Internet of Robotic Things: Issues and Challenges in the Era of Industry 4.0

Geetika Madaan, H. R. Swapna, Sanjeet Singh, and D. Arpana

Abstract IoT is growing at a fast pace, and billions of devices are now associated with the amount expected to reach trillions in the coming years. The Internet of things and the individual systems participate closely in launching the fourth industrial revolution and form alliances and develop the goods of the next generation. The foundation of Industry 4.0 is the transforming innovations. The convergence of robot and IoT agents contributes to Internet of Robotic Things concept, where creativity in automated devices generates different possibilities, both in business and science. It covers a range of sectors, including agriculture, manufacturing, health, education, and surveillance though the application of various technologies. The study discusses the new Internet of Robotic Things developments, which have an influence on the area of health, science, agriculture, manufacturing, education, and surveillance and the key open problems of introduction of robot technology into intelligent spaces. Internet of Robotic Things technology and frameworks are often addressed to highlight their effect on daily life and to promote more study on remote and automatic applications.

Keywords Cyber-physical systems · Education · Health care · Industry 4.0 · Internet of Things

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1 Introduction

Intelligent services become progressively fundamental with the development of the fourth step of Industry 4.0, where emerging technological innovations shift the fields of manufacturing as well as science [1]. Over the first three industrial revolutions, efficiency was improved by the introduction of modern mechanical, electrical, and computer innovations. In recent years, the desire to increase the standard of human life has contributed to further realization and more personal and interactive services development models [2].

The main consequence of the modern fourth industrial revolution is the development of cyber-physical networks and their output. Cyber-physical networks build software that integrate physical assets with computer capabilities [3]. CPS developments include a broad variety of uses such as energy networks, transit structures, surgical facilities, gas delivery. In CPS, contact with physical structures takes place through networks and performs complex analyses as data are extracted [4].

The usage of CPS networking, the Internet, and sensors contributes to the Internet of Things concept [5]. The Internet of Things may be regarded as a facility that facilitates cyber-physical networks since Internet of Things systems depend on protocols of communication, where physical assets will link, transfer, and exchange information. Since the IoT model does not test data and knowledge systems, cyber-physical networks are built to allow dynamic analytics utilizing the IoT connectivity architecture from a single analytical hub, with knowledge derived from raw data to deliver physical asset management commands [4].

The Internet of Devices and the cyber-physical networks both have a strong foundation for developing a new area of science: The Internet of Robotic Things (IoRT). This modern paradigm also incorporated many improvements in various domains including many applications that operate in difficult conditions [1]. For example, IoRT systems may be used autonomously and remotely by manufacturing industries to execute demanding tasks like production, packing, welding, quality control management, etc. Furthermore, IoRT structures have extend to libraries, athletics, and entertainment beyond the sector. Their growth, though, is partly due to the need to build integrated structures for Industry 4.0, [2] digital and real realms are mixing. In this example, IoRT stands for the heart of robotically integrated IoT systems that incorporate cloud computing and networking for intricate responsibilities, enabling robots to share, network and capture numerous types of human and computer knowledge [6]. A robot, cloud, and IoT convergence scheme can be tracked as mentioned in Fig. 1.

In recent years, several reports have been published, but classifies Internet of Robotics Things systems according to intelligent structures [3]. The existing study made an attempt to highlight Internet of Robotics Things applications aligned with numerous smart realms in Industry 4.0, defining the new Internet of Robotics Things innovations, and explaining how in our society, Internet of Robotics Things systems can play a crucial role. The main goal is to explain the primary issues in the field to explain, where Internet of Robotics Things implementations need to be more

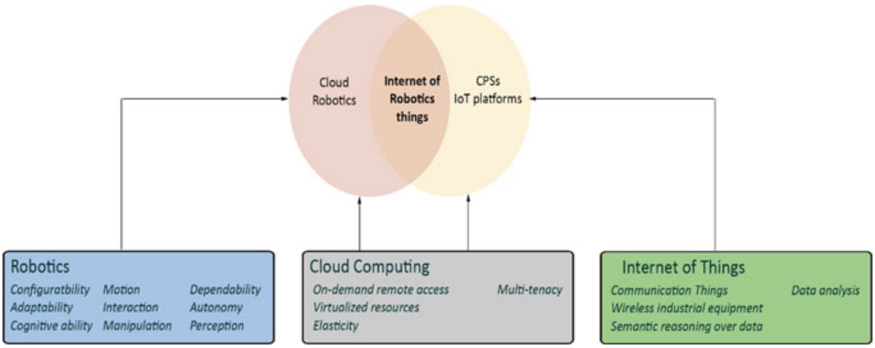

Fig. 1 Diagrammatic presentation of Internet of Robotic Things, robotics, and cloud computing

