Journal of Ambient Intelligence and Humanized Computing
https://doi.org/10.1007/s12652-020-02666-9

ORIGINAL RESEARCH

Automation systems in smart buildings: a review

D. S. Vijayan[1] · A. Leema Rose[2] · S. Arvindan[1,3] · J. Revathy[4] · C. Amuthadevi[5]

Received: 17 August 2020 / Accepted: 3 November 2020

Abstract

In the present scenario everyone turned into smart applications by including the intelligence into the applications and this reduces the burden of frequent interruption or control by the humans. Smartness makes the ability to interconnect more real time parameters by M2M (Machine to Machine) interaction and make wise decisions in harmful situations. Many low-cost devices are available in the market to collect the real time data and transmit them using Internet of Things (IoT). So, the control can be done remotely. In this work, few basic applications in smart buildings are going to be studied to analyze with the technical advances which can bring better solutions automatically. The details collected from different sensors will be useful for analytics and the need for smart design models for better buildings. The services needed in smart building such as security control, energy management, control and monitoring of HVAC system, water management, lighting systems, health system of elders and fire detection are going to be surveyed. The major objective of this study is to identify the issues faced by current methodologies with these applications and give a guideline for future research. From analyzing the relevant methods and needs it is observed that, the buildings construction and usage can depend on the applications, the smart system can respond intelligently for further events. In future all the traditional buildings will be automotive based on HVAC.

Keywords Smart building · IoT · Energy management · HVAC · Fire management · Elderly people care

1 Introduction

In recent scenario, a building means not only considered as simple structures. It is considered along with the systems and technology available within it, so the users can modernize and select the fundamental facilities such as lighting, security, heating, ventilation and air conditioning along with entertainment. In these applications the better utilization of advanced technologies and conservation of energy is to be given as more priority.

✉ D. S. Vijayan
Vijayan@avit.ac.in

1 Department of Civil Engineering, Aarupadai Veedu Institute of Technology, Vinayaka Missions Research Foundation (VMRF), Paiyanoor, Chennai 603104, India

2 Department of Civil Engineering, SRM Valliammai Engineering College, Chennai, India

3 Anand School of Architecture, Chennai 603103, India

4 Department of Civil Engineering, B.S. Abdur Rahman Crescent Institute of Science and Technology, Chennai, India

5 Department of IT, Prince Shri Venkateswara Padmavathy Engineering College, Tamilnadu, India

Conservation of Energy is becoming a global priority, so the primary goal of today is to achieve smart and sustainable development meanwhile lower energy buildings are having biggest threat, because of carbon emission both direct and indirect. Studies show 28–30% of energy consumption globally takes place due to buildings and construction. Hence, smart building or home is the only solution for energy conservation to produce the better environment with advanced technology using IoT. Smart homes are inbuilt with many innovative technologies which let humans to communicate with buildings through smart devices furthermore it also carried out many advance functioning in monitoring of home such as security surveillance, water management, energy management, smart lightings, smart energy management and elderly care.

Security system is very essential to protect our self from unusual events so, automated surveillance system can be adopted using IoT by providing CCTV images of multiple private locations then it is processed by desktop, laptop or smart phone with a help of advanced transmission technologies such as WiFi, ZigBee, Blue tooth etc. and it is known as third generation surveillance system (D'Orazio and Guaragnella 2015). To prevent the occupants from vulnerable

Published online: 19 November 2020

threats, smart homes employ IoT technology that helps to make use of Artificial Intelligence(AI), cloud computing, sensors and actuation (Heartfield et al. 2018). In order to play a huge contribution for 24/7 monitoring, smart home should be intelligent enough to record and analyze the data with proper communication through computational techniques (Abbas et al. 2018).

Energy management system helps to reduce cost, carbon emission and wastage of energy however, this technology needs improvement in some deficiency such as excessive in cost, not an easy handling and maintenance possibilities are hard and less. Therefore, using advanced IoT and bigdata analysis, it can provide better energy consumption assistance to smart building (Al-Ali et al. 2017). Heating, ventilation and air conditioning (HVAC) system can be adopted to increase the indoor comfort level and it constitute around 50% of energy requirement in Europe, meanwhile it rises the attention and priority of using this HVAC in buildings (Solano et al. 2017). HVAC system energy in residential buildings reduces around 6% of consumption and also greatest electricity user of home (Kristen and Catilyn 2016).

Requirement for food and water rapidly increasing every day together with scarcity of water becomes major hazard in many countries including India, so water management system is very essential to save water furthermore applying metering system with IoT, automated system, and helps to predict the water consumption and usage (Punit et al. 2017). Figure 1 describes the application of IoT system in smart building.

IoT technology uses sensors for monitoring the temperature for controlling HVAC, water management, energy management, health system of elders and fire detection with the combination of sensors inside the home and connecting these details to remote server for decision making and

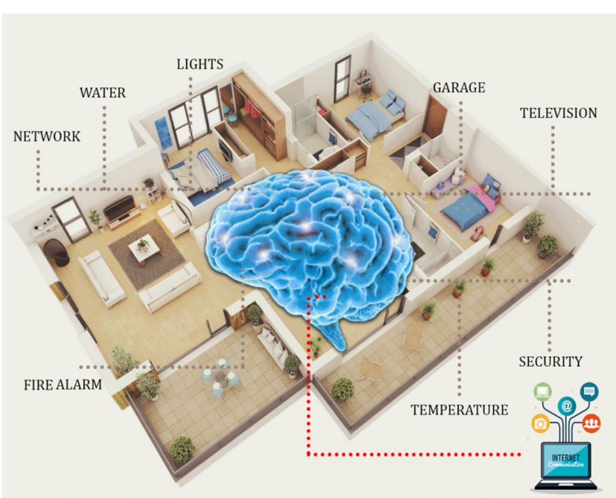

Fig. 1 Application of IoT technology in smart homes

controlling the usage or giving alarm to specific events with the help of advancement in the technologies.

Advancement in the technologies:

- Sensor technology
- IoT
- Software packages
- Artificial intelligence
- Data analytics

Smart lighting system is one of the important features for smart home to look, aesthetic various lighting system are available in market as per design requirement, occupants' comforts and activities (Chao et al. 2012). Fire accidents are barely happening but turns out to be a disastrous event that makes occupants clueless about the situation and they won't be having enough time to evacuate themselves. In order to overcome this situation smart alarm system can be applied in smart homes by adopting smart IoT technology which gives indication about all of sudden hazardous events which leads occupants to evacuate or make remedial action to stop fire (Kunal et al. 2017). Monitoring is very necessary for elderly peoples to keep them in active communication with smart home to follow their illness, diet, emergency call and other activities using smart devices, IoT and advanced wireless sensors (Almeida et al. 2019).

1.1 Overview of the article

The article begins with introduction about smart buildings, in that it covers the concepts which are most valuable and necessary to be executed in smart homes such as fire detection, elderly care, water management, energy management, smart lighting system, smart building surveillance and control of advanced HVAC system. Figure 2 depicts the smart overview of concepts covered in this article.

The overall application applicable to smart homes are portraited in the Fig. 2.

2 Security control in smart building

The surveillance cameras are used widely to ensure the safety of the people. If the camera is fixed in the building, the theft, vandalism and other crimes will be reduced. These cameras will capture the video in real time, so that owner of the smart home shall increase the security. In some cases, the recorded video can be useful for polices for investigating other crimes happened in nearby smart houses.

