and area, generates a hash code to them. Three parameters used include area, thickness, and length. This is followed by generation of hash code. Mean estimation and likelihood thickness limit of multivariate Gaussian scattering are found using the hash value. The absolute circulation work is found. Hence security is increased using the proposal by 4.17% and reliability by 9.5%.

References

1. N. Ambika, Chapter 7: Methodical IoT-based information system in healthcare, in *Smart Medical collection Sensing and IoT Systems Design in Healthcare*, ed. by C. Chakraborthy, (IGI Global, Bangalore, 2020), pp. 155–177
2. F.A. Othman, M. Hashem, I.A.T. Alotaibi, F. Alaba, Cyberspace of Things security: A survey. J. Netw. Comput. Appl., 10–28 (2017)
3. N. Ambika, G.T. Raju, ECAWSN: eliminating compromised node with the help of auxiliary nodes in wireless sensor network. Int. J. Secur. Netw. **9**(2), 78–84 (April 2014)
4. N. Ambika, Energy-perceptive authentication in virtual private networks using GPS collection, in *Security, Privacy and Trust in the IoT Environment*, (Springer, Cham, 2019), pp. 25–38
5. R. Ganesh Babu, P. Karthika, V. Aravinda Rajan, Secure IoT systems using raspberry Pi machine learning artificial intelligence, in *International Conference on Computer Networks and Inventive Communication Technologies*, (Coimbatore, 2019), pp. 797–805
6. A.K. Jain, K. Nandakumar, A. Nagar, Biometric template security. EURASIP J. Adv. Signal Process. **113**, 1–17 (January 2008)
7. J. Zhou, Y. Wang, K. Ota, M. Dong, AAIoT: Accelerating artificial intelligence in IoT systems. IEEE Wireless Commun. Lett. **8**(3), 825–828 (January 2019)
8. S.K. Singh, S. Rathore, J.H. Park, Blockiotintelligence: A blockchain-enabled intelligent IoT architecture with artificial intelligence. Futur. Gener. Comput. Syst., 1–23 (2019)
9. O. Vermesan et al., cyberspace of robotic things: converging sensing/actuating, hypoconnectivity, artificial intelligence and IoT Platforms, in *Cognitive Hyperconnected Digital Transformation: cyberspace of Things Intelligence Evolution*, (River Publishers, Gistrup, 2017), pp. 97–155
10. Z. Allam, Z.A. Dhunny, On big collection, artificial intelligence and smart cities. Cities **89**, 80–91 (2019)
11. S. Soomro, M.H. Miraz, A. Prasanth, M. Abdullah, Artificial intelligence enabled IoT: traffic congestion reduction in smart cities, in *IET 2018 Smart Cities Symposium (SCS '18)*, (University of Bahrain, Bahrain, 2018), pp. 81–86
12. F. Farivar, M.S. Haghighi, A. Jolfaei, M. Alazab, Artificial Intelligence for Detection, Estimation, and Compensation of Malicious Attacks in Nonlinear Cyber-Physical Systems and Industrial IoT. IEEE Trans. Ind. Inf. **16**(4), 2716–2725 (2019)

13. D. Choi, K. Lee, An artificial intelligence approach to financial fraud detection under IoT environment: A survey and implementation. Secur. Commun. Netw., 1–16 (2018)
14. H. Jiang, Mobile fire evacuation system for large public buildings based on artificial Intelligence and IoT. IEEE Access **7**, 64101–64109 (May 2019)
15. W. Lee et al., Automatic agent generation for IoT-based smart house simulator. Neurocomputing **209**, 14–24 (October 2016)
16. L. Liu, B. Zhou, Z. Zou, S.C. Yeh, L. Zheng, A smart unstaffed retail shop based on artificial intelligence and IoT, in *IEEE 23rd International workshop on computer aided modeling and design of communication links and networks (CAMAD)*, (Barcelona, 2018), pp. 1–4
17. A.H. Sodhro, S. Pirbhulal, V.H.C. de Albuquerque, Artificial intelligence-driven mechanism for border computing-based industrial applications. IEEE Trans. Ind. Inf. **15**(7), 4235–4243 (March 2019)
18. A. Rego, A. Canovas, J.M. Jiménez, J. Lloret, An intelligent system for video surveillance in IoT environments. IEEE Access **6**, 31580–31598 (June 2018)
19. M. Muslih, D. Supardi, E. Multipi, Y.M. Nyaman, A. Rismawan, Developing smart workspace based IOT with artificial intelligence using telegram chatbot, in *2018 International Conference on Computing, Engineering, and Design (ICCED)*, (Bangkok, 2018), pp. 230–234
20. E. Alreshidi, Smart sustainable agriculture (SSA) solution underpinned by cyberspace of things (IoT) and artificial intelligence (AI). Int. J. Adv. Comput. Sci. Appl. **10**(5), 93–102 (May 2019)
21. J. Lloret, J. Tomas, A. Canovas, L. Parra, An Integrated IoT Architecture for Smart Metering. IEEE Commun. Mag. **54**(12), 50–57 (December 2016)
22. F. Bu, X. Wang, A smart agriculture IoT system based on deep reinforcement learning. Futur. Gener. Comput. Syst. **99**, 500–507 (October 2019)
23. G.K. Shyam, S.S. Manvi, P. Bharti, Smart waste management using cyberspace-of-Things (IoT), in *2nd international conference on computing and communications technologies (ICCCT)*, (Chennai, 2017), pp. 199–203
24. A. Somov et al., Pervasive agriculture: IoT-enabled greenhouse for plant growth control. IEEE Pervasive Computing **17**(4), 65–75 (October-December 2018)
25. I. García-Magariño, R. Muttukrishnan, J. Lloret, Human-centric AI for trustworthy IoT systems with explainable multilayer perceptrons. IEEE Access **7**, 125562–125574 (August 2019)
26. R. Tolosana, M. Gomez-Barrero, C. Busch, J. Ortega-Garcia, Biometric presentation attack detection: Beyond the visible spectrum. IEEE Trans. Inf. Forensics Secur. **15**, 1261–1275 (August 2019)
27. D. Gafurov, E. Snekkenes, T.E. Buvarp, Robustness of biometric gait authentication against impersonation attack, in *OTM Confederated International Conferences "On the Move to Meaningful cyberspace Systems"*, (Montpellier, 2006), pp. 479–488
28. A. George et al., Biometric face presentation attack detection with multi-channel convolutional neural network. IEEE Trans. Inf. Forensics Secur **15**, 42–55 (May 2019)
29. M.A. Ferrer, M. Diaz, C. Carmona-Duarte, R. Plamondon, A biometric attack case based on signature synthesis, in *International Carnahan Conference on Security Technology (ICCST)*, (Montreal, 2018), pp. 1–6
30. C. Rathgeb, A. Uhl, Statistical attack against iris-biometric fuzzy commitment schemes, in *CVPR 2011 WORKSHOPS*, (Colorado Springs, 2011), pp. 23–30
31. E.M. Nowara, A. Sabharwal, A. Veeraraghavan, Ppgsecure: Biometric presentation attack detection using photopletysmograms, in *12th IEEE International Conference on Automatic Face & Gesture Recognition*, (Washington, DC, 2017), pp. 56–62
32. M. Une, A. Otsuka, H. Imai, Wolf attack probability: A new security measure in biometric authentication systems, in *International Conference on Biometrics*, (Baltimore, 2007), pp. 396–406
33. O.V. Komogortsev, A. Karpov, C.D. Holland, Attack of mechanical replicas: Liveness detection with eye movements. IEEE Trans. Inf. Forensics Secur. **10**(4), 716–725 (February 2015)
34. M. Pal, G. Saha, On robustness of speech based biometric systems against voice conversion attack. Appl. Soft Comput. **30**, 214–228 (May 2015)

35. A.P.S. Bhogal, D. Söllinger, P. Trung, A. Uhl, Non-reference image quality assessment for biometric presentation attack detection, in *5th International Workshop on Biometrics and Forensics (IWBF)*, (Coventry, 2017), pp. 1–6
36. W.J. Scheirer, T.E. Boult, Cracking fuzzy vaults and biometric encryption, in *Biometrics Symposium*, (Baltimore, 2007), pp. 1–6
37. S. Ghouzali et al., Trace attack against biometric mobile applications. Mob. Inf. Syst., 1–15 (April 2016)
38. Q. Gui, W. Yang, Z. Jin, M.V. Ruiz-Blondet, S. Laszlo, A residual feature-based replay attack detection approach for brainprint biometric systems, in *IEEE International Workshop on Information Forensics and Security (WIFS)*, (Abu Dhabi, 2016), pp. 1–6
39. K.B. Raja, R. Raghavendra, C. Busch, Color adaptive quantized patterns for presentation attack detection in ocular biometric systems, in *9th International Conference on Security of Information and Networks*, (Newark, 2016), pp. 9–15

Chapter 17
Cyber-Attacks on Internet of Things (IoT) Devices, Attack Vectors, and Remedies: A Position Paper

Shubham Prajapati and Amit Singh

17.1 Introduction

Internet of things (IoT) facilitate the interconnection of physical and digital world seamlessly. In recent times, IoT find their applications in multiple areas from home automation to ICS industry. As of now a large portion of society is habitual of at least some common IoT utilities in their daily routine, be it a smartwatch, Bluetooth connector, or home solutions. A few examples of IoT other than custom PCs, laptops, and smartphones are manufacturing equipment, connected automobiles, smart home products such as smart light fixtures, networking utilities such as routers, printers, ICS sensors, medical imaging devices, etc. In recent times many predictions have been made about IoT endpoint connections in near future based on the current trends. The IoT market is expected to reach up to $1.46 trillion by 2027 at an annual growth rate of 24.9% [1]. Even for the year 2020 as per Gartner report, there are 5.8 billion endpoints expected in connection, a 21% hike from 2019 [2], and by the end of 2025, 25 billion connected devices are expected [3]. Managing billions of connected endpoints has already been a concern for security because of their various limitations of memory, operating powers, etc. Ease of access for users and low price constraints also open a big door for cyber-attackers. Also users/organizations pay less attention as compared to traditional IT assets (like PCs, laptops) because of their visibility and usage management. Their vulnerabilities or technical issues are not noticed timely as their accessibility and location also put a bar on this. Because of these constraints, IoT devices don't come up with inbuilt security solution or very limited security and also with no forensic capability. In recent years these devices have been an attractive target for attackers. IoT service

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providers don't take security into consideration owing to lacking expertise and low margin as well.

As seen in recent trends about cyber-attacks on IoT, the cyber criminals have been taking great interest in this technology because of the scope in this field. The population of connected devices is growing at a brisk pace relying on same architecture. A large number of devices working on similar technology presents an opportunity to attacker of having a big size network of infected devices to launch multiple attacks against a target server such as distributed denial-of-service (DDoS) or network worm attack which have been seen very frequently in the recent past. The interest of cyber-attacker is going to increase for sure, and it is easy to understand as these are always connected (even without use) and lack traditional antivirus solution/firewall mechanism. They present weak or no security posture at large and depend over legacy protocol, and capability to patch vulnerability is even less.

Researchers have highlighted these issues in various studies and surveys over the period of time and things are improving now. Security researchers are continuously striving to enlighten the issue of cyber security in IoT infrastructure, and service providers are now providing the patches to the vulnerabilities in their products such as networking devices like Wi-Fi routers. Various cyber-attacks disturbed the IoT cyber landscape that led to the loss of reputation, weak financial infrastructure, etc. We are giving an insight view of the chain of infection that started about 2008–2009 [11] against IoT infrastructure and seems to be rampant. The malware attacks against IoT span over a wide area of cyber world fabric such as botnet activity with a huge number of infected devices controlled, launching DDoS attack with record traffic leading the services of victim down, and worm activity. Attacks even lead to crashing or jamming of devices. We think that readers should take cognizance of these attacks and understand infection mechanism and their implications. Being the consumer of this technology in any way, we must enforce the security policies thoroughly and ensure the sanitization of their application against attacks.

In this chapter, we highlight the major cyber-attacks that have taken place in IoT network exploiting the flaws that exist by nature of device characteristics or misconfigurations. The chapter is organized as follows: We classify the IoT sector by their implementation in Sect. 17.2, then we provide various threat vectors and vulnerabilities that are being leveraged against the IoT to launch cyber-attacks in Sect. 17.3, and later in Sect. 17.4 we list the details of major IoT attacks over the last decade that stole the show with their capacity and success against these devices. The best practice and mitigation strategies have been discussed in Sect. 17.5 that must be implemented to thwart the chances of attack and make their use more secure and smooth. Section 17.6 provides the conclusion of this chapter with way forward to future development and usage.

17.2 IoT Classification

IoT devices find applications based on their implementation in almost every horizon of technology. Their categorization may be broadly summarized on the basis of major technology sectors [4].

In **commercial sector, IoT** finds its application in automobiles, healthcare such as smart medical equipment and imaging system, connected cars, etc. The involvement of IoT infrastructure in this sector is really life changing from a common man to scaled setup.

Consumer IoT applications include smart home devices like smart lights, smart AC, etc. These are constantly changing the lifestyle of a mass of citizens toward luxury environment. Saving time and effort, these are taking responsibility away from a manual user to their own intelligent system.

Industrial IoT covers the scope of production environment such as ICS sensors, process monitoring, and controlling systems. This has proved more and more useful to increase the outcome of industries making visibility and management of system easier and accurate.

Infrastructure IoT finds its application in networking infrastructure like routers, printers, modem, etc. These can be viewed as IT assets of an organization.

IoMT (Internet of military things) is another class which is very important from the national security point of view as in the current scenario; warfare is not only limited to traditional weapons. The success also depends on how advanced technological systems a state has to identify and combat the threat. In this field IoT has again proved as a trusted crony helping with intelligence system. Some examples of IoMT include surveillance systems, biometric indicators, etc.

A glimpse of application of IoT in various sectors may be summarized as shown in Fig. 17.1.

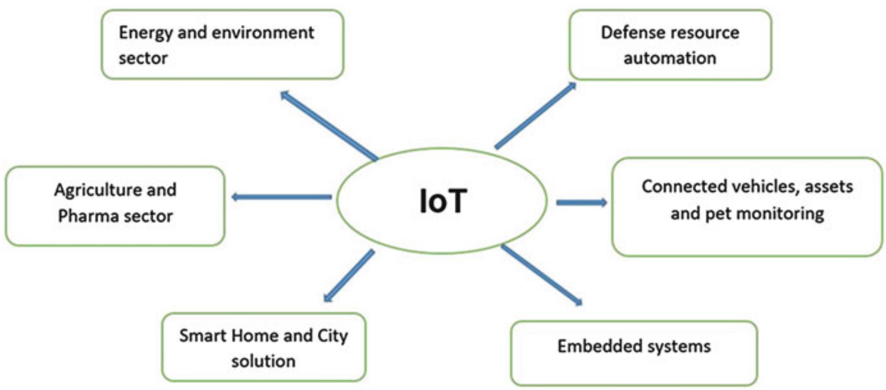

Fig. 17.1 IoT applications

In ensuing sections, we shall highlight the current trends in IoT infrastructure owing to their omnipresence, root cause of attacks, and future endeavors to facilitate this emerging technology in maintaining the sanity against attacks with implementation.