researched and applied [7]. As the objective of this manuscript is on manufacturing and processing, Internet of Robotics Things technology in smart growth and intelligent agriculture is thoroughly studied. Moreover, areas such as wellness, schooling, and monitoring are then discussed to explain how Internet of Robotics Things networks spread across several facets of daily life [8].

The manuscript is arranged accordingly. Section 2 displays the core characteristics of Industry 4.0, concentrating on CPS-based technology [9]. The Internet of Robotics Things is consequently introduced, and its elements and design are evaluated. The new robotic agents and applications in the health sector are described in Sect. 3 where IoT technology incorporates robotic structures. Section 4 addresses transparent obstacles mentioned in Sect. 5 draws the report's conclusions [10].

2 The Role of Smart Technologies in the Fourth Industrial Revolution (Industry 4.0)

Industry 4.0 is considered as the fourth industrial revolution and treated as the next manufactured stage, where digital convergence and smart innovation are used to change the link between equipment and humans. Industry 4.0's development has improved the whole manufacturing industry, establishing the so-called smart space and, in particular, smart factories [11, 12].

The smart computer idea is strictly related to the smart factory. These IoT-based systems have switches, add-on sensors and use their own modules in real time including other self-consciousness and autonomy machines [13]. Auto-consciousness allows machines predict potential malfunctions, and self-comparison encourages the computer to better customize the settings depending on its operating experience. For these reasons, all wired and wireless network designs and networking protocols help to link sensors and actuators for more specific industrial applications. Auto-consciousness allows machines predict potential malfunctions to ensure contact between different equipment and robots and ensure effective and productive manufacturing [14].

3 Framework of CPSs

Cyber-physical system is the most critical elements of Industry 4.0's. To further expand other scientific fields, cyber-physical networking technology becomes important as the Internet became accessible to all physical devices, integration of simulated and physical worlds for smart products and production. The central structure of the CPS is real universe, cyberspace and contact networks: (i) physical universe refers to the artifacts, systems, and ecosystems that are to be tracked or managed, (ii) cyberspace reflects such knowledge structures as utilities, software, and judgments, though (iii) communication networks are those elements that link cyberspace with true existence in the world [15, 16]. As the fourth industrial revolution begins, management and production processes have been very critical in many intelligent sectors. Smart goods and intelligent development structures are in particular narrowly linked to the CPPS and various architectures are meant to fix failures in discrete case processes [17].

CPPS will help boost the versatility of development processes focused on IoRT in smart fields, including production, livestock, medical operation and elderly care. In specific, human–robot interaction (HRI), which includes human beings and robots, in these areas just particularly in manufacturing [18]. In production processes, such as assemblage and welding the details generated by physical interaction between people and robots can be used. The idea of an architecture of the human–robot interaction is essential for the design and implementation of the cyber-physical distribution mechanism and seek to impact the direction of a robot dependent on human labor points [19]. Since the CPS is the first stage of growth, it is important to describe its framework and methodology. The CPS architecture is distinguished by five distinct levels in manufacturing environments that can be seen in Fig. 2. The so-called 5C architecture clarifies how a CPS can be built from initial data collection to final value output. However, many CPS architectures were created, each concentrating on different aspects [20].

In the sense of Industry 4.0, the goal is to better describe manufacturing structures and smart factories. The stages of 5C architecture are listed below.

- Internet of Robotic Things

The fourth industry innovation in recent years has culminated in the creation of the Internet of Robotic Things, that achieve control, vision and exploitation decision-making systems. Figure 3 displays a sketch of the IoRT modules.