Heng et al. (2014) adopted infrared sensors (samsung s3c2440processor) and arm9-linuxas podium for continuous monitoring of real time surveillance in smart home and for video streaming, Moving Picture Experts Group (mpeg-4)

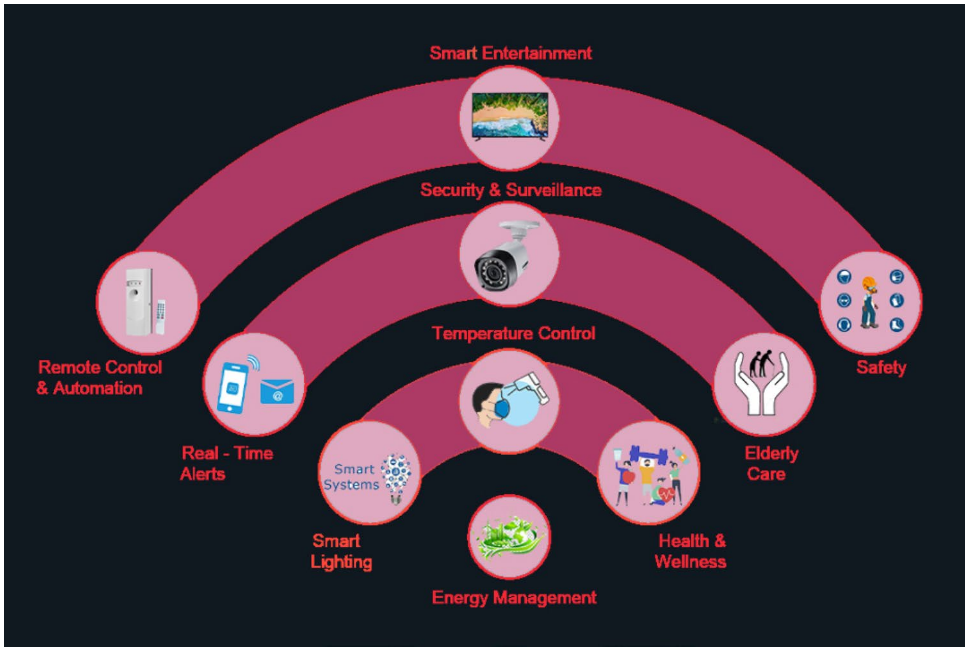

Fig. 2 Smart homes overview

algorithm was used. The recorded video had been summarized and sent to the PC that was connected via Local Area Network (LAN) and the application was established on Video4Linux(V4L2),finally it had been compared with the traditional methods of surveillance systems and results showed that this design concept provided more clarity and defended the system resources. Tiziana and Cataldo (2015) presented a survey of automated event detection using multi-camera to consign multi view issues and information were collected using single processing framework by applying image processing methodology for intelligent 3G surveillance system in smart home.

Ryan et al. (2018) classified 25 different smart-home attacks and discussed about integration with new technologies such as AI, Cloud Computing and IoT which prevented and secured the occupants in home through immense level of sensing and actuations from cyber threats. Peng et al. (2013) discussed about advanced robot surveillance control by adopting the IoT technology to overcome the problems in traditional methods such as information interconnection and human intelligent control. The system consisted of Linux operating system and Samsung S3C2440 hardware platform by employing ZigBee sensor to attain the robot surveillance video, temperature information and intelligent supervision and these systems helped to improve the occupant's living standard and quality.

Surantha and Wicaksono (2018) adopted Rasperry Pi 3 and Arduino embedded systems with Pyroelectric Infrared Sensors (PIR) and all were connected using Universal Serial Bus (USB) cable. PIR sensors helped to detect the intruder (object recognition) using Histogram of Gradient (HoG) and Support Vector Machine (SVM) in 2 s, and the alarm was activated to provide the signal to the occupants. Furthermore, the system gave 89% success in terms of detecting the intruders. Abbas et al. (2018) implemented a motion detected activation recording technique for automating the video recording process by adopting Multi-Scale Structural Similarity (MS-SSIM). For smart home security, this system is cost effective and saved more storage space. Jay et al. (2019) presented a work related to the image prototype instead of video to avoid the internet traffic and make cost effective, the image provided the facial recognition and labels the person who triggered, meanwhile the images uploaded by the system were received through mobile application. The mobile application mechanism had been used to house the doors with remote switching in smart home.

Ravikumar and Kavitha (2020) enforced severe inscription to secure the data in cloud storage in order to prevent the data from the intruders and also to maintain the consistency by using two ESP32 cameras for video sensing. Junge et al. (2015) proposed ISEE system for smart home to analyze the video synopsis, flexible video retrieval, alarm generation in real time, abnormal behavior and also other contributions were:

- Nomination of smart home complete system had been considered, based on the home security intelligent video surveillance.
- Novel foreground segmentation system had been recommended as per history pattern

And it will be very useful for indoor monitoring.

- In order to speed up the human detection, two methods such as scene culture modeling and Region of Interest (ROI) had been adopted.
- To predict the entire behavior and process, robust behavior representation model had been developed

Cristian et al. (2017) discussed about computer vision using IoT to make use of pictures and cameras as sensors and concluded that this automated technique could able to monitor all the sequences that user needed to make a reliable to communicate with smart homes and also helped to improve the security surveillance. Aimen et al. (2020) discussed about the design of IoT architecture for smart building by adopting wireless technology and sensors as key technology and observed the following:

- Design of hardware and software systems should be considering the low consumption of energy
- For security and privacy of smart homes using advanced IoT should have proper wireless technology devices such as ZigBee,WiFi, GSM/GPRS etc.
- Predicting the performance of smart homes through WiFi technology was better than traditional methods
- Stereo matching algorithm provided more accuracy for monitoring system

3 Energy management in smart building

In Eco-system, living and non-living things form cycles to make the sustainability of nature and environment. In the advancement of technologies, multiple components or parameters in particular domain are available and each depend on others with some relationships either directly or indirectly. All these components are related by complex technology and bring the optimized outcome. The nature inspired ideas are implemented in the algorithms for optimized outcome, Benítez-Guijarro et al. (2019).

Ali et al. (2017) discussed about Energy Management System (EMS) with data acquisition chip that helped to collect the energy utilization data in smart homes using IoT. Heating, ventilation and Air Conditioning (HVAC) were turned out to be a case study that came up with 60% of electricity consumption and small residential prototype was built with HVAC system and tested in laboratory. Xiuwang et al. (2021) adopted multi objective home energy optimization system using the advanced butterfly algorithm to speed up the process, furthermore Zigbee wireless system had been used due to minimize the consumption of energy, later on comparison had been carried out between the multi-objective optimization with Particle Swarm Optimization (PSO) and Butterfly Optimization Algorithm (BOA). Moreover, results showed that it was cost effective and satisfactory.

For example, in energy management, the parameters such as lights, home appliances, power generation systems, power storage and utilization are related with each other. If one is changed or affected, it causes changes in others. Eco-system for energy management is given in the Fig. 3.

Kanae et al. (2018) proposed Home Energy Management System (HEMS) in smart homes to predict the indoor comfort level of the occupants and tests were carried out around 12 days for three households in japan and results showed that 5.15% of electricity consumption and increased in comfort level around 16.4%. Cristian et al. (2017) demonstrated an Advanced IoT Energy Platform (IoTEP) based on FIWARE that provided IoT energy data with several features and functionalities. Three buildings with more than 100 sensors were taken for study together with and it was found that this platform was highly successful. Chankook et al. (2018) discussed about electromagnetic radiation risk in IoT based smart home such as environmental extermination, electricity cost changes, performance risk, financial risk etc. Figure 3 represents energy management systems in smart buildings.