17.3 Threat Landscape in IoT Environment

These devices lack built-in security by design. Endpoint protection is designed for PC, laptop, and smartphones, but IoT devices rely on custom or outdated OS without scanning ability. They depend on legacy protocols for their data transfer and network communication which is again a serious problem. Traditional cyber security products and endpoint security applications are not integrated in case of IoT, and that causes a big issue in their security management. Known vulnerabilities such as exposed telnet or default credentials implementation expose IoT devices to various cyber-attacks ranging from DDoS, jamming, crashing to information stealing and many more. This paralyzed security also indicates that smart IoT devices do not streamline security in their "any" paradigm as shown in Fig 17.2.

There is a bunch of vulnerabilities and flaws that are prevalent in IoT applications. An attacker can exploit these vulnerabilities to carry out various attacks [5]. Some of the major flaws are discussed below.

Insecure Network Services The unneeded services that pose the risk of eavesdropping and data leakage. PHP modules that are built into IoT web interface can be exploited for remote execution by attacker.

Lack of Security Software IoT devices generally don't equip firewall or virus scanner/traffic monitoring capability.

Lacking Security Update Mechanism Most of IoT appliances are running on end of support and outdated protocols, and replacing them is also a herculean task. This scenario brings a great threat to security.

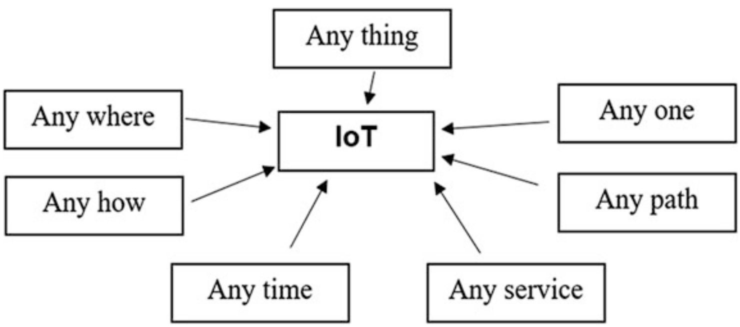

Fig. 17.2 "Any" paradigm in IoT

Insecure Data Transfer As per report of UNIT 42 team of Palo Alto Network in their survey, 98% of IoT traffic is unencrypted that exposes confidential data on network [6].

Device Management Ignorance Enabling proper security hardening and managing its communication, visibility, checking its specifications for deployment

Use of Outdated Insecure Components Third party aggregates that are typically not scanned or fixed with vulnerability patch

Improper Network Management and Configuration For deploying IoT in network, incompetent and ignored behaviors cause problems because these devices should be deployed in dedicated isolated environment, but an administrator typically installs them in integrated environment with traditional IT components that could lead lateral movement to these devices if any IT device is compromised.

Default Settings Default credentials as set by vendors are common and guessable, and consumers don't consider to change them at installation.

Since legacy and critical protocol such as DICOM (Digital Imaging and Communications in Medicine) in medical imaging and information management are employed in IoT application that are vulnerable to cyber-attacks, this attack vector constitutes a major chunk of IoT attacks. The top targeted ports on IoT attacks for example are Port 23 and Port 22 that are utilized for remote access via exposed telnet and relatively secure SSH protocol. Attackers desperately brute-force the vulnerable devices with common user name and password combinations to gain remote access and control the device to perform unauthorized activity. Telnet is rarely used outside the scope of IoT devices. As per the reports of security researchers of F-secure, 497 million hits on Telnet port are observed during the first half of 2020 [7] as visible in Fig. 17.3 with some other targeted ports.

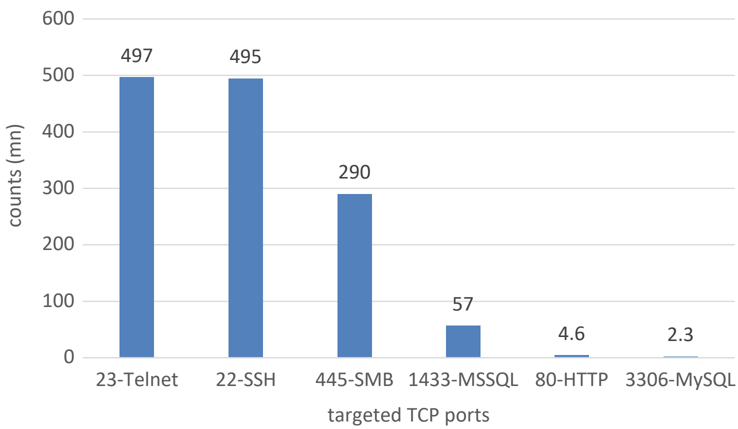

Fig. 17.3 Statistical representation of attack statistics on top TCP ports in the first half of 2020 [7]

Another major risk factor that IoT infrastructure devices such as routers, printers, etc. face is exposed endpoints of UPnP (Universal Plug and Play) service to the Internet due to misconfiguration. This can allow an attacker to set up port forwarding rules to put up proxies for malicious traffic. Vulnerable routers are exposed further compromising the systems behind these routers in the network. As per F-secure blog, nearly 85 million hits on UDP port 1900 that is used for UPnP and SSDB were seen in their research in the first half of 2020 [7]. This could even lead to access of internal computers of network over SMB protocol directly from the Internet, and vulnerability of SMB protocol like EternalBlue (CVE-2017-0144) [8] and EternalRed (CVE-2017-7494) [9] has widely been exploited by several ransomware attacks such as WannaCry and NotPetya.

Network Segmentation This is one good practice that is not followed, and IT assets are kept in the same network as of OT (operational technology) instruments. So if any traditional system such as PC is infected, then the lateral movement to the IoT appliance such as imaging sensor/monitor or biometric device is possible that could lead to life-threatening implications.

In addition to exploiting critical flaws and brute-force attack, IoT worms are also on rise to make lateral movement in the network through IoT.

17.4 Major IoT Attacks in the Wild

Since the inception of IoT, it is continuously getting advanced in terms of utility and technology as well. Due to the nature of services and protocols it involves, IoT is an attractive target of attackers owing to flaws in its implementation as mentioned earlier. Now we shall have a close look at some of the major attacks involving IoT infrastructure over the past years and their attack vectors that shook the world's IT infrastructure and human activities. This led the security professionals to think about improvising the security posture of IoT appliances. However the major cyber-attacks the IoT devices encountered were botnet activity, distributed denial-of-service (DDoS), brute-forcing, and IoT worm. DDoS attacks constitute the major chunk among IoT attacks although the attacks are on rise and diversifying. In DDoS attack in general, the attacker takes the control of Internet-connected infected device with malware to perform the desired activity on his command. The network of infected devices in this attack mechanism is called "botnet," while individual infected devices are called "Bot" or "Zombie." Botmaster commands the bots to make simultaneous request to the victim or target server or website and thus overwhelming the traffic over the network to which the target server was expected to handle. This results in turning down the legitimate request to the service and even leads the victim server/website unresponsive. HTTP, TCP/IP, UDP, and ICMP are the common types of traffic to be used in attack [10, 11]. In some cases uncommon GRE traffic is also used. The generic IoT botnet infrastructure is shown in Fig. 17.4.

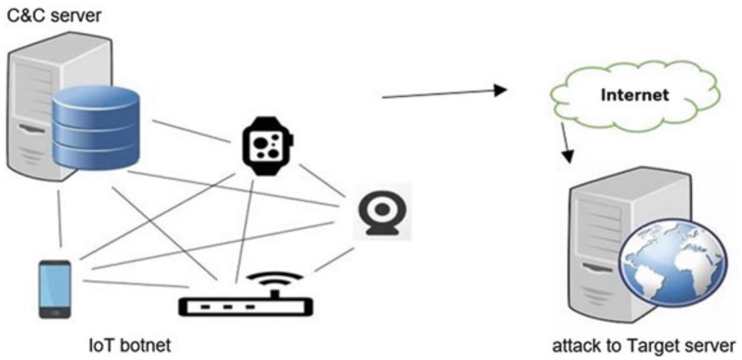

Fig. 17.4 Generic IoT botnet view

Traffic generation by IoT botnet devices is very high in range of 100 Gbps or higher. Infection is hard to locate and remediate. Thus IoT infrastructure seems attractive to attackers for botnet activity for launching further attacks.

Below we provide a study of major malware attacks on IoT devices and their impact on cyber world with relevant statistics over the last decade. The list of malware attacks is not giving wholesome number, and data of attacks as IoT attacks are continuously developing in their TTP and attacking strategies with each passing day involving attacks on specific area or purpose. So we provide the list and details of some prominent IoT attacks here.

Linux/Hydra (IRC bot)
This IoT botnet framework came into picture in 2008 and infected routers. It was capable of performing DDoS attack and spreading features like worm inbuilt [12].

Psyb0t or Bluepill
This is another IoT worm that emerged in 2009 and known to be the first malware to infect residential routers and DSL modems. It is quivered with 6000 usernames and 13000 popular passwords to brute-force into network. It was believed to infect 100000 systems [13]. This could even steal the personally identifiable information (PII) [14].

Chuck Norris
This variant of IoT malware resembles Hydra exploded in 2010 targeting DSL modems and D-Link routers with worm capability by brute-forcing default credentials [15]. Exploitation of Microsoft vulnerability MS03-039 Buffer Overrun in RPCSS service was also developed [16]. It was also equipped with backdoor capability facilitating remote code execution to launch further attacks and loss of PII.

Aidra/LightAidra
It came into the wild in 2012. It was an IRC-based router scanning and exploitation tool that exploited open telnet ports with default credentials, and code was made

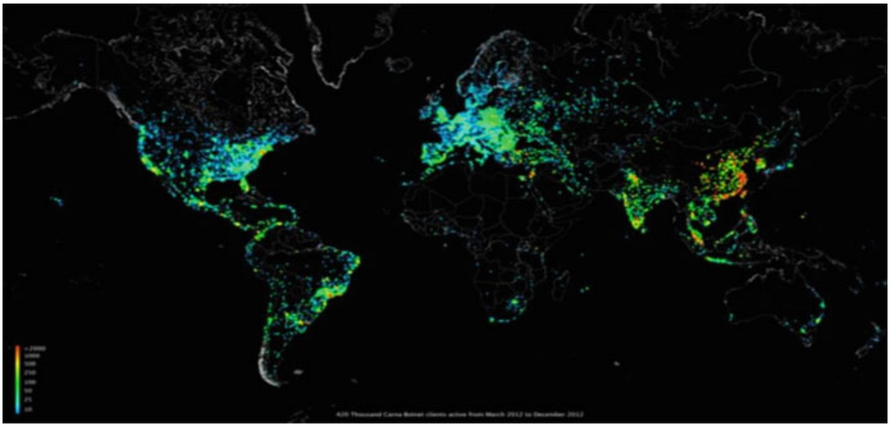

Fig. 17.5 Collected data of Carna during 24 hrs utilizing IPv4 address, March to December 2012 [19]

available online. It also originated from digital video recorder (DVRs), IP camera, smart TVs, etc. This botnet targets devices with multiple architecture like MIPS, ARM, MIPSeL, PPC, x86/x86-64, and SuperH architectures. Later in 2014, it was discovered that modified version of Aidra can be employed to mine Bitcoin in infected device [17].

Carna Botnet

It was a botnet developed by an unknown hacker and comprised 420000 devices to find the extent of Internet and IP ranges. It intruded Internet devices especially routers with default credentials and collected data about Internet use shown on Gif projection during June to October 2012 for IPv4 address [18, 19]. The image view of Gif projection is shown in Fig. 17.5.

Linux.Darlloz

As discovered by Symantec, the IoT worm targets various architecture like Aidra such as ARM, MIPS, PowerPC architecture on router, set-top box, and also computers running x86 architecture. This attack again brute-forces the common credentials. After infection it terminates telnetd process to block the access of infected device via telnet. Till February 2014, 31000 infected devices are observed. In its new updated version, it also deployed for mining Mincoin and Dogecoin on home PC through CPU miner [20]. It targets LightAidra and tried to remove files and blocking communication port used by Aidra.

Linux.Wifatch/Zollard/Reincarna

The malware was active in November 2014. It affects routers with default credential over telnet, and it is probably defending over other malwares by disabling telnet and guiding to change telnet passwords or update firmware. It updates its definition through peer to peer network and deletes residual [21, 22].

Spike/Dofloo
Discovered in 2014, this DDoS attack is capable of infecting wireless system, Linux-based PC, and IoT devices as routers, smart thermostat, etc. based on ARM and MIPS architecture. Attacks even once peaked at 215 Gbps. This malware can launch attack with various payloads including SYN flooding, UDP flooding, DNS query flooding, etc. [23, 24].

BashLite/Lizkebab/Torlus/gafgyt [10]
Discovered in 2014, this botnet attack exploited Shellshock or bash vulnerability to compromise Linux-based IoT and launch DDoS attack. Since its source code was made public in 2015, till 2016 1 million devices are affected including DVRs, routers, Linux servers, etc. It was active till 2019. It can generate traffic up to 400 Gbps. Its variants tracked by TrendMicro infected WeMo devices to mine cryptocurrency [25]. The exploit attack requires to check if WeMo device has WeMo UPnP API. The infection dominated in Brazil, Taiwan, and Columbia. In its arsenal of botnet activity, 96% devices are IoT devices, 4% are home routers, and 1% are Linux servers [26, 27]. This also operates on brute-forcing the devices. Its most variant has its C2 IP hardcoded in its payloads. Another variant of this was observed later called "Ayedz." It was considered as predecessor of Mirai attack [28, 29].

LuaBot
It is known as the first malware written in Lua programming language. It targeted Linux servers and IoT devices. It was reported in 2016 by MalwareMustDie [30]. It was capable of performing DDoS attack, and C2 server was hosted in Netherlands.

Tsunami
It was an IRC bot backdoor and a variant of Hydra botnet to launch DDoS. It modifies the DNS configuration on infected devices to redirect malicious traffic to C2 of IoT [10, 11].