The most sophisticated robotics principle is located in IoRT, where CPSs offer a clear base for developing IoT itself. New robotic developments have been paired with cloud computing in IoRT systems networking, CPSs and IoT protocols incorporation in the creation of emerging technologies. This modern method integrates

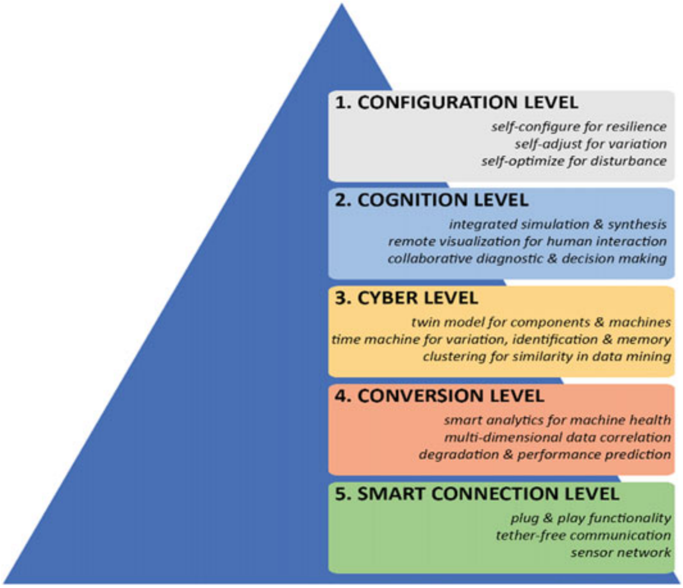

Fig. 2 Diagrammatic presentation of CPS architecture

multiple technology for complex activities and in a heterogeneous setting. In addition, wireless sensor networks (WSNs) have been an important topic in recent years. In particular, the need to mount sensor nodes according to such algorithms and circumstances implies that certain sensors may be built into robot networks [21]. These robots coexist with sensors to increase the WSN's capacity. The development of modern Internet of Robotic Things-related technologies and applications to solve different roles and software that can address diverse roles. Also, installation of robotic networks with wireless sensors was also allowed from deployment to connectivity [22].

Robotic devices have triggered major improvements in different areas of human life. Robots have been used in business and academia to conduct all kinds of complicated and difficult activities, such as packing, assembling, and welding. In this sense, the creation of modern heterogeneous robotic systems is a consequence of IoT and robotic convergence, in order to enhance the autonomous actions of robots. The incorporation of robotics and networking is also important for the creation of IoRT systems [23]. Networked robots combine device structures (both software and hardware) and network implementations to determine optimal intervention series of local and distributed details and then comply to change the physical state physically [24].

As shown in Figure 4, the core architecture of the Internet of Robotics is made of three main layers:

- Physical layer
- Network and control layer

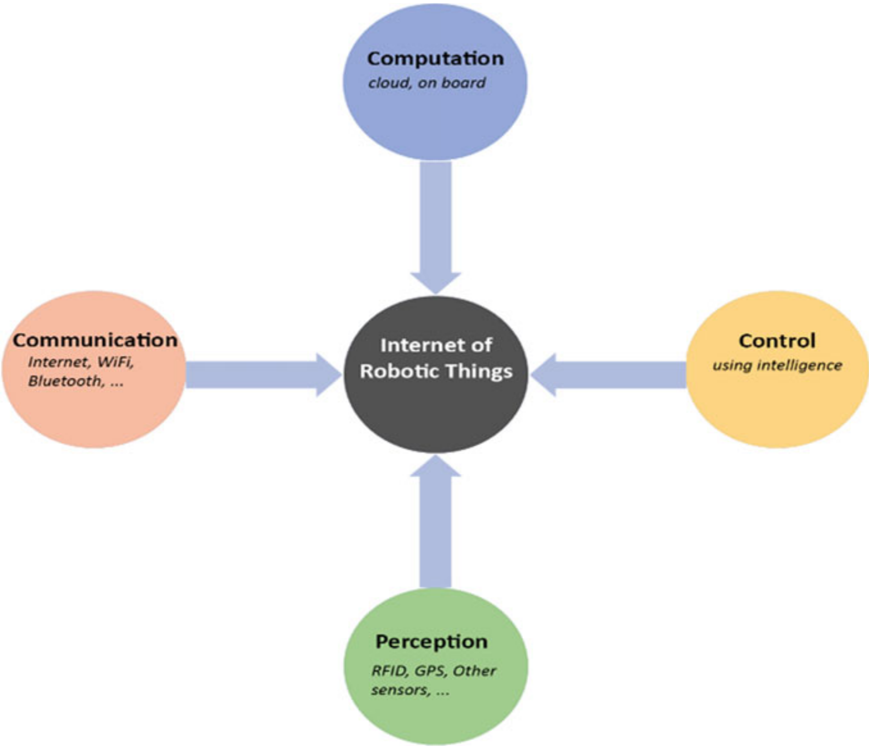

Fig. 3 Diagrammatic presentation of IORT architecture

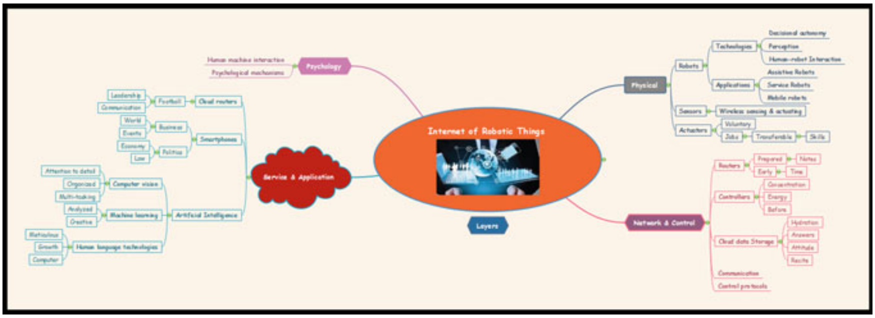

Fig. 4 Internet of Robotics Things architectures layers

- Service and application layer.

With robots, sensors and actuators, the physical and psychological layers are the lowest stage of IoRT architecture. In order to optimize, track and manage different procedures, such as robotic applications may also involve navigation, setup, tuning, sensors, and actuators. The total and efficient integration of sensors and actuators into the network and control layer for robot implementations is therefore feasible, where separate components can be interacted and managed by similar protocols [25]. Basic connection is used for smooth transfer of information between short- and long-distance robotic systems close field contact and the WSN.

Lastly, the layer of service and device determines the maximum standard of IoRT architecture, namely the deployment of programs in smart settings, to monitor, to process and to evaluate all environmental parameters (robots, sensors, and actuators). Additionally, this layer also contains artificial intelligence and machine learning algorithms that enables smooth incorporation of robotic systems and IoT systems in order to find personalized solutions to real-physical problems [26].

4 The Role of IoRT in Different Domains

In the fields of health treatment, schooling, and monitoring, IoRT networks are known to have tremendous importance, depicts a summary of the literature for this portion. Specifically, in certain applications, the IoRT may have well-being, community, and economic advantages, for special needs groups, including mental disorders, stroke survivors, patients, amputees, etc. IoRT systems may also provide several benefits for other uses, such as patient monitoring, personnel and clinics, automated data storage, and sensing (Table 1).

To concentrate on the education area, robots need suitable and adaptive behaviors to establish and sustain sufficient social connections with individuals, in order to be utilizable in resources of help such as homework and education. In comparison, EDA reactions assessed in children will vary greatly from a typical adult reaction since children cannot respond to such desires like adults do. Under these cases, the IoRT technology used for child education problems would capture, store, and interpret data such that child behavior and condition are automatically predicted.

It is a recognized problem to track areas and individuals in order to regulate human well-being and preserve certain habitats. IoRT devices have a vital role to play in delivering intelligent high-monitoring technology in locations including vulnerable places, clinics, military boundaries, government facilities, and households. Closed circuit TV cameras (CCTV) are typically used for indoor and outdoor tracking. However, such equipment needs certain obstacles and restrictions, mostly because of collateral damage and blind spots. The rise in the number of cameras inside the device will partially overcome those limitations and to cover more nooks while growing expense and sophistication of systems.

The addition and development of IoRT management tools tend to be the most powerful way to track contexts, while IoRT systems can easily and efficiently be designed and distributed to cover broader areas to defend a certain room. In addition, robotics-integrated cloud systems to ensure real-time tracking are also useful for remotely controlling settings such as buildings, factories, retail and wholesale shops, as well as the identification of human activity in multiple scenarios. Measuring