Naeem et al. (2019) discussed about monitoring and management of IoT based home using sensors, WiFi, and microcontroller, furthermore it was equipped with small circuit to provide a proper layer for Applied Load Monitoring (ALM) that helped to predict the energy consumption through smart data collection. Hong et al. (2020) adopted IoT mechanism to predict the indoor temperature of the smart homes and the data received through experiment helped to build the performance and energy efficient in smart building. The following were observed by the method:

- The prediction accuracy level of was 91.5%
- For Neural Network (NN) gave accuracy of 89.3%
- Random forest (RF) gave accuracy of 87.8%
- Support Vector Machine (SVM) gave accuracy of 78.5%

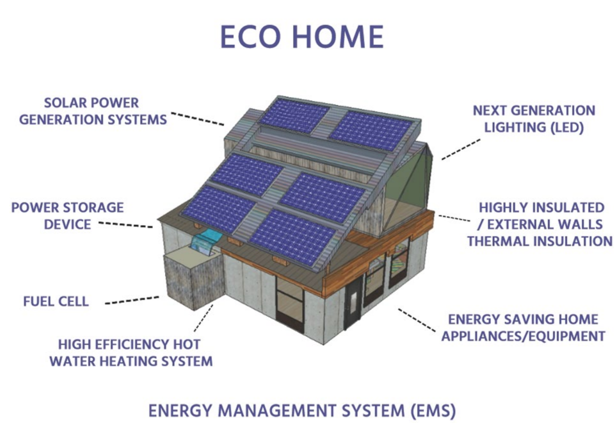

Fig. 3 Energy management system in smart buildings

Uthpala et al. (2015) had discussed about energy consumption in smart homes by adopting robust technique to collect the accurate information such as dynamic real time data, nature, and contextual information for entire resource management system. Hoon et al. (2020) discussed about AI with advanced wireless technology for energy management to look energy flow and predict the wastage of energy together with special strategy that had been adopted to monitor a smart home based on human behavior and this system provided valid information and energy efficient.

4 Control and monitoring of HVAC system

All the basic devices used in the HVAC system have to be monitored and analyzed for effective utilization power to balance the cumulative loads of all appliances. The loads generated by each component in the building comes under the HVAC system should be audited for balancing the supply and usage.

Feng et al. (2020) demonstrated a new technique for energy management termed as two stage Conditional Value at Risk (CVaR) model to determine the optimization in energy by adopting HVAC system. First stage of model reduced the electricity consumption whereas second stage minimized power exchange with external grids. Erdem and Inallı (2018) performed thermal design system around 50 cities located at turkey by adopting general directorate of meteorology together with the following studies has been done:

- Artificial neural network (ANN) and adaptive network based fuzzy was considered
- Prospective data forecasting and modeling were done using Matlab
- To create solar radiation maps, temperature and humidity ArGIS and Surfer software were employed
- To validate the results coefficient of determination (R^2), Co-efficient of Variation (COV), Mean Absolute Error (MAE) and Root mean square error (RMSE) were adopted
- R^2, MAE, COV, RMSE results were found as satisfied
- MGM was compared with annual data of solar power potential maps and results showed favorable for MGM.

Solano et al. (2017) carried out both experimental and analytical studies by adopting Battery Energy Storage System (BESS) and HVAC system with Photo-Valtic (PV) system to predict the PV generation, thermal loads. HVAC consumption were simulated and the results showed that 30% self-consumption rate for building without BESS and possibilities were higher to attain 50% with BESS. Adopting the combined experiment of both showed that 49% of energy consumption with 77% of contracted power reduction. Paulo et al. (2018) adopted HVAC system to reduce the energy consumption and increase the comfort of occupants and introduced an advanced monitoring to track the occupants, managing, and learning using HVAC automatically. To reduce the energy consumption k-means learning techniques had been employed. Figure 4 conveys HVAC system in smart building using IoT.

In the Fig. 4, load factors such as thermal and energy needs are considered for supply and return. In case of efficient usage, the extra supply will be returned.

Alfonso et al. (2017) carried out real time monitoring and simulation in Zaanstad town hall, Netherlands using HVAC system and outcome of the monitoring showed that 14% of reduction in electricity consumption. Kristen and Catilyn (2016) had carried out continuous monitoring of residential buildings which had HVAC system by using history-based model approach and found that 6% of reduction in annual energy usage. Francesca et al. (2017) used wireless sensor network in HVAC monitoring to predict the faults in sensors.

Kwonsik et al. (2020) carried out real time HVAC control monitoring in seven dormitory buildings located at koreato maintain the consistency in usage of energy during the winter season for both night and day time. Ricardo et al. (2020) examined the people's mind set and willingness to pay and stay in smart homes and also studied about few strategies of home energy managements and smart energy technologies. Jose et al. (2019) investigated about recent technological development in data processing and computing to collect the sensors output from smart buildings, automatic energy controllers and control algorithms, furthermore introduced a simulation environment using tenser flow combined citysim, building energy simulator and also presented the demand response and energy savings in smart building.

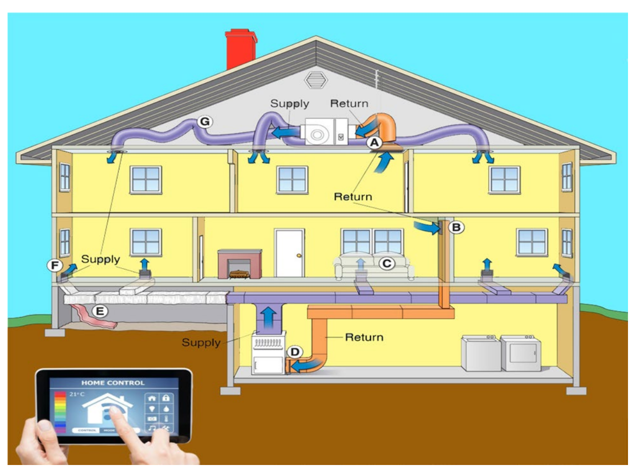

Fig. 4 HVAC control in smart building

Tianyuan et al. (2019) evaluated the run time of the HVAC system by adopting the temperature methods and real time data was collected from three places such as austin, ontario and Toronto. Finally, temperature method was compared with direct methods to predict the outdoor temperature and ambient conditions and concluded that temperature methods were reliable for relevant smart home. Dashamir et al. (2013) carried out both real time and simulation with15 apartments with floor area 1050m^{2}under three different climatic conditions and modeling had been done using energy plus. Five HVAC systems were approached for studies.

- Boiler and Split system (B&S)
- Air to Air Heat pumps (AAHP)
- Air to Water Heat Pump (AAHP)
- Ground Water Heat Pump (GWHP)
- Ground Couple Heat Pump (GCHP)

The results showed that GWHP and GCHP saved around 62.6% and 59.6% respectively. Furthermore, AWHP and AAHP heat pump system saved energy approximately around 23.3% and 14.8% respectively and compared with B&S system meanwhile as per 20 years monitoring period, outcome of GWHP was found more cost effective after 9 years.

Bichiou and Moncef (2011) considered three algorithms to carry out the optimization on HVAC system in residential building with sequential search algorithm, PSO algorithm and Genetic Algorithm (GA) and compared with simulation performance. Monitoring had been carried out for five US family's homes in different climatic conditions and design application concluded that life cycle optimization was 10–25% depended on type of homes and climate. Antoine et al. (2014) carried out monitoring and simulation for multizone HVAC system for non-residential buildings to reduce the energy consumption and increase thermal comfort. GA was used for optimization and EnergyPlus software was used for modeling, furthermore another studies adopted Predictive Mean Vote (PMV) and ANN algorithm to reduce electricity consumption and increase thermal comfort.

Wei et al. (2017) carried out real time monitoring to detect the occupancy in office buildings which used HVAC system by adopting Time-Window based Markov chain (TWMC) model and advanced WiFi technology. The data had been compared with model and the results showed that 88% of air supply in energy reduction. Turner et al. (2017) carried out experiment to detect the faults in HVAC system in residential buildings for both indoor and outdoor temperature to increase the thermal comfort and reduce energy consumption.

5 Water management in smart building

The requirement of water and food is increasing in worldwide and propositional to the population. Water management in smart buildings is needed to create the awareness, better utilization and also reduce the water scarcity in the future at the possible extent. For prediction of water usage related to geographical position, the current research ideas are explained in this section.