Remaiten/KTM-RM
It was released in 2016 and combines the DDoS features of Tsunami and capability of BashLite. Once it gets the access to IoT devices via brute-forcing default credentials [31], it downloads the bot executables based on specific architecture. C2 communication takes place over IRC channel [32].

Mirai
It is one of the most prominent and severe DDoS IoT attacks in recent times. Since its inception in 2016, its multiple variants have hit the world's cyber infrastructure as its source code was made public (which was in "C") by its alleged author "Paras Jha" having his online pseudonym "Anna-senpai." In its attack chain, Mirai first infects the IoT devices such as printer, DVR, smart TV, routers, etc. It scans the network devices, IoT on public IP address through TCP port 23 or 2323, and brute-forces with default credentials. As identified there are 62 username and password combinations hardcoded in Mirai payload [33].

Operations of Mirai attack are carried out by four major components as discussed below [34]:

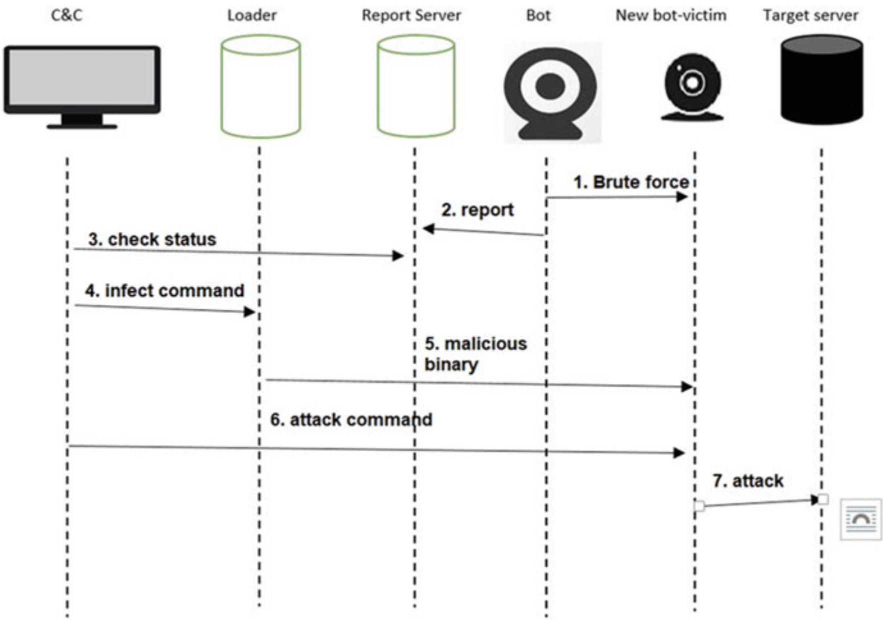

Fig. 17.6 Mirai botnet operation with IoT devices conducting DDoS attack [34]

1. The "bot" component tries to compromise the device via brute-forcing default credentials and attacking target server on the command of Botmaster.
2. C&C server is a central server to send command for DDoS and check the status of botnet. Communication with other segments of botnet is carried out over Tor network.
3. The loader component sends the malware binary to victim of various architecture such as ARM, MIPS, x86, etc.
4. Report server maintains the repository of devices in botnet.

Mirai generated traffic floods of GRE IP, SYN and ACK, DNS, UDP, or HTTP, against target. Mirai expands its attack campaign to Windows device and MySQL servers also over the time.

The attack strategy of Mirai is demonstrated in Fig. 17.6.

Major instances of Mirai attack:

1. In September 2016, computer security consultant Brian Krebs' blog website KrebsOnSecurity.com was hit by a phenomenal 623 Gbps traffic. Initially the attack was constituted with 24000 IoT devices, and most of them were DVR and IP cameras [35]. It infected 4000 devices per hour at its peak. The attack traffic was mostly GRE. The geolocation distribution of Mirai-infected devices targeting Brian's website is shown in Fig. 17.7.

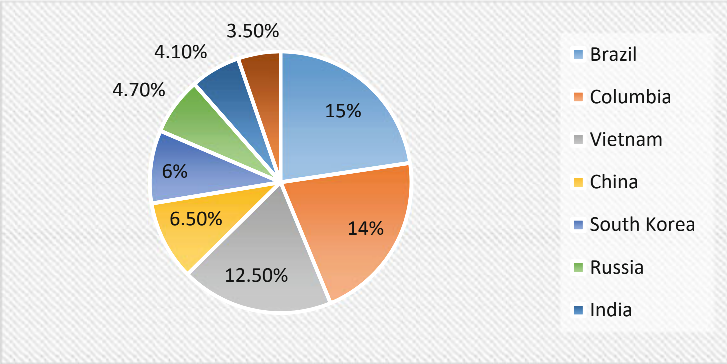

Fig. 17.7 Mirai-infected device distribution targeting Brian’s website [33]

2. *OVH:* This French cloud service provider company was hit by a record-breaking 1.1 Tbps [36] that may be as high as 1.5 Tbps with almost 148000 IoT devices majorly DVR and routers. Since the code of Mirai was made public, the number of infected devices increased from 200000 to almost 500000 within a short span of time.
3. *Dyn:* Just 1 month after above attack, the Internet performance management and web application security company Dyn also faced heavy DDoS traffic on their DNS from almost 1000000 infected devices such as printer, IP camera, and gateways, and that was a masked TCP and UDP traffic over port 53. This attack took down the services of some very famous websites whose DNS services is managed by Dyn like Airbnb, Amazon, Reddit, and Spotify for several hours [37].

Mirai could be wiped out by rebooting the infected device, but it’s a matter of time to get the device reinfected again as that is continuously scanning the public Internet leading to infection. Some other examples of Mirai DDoS attack include attack on telecom infrastructure of Liberia and traffic up to 500 Gbps [38]; cyber-attack on housing blocks in Lappeenranta, Finland [39]; and compromising of “Speedport” home routers of Deutsche Telekom, a German telecom company [40]. There are many other attacks that Mirai imposed over cyber infrastructure worldwide leading to failure of Internet activity and wasted resources. We have listed here some of them for purview of our study.

There are updated variants of Mirai IoT botnet which infected the IoT appliances since 2017 onward; an overview of those variants is highlighted below.

Persirai

It has been active since April 2017, targeting IP cameras of many OEM, and has detected almost 120000 IP cameras vulnerable to this attack [41]. It communicates through TCP port 81 to get access of webcams and exploit UPnP flaws and further to download malicious binary and execution. Infected IP cameras attack other IP cameras after receiving commands from attacker exploiting zero-day vulnerability [42].

BrickerBot
It was active in 2017 and an advanced variant of Mirai. It has its two versions which attack with their features. Version 1 targets devices which are running BusyBox with exposed telnet, running older version of Dropbear SSH server causing SSH exposure. As per security firm Radware [43], version 1 now ceased. Version 2 attacks Linux-based device that are with or without BusyBox, and it uses Tor exit nodes [44].

IoT Reaper/IoTroop Botnet
This also emerged in 2017 borrowing the source code from Mirai targeting IoT devices CCTV camera and Wi-Fi router and spreading unabated. However, it is different from Mirai in its key behavior as it doesn't involve brute-force activity for weak credentials; rather it exploits IoT vulnerability and is a LUA execution environment supported, so it is more sophisticated [45].

The routers which are vulnerable to this attack are from various vendors such as DLink, Netgear, etc., and similarly vulnerable cameras are from AVTech, Goahead, JAWS, etc. [46].

Satori
This is another variant of Mirai DDOS malware which has worm-like capability. It's different from Mirai in its feature as it doesn't scan for open telnet; rather it scans TCP ports 37215 and 52869 on random IP address. It exploits the flaw that works on TCP port 52869 exploiting the vulnerability CVE-2014-8361 [47, 48].

The usual problem with ISP-supplied routers is that many home routers have Port 7547 open for remote management of CPE using TR069 protocol which requires no password or weak HTTP digest authentication over unencrypted path, and that is improperly managed by manufacturer.

Hajime
It was discovered in 2016, and it doesn't involve on DDoS activity with its bots; rather it closes some ports of devices to prevent them against Mirai-like infection [49]. It relies on peer to peer network communication and utilizes distributed hash table (DHT) protocol that differs Mirai. Till 2017, it trapped almost 300,000 devices into its botnet as reported by Kaspersky [50].

Mozi
It was first analyzed in late 2019 and developed with source code of malware families Mirai, Gafgyt, and IoT Reaper. As discovered by IBM X-Force, around 90% of IoT network traffic is contributed by Mozi from October 2019 to June 2020 [51]. It's a P2P botnet network and relies on DHT protocol. It employs ECDSA384 and the XOR algorithm for integrity in its botnet [52]. It compromises the IoT devices through exposed telnet with default credentials for structuring botnet. It mainly targets DVRs and home routers and exploit their vulnerabilities also as its

Table 17.1 Approximate botnet size of major IoT malware families [53–56]

Malware	Botnet size (approx.)	Major types of infected IoT devices	Effective timeline
BrickerBot	10000000+	Linux/BusyBox-based devices with exposed telnet, devices running with older version of Dropbear SSH server with exposed port 22 (SSH), access points, etc.	2017
IoT Reaper	1000000+	Router, IP camera of various OEM such as DLink, Netgear, Linksys, AVTECH, Goahead	2017
Mirai	600000	Home routers, air-quality monitors, surveillance cameras, printers, smart TVs, etc.	2016–2017
Chuck Norris	300000	Routers, DSL modems and spread across shared networks through exploiting MS03-039 – Critical Buffer Overrun in RPCSS service	2012
Hajime	130000–300000	MikroTik router exploiting bug known as “Chimay Red” in firmware 6.38.4 or earlier	2016–2017
Wifatch	60000–300000	home router, CCTV	2015
BashLite/Gafgyt	120000	Camera, DVR, home router	2016
Persirai	120000	IP cameras	2017
Psyb0t	100000	Cable/DSL modems and routers of various organizations as Linksys, Netgear, etc.	2012
Darlloz/Zollard	31000	Routers, security cameras, set-top box, and PCs	2014
TheMoon	1000	Broadband modem and router of various OEMs Linksys, ASUS, MikroTik, and D-Link	2014

infection mechanism. It is capable of DDoS attack, payload execution, and custom command function.

Some other notable variants of Mirai are **TheMoon, DvrHelper, Okiru,** and **Masuta** abusing the default credentials over open telnet, exposed UPnP service, and command injection vulnerability.

The attacks on IoT devices are on rise as the script player is continuously developing new malware utilizing existing source code of old malwares. Here we have provided a picture of threat landscape in the IoT realm that needs to be addressed and try to give reader insights of IoT attack vectors and strategies to be observed.

In Table 17.1, we provide some statistics in tabulated form to give an idea about size of major IoT botnets.

17.5 Remedies/Best Practices

One critical aspect that impacts the IoT security is the expectations from these devices to be at ease of access pegged at low cost. Many manufacturers have low margins on these products and in haste to deliver them in competitive market without taking much pain about their cyber security. Many of these devices are running on end of life OS (e.g., Windows 7), and software and are not even able of getting patches. Securing IoT infrastructure is a collective responsibility of manufacturers as well as of organizations/end-users deploying them in their network environment.

The IoT service providers may impose some restrictions on device communication in network to make them shielded against attacks as follows:

1. IoT devices may be restricted to communicate with owner's website or defined private IPv4 address as hardcoded in device (RFC 1918).
2. Every device should be enabled with unique default credentials that are not guessable. The passwords much be complex enough such as comprising special characters.
3. Cellular firewall may also be employed to limit the communication of device to defined subset of IP address, thus protecting against remote access stealing. In this way the firewall located on cellular connection is out of reach of the attacker [57].
4. End-users should redirect to manufacturer's website while installing the device and enabling the network. In this way the proper instruction and work around in any difficulty would be available without risk.
5. Standard operating procedure (SOP) should be prescribed by manufacturers in case of device failure or troubleshooting.
6. Strict policy should be implemented in IoT market, i.e., over producers, suppliers, and end-users, to be complied upon. Provisions of penalty should also be introduced.

As the end-users/organizations are deploying the IoT devices in their network environment, they must take care of security concerns of their network and risk management of IoT devices. Execution of proper security measures is critically important while configuring these devices in network communication. Organizations must take the following security measures into their consideration:

1. Conventional IT assets infrastructure must be isolated from OT (operation technology) environment as any traditional IT asset infection could lead to infect IoT device that could be life-threatening. For example, in healthcare if imaging solution be in the same network as of user PC, then infection to PC may lead to compromising of OT imaging solution. So dedicated network segment or VLAN for IoT is recommended rather than shared LAN or Wi-Fi [6].
2. Active monitoring of network traffic to identify any unusual traffic and monitoring telnet connection. Device visibility should also be ensured all the time [6, 57].

3. IoT devices may be remotely accessed over intra-cloud network rather publically exposed to the Internet.
4. Users must change default credential while deploying these devices to prevent brute-forcing over telnet with default credentials.
5. Before deploying IoT device in network, the device must be scanned for any flaw or vulnerability, open port, insecure protocol, and services that are targeted by an attacker.
6. Users should always update the security protocols/software/firmware wherever possible to latest available versions that are patched with known vulnerabilities.
7. Disable UPnP service if not absolutely necessary. Similarly telnet and SSH should be disabled if remote management is not necessary.
8. Network administrator should periodically monitor firewall logs for any malicious traffic over port 23 or 2323.
9. Egress and ingress filtering should be applied at router level.
10. IoT devices should support lock or logout features if left unattended for specific time so as to require re-authentication.

IoT devices or even network security of IT asset can be realized by proper understanding the risks and failure. While dealing with IoT, handler must have in and out idea of particular device as different vulnerabilities can be exploited in unique way to launch severe cyber-attack on the infrastructure.

17.6 Conclusion

It is evident that IoT is continuously growing in its technology and implementation. Many surveys show that in the near future everything will be related to IoT. This smart technology is making life easier in all dimensions be it home or ICS or any other domains.

But as discussed in this chapter, with evolvement of technology, cyber-attacks on IoT are also on rise exploiting various vulnerabilities. The attackers are developing new malware families to target the devices with sophisticated mechanism and are hard to tackle. This creates the disturbance in cyber ecosystem ranging from reputation loss, ransom demand to life-threatening issues if leveraged in OT healthcare or ICS systems.

The security protocols and services that are to be considered for IoT appliances must be given utmost importance and implemented thoroughly. Manufacturers and end-users must understand the implications of negligence and apply the security protocols/policies on solutions. The threat vectors and flaws in security implementation of IoT that were discussed in this chapter may provide the comprehensive picture of the things to be taken care of to be secure against multitude of cyber-attacks against IoT. The major attacks on IoT infrastructure that we discussed in our study can help readers understand about various cyber risks and implications in this field. The number of attacks exponentially increased exploiting various flaws of IoT devices. So the remedies and best practice/solutions that are discussed above must be employed in the IoT network devices eradicating the chances of cyber-attacks. Then this emerging technology will go far and wide, making the world more ecstatic with its services.