Table 1 Comprehensive review of role of IoRT in different domains

References	Domain	Technology	Findings
[26]	Agriculture domain	Robot navigation Multi-robots Path planning Cloud computing	Various UAVs are used for data processing through ground surveillance and mapping to varying levels of fertilizer, spraying, etc.
[25]	Agriculture domain	Robot navigation Path planning Multi-robots	Cooperation between heterogeneous robots from the agricultural field utilizing a new method focused on a theory of independent events (DES) and Rama-Wonham (RW) that governs the complex dynamics of heterogeneous multi-robot systems used for intelligent agricultural applications
[5]	Health care (medicine)	Robot navigation Cloud computing	Indoor robot (CIoT) focused on the multimedia platform cloud and IoT, contact protocol RFID and IEEE802.11 and cloud platforms help medicine
[22]	Healthcare system	Robot navigation Cloud computing Human–robot interaction	IoT-compatible telerobotic architecture designed to represent home-telebot-centric health care infrastructure, and combine the unit of robot operation with a human movement capture device. The used robot is a mutual double-armed robot named Yu Mi, imitating human behavior captured using wearable gesture selection systems
[23]	Healthcare system	Robot navigation Human–robot interaction	A health evaluation kiosk is introduced by the implementation of a robotic interface that ensures links to intelligent urban knowledge, connectivity networks and specialized tasks through designing apps that address patient needs
[15]	Manufacturing domain	Robot navigation Cloud computing Human–robot interaction	A health evaluation kiosk is introduced by the implementation of a robotic interface that guarantees its availability in the smart city knowledge and connectivity networks and can provide unique tasks through designing apps that address patient needs
[27]	Manufacturing domain	Robot navigation Path planning Data gathering	Error transmission based on the next iterative point algorithm for the robot manipulator to measure data from cloud points on different stereo viewing systems

(continued)

Table 1 (continued)

References	Domain	Technology	Findings
[14]	Manufacturing domain	Robot navigation Cloud computing	The incorporation of robotics into CPPS in order to handle various weight items, integrating UGVs with robot manipulator and air moving systems for intelligent processing and smart production
[19]	Surveillance domain	Robot navigation Path planning	IoT-based robot device, identified as the Inter Bot 1.0, fitted both with contact networks for long and short distances. The robot monitors smart monitoring in real-time settings
[7]	Surveillance domain	Robot navigation Data gathering	Surveillance robot for horizontal and vertical surfaces during the monitoring of surface shifts, explore room and send live video to the remote workstation through Wi-Fi
[8]	Surveillance domain	Cloud computing Robot navigation Path planning	Autonomous networked robots (ANR) are built on a WSN to control any sensor node, including smoke, infraround fire, odor, activity sensors and network touch and RF transceiver
[20]	Surveillance domain	Robot navigation Path planning Data gathering Multi-robots	Multi-robot framework for monitoring and rescue activities focused on swarm intelligence with IoT real-time uploading data into the cloud, leveraging the wireless links between many officers, PID strategies and the ACO such that they can execute tasks synchronously
[21]	Education domain	Path planning Cloud computing Human–robot interaction	Architecture and architecture of a portable, cognitive processing, affective robot dubbed Fitbot. Such a robot may conduct the interpretation of multimodal data to understand the patient's emotions
[17]	Education domain	Robot navigation Data gathering	Explore room and send live video to the remote workstation through Wi-Fi to episodes of focus, upheaval and enthusiasm in the skin

sensors including GPS, magnet area, air quality, and environmental values can also help to monitor indoor and outdoor situations when the robot passes data in real time during a monitoring mission.

5 Issues and Challenges

Internet of Robotics is a recent idea aiming to outline the integration of robots and IoT systems with cloud computing. The consequence of this convergence is an increasingly increasing relationship between IoT, cloud computing, and robotic science. The incorporation of smarter robot systems guarantees interoperability, creative technology, and implementations in real time and autonomous cooperation. However, certain IoRT implementations are not sufficient to be entirely translated to business scenarios, as the key studies in the subsequent literature are performed in academic laboratories.

A core problem in smart environments is the need for collaboration between different robots and the sharing of room with people. More than one challenge also remains for multi-robot collaboration with respect to consensus networks, control management, cooperation both against infrastructures and other robots and coordinated monitoring. The absence of help for heterogeneous robot configurations would also be a specific problem. In multi-robot activities, IoRT technology from various vendors is considerably challenging to combine, customize, and teamwork, sometimes utilizing different technologies. Several developments have been achieved for some functionality of multi-robot systems in the area of science, yet further advances ultimately include the robot producers' themselves' active involvement. Moreover, communications with human machines are becoming gradually pertinent in diverse locations, such as prisons, restaurants, and places of service. Smart robots will react to popular human gestures in HRI. The related data processing often strives to achieve full autonomy and stability in HRI. However, several restrictions continue to impede the production of HRI. New HRI forms, such as eye-tracking, speech interactions, and biodegradable recognition have been researched in recent years yet they still require testing, because several were just analyzed and have not yet been widely deployed in research laboratories.

