International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 6 Issue 4, May-June 2022 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Internet of Robotic Things

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ABSTRACT

As the name implies, Internet of robotic things (IoRT) is the amalgamation of two emerging technologies, the Internet of things and robotics. Internet of robotic things is a branch of robotics that describes how to empower a robot with intelligence to execute critical tasks by itself. It is a concept in which intelligent technology can monitor and manipulate the events happening around robots. IoRT is a relatively new field, where autonomous machines gather data from multiple sensors and communicate with each other to perform given tasks. This paper introduces IoRT and its aplications.

KEYWORDS: *robots, robotics, Internet, Internet of things, Internet of robotic things*

How to cite this paper: Matthew N. O. Sadiku | Uwakwe C. Chukwu | Abayomi Ajayi-Majebi | Sarhan M. Musa "Internet of Robotic Things" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-6 | Issue-4, June 2022, pp.445-451, URL: www.ijtsrd.com/papers/ijtsrd50064.pdf

IJTSRD50064

INTRODUCTION

Robots are entering our everyday life. The number of robots used worldwide is rapidly increasing. Robotics involves design, construction, operation, and use of intelligent machines that possess the ability to sense, compute, manipulate, and navigate environments. Traditionally, robotic systems are programed and designed for repetitive, labor-intensive work, including sensing and acting upon an environment. Robots have been applied in various areas such as domestic support, manufacturing, healthcare, agriculture, monitoring and surveillance, military and defense, rescue operations, and entertainment. The ever-evolving robotics has merged with the Internet of things (IoT), generating something called the Internet of robotic things. Robots and IoT devices are similar in that they both rely on sensors to understand their environment [1].

The Internet has been a miracle on its own. It has taken the world by storm. Internet has evolved rapidly into Internet of things technology, which builds connections with other objects over the Internet. Internet of things is about limiting human involvement in communication network. It allows massive number of uniquely addressable ‘‘things’’ to communicate with each other and transfer data over the Internet. Internet of robotic things (IoRT) is an amalgamation of robotics and Internet of things. It involves technology interacting with our senses of sight, hearing, taste, smell, touch, enabled by AI, VR/AR, intelligent connectivity, and automation. Sensing is a common characteristic of the IoT and robotic systems. Although robotics and IoT are similar in that they both rely on sensors to understand their environment, they have been supported by different but highly complementary goals; the first aimed to promote information services for detection, tracking, and ubiquitous surveillance, and the second to create movement, interaction, and interaction behavior [2].

To understand what describes an IoRT system, it is expedient to first look at the features that characterize IoT and robotics separately.

WHAT IS A ROBOT?

The word "robot" was coined by Czechriter Karel Čapek in his play in 1920. Isaac Asimov coined the term "robotics" in 1942 and came up with three rules to guide the behavior of robots [3]:

1. Robots must never harm human beings,
2. Robots must follow instructions from humans without violating rule 1,
3. Robots must protect themselves without violating the other rules.

Robotics has advanced and taken many forms including fixed robots, collaborative robots, mobile robots, industrial robots, medical robots, police robots, military robots, officer robots, service robots, space robots, social robots, personal robots, and rehabilitation robots [4,5]. Robots are becoming increasingly prevalent in almost every industry, from healthcare to manufacturing.

Although there are many types of robots designed for different environments and for different purposes/applications, they all share four basic similarities [6]: (1) All robots have some form of mechanical construction designed to achieve a particular task; (2) They have electrical components which power and control the machinery; (3) All robots must be able to sense its surroundings; a robot may have light sensors (eyes), touch and pressure sensors (hands), chemical sensors (nose), hearing and sonar sensors (ears), etc. (4) All robots contain some level of computer programming code. An autonomous robot must have a basic body structure (the chassis), sensors, a central control system (microprocessor), actuators (motors), a power supply and an overall program for its behavior. Programs are the core essence of a robot since they provide intelligence. There are three different types of robotic programs: remote control, artificial intelligence, and hybrid. Some robots are programmed to faithfully carry out specific actions over and over again (repetitive actions) without variation and with a high degree of accuracy.

The advantages of robotics include heavy-duty jobs with precision and repeatability. Despite these advantages, there are certain skills to which humans will be better suited than machines for some time to come. Humans have the advantages of creativity, decision-making, flexibility, and adaptability. Figure 1 illustrates the design space of robots [7].

OVERVIEW ON INTERNET OF THINGS

The term "Internet of things" was introduced by Kevin Ashton from the United Kingdom in 1999. Internet of Things (IoT) is a network of connecting devices embedded with sensors. It is a collection of identifiable things with the ability to communicate over wired or wireless networks. The devices or things can be connected to the Internet through three main technology components: physical devices and sensors (connected things), connection and infrastructure, and analytics and applications.