References

1. Fortune Business Insights report., https://www.fortunebusinessinsights.com/industry-reports/internet-of-things-iot-market-100307. Last accessed 13 Nov 2020
2. Gartner, Inc. report (2019), https://www.gartner.com/en/newsroom/press-releases/2019-08-29-gartner-says-5-8-billion-enterprise-and-automotive-io. Last accessed 11 Nov 2020
3. Gartner, Inc. report (2018), https://www.gartner.com/en/newsroom/press-releases/2018-11-07-gartner-identifies-top-10-strategic-iot-technologies-and-trends. Last accessed 06 Nov 2020
4. G.D. Maayan, Security today article. The IoT Rundown for 2020: Stats, Risks, and Solutions. (2020), https://securitytoday.com/Articles/2020/01/13/The-IoT-Rundown-for-2020.aspx? Page=1. Last accessed 08 Nov 2020
5. OWASP Internet of Things Project, https://wiki.owasp.org/index.php/OWASP_Internet_of_Things_Project#tab=IoT_Top_10. Last accessed 08 Nov 2020
6. Unit 42 (Palo Alto Networks) IoT threat report/white paper (2020), https://iotbusinessnews.com/download/white-papers/UNIT42-IoT-Threat-Report.pdf. Last accessed 10 Nov 2020
7. Attack Landscape H1 2020. Blog F-Secure. https://blog-assets.f-secure.com/wp-content/uploads/2020/09/17142720/F-Secure-attack-landscape-h12020.pdf. Last accessed 14 Nov 2020
8. EternalBlue (CVE-2017-0144). https://cve.mitre.org/cgi-bin/cvename.cgi?name=cve-2017-0144
9. EternalRed (CVE-2017-7494). https://cve.mitre.org/cgi-bin/cvename.cgi?name=cve-2017-7494
10. K. Angrishi, Turning Internet of Things (IoT) into Internet of Vulnerabilities (IoV): IoT Botnets. arXiv:1702.03681v1 [cs.NI]. https://arxiv.org/pdf/1702.03681.pdf, Pages 5–7, 9. (2017)
11. Trend Micro Security news. Into the Battlefield: A Security Guide to IoT Botnets (2019), https://www.trendmicro.com/vinfo/us/security/news/internet-of-things/into-the-battlefield-a-security-guide-to-iot-botnets#:~:text=LuaBot%20is%20notable%20for%20being,conducted%20application%20level%20DDoS%20attacks. Last accessed 12 Nov 2020
12. P. Macgregor., insecurety.net news. Hydra IRC bot, the 25 minute overview of the kit. http://insecurety.net/hydra-irc-bot-the-25-minute-overview-of-the-kit/. Last accessed 13 Nov 2020
13. I. Paul, PCWorld article. Nasty new worm targets home routers, cable modems. (2009), https://www.pcworld.com/article/161941/nasty_worm_targets_home_networks.html. Last accessed 04 Nov 2020
14. Dronebl Blog. https://www.dronebl.org/blog/8
15. C. Guevarra, Blog Trend Micro. Botnet Rises in the Name of Chuck Norris. (2010), https://blog.trendmicro.com/trendlabs-security-intelligence/botnet-rises-in-the-name-of-chuck-norris/?_ga=2.95967583.233007207.1604856463-1391622009.1604698086. Last accessed 14 Nov 2020
16. Microsoft Security Bulletin MS03-039 – Critical (10/09/2003), https://docs.microsoft.com/en-us/security-updates/securitybulletins/2003/ms03-039. Last accessed 14 Nov 2020
17. NJCCIC Threat Profile (2016), https://www.cyber.nj.gov/threat-center/threat-profiles/botnet-variants/aidra-botnet. Last accessed 10 Nov 2020

18. I Thomson, The Register. Researcher sets up illegal 420,000 node botnet for IPv4 internet map. (2013), https://www.theregister.com/2013/03/19/carna_botnet_ipv4_internet_map/. Last accessed 10 Nov 2020
19. Internet Census 2012. Port scanning /0 using insecure embedded devices. https://web.archive.org/web/20130325080636/http://internetcensus2012.bitbucket.org/paper.html. Last accessed 11 Nov 2020
20. Broadcom Community, IoT worm used to mine cryptocurrency. (2014), https://community.broadcom.com/symantecenterprise/communities/community-home/librarydocuments/viewdocument?DocumentKey=00fcdbad-954d-42ff-af50-4d74001bdcbb&CommunityKey=1ecf5f55-9545-44d6-b0f4-4e4a7f5f5e68&tab=librarydocuments. Last accessed 10 Nov 2020
21. S. Schick, SecurityIntelligence news. Linux.Wifatch: The router virus that may be secretly defending you from other Malware. (2015), https://securityintelligence.com/news/linux-wifatch-the-router-virus-that-may-be-secretly-defending-you-from-other-malware/. Last accessed 11 Nov 2020
22. Broadcom Community, Is there an Internet-of-Things vigilante out there? (2015), https://community.broadcom.com/symantecenterprise/communities/community-home/librarydocuments/viewdocument?DocumentKey=ef23b297-5cc6-4c4a-b2e7-ff4163596S5fe&CommunityKey=1ecf5f55-9545-44d6-b0f4-4e4a7f5f5e68&tab=librarydocuments. Last accessed 10 Nov 2020
23. Akamai [state-of-the-internet] Threat-advisory., https://www.akamai.com/fr/fr/multimedia/documents/state-of-the-internet/spike-ddos-toolkit-threat-advisory.pdf. Last accessed 14 Nov 2020
24. T.H. Phu, K.H. Dang, D.N. Quoc, N.T. Dai, Binh NN. A novel framework to classify malware in MIPS architecture-Based IoT devices". (2019). Editor: Genge Bela (academic). https://www.hindawi.com/journals/scn/2019/4073940/. https://doi.org/10.1155/2019/4073940
25. M. Vicente, B. Gelera, A. Remillano II, C. Toyama, J. Urbanec, TrendMicro News. Bashlite updated with mining and backdoor commands. (2019), https://www.trendmicro.com/en_us/research/19/d/bashlite-iot-malware-updated-with-mining-and-backdoor-commands-targets-wemo-devices.html?_ga=2.24141561.233007207.1604856463-1391622009.1604698086. Last accessed 14 Nov 2020
26. L. Loeb, SecurityIntelligence news. BASHLITE malware uses IoT for DDoS attacks. (2016), https://securityintelligence.com/news/bashlite-malware-uses-iot-for-ddos-attacks/. Last accessed 10 Nov 2020
27. D. Voolf, S. Boddy, R. Cohen, S. Vinberg, F5-Labs Article. Gafgyt Targeting Huawei and Asus Routers and Killing Off Rival IoT Botnets. (2019), https://www.f5.com/labs/articles/threat-intelligence/gafgyt-targeting-huawei-and-asus-routers-and-killing-off-rival-iot-botnets. Last accessed 14 Nov 2020
28. W. Ashford., ComputerWeekly.com news. LizardStresser IoT botnet launches 400Gbps DDoS attack. (2016), https://www.computerweekly.com/news/450299445/LizardStresser-IoT-botnet-launches-400Gbps-DDoS-attack. Last accessed 10 Nov 2020
29. P. Paganini, Security Affairs Article. A new BASHLITE variant infects devices running BusyBox. (2014), http://securityaffairs.co/wordpress/30225/cyber-crime/bashlite-exploits-shellshock.html. Last accessed 11 Nov 2020
30. The MalwareMustDie Blog (2016), https://blog.malwaremustdie.org/2016/09/mmd-0057-2016-new-elf-botnet-linuxluabot.html. Last accessed 09 Nov 2020
31. P. Paganini, Security Affairs news. The Linux Remaiten malware is building a Botnet of IoT devices. (2016), http://securityaffairs.co/wordpress/45820/iot/linux-remaiten-iot-botnet.html, Last accessed 09/11/2020
32. M. Malik, M-E. Léveillé, ESET. Meet Remaiten – a Linux bot on steroids targeting routers and potentially other IoT devices. (2016), https://www.welivesecurity.com/2016/03/30/meet-remaiten-a-linux-bot-on-steroids-targeting-routers-and-potentially-other-iot-devices/. Last accessed 13 Nov 2020

33. E. Bursztein, The Cloudflare blog. Inside the infamous Mirai IoT Botnet: A retrospective analysis. (2017), https://blog.cloudflare.com/inside-mirai-the-infamous-iot-botnet-a-retrospective-analysis/#:~:text=By%20the%20end%20of%20its,infected%20over%20600%2C000%20IoT%20devices. Last accessed 14 Nov 2020
34. C. Kolias, G. Kambourakis, DDoS in the IoT: Mirai and other botnets. (2017), https://www.researchgate.net/profile/Constantinos_Kolias/publication/318288727_DDoS_in_the_IoT_Mirai_and_other_botnets/links/59dba11a458515e9ab451487/DDoS-in-the-IoT-Mirai-and-other-botnets.pdf. Last accessed 13 Nov 2020
35. Krebs B, KrebsOnSecurity, KrebsOnSecurity Hit With Record DDoS. (2016), https://krebsonsecurity.com/2016/09/krebsonsecurity-hit-with-record-ddos/. Last accessed 14 Nov 2020
36. D. Goodin, ars TECHNICA article. Record-breaking DDoS reportedly delivered by >145K hacked cameras. (2016), https://arstechnica.com/information-technology/2016/09/botnet-of-145k-cameras-reportedly-deliver-internets-biggest-ddos-ever/. Last accessed 14 Nov 2020
37. C. Williams, The Register. Today the web was broken by countless hacked devices – your 60-second summary. (2016), https://www.theregister.com/2016/10/21/dyn_dns_ddos_explained. Last accessed 11 Nov 2020
38. B. Krebs, KrebsOnSecurity. Did the Mirai botnet really take Liberia offline? (2016), https://krebsonsecurity.com/2016/11/did-the-mirai-botnet-really-take-liberia-offline/. Last accessed 14 Nov 2020
39. S. Moss, Data Centre Dynamics. DDoS attack knocks out Finnish heating. (2016), https://www.datacenterdynamics.com/en/news/ddos-attack-knocks-out-finnish-heating/. Last accessed 14 Nov 2020
40. J. Kirk, Bank Info security news. Mirai botnet knocks out Deutsche Telekom Routers. (2016), https://www.bankinfosecurity.com/mirai-botnet-knocks-out-deutsche-telekom-routers-a-9565. Last accessed 14 Nov 2020
41. T. Yeh, D. Chiu, K. Lu, Trend micro alert news. Persirai: New IoT botnet targets IP cameras. (2017), https://www.trendmicro.com/en_us/research/17/e/persirai-new-internet-things-iot-botnet-targets-ip-cameras.html. Last accessed 14/11/2020
42. P. Kim, Github blog. (2017), https://pierrekim.github.io/blog/2017-03-08-camera-goahead-0day.html. Last accessed 14 Nov 2020
43. Radware Threat Advisory, BrickerBot results in PDoS attack. (2017), https://security.radware.com/ddos-threats-attacks/brickerbot-pdos-permanent-denial-of-service/. Last accessed 14 Nov 2020
44. Trend Micro Security News, BrickerBot malware emerges, permanently bricks IoT devices. (2017), https://www.trendmicro.com/vinfo/us/security/news/internet-of-things/brickerbot-malware-permanently-bricks-iot-devices. Last accessed 14 Nov 2020
45. 360 NetLab Blog (2017), https://blog.netlab.360.com/iot_reaper-a-rappid-spreading-new-iot-botnet-en/. Last accessed 08 Nov 2020
46. Check Point Research, A new IoT botnet storm is coming. (2017), https://research.checkpoint.com/new-iot-botnet-storm-coming/. Last accessed 10 Nov 2020
47. Malpedia News., https://malpedia.caad.fkie.fraunhofer.de/details/elf.satori. Last accessed 14 Nov 2020
48. 360 NetLab Blog (2017), https://blog.netlab.360.com/warning-satori-a-new-mirai-variant-is-spreading-in-worm-style-on-port-37215-and-52869-en/. Last accessed 14 Nov 2020
49. J. Leyden, The Register. Mysterious Hajime botnet has pwned 300,000 IoT devices. (2017), https://www.theregister.com/2017/04/27/hajime_iot_botnet/. Last accessed 14 Nov 2020
50. Kaspersky/Press- release (2017), https://www.kaspersky.com/about/press-releases/2017_300000-obeying-devices-hajime-is-conquering-the-internet-of-things-world. Last accessed 14 Nov 2020
51. D. Macmillen, W. Gao, C. Debeck, Security intelligence post. A new botnet attack just mozied into town. (2020), https://securityintelligence.com/posts/botnet-attack-mozi-mozied-into-town/. Last accessed 14 Nov 2020

52. 360 NetLab Blog (2019), https://blog.netlab.360.com/mozi-another-botnet-using-dht/. Last accessed 14 Nov 2020
53. Cynet report. https://www.cynet.com/endpoint-protection-and-edr/edr-cybersecurity-unlocking-the-black-box-of-endpoint-protection/. Last accessed 14 Nov 2020
54. A. Costin, J. Zaddach, BlackHat, USA (2018), https://i.blackhat.com/us-18/Thu-August-9/us-18-Costin-Zaddach-IoT-Malware-Comprehensive-Survey-Analysis-Framework-and-Case-Studies-wp.pdf
55. Z. Whittaker, ZDNet Article. Fear the Reaper? Experts reassess the botnet's size and firepower. (2017), https://www.zdnet.com/article/reaper-botnet-experts-reassess-size-and-firepower/. Last accessed 25 Nov 2020
56. D. Holmes, J. Shuttuck, F5 Labs. Blog reaper: The professional bot Herder's thingbot. (2017), https://www.f5.com/labs/articles/threat-intelligence/reaper-the-professional-bot-herders-thingbot#:~:text=Size%20and%20Position,nearly%2085%2C000%20devices%20per%20day. Last accessed 25 Nov 2020
57. EMnify Article, "Iot for all" IoT attacks, hacker motivations, and recommended countermeasures. (2020), https://www.iotforall.com/iot-attacks-hacker-motivation#:~:text=IoT%20attacks%20increased%20by%20900%25%20in%202019.&text=Multiple%20devices%20with%20the%20same,owners%20deploy%20their%20machines%20remotely, Last accessed 14/11/2020

Chapter 18
Privacy-Secure Link Utilization Routing Algorithm (PSLU) for Improving Performance in IoT and Cloud Computing

P. Deepavathi and C. Mala

18.1 Introduction

Cloud provides data storage capacity and provides on-demand resources whenever and wherever needed. Many data centers are available for providing services to the clients. Cloud servers are located in multiple locations that are managed by the central server. The main advantages of the cloud are sharing the resources to reduce the cost. Industries and companies are using the cloud to upload and run applications quickly.