As CPS and Business 4.0 develop remote operation innovations are being adopted by an increasingly lucrative sector, where human operators operate remotely, reprogram, and control robots from a protected space. In certain circumstances, HRI plays a new and valuable role in the need to improve the technology, and it can be highly beneficial for remote supervision of manufacturing robotics by human operators. Advances in IoRT technology would respond to a faster, more modern form of handling industrial activities. Just, remote study has drawn tremendous attention owing to its immense advantages. Remote job was found to boost production quality due to an improved balance between work and life. IoRT systems will further accelerate those developments, opening up different possibilities for remote usage of industrial robotics. Moreover, every other implementation of this survey will conveniently export the same paradigm. In school, for example, in an IoRT scenario, students learn by incorporating social robots. These problems contribute to deepening of connections between human beings and robotics for schooling. In addition, more research on IoRT technologies would be of extreme importance. Besides improving multi-robot and HRI systems in smart settings, the development of IoRT applications is a major concern in the age of Industry 4.0. In recent years, it has the interest in examining energy spending among researchers been growing. The challenge in measuring and enhancing energy quality in a smart world derives primarily from an inadequate knowledge of the behavior of energy use. This expertise, for example, needs to be integrated into efficient manufacturing management to achieve successful processes on a long-term basis.

In these applications, additional computation and saving features should be applied to the IoRT network, since robots cannot handle and retain vast amounts of data at the edge. The major challenges with cyber protection include insecure user and robot connectivity, authentication difficulties, confidential data leakage, and bad default robot setup.

As protection in networked robotics is fundamental, modern smart network architectures become necessary to secure not only data knowledge, but also individuals in HRI systems. Indeed, human–robot protection cooperation is a crucial concern in the automotive world, mainly for IoRT systems. The smooth running of such industrial networks will jeopardize cyber-attacks from the network or through the Internet. To address these issues, CPS protection vendors need to help to distinguish possible threats by comparing, data processing and compilation from different sources. Taking into consideration, the period expended on person and machine designing IoRT structures, classification and near monitoring of production data and other industrial management applications, since it might be necessary to properly collect information background in order to maintain cyber-physical protection. The output data should be maintained in the same format with the same material as it was produced and should be shared with any other compatible industrial system worldwide utilizing the same protected protocol.

Through unified verification and authorization procedures, cyber-physical protection challenges can be solved by streaming output details such as data pieces, assigned liability, managed operator access and granular licensing. Since the connection between intelligent devices is critical for further development in business and research, solving cyber-physical security problems is essential to boost IoRT systems' growth in smart spaces. Protection concerns with both CPS and robot links must also be studied further.

6 Conclusions

The manuscript highlighted the development of primary Industries 4.0 that helped develop IoRT structures. A description of how CPS handles the relation between actual and virtual reality to incorporate an internet importance. The architectures of both systems have been identified and numerous IoRT implementations in various intelligent areas mentioned, showing how IoRT-based devices carry out conventional robotics. The convergence of robotics with the IoT and artificial intelligence would be critical. IoT provides the ability to communicate with various stakeholders such as applications, smartphones, and people contact, providing the right option for multiple application domains. The combination of robotics, IoT and artificial intelligence results in robots that can execute more complicated tasks independently or in collaboration with humans.

In fact, the state-of-the-art technologies in smart realms is evaluated after 2018, revelation that IoRT devices are now central in multiple contexts, beginning with industrial ones, such as manufacturing and forestry, and impacting regular life, for example, health care, education sector, and surveillance. IoRT applications will also pave the groundwork for the growth of other sectors beyond the manufacturing sector, such as culture, museums visit, and athletic events, to enhance progressively the facets of human existence. Furthermore, it has been noted that designing IoRT systems will provide an effective solution to the need for remote work, through which the current criteria of remote human–robotic interactions can be the key to greater fulfillment and efficiency.

The key subject of this study was those IoRT-based structures in the manufacturing and development sectors. IoRT problems and obstacles have been extensively examined and highlight. The increasing need to study in the partnership between robots and robots, particularly in heterogeneous robotics, human–robotic interfaces for oriented human communications, energy management for performance optimization and computer defense for critical data safety. The expected increases in performance, robustness and protection would open up new doors for even new applications that can benefit from new developments in the fields of robotics and networking.

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