The IoT is a worldwide network that connects devices to the Internet and to each other using wireless technology. IoT is expanding rapidly and it has been estimated that 50 billion devices will be connected to the Internet by 2020. These include smart phones, tablets, desktop computers, autonomous vehicles, refrigerators, toasters, thermostats, cameras, pet monitors, alarm systems, home appliances, insulin pumps, industrial machines, intelligent wheelchairs, wireless sensors, mobile robots, etc.

There are four main technologies that enable IoT [8]:

1. Radio-frequency identification (RFID) and near-field communication.
2. Optical tags and quick response codes: this is used for low cost tagging.
3. Bluetooth low energy (BLE).
4. Wireless sensor network: they are usually connected as wireless sensor networks to monitor physical properties in specific environments

Other related technologies are cloud computing, machine learning, and big data.

The Internet of things (IoT) technology enables people and objects to interact with each other. Its main applications domains are illustrated in Figure 2 [9]. It is employed in many areas such as smart transportation, smart cities, smart energy, emergency services, healthcare, data security, industrial control, logistics, retails, government, traffic congestion, manufacturing, industry, security, agriculture, environment, and waste management [10].

IoT supports many input-output devices such as camera, microphone, keyboard, speaker, displays, microcontrollers, and transceivers. It is the most promising trend in the healthcare industry. This rapidly proliferating collection of Internet-connected devices, including wearables, implants, skin sensors, smart scales, smart bandages, and home monitoring tools has the potential to connect patients and their providers in a unique way.

Today, smartphone acts as the main driver of IoT. The smartphone is provided with healthcare applications.

The narrowband version of IoT is known as narrowband IoT (NBIoT). This is an attractive technology for many sectors including healthcare because it has been standardized [11]. The main feature of NBIoT is that it can be easily deployed

within the current cellular infrastructure with a software upgrade.

In recent years, the Internet of Things has been hailed as a game changer for businesses.

BACKGROUND ON INTERNET OF ROBOTIC THINGS

As the Internet of Things (IoT) continues to penetrate different domains, it has recently entered the world of robotics. The IoT and robotics communities are coming together to create the Internet of robotic things [12]. The term "Internet of robots" (IoRT) refers to a set of interconnected robots, which can react autonomously to changes in their environment, sense other objects around them, communicate with each other without human intervention. It is the combination of robotics with the manipulation/interaction/perception/motion ability in the physical world and Internet of things (IoT) with the realization ability of independent and smart networks. The combination of these two powerful technologies has given rise to a vital element that is going to speed up human development. The integration of IoRT with various technologies, such as edge computing, cloud computing, fog computing, cloud robotics, and AI, is increasing numbers of application areas [13]. This is illustrated in Figure 3 [14].

As IoT devices and robots, IoRT devices perceive the environment through software, sensors, and technology like RFID and GPS. Philip Solis, research director at ABI Research, is credited for first naming and defining IoRT. Since IoRT is a combination of IoT and robotics, it has components in both with better integration and extensive capabilities. The components in robotics are [15]:

1. **Sense:** The devices have in built sensors in them which make them able to read the state of the environment.
2. **Analyze:** The brain of the device processes the data and analyzes what it should do depending on the instructions set.
3. **Act:** Then according to the "brains," it reacts to its surrounding things.

The components in IoT are [15]:

1. **Sensor:** IoT devices mostly consists of sensors that reads/writes the data.
2. **Data transfer:** After the data is read from the sensor, or if it receives any instructions from the user it processes it and sends it to the user/sensor (if required).

Figure 4 illustrates the components of IoRT [16]. The IoRT allows robotic things and smart networks to interact and exhibit smart behavior.

APPLICATIONS OF INTERNET OF ROBOTIC THINGS

IoRT is a disruptive technology that opens new possibilities in several research fields Its potential applications are many since it combines applications of both IoT and robotics. IoRT is a powerful technology and is already playing a major role in our manufacturing, healthcare, security, surveillance, education, agriculture, supply chain, military and defense, and transport. The following applications of IoRT are typical [17].