The low-cost systems, large storage capacity, and highly connected computers, hardware virtualization, autonomous, and utility computing lead to the growth of cloud computing. The cloud service provider should have known about intrusion detection, firewall, and unwanted attacks inside the network. Cloud computing providers offer many services related to different models likes Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (SaaS). All models are independent of each other.

All these models are offering more operational facilities, depending upon the environment in which each model is used. Cloud computing has the option to access the services at any time. Purposefully or accidentally the information might be altered or deleted. Many cloud servers share information with other cloud servers. So the cloud users should use some of the encryption techniques when storing the data in the cloud for avoiding unauthorized access.

The following different types of threats affect cloud infrastructure: insecure interfaces, hardware failures, data loss, and leakages. These all together make the shared environment vulnerable. The cloud infrastructure is used by many of the

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users; hence there are the possibilities of information belonging to different clients which resides on the same cloud server. Additionally, advanced technologies and hackers are waiting and looking for ways to penetrate cloud networks. Because thousands of organization's data are stored on cloud servers, the hacker can gain huge information through a single attack known as hyperjacking.

Confidentiality and security are very important when a new technology is shared by many users. Encryption of original data is making them difficult to identify the intruders. Using some of the advanced tools for encryption, for example, proxy re-encryption [13] for implementing dynamic tree structure for document sharing, so indexation and de-duplication can be implemented, some of the models are developed with zero-knowledge privacy for making unidirectional proxy signature [14] reducing the computation cost while maintaining the security. But it is not suitable in large datasets. Wang [15] designed BP-XOR codes for secretly sharing data using three Schemes BP-XOR, LDPC, and Pseudo BP-XOR. But here collusion attack prevention is very difficult.

The latest technology in the Internet of things brings small-size and low-cost IoT-enabled infrastructures. It generates lots of interest in research and the industrial revolution. IoT belongs to heterogeneous networks that have security problems in sensor networks and communications through the Internet. And also IoT brings privacy problems in networks, authentication problems, and security problems in routing. Users feel insecure in IoT and cloud when facing unauthorized attacks and machines connected worldwide through the network. The basic structure of IoT is the interconnection of networks; here routing plays a major role in the network. The routing has several problems like traffic in routes, packet loss, and consuming more power. Securing the IoT networks from various threats and attacks is a challenging task. These IoT and cloud technologies are used in every person's daily life, e.g., banking, ATM, and in many home appliances. This book chapter considers routing and security in cloud and IoT-related things, so it will reduce the waiting time, minimize the information loss, and also improve the security, so automatically these concepts help to improve the performance of various things in society.

This chapter proposing privacy-secure link utilization (PSLU) routing algorithm considers the congestion problem in routing and energy consumption of each link. The low utilization links are identified and make a disabling link. Then by using packet encapsulation techniques, privacy is provided for each packet. The remaining sections of this chapter are Sect. 18.2 which is related work. Section 18.3 gives the detailed processes of working methodologies. Section 18.4 explains the simulation results and performance analysis. Section 18.5 gives the conclusion of this proposed method.

18.2 Literature Survey

Many of the research are going under cloud and IoT environment routing problems; some of the existing technologies are surveyed in the following section.

In this paper Ang Dingde, Xu Zhenzheng et al. considered estimates in the traffic matrix problem in large-scale backbone networks. To get an accurate estimation, the author has used recurrent multilayer perceptron (RMLP) techniques. To improve the constraints relations between traffic matrix and link loads, the author has introduced spatial and temporal correlations concepts, it make changes in traditional recurrent multilayer perceptron model.

Here Md. Trareq Mahmud, Md. Obaidur Rohman et al. proposed reliability-based distance-aware cooperative medium access control for wireless networks. Here the authors have considered several metrics, residual energy, delay, and signal to noise ratio. It is suitable for selecting a relay node by using a supportive trustworthy factor. It increases performance than the existing concepts [2].

In this paper, Francesco et al. proposed a study of unsupervised learning techniques applied in IoT data to support decision-making processes inside intelligent environments. The authors have discussed two case studies to assess the proposed approach, and the unsupervised learning techniques complement the traditional services with the new decision-making one [3].

Tian Wang, Yaxin Mei et al. proposed the edge-based model for data collections. Here the author introduced twofold concepts, where a small amount of data stored in local systems and the remaining parts of data are stored in the cloud, so the hackers cannot hack the full information. But the disadvantage is if one part of the data is destroyed, it is very difficult to recover [4].

In this paper the authors have explained and discussed how the trusted data are collected from sensors; to collect trusted data, the author proposed trustworthy data collection model, evaluating sensor nodes in multiple dimensions to obtain accurate trusted values. The main drawback of this model is the sensor may collect trusted data but in the next level process may be penetrated by hackers [5].

Antonio Ciatrani, Vincero Eramo et al. proposed a three-phase algorithm, in that the first phase is to elect router with their own shortest path, in the second phase the neighbor routers are power off, and in the third phase, new modified path will be computed. But the major drawback is all processes will take more time [6].

The authors Nai-Wei lo, Chao Yang et al. proposed anonymous secure routing protocol based on hash functions for avoiding many types of security threats; the major drawback is that calculating hash function is a time-consuming process [7].

In this paper, the authors proposed hierarchical data job scheduling strategy based on intelligent sensor cloud in fog computer (HDJS) to avoid the problems of starvation. So resource utilization was improved and execution time also reduced. The problem is all the jobs are getting the chance to execute, so unnecessary process takes CPU time [8].

In paper [9] the authors have explained mobile intelligent computing based on compressive sensing data gathering (MIC-CSDG) algorithm for reducing energy exhaustion in rapid networks [9].

Wenwen Gong et al. described locality-sensitive hashing that protects the privacy of users over multiple quality dimensions. While users going to access a wide range of services like movies and food are migrating to the mobile infrastructures, it makes the user's information vulnerable to leakage. In this paper, only one dimension is considered, but multiple quality dimensions are not considered [10].

The authors proposed SimHash function that is SerRec Sim Hash for avoiding scalable service and for privacy preservation. The main drawback is SimHash is probability based that it failed in some of the situations. To avoid this, the author should add more semantic information [11].

Yilei Wang, Minghao Zhao, et al. discussed a secure computation protocol under asymmetric information. But the author proved only in theory; this proposed method lacks in real data [12].

Jose V.V Sobral et al. proposed lightweight on-demand ad hoc distance vector routing protocol next generation for considering shortest path creation and avoiding transmitting packets through broken routes, but it increased memory usage [15]. Fatemeh Safara et al. proposed a priority-based energy-efficient routing method for IoT systems for reducing the problem of low power and lossy data and improving robustness [16].

18.3 Proposed Work

In this chapter the proposed algorithm is privacy-secure link utilization algorithm, the block diagram of the proposed algorithm (see Fig. 18.1). This proposed algorithm (see Algorithm 1) includes the initialization to find a secure path and optimized disable path algorithm to disable the paths that are not used. Then checks the authentication of each packet when it traversing through the particular route. If it is authenticated each router adds the encapsulation header which improves the strength of each packet. The whole process is repeated until the whole information are received by the corresponding receiver.

Consider the graph G: V is a group of nodes, E is a group of links, and W denotes link weight. To calculate the energy consumption of the network, the following formula is used:

$$\eta = Th_{net} / E_c \tag{18.1}$$

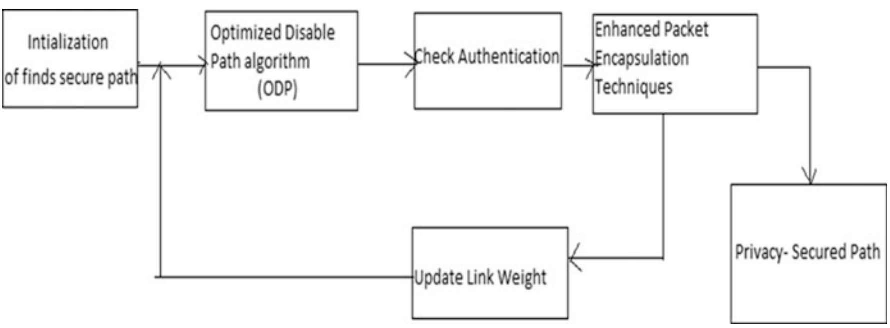

Fig. 18.1 Block diagram of the PSLU algorithm

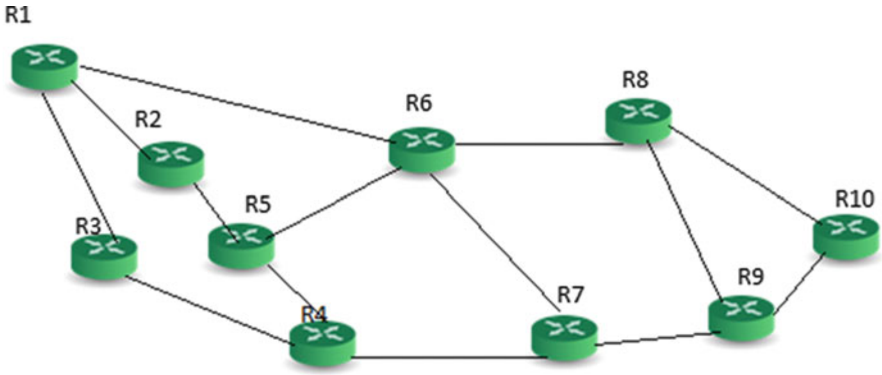

Fig. 18.2 Cloud and IoT network routing

In the above Eq. (18.1), Thnet denotes the throughput of networks. Ec denotes energy consumption of networks.

$$Ec = \Sigma SN \ \epsilon V \ \ \Sigma SD\epsilon V \tag{18.2}$$

In the network, the consumption of energy is computed by Eq. (18.2). Here SN denotes source node and SD denotes destination node. The cloud and IoT network routing structure is shown in Fig. 18.2.

The network energy is constructed by using a lot of links, and each link has some features that are denoted by Eq. 18.3:

$$LE = \Sigma LNij\epsilon E \ Pij\epsilon E \tag{18.3}$$

In Eq. (18.3), LNij tells the number of links, and Pij denotes the power of each link belonging to the particular source and destination. Reducing the energy consumed by the whole network is solved by the proposed optimized disable path (ODP) algorithm. This algorithm disables the link which is not used at that time. The links are disabled not permanently. The disabled links will be enabled if the next transmission needs that link for further communication, but at that time some other unused links are disabled. This disabling process will reduce the energy consumption of networks and also reduce congestion.

18.3.1 Optimized Disable Path (ODP) Algorithm

This proposed algorithm disables the unused links which are not passing any information in that particular time. For example, consider Fig. 18.2. Router R1 wants to forward the data packet to Router R6. There are many ways possible.

Based on the link weight and by using Dijkstra's shortest path algorithm, the path is selected:

$$R = \{ri, \quad 1 \le i \le N\} \tag{18.4}$$

In Eq. (18.4), R denotes the maximum possible paths between source and destination. So any one of the routing among the three is used, so the other two routers are active in the time, but not forwarding any packets, so the proposed algorithm takes steps to disable the unwanted paths. Eqs. (18.5) and (18.6) denote the maximum used paths and not used paths:

$$MaxUL = \Sigma Ri \;\; 1 \le i \le N \tag{18.5}$$

$$LinkNU = \Sigma Ui \;\; 1 \le i \le N \tag{18.6}$$

18.3.2 Privacy-Secure Link Utilization (PSLU) Algorithm

This proposed privacy-secure link utilization (PSLU) routing algorithm concerns about the privacy of each packet. After considering the link utilization, the secure transmission of the packet is processed. The protocol structure of the proposed algorithm is shown in Fig. 18.3.

In Fig. 18.3 (see Fig. 18.3), the version tells the current version of this protocol, types give identification of message type, code identifies the message code, status tells the current status of the packet, header checksum detects an error if occurred, and hop limit gives the hop count between source and destination. Router ID gives the intermediate router information, and the sequence number is used for identification of order of packets, the message is the information in each packet, and finally, the authentication field improves the security of this protocol:

<table>
<tr><td>version</td><td>type</td><td>code</td><td>Status</td><td>Header checksum</td></tr>
<tr><td colspan="2">Hop limit</td><td colspan="3">Router ID</td></tr>
<tr><td colspan="2">Sequence Number</td><td colspan="3">Message</td></tr>
<tr><td colspan="5">Authentication</td></tr>
</table>

Fig. 18.3 PSLU protocol structure

$$AP = \Sigma\Sigma CLij = 2nMT\left(L^{+}\right) \tag{18.7}$$

Eq. 18.7 has AP (authenticated packets) and MT which denotes transform matrix. To normalize the authenticated packet network path, the following Eq. 18.8 is used. If the packet is encapsulated and authenticated, it will be delivered; else it will be dropped:

$$C^{'} = 2MT\left(L^{+}\right) / (n–1) \tag{18.8}$$

Algorithm 1: Privacy-Secure Link Utilization Algorithm

```
1)     Input: Given Networks and Information's to send
2)     Output: Privacy Secure Link
3)     Set: LW (Weight of the Link)
4)     RP(Router finds the path)
5)     Lmax (Capacity of the Link)
//Invoke Optimized Disable Path Algorithm to disable the unused
      Links
6)     [new_LW, DL]= ODP (R,LW);
//new_LW denotes weight of the new link
//DL denotes the Disabling Link
7)     S=constant %Number of paths between source and destination
8)     for i=1,2,....s do
//Use Dijisktra Algorithm
9)                        Short_Path=Dijkstra(LW,Src,Desn)
% After updating Weight of the Shortest Path
10)                    If short_path=0 do
11)                       h=len(short_path)
%Invoke Privacy Secure Algorithm
12)                        CALL S^P=Secure(S^max)
13)                        Temp=S^max
%Checks Path whether it is Encapsulated or Not.
14)                    For k=1 to m-1 do
15)                        If S^max(short_path(m),short_path(m+1))
16)                      LW(short_path(p), short_path(p+1) *100
17)                    Accept
18)                    Else
19)                   Reroute Processin
20)                       Goto CALL
21)               End
22)            End
```

18.4 Simulation Results and Performance Analysis

The proposed privacy-secure link utilization (PSLU) routing algorithm is simulated by using NS2 simulators. The following simulation parameters are used to validate the proposed algorithm (see Table 18.1).