Punit et al. (2017) employed an advanced wireless technology and automated learning to upgrade the water management system in smart home using IoT and cloud computing for daily usage. Luciana et al. (2020) applied automated ML algorithm to categorize people's messages and tweets through social media to improve the management of water as well as sanitation. This technique employed two social media colab.re (65,000 post) and twitter (1900 tweet) for different International Organization for Standardization (ISO) categories. Sophie et al. (2017) demonstrated new initiative called as smart water consumption approach to aware and encourage the household for smart usages of water.

Mohd et al. (2020) adopted several technologies such as IoT, protocols, AI and wireless technology to communicate with smart home and smart cities. Various sensors and actuators were employed for automated decision making to predict the water usage to improve water management. Other advanced technology such as Nano technology, quantum technology and sustainability is also adopted. John et al. (2019) presented a review through complete study of 82 peer reviewed journals to focused on strategy, vision, framework and benefits to water management system in smart home. Figure 5 shows graphical information about water management systems in smart buildings. The sensors give the information about the rain, ground water level and harvesting details. All these

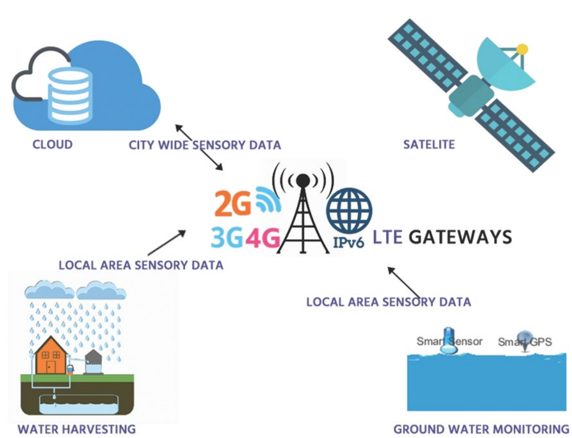

Fig. 5 Water management systems smart buildings

details are collected, transmitted and stored in the cloud systems by wireless communication. Then region wise data-analytics can be done to create awareness and provide better solutions for recycling needs, remarks by Fong et al. (2018).

Mohammed and Bagavathi (2016) employed advanced technology and predictive analysis to detect water consumption and leakage in smart home such as IoT and advanced computing. Furthermore, they mainly focused on improving smart water management system to reduce the scarcity of water. Sonali et al. (2020) adopted KNN based ML and IoT technologies to minimize the wastage of water through two levels of focus, first level was segregation of water for individual house and second level was to receive the alert messages from three sensors to indicate the water wastage.

Shaun et al. (2017) carried out experiment using IoT and semantic web technologies to apply the advanced data analytics, art sensing, smart metering, telemetry and geographic information system meanwhile the results indicated that these technologies were more powerful and satisfactory. Manu et al. (2020) used hybrid multi-criteria decision making methods (MCDM), then it spotted out 15 IoT Barriers (IoTBs). The following approaches are used to develop framework:

- Total Interpretative Structural Modeling (TISM)
- The fuzzy Matrices Impacted Croises Multiplication Appliquean Classment (MICMAC) model
- Decision Making Trial and Evaluation Laboratory (DEMATEL) method
- To develop a structural framework of IoTBs in Smart Cities, Waste Management (SCWM) projects TISM approach has been used
- To calculate the dependence and driving power of the IoTBs fuzzy-MIMAC approach has been used
- In order to reveal the strength of IoTBs which disturbed SCWM, the method DEMATEL had been adopted

Marijana et al. (2020) adopted ML algorithm and big data platform to enhance the water management and energy efficiency in smart building. The ultimate motive and focus must be on reducing energy consumption and cost. Hariprasath et al. (2020) used WSN technology to produce the proper communication for water management system and MATLAB model was also presented to predict the response and acquiring data. Yuanping et al. (2019) presented a in depth review to promote smart homes and smart cities in energy efficiency sector to produce low carbon and better industrial planning for future renewable energy and sustainability.

6 Advanced lighting systems

Smart lighting is one of the energy saving systems to combine the natural lighting with the required lighting within a room or in the buildings. The lighting necessity depends brightness needed for the users and the activity to be done inside the building. If the lighting can be adjustable from the remote or decided from previous trained scenario, the task can be automated. The method called task-based lighting and user-based lighting and evades the waste of energy. Integrated control in all the rooms of the building may save the cost up to 40%.

Chao et al. (2012) demonstrated a new lighting system termed as context –aware lighting control system to overpower manual lighting system using advanced IoT, furthermore it was automated technology to detect context changes in lightings in smart homes. Zhenfeng et al. (2020) employed arduino as primary controller meanwhile it was combined with light sensors and infrared sensors to detect the lighting environment, dimming condition, delay in lightings and control in turn-off to provide low carbon and low cost for environmentally friendly. Tang et al. (2017) developed a prototype for intelligent lighting for security issues in smart homes using ambient light sensors and results showed as cost effective and long performing. Figure 6 describes about smart light system in building.

In the Fig. 6, the smart assistant system converts the voice command into on/off mode of light in remote access. Phone App also can be created by using blue tooth or wifi connectivity.

Yingming et al. (2019) combined electric light and day light to predict the dimming level of the electric light, furthermore this method was based on PWM dimming approach by employing photo sensor TEMT6000 and final outcome was successful. Bicakci and Huseyin (2020) developed

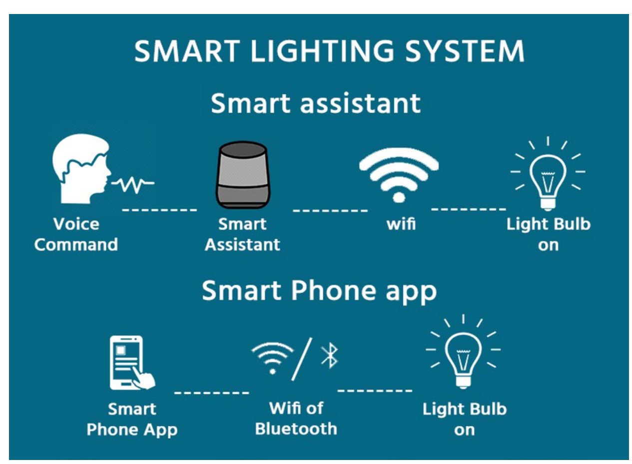

Fig. 6 Smart lighting system using IoT

advanced technique termed as hybrid smart home simulation that was ran in real and virtual smart homes simultaneously together. Initially, real smart home system was installed for hybrid simulation, later with occupants living virtual home and in finally with both real and virtual occupant in a hybrid simulation. After operational evaluation of hybrid simulation, results was better with AI after two months of monitoring under different condition.

Arunkumar et al. (2017) adopted advanced WiFi to support the communication for Wireless Sensors and Actuators Network (WSAN) in smart home study. Different energy protocols and designs had been implemented for advanced lightings system with smart LED and finally the system reduced the energy approximately around 60%-70% to provide the delightful visual comfort zone for occupants. Juan et al. (2016) carried out real time testing and operational evaluation for smart intelligent lighting system by combining several techniques together such as AI,ANN, Expectation Maximization algorithm, service oriented approach, multi-agent system and method based on ANOVA meanwhile, it attained optimization in both cost and energy and the experiment was successful.

Nandha et al. (2018) adopted ANN and Internal Control Model (IMC) to control the smart lighting system to be favorable for Net Zero Energy Buildings (NZEB). ANN and IMC received signal from sensors to increase the accessories for smart lighting to provide better visual comfort for occupants. Ivan et al. (2017) presented a review by focusing on advanced smart lighting system, energy saving, current technology in smart lighting technology to control the lighting system by adopting various sensors, cloud services and user data.

Vanus et al. (2013) carried out optimization in energy saving and cost reduction process in smart home by providing smart lighting system with artificial lightings which works with daylight combination and smart home usages with efficient care. Jan et al. (2016) adopted KNX control system to acquire the data from sensors to control the lighting system in smart home for long term in indoor places of office and regression model was created to examine the system, meanwhile results showed that it was not only all cost effective but satisfied requirements.