Table 18.1 NS2 simulation parameters

Parameters	Values
Runtime	120 sec
Coverage region	500 m *500 m
Protocol	PSLU
Process interval	0–30s
Packet load	1000 packets
Total links	30
Total nodes	30

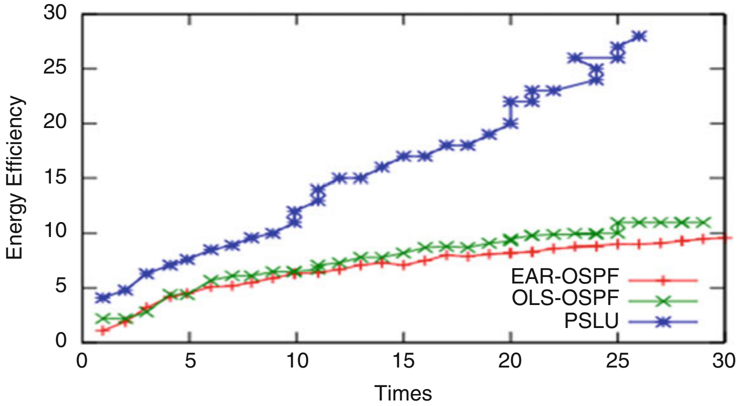

Fig. 18.4 Energy efficiency of PSLU algorithm

The experiment was conducted with 30 nodes with 50 routing links. Here we will compare the proposed PSLU algorithm with energy-efficient algorithm based on OSPF that is EAR-OSPF, and another one algorithm is optimal link sleeping based on OSPF that is OLS-OSPF. The simulation result of energy efficiency is achieved by the PSLU algorithm (see Fig. 18.4). The horizontal axis denotes the number of the user request, and the vertical axis denotes the energy level of each algorithm.

The simulation result of the number of disabled links is shown in Fig. 18.5. The proposed algorithm has taken the responsibility of disabling the links which are not in use. The existing algorithms have not taken any steps to unused links. So the unused links are also consuming energy. This proposed algorithm overcomes the existing one.

The unused links are disabled, so the network's life span has increased compared to the existing algorithms. Here in the x-axis, the network range is given in meter. The y-axis has how many levels the network life span increased. The relationship between the network range and network life span is given (see Fig. 18.6).

The simulation result of link utilization in the proposed algorithm is shown in Fig. 18.7. In this figure, the networks' link utilization in some areas is higher than existing algorithms and sometimes lower than existing algorithms, which shows

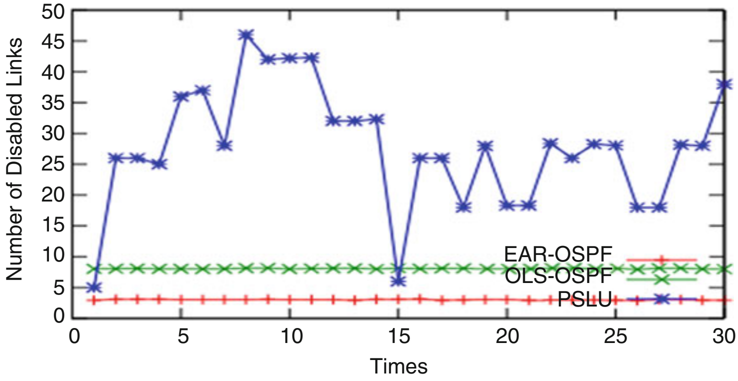

Fig. 18.5 Number of disabled links

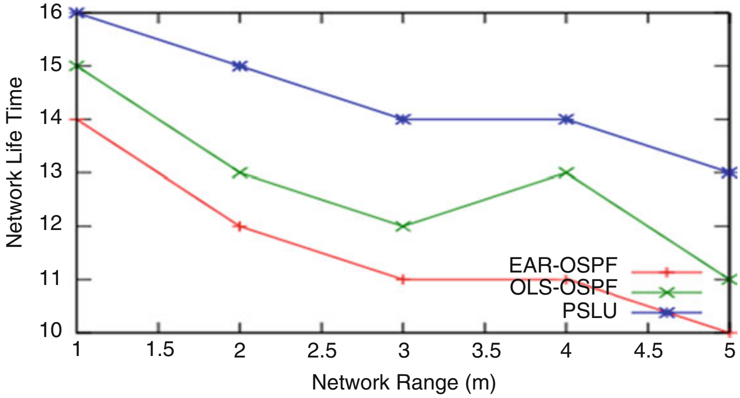

Fig. 18.6 Network life span increased by PSLU algorithm

the proposed algorithm reduces the wastage of links as well as reduces congestion occurrences of links.

The link utilization of existing algorithms and the proposed algorithm is shown in Fig. 18.8. Here on the x-axis, the number of nodes used in the experiments is given, and on the y-axis, the link utilization of three algorithms is given. The link utilization of the proposed algorithm is higher than existing algorithms for reducing the wastage of links and is lower than existing algorithms to reduce the congestion.

This proposed privacy-secure link utilization (PSLU) routing algorithm is using packet encapsulation techniques to protect each packet from an unnecessary network problem. So the maximum numbers of packets are transmitted securely without any packet loss. The network range is 500 m; 1000 packets are transmitted. Initially, maximum numbers of packets are transmitted; if the network range is increased, the number of packets transmission slowly goes down. The proposed algorithm gives a better result than the existing algorithm (see Fig. 18.9).

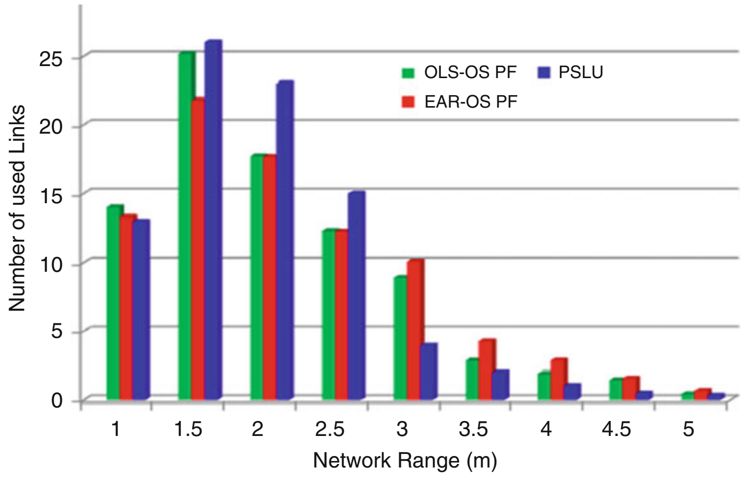

Fig. 18.7 Number of used links

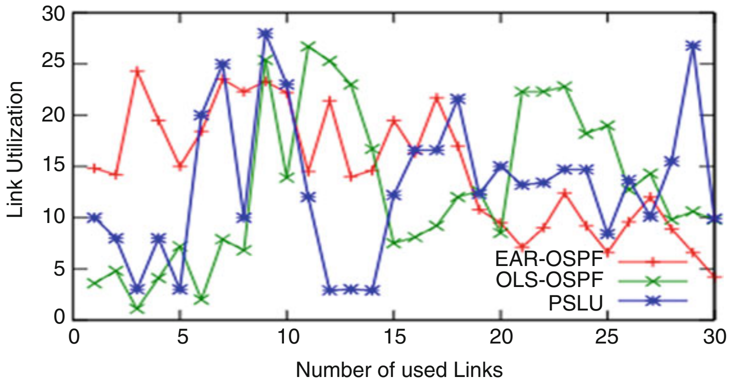

Fig. 18.8 Link utilization of PSLU algorithm

The number of dropped packets also reduced by using the proposed algorithm (see Fig. 18.10).

18.5 Conclusion

This chapter proposed privacy-secure link utilization (PSLU) routing algorithm to reduce the routing problems in IoT and cloud infrastructure. The low utilization links are identified and disabled by using the optimized disable link algorithm. It reduces the traffic and congestion and increases energy efficiency and networks' life span of cloud and IoT networks. Moreover, privacy-secure link utilization

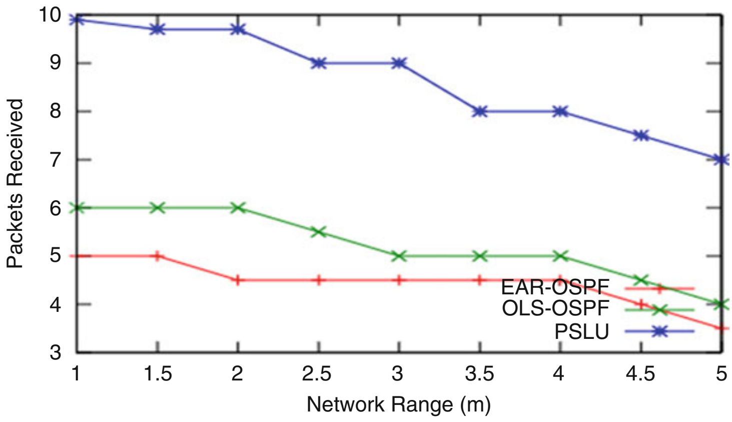

Fig. 18.9 Number of packets received

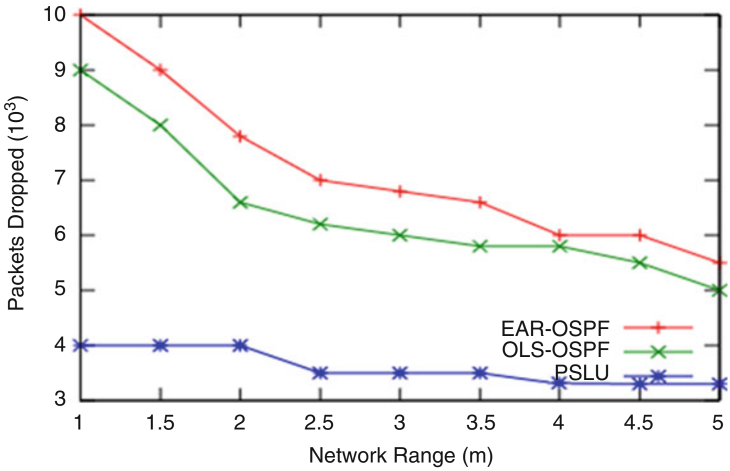

Fig. 18.10 Number of dropped packets

(PSLU) routing algorithm uses packet encapsulation techniques to make secure transmission which improves the robustness of cloud and IoT infrastructure. This concept improves the performance of various cloud and IoT-related things in society. The NS2 simulation results show that the PSLU routing algorithm gives better performance than the existing routing algorithms.

References

1. D. Jiang, X.U. Zhenzheng, et al., An approximate approach to end-to-end traffic in communication networks. Chin. J. Electron. **21**(4) (Oct 2012)
2. Md.Trareq Mahmud, Md. Obaidur Rohmen, et al, An efficient cooperative medium access control protocol for wireless IoT networks in smart world system. J. Netw. Comput. Appl. **133**, 26–38 (2019)
3. F. Piccialli, G. Casolla, et al., Decision making in IoT environment through unsupervised learning. IEEE Intell. Syst. (2020)
4. T. Wang, Y. Mei, Edge-based differential privacy computing for sensor cloud systems. J. Parallel Distrib. Comput. **136**, 75–85 (2020)
5. T. Wang, L. Qiu, et al., Edge-computing-based trustworthy data collection model in the internet of things. IEEE Internet Things J. (2020)
6. A. Ciafrani, V. Eramo, et al., *An Energy Saving Routing Algorithm for Green USPF Protocol* (IEEE INFO COM, 2010)
7. N-W. Lo, C. Yang, Hash-based Anonymous Secure Routing Protocol in Mobile Adhoc Networks. 2015 10th Asia Joint Conference on Information Security
8. Z. Sun, Chuanfeng, Intelligent sensor cloud in fog computer: A novel hierarchical data job scheduling strategy. (2019)
9. H. Shao, X. Zeyusun, Mobile intelligent computing in the internet of things: An optimized data gathering method based on compressive sensing. IEEE Access (2019)
10. W. Gong, Lianyong, Privacy-aware multidimensional mobile service quality prediction and recommendation in distributed fog environment. (April 2018)
11. Y. Xu, L. Qi, et al., Privacy-preserving and scalable service recommendation based on SimHash in a distributed cloud environment. Complexity (2017)
12. Y. Wang, M. Zhao, et al., Secure computation protocols under asymmetric scenarios in the enterprise information system. Enterp. Inf. Syst.. ISSN:1751-75 (2019)
13. M. Adil, R. Khan, et al., An efficient load balancing scheme of energy gauge nodes to maximize the lifespan of constraint oriented networks. IEEE Access (2020)
14. W. Wei, J. Wu, Special issue on situation awareness in intelligent human- computer interaction for time-critical decision making. IEEE Intell. Syst. (2020)
15. J.V.V. Sobral, J. Jose, Improving the performance of LOADng Routing Protocol in Mobile IoT Scenarios. IEEE Access, Digital Object Identifier, Access (2019)
16. F. Safara, A. Souri, et al., PriNergy: a prioriy-based energy-efficient routing method for IoT systems. J. Super Comput. **76**, 8609–8626 (2020)

Chapter 19
A Smart Home Appliances Controlling Application (HACA-App) with Highly Secretive System

Mohammad Zeyad, S. M. Masum Ahmed, Md Sadik Tasrif Anubhove, and Md. Shehzad

19.1 Introduction

The advancement of information technology has resulted in a modern way of transmitting and disseminating information. Updated IT technology and digital media have given rise to the changing role of government in transforming ordinary cities into smart cities. It is possible to render house smarts by controlling the appliances remotely. However, technologies such as ICT and IoT have generated good potential for smart cities which have social responsibility for local protection. Smartphones and app are becoming famous and growing the effect of IT on the security of local culture.

The key goal of today's scientific research is to simplify life. The environment today is strong on the demand for an electronic control device for domestic appliances. During this time-consuming energy, energy can be saved without

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disrupting our everyday lives when automatic remote load control applications are used [1, 2]. Fossil materials, diesel, and natural gas are being consumed in the wild; natural energy sources are being exhausted in nature [3–7]. Clandestinely, a lot of energy is continually being lost in households. When people sleep or stay away from home, they fail to turn off appliances such as TV, lamps, etc. So they're not mindful of the amount of energy they use. Hence, often people have a lot to pay for the energy bill. If this issue is not addressed explicitly, the upcoming generation will face many challenges due to the dwindling quantities of fossil fuels remaining in the country.

Now anyway, home security monitoring has become highly important and enticing. It represents the effectiveness of our lifestyles by digitizing different electrical and electronic systems or resources. Android cellphone app is becoming even more prominent with application developers due to its strong capability and role identity. It's a great medium for ultimate device control because it provides enough tools and also involved several features.

Most of the time, technology is being built which unlocks household equipment in our house to switch on and off dynamically, based on human operation [8]. The IoT infrastructure is a device that includes many forms of electrical Internet-based devices. At present, the pace of mobile growth is unparalleled. Thus, citizens can control household equipment remotely from almost everywhere from virtually any distance utilizing a mobile, through which the application is adequately prepared to display all of the information promptly.

However, operating household appliances using an app is not a widespread habit in some countries like Bangladesh. This paper illustrates the suggested strategy for designing such a safe device control scheme that will operate with the Android smartphone application. Pattern identification, fingerprinting, and face/image detection and recognition capabilities have been applied to this app to boost device reliability. Nevertheless, both the program and the device will require a binary password authentication protocol. This program will be used in any residence of the city to complete the smart city administration project, and the overall energy method can be measured precisely for the entire city or district. The application offers a systematic human life to avoid the lack of energy consumption, making daily life more comfortable for people. Characterizing the chapter, Section II describes the analysis of the literature; Section III describes the work description of the HACA-app; Section IV describes the architecture of the system proposed, including hardware and software execution; Section V describes the implemented application design; and Sect. VI ends the report.

19.2 Literature Review

Smart home appliances are becoming highly popular with them with its many advantages [1, 2]. In the past few years, homeowners and consumers alike have had secure, reliable, and smart home app devices as vital needs. The market for smart home solutions is growing regularly. There is also a need for comprehensive analysis and analysis, including relevant applications, definitions, and details on the manufacture of its components. Khilda A. and her team have created a limited, Android-based wireless home entertainment system. The machine only runs on low-power equipment. They are designing a really basic but intelligent home technology with a different strategy. The application will run upon many mobile models, as well as on J, K, L, and M versions of the Android operating system. The ignorance evaluation of the primary theme shade was the core objective of this research [9]. On the other side, a mobile app for a museum based on iBeacon and cloud storage has been suggested by Binyue Cui and his staff. In reality, they suggested the creation of the software museum focused on multiple interests or tailored to iBeacon smartphones. The app was a conduit between mobile users and a set of visual aids, including regional and virtual. They also developed a method designed by Android Studio (client) and Eclipse (server). This device successfully manages the museum equipment that operates on a computer [10].

M. N. Jivani has suggested a GSM-based smart home system using the Android smartphone app inventor, which defines the GSM (Global System Messaging)-based protected remote controller scheme using the Android smartphone application innovator. The aim of the GSM home appliance system (GHAS) is to use the built-in SMS and GSM modem smartphones for the automation of household appliances. The entire framework program has been developed using the Android and C language app inventor [11]. X. Mao and his partners have developed and deployed a modern smart home monitoring scheme based on the Internet of things that proposes a new infrastructure based on the Internet of things and a cloud computing network, a handheld android terminal, and an integrated home portal. It relies on human-computer interaction, however. A large proportion of intellectual controllers are signaled by the user to the active systems, although the technology cannot be suitable based on environmental conditions and needs to adapt to adjustment [12].

Tanweer A. presented a concept with his team that focused on smart home automation for the growth of smart cities. The device was able to monitor home automation remotely using Bluetooth. It has the ability to automate with just a simple press of a button or a voice order to handle items at home. The device would give the customer a chance to select Bluetooth or Wi-Fi shortly [13]. Robert S. and Raul R. proposed distant control Android-based home automation systems with Arduino Super 2560 and ESP 32. They also developed safe and inexpensive home apps and explored how some of the applications can be run from very wide distances using Wi-Fi and mobile technologies [14]. Dan I. G. and his team are developing a technology based on a home automation system via Arduino microcontrollers. A scale model was a smart house. It used actuators with a set movement from 0 ° to 180 ° for the closure and openings of walls and ceilings and was used as a door lock monitored and controlled by a development environment [15].

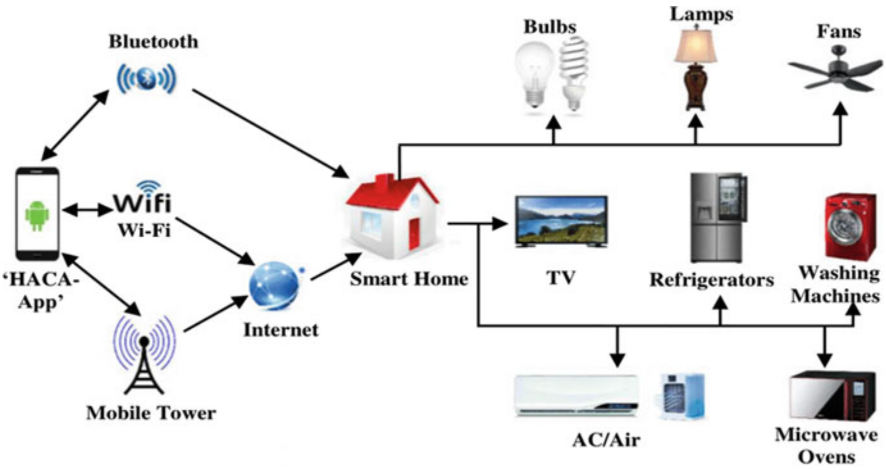

Fig. 19.1 Operating principle of smart home mobile device framework

19.3 Operational Framework of HACA-App

A smart home mobile application technology indicates that electrical and electronic appliances can even be centrally and intelligently controlled in a home atmosphere which makes life more comfortable while providing flexibility, security, safety, and durability to its inhabitants. The idea seeks to render the home appliance device more diffuse and interactive. Besides, residential electrical devices, closed-circuit televisions (CCVTs), detectors, etc. have been upgraded to a broad variety of appliances to enable comfortable access and connectivity. The IoT will help create several techniques that use data gathering from a framework like this to provide technological services to individual organizations, diverse processes, individuals, and many service-oriented sectors [6, 16]. The idea of home appliances operating the device through a smartphone application is displayed in Fig. 19.1.

Figure 19.1 depicts a framework that utilizes intelligent devices to smartly monitor home appliances from anywhere via cell data/Bluetooth connectivity/Wi-Fi link through an application to enable human life appealing and simpler. For the city that's smart, home appliances play an extremely significant place among many Internet of things (IoT) applications. The current Bangladeshi government plans to create green cities in the world and will rapidly maintain a wide variety of smart home automation solutions.

19.4 System Design

An application that is usable on the smartphone is the main goal of combining system operating devices based around the microcontroller. Nowadays, most of the smartphone was used Android as its Operating System (OS), so Android is the selected OS for the proposed app design. Essentially, during the device runtime, the Android framework generated two files. The very first of these is the Java file for controlling the entire process, and the second is an XML file and is only used on the application itself to customize the viewpoint to all methods. Jelly Bean 4.1 Android is the default Android operating system version for all handheld Android users. The standard procedure for the production of a home appliances controlling application (HACA) based on the microcontroller is described in this segment. Then it includes a schematic for the device blocks and a helpful flowchart. The HACA-App device configuration and application method of the whole system is often seen to explain the system protocol. The proposed design of the system comprises hardware and software. Besides, the system is designed as per the regulations of the integrated structure. To complete the software section and develop the HACA application, a new innovative C-code algorithm for the precision functionality of the microcontroller is expected. The management and control of device components, such as cell data (GSM method)/Bluetooth connectivity/Wi-Fi link, were often pursued in the same way.

19.4.1 System Hardware Design

The circuit is designed to take into account the simplification of applications. Various interchangeable modules may be linked and communicated to provide the highest quality of service to the smart home monitoring system. The principal area used to track the smart home loads over the smart asset was selected as microcontroller (MCU-ATmega32p). The main portion for the network circuit architecture was chosen as the GSM module, the Wi-Fi module, and the Bluetooth (BT). Some modules are also used to fulfill the design purpose of the unit, such as the Arduino Uno board, condensers, resistive systems, buck conversions, glass oscillators, connections, transistors, etc. A microcontroller is a self-contained device that can be used as an incorporated peripheral, memory, and processor unit [1, 2, 17–23]. So that's why the microcontroller is classified as an "embedded controller" [1, 2, 18, 22, 23].

The majority of programmable microcontrollers are used as an embedded interface for many consumer products and equipment components such as computers, vehicles, peripherals, and household appliance systems [1, 2]. GSM plays a crucial role and can have a major effect on network trust, communication distance, shared use of power, and other indicators, in acquiring and transmitting information across the cellular networks.

The structural block diagram of the home equipment system based on the microcontroller is shown in Fig. 19.2. This diagram marks the MCU, Bluetooth is a slave module for supplying Bluetooth-based connectivity for a technical device [24, 25], the Wi-Fi device has been interconnected from its dispersed modules to the home networking platform [26], and the GSM/GPRS mechanism via an SMT

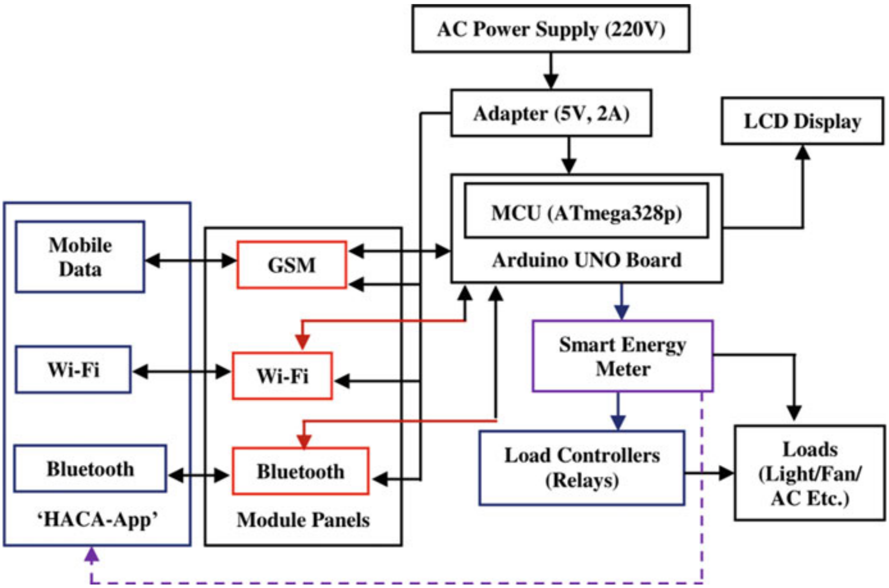

Fig. 19.2 Proposed system systemic block diagram

(surface-mount technology) formula can be implemented into client applications [25, 26]. GSM is indeed a quad-band in its entirety.

The microcontroller is still the most common programmable device used to create a smart home technology platform [2, 18–23]. The MCU (ATmega328p) is used to execute the system's hardware (prototype). The adapter (5 V, 1A) system for AC-DC (220 V AC-5 V DC) was used, which obtained the correct voltage for the MCU. To run the loads with the required voltage, the microcontroller was attached to the load controls (such as the relay). A bucking transformer has been used to reduce the voltage of the microcontroller. The crystal oscillator was initially used in the circuit to lower the negative polarity of a molar by an unknown negative polarity. A buck converter often plays an important part in reducing the negative cycle polarity.

For the energy meter, on the other hand, the MCU transforms analog data to digital data after obtaining data from analog-formed power meters. In the HACA-App, MCU transfers the next instruction, the electrical bill, for the whole load. Via the analog energy meter, the microcontroller can obtain guidance. MCU then transforms the analog to the automated command and submits it to the HACA application. Thus the consumers know the load usage ease. Besides, for protection reasons, the consumer may obtain an alert from the device. A self-alarm system to warn the consumer about any incident was also introduced to the system.

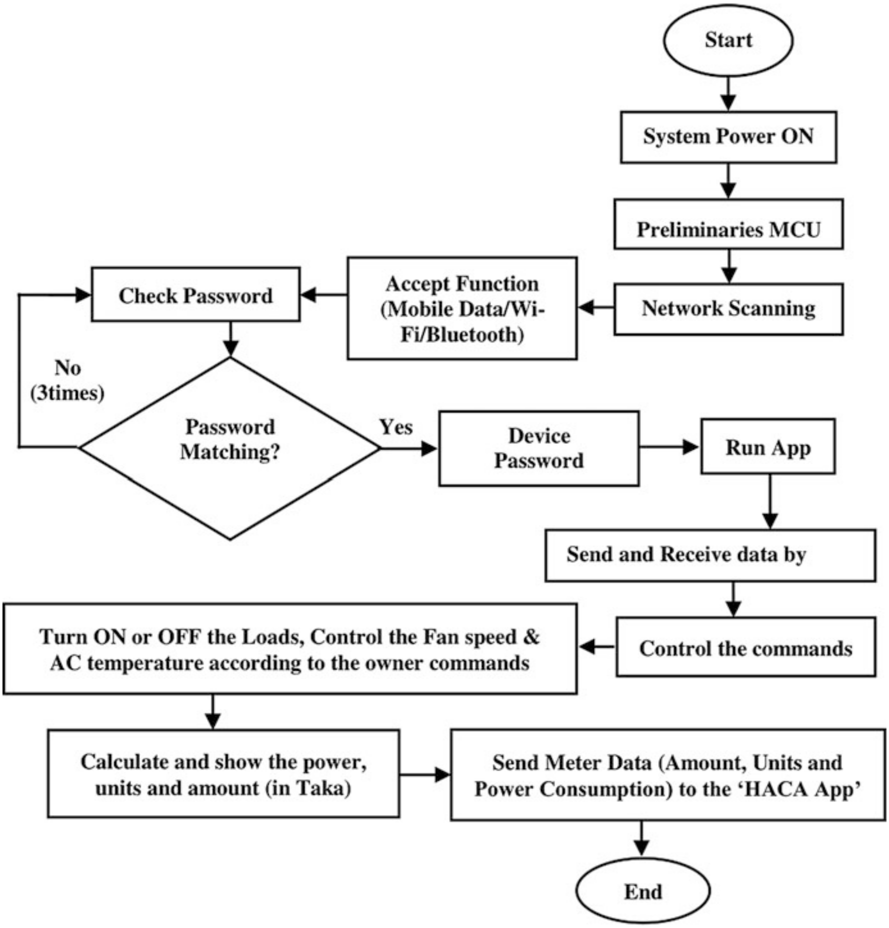

Fig. 19.3 HACA-App flowchart configuration of the proposed framework

19.4.2 System Software Design

Figure 19.3 demonstrating an algorithm flowchart of "HACA-App." In ATmega328p, i.e., microcontroller (MCU), the system files will initially be imported. Specific work began to be carried out by the system, like checking the whole process, the necessary input voltage (V_I), current (I), and so on.