7 Fire detection in smart building

Fire alarm is one of the important aspects of Intelligent Building management which directly affects all the people inside the smart building. The reasons of fire may be leakage of gas, problems in power cables in any electronic items, climate (extreme heat). So different kind of sensors should monitor the changes in all the above parameters should be monitored and give correct alarm before the fire.

Kunal et al. (2017) adopted a fuzzy logic based smart rules to detect the gas leak before the fire and also to reduce the number of false alarming. This approach assisted to reduce the fire calamity, furthermore it was reliable, cost effective and simple. Xia et al. (2014) demonstrated a probabilistic approach to initiate the occupant's response in mid-rise building and various fire alarms such as central alarm, sprinklers and local alarm were used. The study showed prolonged response that was essential for asleep occupants and evacuation possibilities were slower and lower comparing to the awake occupants. Figure 7 describes fire alarm system using IoT.

The Fig. 7 shows the different sensors for detecting fire by the temperature, heat, water flow and some detectors. In case of fire/fire causing symptoms, the alert can be given by flashing lights, chimes, horns and annunciator. The smart system also communicates to other systems through network to activate the emergency operations to safeguard the people in smart building.

Allan et al. (2014) adopted k-Nearest Neighbor (k-NN) algorithm to detect the fire in initial stage based on the burning smell occurs due to fire. The real experiment were carried out by using smell samples with frequently available odour sources, mosquito coil, newspaper, plastic materials, air freshener, joss sticks, wood, styro foam including candle and for measurement Portable Electronic Nose (PEN3) from air sense analytics were employed and 99.6% average accuracy were found. Abdalsalam et al. (2015) had designed and fabricated a sprinkler fire system to detect the smoke which activated alarm. Integrating microcontroller in circuit of smoke detector had a sensing capability and sent the signals to air suckers, valves and water pump. The design was cost effective, easy to install and solid design.

Wonju et al. (2013) proposed a new fire safety system in high-rise residential building to predict the false alarm and battle fire by adopting new sensors which grants information via alarms and LCD and experiment. This showed that 63% of successful rate compared with other devices. Fernandez et al. (2020) carried out real time monitoring using data from 289 fatal dwelling fire to determine the safety precaution and prevention strategies to protect peoples from death along with installed household sprinkler and automated extinguishing system to prevent occupants from fire. Yufeng et al. (2020) adopted two techniques Infra-Red Beam Smoke Fire Detector and Fire Dynamics Stimulators (FDS) to predict the smoke spread across the smart homes so that both experimental and numerical simulation were carried out by employing basic alarm in large area buildings.

Rasyid et al. (2019) adopted an advanced WSN technology with multiple sensors for smart home to predict the possibility of fire occurrence and early detection of damage. To process the data, fuzzy logic system was used to detect various stages of fire danger such as smoke, carbon monoxide and humidity

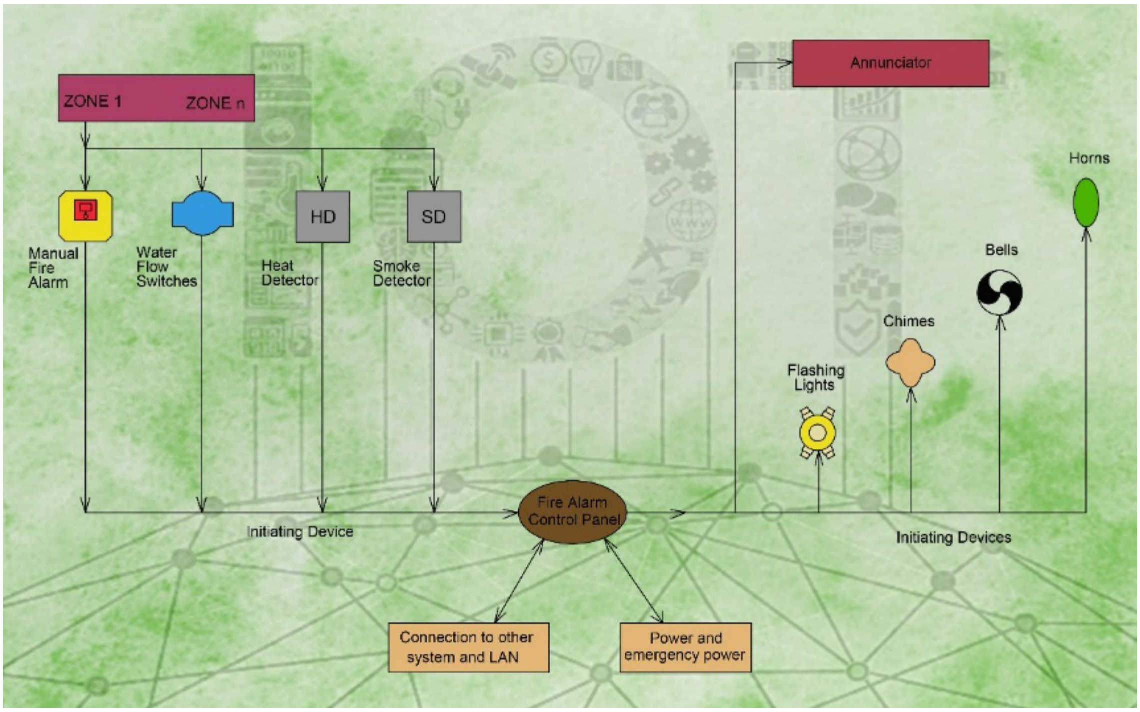

Fig. 7 Fire alarm system in smart building

and also approached methods of sleep schedule. Sierra et al. (2012) carried out real time monitoring in 146 hotels in the year 2004 to inspect and check with technical requirement such as defective signage, smoke detection, alarm devices and firefighting equipment. Rahardjo and Morry (2020) investigated about fire safety and building sustainability for high rise building in Jakarta and results shows that 40% were low in safe condition and 18% were not safe through data received using Analytic Hierarchy Process (AHP), Objective Matrix (OMAX) and traffic light systems.

Geraldine et al. (2020) carried out experiment to detect the smoke alarm in thermal environment when signal started to receive in 56°C then stop around 144°C. NIST home smoke alarm tests were conducted and results showed as failure. So, it needed improvement in broad-spectrum of alarm and advanced methodology were to be studied. Zahra et al. (2011) adopted WSN technology to detect fire in smart home to evacuate occupants at right moment using sensor nodes and numerical simulation utilizedNS2 and Tcl approach to determine secure path for occupants.

8 Health system and elderly care in smart building

Some elderly people or patients may not have take-carers in all the times. That people should have safety related services and also able to access the house-hold appliances with minimum movements or mental mapping. For them, the health status should be monitored frequently and also able to access the emergency services.

Aitor et al. (2019) adopted Ambient Assisted Living (AAL) system to monitor the elder peoples in smart home meanwhile the target of this analysis are three primary system components.

- Risk analysis and prediction module
- Cloud based centralized data
- City–wide data capturing layer

These systems are used to early detection of health issues to provide the medical support and care. Mahdi et al. (2020) employed advanced IoT technology with Wireless Body Area Network (WBAN) to interact with patients. Prove if tool were adopted for all safety and security authentication and simulation executed using OPNET network simulator however when compared with related system WBANs provided more feature for security concern. Maheswaree et al. (2019) introduced a new platform in smart home for elderly peoples called SofiHub that provides emergency assistance, passive monitoring, interaction and sensing. multiple experiments were carried out for elderly people which really helped them emotionally and responded according to emotional requirement and provided outstanding response from elderly occupants.

Figure 8 provides authentic information about health system and elderly care in smart buildings. The elderly people should be able to access the basic appliances in the house at the same time able to make the emergency call.