Every assignment was then re-established to execute commands. A voltage (V) and current (I) control framework was built in the graphical interface using the programming language C. The method introduces the hardware and software and then releases several task modules, beginning each module according to the initialization process known as priority. Initially, the start-up process begins the scheme clock and performs the codes to initiate the interrupt operation. Then the scheme can be tested, and the module phase can be triggered. Eventually, the scheme can begin to perform a variety of operations. Using the assembly language, the code was written and compiled using Arduino, which created a hex file that was burned with an IC burner.

Next, the device file was mounted to the microcontroller [MCU-ATmega328p]. The software would continue incorporating its range of operations, including certain global mobile control, GSM, Wi-Fi, Bluetooth compatibility tests, and so on. Therefore the instructions are restarted for every node. Request the accepted function by connecting it to the request, i.e., cell data/Bluetooth connectivity/Wi-Fi link access. The HACA-App then asks the consumer for a pin that is set by your computer. The command will be sent to the machine to verify the pin code if it fits the login stated. Moreover, pattern recognition, fingerprint, face/image detection, and recognition features are also available for the user. This method also prevents the system from accessing the entire framework. When the user places the incorrect pin code/pattern three times successively, the device will lock the application and alert the user of an unlocking instructions guide with an email or SMS.

19.5 Application Design

The key objective of the system is to combine such a sort of home automation network operating method with an Android mobile application that enables household appliances and even some appliances from there and any range to be tracked and managed to transform a typical home into an elegant building. The HACA-App is built to maintain in mind that the device will have an expanded, adaptable home control system, with a highly confidential system that offers a user-friendly interface and facilitates the installation.

The app complies with the specifications:

1. An Android-based app (see Fig. 19.4) was designed to remotely monitor the home gadgets by running the proposed framework from anywhere. Besides, a manual and automatic setup are both provided in the system setup.
2. First of all to link to Bluetooth/Wi-Fi/mobile data for accessing the software and for running it.
3. The HACA-App allows a password to be entered such that the user can set his/her password. Furthermore, users should still adjust their password. The software will monitor the load of home appliances after entering the password.
4. User can also set the security of the app through pattern recognition, fingerprint, and face/image detection.
5. User can change anytime the security pattern by just entering in the "HACA Account" section which is available in the "Manage" segment.
6. Moreover, recognition features have been added to improve system reliability.

Fig. 19.4 (**a**) Specify password, login HACA-App; (**b**) paired with cell data/Bluetooth connectivity/Wi-Fi link; (**c**) welcome to HACA-App, *Select options*; (**d**) select Settings: add locations, check connected appliances, notifications, update HACA-App, etc.; (**e**) select Add: add rooms, appliances, devices, energy meter, etc.; (**f**) select Manage/Edit: manage HACA account, edit features, manage temperature, etc. HACA-App flowchart configuration of the proposed framework [screenshots]

7. To render home smart, a user-friendly security mechanism is incorporated into an application that regulates lighting, fans, and other gadgets from smartphones that helps defend home appliances against unintended users (Fig. 19.4).
8. It will help to allow the app their number of operations known, such as GSM, Wi-Fi, and a Bluetooth processor. The instructions for each node are then restarted. Request the accepted function by linking to the application connectivity/Wi-Fi cell data/Bluetooth connection. The HACA-App then calls the consumer for a pin that is set to the computer. To validate the pin code if it matches the username defined, the command is sent to the computer. Besides, the consumer is also equipped with pattern recognition, fingerprint, face/image identification, and reconnaissance features. This approach stops the whole mechanism from being accessed by the machine. In three consecutive instances if the user positions the incorrect pin code/template, the computer locks the program and reminds the user of an email or SMS unlocking guidance guide.
9. Home devices monitoring over any vulnerable Android Wi-Fi device: the device can manage home devices chosen from anywhere and any distance via any Android-based Wi-Fi-sensitive computer.
10. Home devices are controlled by any responsive mobile system centered in Android: the software may pick house devices from anywhere and from any distance from Android mobile data susceptible devices.
11. Home devices monitoring via any susceptible Bluetooth system dependent on Android: the device may pick home devices from anywhere or from anywhere in the world via any susceptible Android Bluetooth device.
12. The fan regulates the pace: the fan speed can be controlled through the HACA program. Fan speed can also be operated without the manual fan speed controller.
13. The light intensity control (LIC) is tracked employing the HACA-App. The light intensity may be regulated. Thus the light strength can be regulated without the manual LIC.
14. Home appliances may be conveniently operated by turning on or off from either room, both on the building and in the property.
15. Further development can be achieved: by introducing new appealing graphical user interface (GUI) elements and the HACA framework to make the software more user-friendly and relaxing.
16. It is possible to find any nearly smart devices from HACA-App.
17. Energy meter of the apartment is also connected with the HACA-App, so that user can check the energy consumption, energy cost, and daily/weekly/monthly/yearly energy consumption.
18. In the "Settings" section, user can add more than one location and set own control/routine method. Also, in setting portion, it is possible to manage all added devices and energy meter.
19. Option like "ALERT" is also added in the HACA-App. App will automatically alert the user for any type of incidence, or it will guide user to reduce the energy consumption at daily basis.

20. Notifications, User manual, and Contact with HACA-App features are also added to the app.
21. User can "ADD" any appliances, smart devices, other smart apps, etc.
22. Moreover, in ADD section, user can create rooms so that user can control each room appliances just by entering that room in one tap.
23. It is possible to manage the home appliances through the HACA-App from any distance if the device server is active in the home.
24. User can manage or edit anything just by entering the "MANAGE" section. Features like temperature, heating, cooling, lighting, etc. can be possible to control by entering these sections.
25. Finally, user can change any security pattern by just entering the portion of HACA Account.

Based on an overview of the existing smart home app response platforms, the major specifications of this application are as follows:

1. User-friendly: the device and applications suggested can be installed quickly. Furthermore, the device is so simple to operate and track. The system is built to be more user-friendly and relaxed.
2. Privacy, confidentiality, and pseudonymity: protects privacy and making it convenient to contribute to people. There is a two-stage method for password authentication. Furthermore, the program would be blocked for 30 seconds if the incorrect password is placed in series three times. The system, as well as the app, is designed to keep in mind that to make it more user confidential, anonymous, and pseudonym.
3. Method of the bidirectional interface: contact between system users and emergency respondents is possible.
4. Real-time updating and viewing: Real-time updating and viewing of posted geographic information are also available in the HACA-App.

19.6 Conclusion

Today, in a modern age of the sophisticated home automation system, home appliances control system can be remotely controlled or worked anywhere. The innovations are being updated every day, and all of them are built to ensure one thing that allows jobs for humans simple and convenient. This paper is intended to describe and update an application for simple, financially informed, smart home automation. The Android OS platform is selected to introduce the HACA-App. The purpose is to track home loads by using the mobile device (Android) of the consumer using Bluetooth, Wi-Fi, and mobile data through the HACA application. The HACA application will save resources. The HACA-App will enable real-time monitoring from anywhere. In this security system, pattern recognition, fingerprint, and face/image detection and recognition features have been improving system reliability. Furthermore, connecting the HACA-App with the smart meter for the calculation of energy consumption through the household can be done easily. Also, the smart meter is operated on the app through two different pathways: one for high-voltage appliances and another one for low-voltage appliances. The application is also really user-friendly, simple to navigate, and secure to use. Consequently, the whole method functions. On the other side, no prior training or skills would be needed to run the program manually on the mobile. It could be deduced that the HACA-App will have substantially more research and growth space in the near future. We expect that more investigation can be conducted, which will boost user-friendliness and convenience for both the software and the system quickly.

References

1. M. Zeyad, S.M. Ahmed, M.T. Maruf, M. Shehzad, M.A. Walid, Design & implementation of a micro-controller based home appliances controlling with dual verification application system, in *2020 International Conference on Computational Performance Evaluation (ComPE)*, (IEEE, 2020 Jul 2), pp. 665–670
2. M. Zeyad, P. Biswas, M.Z. Iqbal, S. Ghosh, P. Biswas, Designing of microcontroller based home appliances governor circuits. Int. J. Comput. Electr. Eng. (IJCEE) **10**(2), 94–105 (2018)
3. S.M. Ahmed, M.R. Al-Amin, S. Ahammed, F. Ahmed, A.M. Saleque, M.A. Rahman, Performance analysis of parabolic solar cooker with different reflective materials, in *2019 International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST)*, (IEEE, 2019 Jan 10), pp. 297–302
4. S.M. Ahmed, M.R. Al-Amin, S. Ahammed, F. Ahmed, A.M. Saleque, M.A. Rahman, Design, construction and testing of parabolic solar cooker for rural households and refugee camp. Sol. Energy **205**, 230–240 (2020 Jul 15)
5. S.M. Ahmed, F. Ahmed, S. Ahammed, M.R. Al-Amin, M.N. Maruf, A.M. Saleque, M.A. Rahman, Construction of a Parabolic Solar Cooker using Mylar Tape for Rohingya Refugee Rehabilitation Program, in *2020 6th IEEE International Energy Conference (ENERGYCon)*, (IEEE), pp. 439–444
6. M. Zeyad, S.M. Ahmed, A.K. Pramanik, M.M. Rahman, M.T. Maruf, D. Ghosh, Performance analysis and scaling behavior of ultra-scaled III-V (InAs) HEMTs system with 2-D tunneling effects on leakage current, in *2020 IEEE Region 10 Symposium (TENSYMP)*, (IEEE, 2020 Jun 5), pp. 48–51
7. S.M. Ahmed, S.M. Ahmed, M. Zeyad, An approach of a Nearly Zero-Energy Building (nZEB) to build an official zone with Micro-grid, in *2020 6th IEEE International Energy Conference (ENERGYCon)*, (IEEE), pp. 662–667
8. T. Adiono, S. Harimurti, B.A. Manangkalangi, W. Adijarto, Design of smart home mobile application with high security and automatic features, in *2018 3rd International Conference on Intelligent Green Building and Smart Grid (IGBSG)*, (IEEE, 2018 Apr 22), pp. 1–4
9. K. Afifah, S. Fuada, R.V. Putra, T. Adiono, M.Y. Fathany, Design of low power mobile application for smart home, in *2016 International Symposium on Electronics and Smart Devices (ISESD)*, (IEEE, 2016 Nov 29), pp. 127–131
10. B. Cui, W. Zhou, G. Fan, Y. Wu, Smart mobile APP of museum—Investigations and design for local culture protection, in *In 2017 12th International Conference on Computer Science and Education (ICCSE)*, (IEEE, 2017 Aug 22), pp. 38–41
11. M.N. Jivani, GSM based home automation system using app-inventor for android mobile phone. Int. J. Adv. Res. Electr. Electron. Instrum. Eng. **3**(9) (2014 Sep)

12. X. Mao, K. Li, Z. Zhang, J. Liang, Design and implementation of a new smart home control system based on internet of things, in *2017 International Smart Cities Conference (ISC2)*, (IEEE, 2017 Sep 14), pp. 1–5
13. T. Alam, A. Salem, A.O. Alsharif, A.M. Alhujaili, Smart home automation towards the development of smart cities. Tanweer Alam. Abdulrahman A. Salem. Ahmad O. Alsharif. Abdulaziz M. Alhujaili. “Smart Home Automation Towards the Development of Smart Cities”. Comput. Sci. Inf. Technol. **1**(1) (2020 Jun 30)
14. R. Susany, R. Rotar, Remote Control Android-based Applications for a Home Automation implemented with Arduino Mega 2560 and ESP 32. Technium: Romanian J. Appl. Sci. Technol. **2**(2), 1–8 (2020 Mar 29)
15. D.I. Gota, A. Puscasiu, A. Fanca, L. Miclea, H. Valean, Smart home automation system using Arduino microcontrollers, in *2020 IEEE International Conference on Automation, Quality and Testing, Robotics (AQTR)*, (IEEE, 2020 May 21), pp. 1–7
16. K. Mandula, R. Parupalli, C.A. Murty, E. Magesh, R. Lunagariya, Mobile based home automation using Internet of Things (IoT), in *2015 International Conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT)*, (IEEE, 2015 Dec 18), pp. 340–343
17. I. Potamitis, K. Georgila, N. Fakotakis, G. Kokkinakis, An integrated system for smart-home control of appliances based on remote speech interaction, in *Eighth European Conference on Speech Communication and Technology*, (2003)
18. M. Zeyad, S. Ghosh, Designing of a low cost handy cooling system, in *2018 4th International Conference on Electrical Engineering and Information & Communication Technology (iCEEiCT)*, (IEEE, 2018 Sep 13), pp. 557–560
19. M. Zeyad, S. Ghosh, M.R. Islam, S.M. Ahmed, P. Biswas, E. Hossain, Design proposal of an automatic smart multiinsect (mosquito) killing system, in *2019 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT)*, (IEEE, 2019 Feb 20), pp. 1–6
20. M. Zeyad, S. Ghosh, S.M. Ahmed, Design prototype of a smart household touch sensitive locker security system based on GSM technology. Int. J. Power Electron. Drive Syst. **10**(4), 1923 (2019 Mar)
21. M. Zeyad, S. Ghosh, M.R. Islam, S.M. Ahmed, S.R. Shoshi, Proposing a technique of a low cost automatic cooling and exhaust system for old age home kitchen, in *2019 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT)*, (IEEE, 2019 Feb 20), pp. 1–5
22. M.A. Alam, M. Zeyad, Smart cities and buildings: GSM based smart electric energy meter billing system, in *2019 IEEE International Conference on Power, Electrical, and Electronics and Industrial Applications (PEEIACON)*, (IEEE), pp. 1–4
23. M. Zeyad, P. Biswas, S. Ghosh, M.T. Maruf, M. Shehzad, M.I. Hasan, S.R. Shoshi, Design and implementation of temperature & relative humidity control system for poultry farm, in *2020 International Conference on Computational Performance Evaluation (ComPE)*, (IEEE, 2020 Jul 2), pp. 189–193
24. A.R. Delgado, R. Picking, V. Grout, Remote-controlled home automation systems with different network technologies
25. A. ElShafee, K.A. Hamed, Design and implementation of a WIFI based home automation system. World Acad. Sci. Eng. Technol. **68**, 2177–2180 (2012 Aug 28)
26. N.P. Jawarkar, V. Ahmed, S.A. Ladhake, R.D. Thakare, Micro-controller based remote monitoring using mobile through spoken commands. J. Networks **3**(2), 58–63 (2008 Feb)

Correction to: Internet of Things Based Best Fruit Segregation and Taxonomy System for Smart Agriculture

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This chapter was inadvertently published with an incorrect affiliation for the first author, Ganesh Khekare, as G H Raisoni College of Engineering, Nagpur, India. Whereas it should be Parul University, Vadodara, India. This has now been corrected.

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