Debauche et al. (2019) adopted Fog IoT cloud-based health monitoring system for health care system in smart building, furthermore to process the data and storage lambda cloud architecture had been used meanwhile, it helped the hospital staffs to access the data more quickly and granted them legitimize automatically. Dimitrios and Burgos 2017) developed an advanced design of IoT technology to predict the health status of the elderly peoples through smart device, meanwhile managing their health and also enhancing the quality of activity. Sugam and Johnny (2020) demonstrated a graphical interface suitable for mobile, laptop and desktop to predict the stress and illness of the elderly people in smart home and this method auspiciously applied in smart home laboratory which is present in Lowa state university.

Tiziana and Cataldo (2015) adopted IoT platform for health care system in smart home to follow essential diet for occupants and the smart home appliances, Faisal et al. (2019) which acted as a e-health platform which indicated all food intake, nutrition intake and record of food consumption then it kept occupants to stay healthy and active. Hosseinzadeh et al. (2020) used geographical and the historical details of elder people or patients along with IoT technology to track the status of patients to give the better care.

9 Conclusion and future scope

In this entire article, different types of applications in smart building were discussed. The first application is security in smart buildings. Most of the smart home applications use low cost sensors used to collect the images or videos and periodically send them to central-control stations by means of IoT technology. The Image processing or MPEG algorithm was used for video streaming. These applications are remotely assessed using mobile systems.

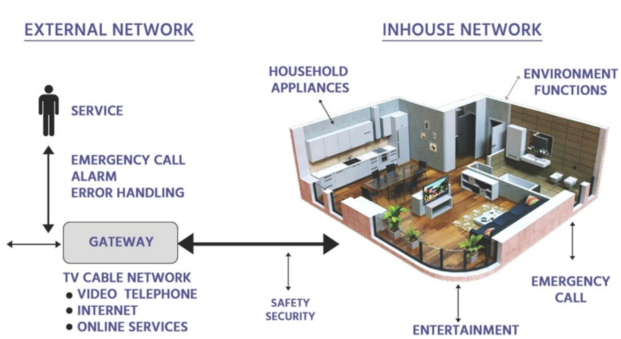

Fig. 8 Health system and elderly care in smart buildings

Automated control of lighting system makes the adjustment of dim level of lights based on the day light and lighting required in the room by the occupants. This lighting requirement is connected with energy conservation. This saves the consumption of power and makes better visual comfort. The comfort level of ventilation and air conditioning differs from one person to others and one climatic condition to others. Based on the scenarios, the automatic adjustment will be helpful for efficient consumption of power.

Water scarcity is the most important problem in today's scenario. The scarcity level differs from one zone to others (based on geographical regions). Not only urbans, even small villages peoples are facing scarcity problems. Using sensors, the usage level meters for building can be used as monitors and giving the awareness and alert which will be helpful to manage the water in the summer seasons.

The fire detection algorithms in smart buildings focuses on detection of smoke and temperature before the fire level becomes great. Here, the main objectives discussed are rescuing the occupants as early as possible in the secure path and also usage of household sprinklers. The real experiments with different smells of fire on various objects can be used for training to predict correctly and also reduce the false alarms. For the training and testing, ML algorithms such as ANN, SVM and K-NN etc. Can be used.

The current issues/findings are:

- The amount of data collected may be huge and sensitive (as video and image are involved) and there is a possibility of cyber threat if location of building and occupants' details are shared. The attack may happen during the time of transmission to remote data center. This data collection may also affect the privacy of occupants. Also, these applications consume most transmission bandwidth and needs huge system resources.
- To reduce the transmission bandwidth, encoding and decoding methods can be suggested, but this will reduce the clarity of image or video.
- To avoid the cyber threat, security algorithms such as encryption and decryption and authentication algorithms can be employed.
- In this article, the content was framed based on the general applications needed in smart building. In real time, the specification of the needs will be changed based on the locality. If all the applications are combined in a smart building, the data transferred will be more and there is a possibility of missing any important event.
- The usability should be key concern in the smart building along with functionality.

10 Future scope

- Each component inside the smart building has to be adoptable to change in the technological advancement to give better feel to the users.
- In future, all the buildings will be constructed with provisions of sensors and communication methods according to the comfort desired by the occupants. Therefore, it will shape the construction of buildings in future.
- Even non-residential buildings such as hotels, air ports will be like smart buildings. Many creative smart building life cycle models will be available.

References

Abbas KH, Tolba A, Rashid MZ (2018) Event triggered intelligent video recording system using ms-ssim for smart home security. Ain Shams Eng J 9(4):1527–1533. https://doi.org/10.1016/j.asej.2016.10.001

Abdalsalam A, Abdulsalam M, Abdulgani A (2015) Design and fabrication of an automatic sprinkler fire fighting system. Springer Int Publ Switz 2015(789):41–49. https://doi.org/10.1007/978-3-319-17527-0

Aimin Y, Zhang C, Chen Y, ZhuZhuansunLiu YYH (2020) Security and Privacy of Smart Home Systems Based on the Internet of Things and Stereo Matching Algorithms. IEEE Internet Things J 7(4):2521–2530. https://doi.org/10.1109/JIOT.2019.2946214

Aitor A, Mulero R, Rametta P, Vladimir U, Andrić M, Patrono L (2019) A critical analysis of an IoT—aware AAL system for elderly monitoring. Fut Gener Comput Syst 97:598–619. https://doi.org/10.1016/j.future.2019.03.019

Al-Ali AR, Zualkernan IA, Rashid M, Gupta R, Mazin A (2017) A smart home energy management system using IoT and big data analytics approach. IEEE Trans Consum Electron 63(4):426–434. https://doi.org/10.1109/TCE.2017.015014

Alfonso C, SavinoPiscitelli M, Gorrino A, BallariniCorrado IV (2017) Data analytics for occupancy pattern learning to reduce the energy consumption of HVAC systems in office buildings. Sustain Cities Soc 35:191–208. https://doi.org/10.1016/j.scs.2017.07.016

Allan AM, Kamarulzaman K, Syed MM, Ali YMS, Ammar Z, Abdul HA, David LN, Santiagoo R (2014) Classification of domestic burning smell using covariance K-nearest neighbour algorithm for early fire detection application. Chem Eng Trans 40:271–276. https://doi.org/10.3303/CET1440046

Antoine G, Julien E, Matthieu C, Stéphane G (2014) Predictive control of multizone HVAC systems in non-residential buildings. IFAC Proc Vol 19(2013):12080–12085. https://doi.org/10.3182/20140824-6-za-1003.01826

Arunkumar A, Pushpendu K, Rakesh W, Aditi K, Sanjib KP (2017) Implementation of smart LED lighting and efficient data management system for buildings. Energy Proced 143:173–178. https://doi.org/10.1016/j.egypro.2017.12.667

Benítez-Guijarro A, ZoraidaCallejas MN, Benghazi K (2019) Architecting dietary intake monitoring as a service combining NLP and IoT. J Ambient Intell Humaniz Comput. https://doi.org/10.1007/s12652-019-01553-2

Bicakci S, Huseyin G (2020) Hybrid simulation system for testing artificial intelligence algorithms used in smart homes. Simul Model Pract Theory 102:101993. https://doi.org/10.1016/j.simpat.2019.101993

Bichiou Y, Moncef K (2011) Optimization of envelope and HVAC systems selection for residential buildings. Energy Build 43(12):3373–3382. https://doi.org/10.1016/j.enbuild.2011.08.031

Chankook P, Kim Y, Jeong M (2018) Influencing factors on risk perception of IoT-based home energy management services. Telemat Inform 35(8):2355–2365. https://doi.org/10.1016/j.tele.2018.10.005

Chao L, Lijun S, Xiangpei H (2012) A context-aware lighting control system for smart meeting rooms. Syst Eng Proced 4:314–323. https://doi.org/10.1016/j.sepro.2011.11.081

Cristian GG, Daniel ML, Cristina PGB, Juan M, Cueva L, Nestor G-F (2017) Midgar: detection of people through computer vision in the internet of things scenarios to improve the security in smart cities, smart towns, and smart homes. Fut Gener Comput Syst 76:301–313. https://doi.org/10.1016/j.future.2016.12.033

D'Orazio T, Guaragnella C (2015) a survey of automatic event detection in multi-camera third generation surveillance systems. Int J Pattern Recogn Artif Intell 29(1):1–29. https://doi.org/10.1142/S0218001415550010

Dashamir M (2013) Optimization of HVAC systems for distributed generation as a function of different types of heat sources and climatic conditions. Appl Energy 102:813–826. https://doi.org/10.1016/j.apenergy.2012.08.043

Debauche O, Mahmoudi S, Assila A (2019) Fog Iot for health: a new architecture for patients and elderly monitoring. Proced Comput Sci 160:289–297. https://doi.org/10.1016/j.procs.2019.11.087

Dimitrios G, Burgos J (2017) I'm in! Towards participatory healthcare of elderly through IOT. Proced Comput Sci 113:647–652. https://doi.org/10.1016/j.procs.2017.08.325

Erdem I, Inallı M (2018) Artificial neural networks and adaptive neuro-fuzzy inference systems approaches to forecast the meteorological data for HVAC: the case of cities for Turkey. Energy 154:7–16. https://doi.org/10.1016/j.energy.2018.04.069

Faisal M, Ullah I, Ahmad S, Kim DH (2019) Object detection mechanism based on deep learning algorithm using embedded IoT devices for smart home appliances control in CoT. J Ambient Intell Humaniz Comput. https://doi.org/10.1007/s12652-019-01272-8

Feng W, Wei Z, Sun G, Zhou Y, ZangChen HS (2020) A conditional value-at-risk-based dispatch approach for the energy management of smart buildings with HVAC systems. Electr Power Syst Res 188:106535. https://doi.org/10.1016/j.epsr.2020.106535

Fernández-Vigil M, Gil Rodríguez B, Echeverría JBT (2020) Fire safety strategies to reduce mortality in dwellings occupied by elderly people: the Spanish case. Fire Technol 56(5):2257–2281. https://doi.org/10.1007/s10694-020-00972-4

Fong S, Li J, Song W, Tian Y, WongDey RKN (2018) Predicting unusual energy consumption events from smart home sensor network by data stream mining with misclassified recall. J Ambient Intell Humaniz Comput 9(4):1197–1221. https://doi.org/10.1007/s12652-018-0685-7

Francesca B, RedonaReci AC, Parisini T (2017) Distributed clustering-based sensor fault diagnosis for HVAC systems. IFAC-Pap Online 50(1):4197–4202. https://doi.org/10.1016/j.ifacol.2017.08.811

Geraldine M, Haavard B, Stephen MO (2020) Thermally-induced failure of smoke alarms. Fire Technol 56(2):673–692. https://doi.org/10.1007/s10694-019-00898-6

Hariprasath M, Basha AR, TeekaramanManoharan YA (2020) Smart home autonomous water management system for agricultural applications. World J Eng 17(3):445–455. https://doi.org/10.1108/WJE-07-2019-0194

Heng X, Cheng Hua Fu, Yang JJ (2014) A design and implementation of video monitoring system at smart home. Appl Mech Mater

568–570:1162–1167. https://doi.org/10.4028/www.scientific.net/AMM.568-570.1162
Hong X, He Y, Sun X, He J, Xu Q (2020) Prediction of thermal energy inside smart homes using IoT and classifier ensemble techniques. Comput Commun 151:581–589. https://doi.org/10.1016/j.comcom.2019.12.020
Hoon K, Kim JH, An K, Mesicek L, Goreti M, PanKim SBP (2020) Smart home energy strategy based on human behaviour patterns for transformative computing. Inf Process Manag 57(5):102256. https://doi.org/10.1016/j.ipm.2020.102256
Hosseinzadeh M, Koohpayehzadeh J, Ghafour MY et al (2020) An elderly health monitoring system based on biological and behavioral indicators in internet of things. J Ambient Intell Humaniz Comput. https://doi.org/10.1007/s12652-020-02579-7
Ivan C, Karunatilaka D, Tan CP, Kalavally V (2017) Smart lighting: the way forward? Reviewing the past to shape the future. Energy Build 149:180–191. https://doi.org/10.1016/j.enbuild.2017.04.083
Jan V, Valicek P, Novak T, Martinek R, Zidek J (2016) Utilization of regression analysis to increase the control accuracy of dimmer lighting systems in the smart home. IFAC-Pap Online 49(25):517–522. https://doi.org/10.1016/j.ifacol.2016.12.072
Jay P, Anand S, Luthra R (2019) Image-based smart surveillance and remote door lock switching system for homes. Proced Comput Sci 165(2019):624–630. https://doi.org/10.1016/j.procs.2020.01.056
John I, Kayode O, Muhammad UM (2019) Exploring knowledge management perspectives in smart city research: a review and future research Agenda. Int J Inform Manag. https://doi.org/10.1016/j.ijinfomgt.2019.07.015
José VCR, Stepan U, Jérôme K, Zoltán N (2019) Fusing tensorflow with building energy simulation for intelligent energy management in smart cities. Sustain Cities Soc 45:243–257. https://doi.org/10.1016/j.scs.2018.11.021
Juan PF, De JB, Rodríguez S, Villarrubia G, Corchado JM (2016) Intelligent system for lighting control in smart cities. Inf Sci 372:241–255. https://doi.org/10.1016/j.ins.2016.08.045
Julien GE, Matthieu C, Stéphane G (2015) Predictive control of multizone heating, ventilation and air-conditioning systems in non-residential buildings. Appl Soft Comput J 37:847–862. https://doi.org/10.1016/j.asoc.2015.09.022
Junge Z, Yanhu S, Kaiqi H (2015) ISEE smart home (ISH): smart video analysis for home security. Neurocomputing 149:752–766. https://doi.org/10.1016/j.neucom.2014.08.002
Kanae M (2018) An information provision system to promote energy conservation and maintain indoor comfort in smart homes using sensed data by IoT sensors. Fut Gener Comput Syst 82:388–394. https://doi.org/10.1016/j.future.2017.10.043
Kristen CS, Catilyn K (2016) Data-driven methodology for energy and peak load reduction of residential HVAC systems. Proced Eng 145:852–859. https://doi.org/10.1016/j.proeng.2016.04.205
Kunal K, Navneet S, Sheikh A, Utkal M (2017) A fuzzy decision in smart fire and home security system. Proced Comput Sci 105:93–98. https://doi.org/10.1016/j.procs.2017.01.207
Kwonsik S, Jang Y, Park M, Lee HS, Ahn J (2020) Energy efficiency of end-user groups for personalized HVAC control in multi-zone buildings. Energy 206:118116. https://doi.org/10.1016/j.energy.2020.118116
Luciana B, Cechinel C, Munoz R (2020) Automated classification of social network messages into smart cities dimensions. Fut Gener Comput Syst 109:218–237. https://doi.org/10.1016/j.future.2020.03.057
Mahdi F, Majid B, Ashok KD, Hossein ANF, Morteza P, Doostari MA (2020) A lightweight and secure two-factor authentication scheme for wireless body area networks in health-care IoT. Comput Netw. https://doi.org/10.1016/j.comnet.2020.107333
Maheswaree KC, Niroshinie F, Mohamed A, Rajesh V, John G, Kon M (2019) Emotion-oriented requirements engineering: a case study in developing a smart home system for the elderly. J Syst Softw. https://doi.org/10.1016/j.jss.2018.06.077
Manu S, Joshi S, Kannan D, Govindan K, Singh R, Purohit HC (2020) Internet of things (IoT) adoption barriers of smart cities' waste management: an Indian context. J Clean Prod 270:122047. https://doi.org/10.1016/j.jclepro.2020.122047
Marijana Z-S, Mitrović S, Has A (2020) Machine learning based system for managing energy efficiency of public sector as an approach towards smart cities. Int J Inform Manag. https://doi.org/10.1016/j.ijinfomgt.2020.102074
Mohammed KS, Bagavathi PS (2016) Framework for a smart water management system in the context of smart city initiatives in India. Proced Comput Sci 92:142–147. https://doi.org/10.1016/j.procs.2016.07.337
Mohd AA, Sara P, Gautami T, Noushaba F (2020) Enabling technologies and sustainable smart cities. Sustain Cities Soc 61:102301. https://doi.org/10.1016/j.scs.2020.102301
Naeem AO, Ahmad A, Saleh M, Alaqtash M (2019) Iot-based home and community energy management system in Jordan. Proced Comput Sci 160(2018):142–148. https://doi.org/10.1016/j.procs.2019.09.454
Nandha KK, Giridharan K, Tseng KJ, Soong BH (2018) Smart lighting system using ANN-IMC for personalized lighting control and daylight harvesting. Build Environ 139(March):170–180. https://doi.org/10.1016/j.buildenv.2018.05.005
Paulo C, António AC, Vitor M, Artur A (2018) Can HVAC really learn from users? A simulation-based study on the effectiveness of voting for comfort and energy use optimization. Sustain Cities Soc 41:275–285. https://doi.org/10.1016/j.scs.2018.05.043
Peng JS, He QW, Wei QJ, Huang ZC, Chi SB, Huang YY (2013) Design of smart things robot system. Inform Technol J. https://doi.org/10.3923/itj.2013.8514.8520
Punit G, Dilpreet S, Anuj P, Mohit P (2017) Automated learning based water management and healthcare system using cloud computing and IoT. Springer Nat Singap. https://doi.org/10.1007/978-981-10-5427-3_48
Rahardjo H, Morry P (2020) The most critical issues and challenges of fire safety for building sustainability in Jakarta. J Build Eng 29:101133. https://doi.org/10.1016/j.jobe.2019.101133
Rasyid HA, Udin M, Depandi E, Ferry AS (2019) Smart home system for fire detection monitoring based on wireless sensor network. Int Electron Sympos. https://doi.org/10.1109/ELECSYM.2019.8901528
Ravikumar S, Kavitha D (2020) IoT based home monitoring system with secure data storage by Keccak-Chaotic sequence in cloud server. J Ambient Intell Humaniz Comput. https://doi.org/10.1007/s12652-020-02424-x
Ricardo DA (2020) Flexible customer willingness to pay for bundled smart home energy products and services. Resour Energy Econ 61:101175. https://doi.org/10.1016/j.reseneeco.2020.101175
Ryan H, Loukas G, Budimir S, Bezemskij A, Fontaine JRJ, FilippoupolitisRoesch AE (2018) A taxonomy of cyber-physical threats and impact in the smart home. Comput Secur 78:398–428. https://doi.org/10.1016/j.cose.2018.07.011
Shaun H, Yacine R, Thomas B (2017) Integrating building and urban semantics to empower smart water solutions. Autom Constr 81:434–448. https://doi.org/10.1016/j.autcon.2017.02.004
Sierra M, José F, Rubio-Romero JC, Gámez MCR (2012) Status of facilities for fire safety in hotels. Saf Sci 50(7):1490–1494. https://doi.org/10.1016/j.ssci.2012.01.006
Solano JC, Olivieri L, Caamaño-Martín E (2017) Assessing the potential of PV hybrid systems to cover hvac loads in a grid-connected residential building through intelligent control. Appl Energy 206:249–266. https://doi.org/10.1016/j.apenergy.2017.08.188
Sonali D, Singh P, Yadav P, Singh KK (2020) Household waste management system using IoT and machine learning. Proced

Comput Sci 167(2019):1950–1959. https://doi.org/10.1016/j.procs.2020.03.222
Sophie W (2017) Consuming water smartly: the significance of sociocultural differences to water-saving initiatives. Local Environ 22(10):1237–1251. https://doi.org/10.1080/13549839.2017.1334143
Sugam S, Johnny W (2020) Three-button gateway smart home interface (TrueSmartface) for elderly: design development and deployment. Measurement 149:106923. https://doi.org/10.1016/j.measurement.2019.106923
Surantha N, Wicaksono WR (2018) Design of smart home security system using object recognition and PIR sensor. Proced Comput Sci 135:465–472. https://doi.org/10.1016/j.procs.2018.08.198
Tang S, Vineetha K, Kok YN, Jussi P (2017) Development of a prototype smart home intelligent lighting control architecture using sensors onboard a mobile computing system. Energy Build 138:368–376. https://doi.org/10.1016/j.enbuild.2016.12.069
Terroso-Saenz F, González-Vidal A, Ramallo-González AP, Skarmeta AF (2019) An open IoT platform for the management and analysis of energy data. Fut Gener Comput Syst 92:1066–1079. https://doi.org/10.1016/j.future.2017.08.046
Tianyuan L, Masih A, Jeffrey AS (2019) Measurement of Residential HVAC System Runtime. Build Environ 150:99–107. https://doi.org/10.1016/j.buildenv.2019.01.004
Turner WJN, Staino A, Basu B (2017) Residential HVAC fault detection using a system identification approach. Energy Build 151:1–17. https://doi.org/10.1016/j.enbuild.2017.06.008
Uthpala PS (2015) Reliable context-aware multi-attribute continuous authentication framework for secure energy utilization management in smart homes. Energy 93:1210–1221. https://doi.org/10.1016/j.energy.2015.09.050
Vanus JT, Novak J, Koziorek J, Konecny J, Hrbac R (2013) The proposal model of energy savings of lighting systems in the smart home care. IFAC Proc Vol. https://doi.org/10.3182/20130925-3-CZ-3023.00014
Wei W, Lin Z, Chen J (2017) Promoting energy efficiency of HVAC operation in large office spaces with a Wi-Fi probe enabled markov time window occupancy detection approach. Energy Proced 143:204–209. https://doi.org/10.1016/j.egypro.2017.12.672
Wonju L, Minkyu C, Chang HH, Mignon P (2013) Development of building fire safety system with automatic security firm monitoring capability. Fire Saf J 58:65–73. https://doi.org/10.1016/j.firesaf.2013.01.003
Xia Z, Li X, Hadjisophocleous G (2014) A probabilistic occupant response model for fire emergencies. Fire Saf J 68:41–51. https://doi.org/10.1016/j.firesaf.2014.05.017
Xiuwang W, Xinna M, Hossein K (2021) A multi-objective home energy management system based on internet of things and optimization algorithms. J Build Eng 33:101603. https://doi.org/10.1016/j.jobe.2020.101603
Yingming G, Yukai C, Huanyue Z, Nianyu Z (2019) Dynamic illuminance measurement and control used for smart lighting with LED. Measurement 139:380–386. https://doi.org/10.1016/j.measurement.2019.03.003
Yuanping W, Hong R, Liang D, Hung SP, Yuepeng Z, Yanwei X (2019) Smart solutions shape for sustainable low-carbon future: a review on smart cities and industrial parks in China. Technol Forecast Soc Change 144:103–117. https://doi.org/10.1016/j.techfore.2019.04.014
Yufeng H, Wang E, Bie Y (2020) Simulation investigation on the smoke spread process in the large-space building with various height. Case Stud Therm Eng 18:100594. https://doi.org/10.1016/j.csite.2020.100594
Zahra N, Sohaiba I, Majid IK, Muhammad T (2011) WSN-based fire detection and escape system with multi-modal feedback. Commun Comput Inform Sci 149:251–260. https://doi.org/10.1007/978-3-642-21512-4_30
Zhenfeng L, Li J, Li X, Yang Y, Xiao J, Bowen Xu (2020) Design of office intelligent lighting system based on arduino. Proced Comput Sci 166:134–138. https://doi.org/10.1016/j.procs.2020.02.035