- **Manufacturing:** Manufacturing and transportation and logistics industries have been pioneers of IoRT revolution. IoRT has several applications in industrial manufacturing environments. IoRT-based manufacturing systems can help in mass production. Robots and cobots are already revolutionizing manufacturing processes all around the globe. They can perform repetitive and challenging with an unprecedented level of precision and speed. The fusion between robots and IoT technology have significantly improved manufacturing supply chain operations, boosting efficiency, productivity, and revenue. Figure 5 shows IoRT-based robotic manufacturing [18].
- **Industrial Robots:** IoRT can be the perfect choice for industries that deal with heavy duty work or repetitive manual jobs. Most of the current applications of IoRT are with industrial robots. Industrial robots have become commonplace in factory settings across the world. They continue to gain popularity for their high level of accuracy, precision, endurance, speed, productivity, and profitability. From 2020 to 2022, almost two million new units of industrial robots are expected to be installed in factories worldwide. Industrial robots are now equipped with human capabilities like memory, sensing, trainability, and dexterity, making them suitable for more sophisticated jobs like assembling, packaging, testing, inspection, packaging, taking inventory, putting things on pallets, etc.
- **Autonomous Supply Chain:** Perhaps the most prevalent use of IoRT is to form autonomous supply chains in e-commerce. All aspects of a supply chain from the production of raw materials to the delivery systems can be automated using IoRT systems. The combination of robots and IoT technology have enhanced supply chain operations. It reduces the challenges of rising e-commerce demands and warehouse worker shortages. It also streamlines operations by developing process-driven automated functions

and making industry processes to be more efficient and cost-effective. IoRT powered robots limit human interference in supply chains. When an order is placed, an autonomous IoRT system finds the product, packs it, labels it, and sends it over for shipping. The use of IoRT in the supply chain can boost both productivity and revenue. Automated guided vehicles (AGVs) are quickly becoming a staple in supply chain warehouses and the key to increased supply chain productivity. AGVs work to navigate the warehouse floor faster than human workers, and they can work 24/7. Amazon currently has more than 200,000 robots operating in its warehouse automation and delivery-fulfilment centers [19].

- **Precision Agriculture:** We all need food to survive as humans and animals.

  With the human population exploding, the world will need to produce 70% more food in 2050. Precision agriculture is a promising domain for IoRT. IoRT can be used in precision agriculture for the targeted delivery of fertilizers, pesticides, and water. IoT-based smart farming is also beneficial in terms of environmental issues.

- **Healthcare:** Robotics has been one of the most advanced and emerging technologies in healthcare. Robotic innovations are introduced in numerous areas that influence the understanding and consideration of patient care. With sensors connected to a patient's body, real-time monitoring of their health can be done.

- **Smart Homes:** IoRT will be the cornerstone of the fully automated smart homes of the future. Homes of the future can be managed completely by IoRT. In automated systems for household works, security, comfort, and convenience are all interconnected to give one a seamless experience.

- **Military and Defense:** The army is adopting IoRT for advanced solutions as technology advances. It is not far from using unmanned drone attacks for monitoring and even to eliminate terrorist cells.

- **Automated Vehicles:** Driverless cars are the future of transportation. With IoRT, cars can maintain communication with other cars, preventing accidents, predicting traffic, and finding comfortable routes.

- **Surveillance System:** This kind of systems has become indispensable in daily life. The IoRT-based surveillance system can be used as a remotely monitoring technology. The system uses controller interface system with Raspberry Pi which is low cost and consumes smaller amount of power. The camera is interfaced with Raspberry Pi which is mounted on robot [20].

BENEFITS AND CHALLENGES

Robotics have long been successful in several structured industrial applications, due to their high level of accuracy, precision, endurance, and speed. Robots have largely become more affordable in recent years. In the supply chain, the deployment of robotics focuses mainly on increasing productivity and lowering operational costs.

Using IoT in robotic automation results in more ways to improve productivity, increase the lifespan of the robots, and optimize maintenance. IoRT is bringing unprecedented insight and applications in autonomous networks globally in smart homes, smart cities, smart factories, offices, and more. Now that robots can learn from IoT collected data, robots are being programmed to take corrective and predictive actions not previously seen before.

In view of the benefits of the IoRT, several forward-thinking companies are investing heavily in this technology. Companies such as Amazon.com, Wal-Mart Stores, Apple, and Dell are facing challenges such as insufficient warehouse space, large stock keeping unit counts, and pressure of fast delivery, among others. The Internet of robotic things would help to overcome these challenges [21].

However, there are challenges yet to be addressed such as the unreliable cognitive capacity among IoRT entities and the unreliable cognitive progress of artificial intelligence for intelligent robots. The need to make robots economical still stands as a challenge. The IoT is still not used at its full potential in robotics.

CONCLUSION

The IoT and robotics communities are coming together to create IoRT. Robotics together with IoT constitute dynamic and active research fields. The resulting combination, Internet of robotic things, is a novel field of research. Although robotic systems face many challenges, there is no doubt that robots are here to stay. More information about IoRT can be found in the books in [22-24] and the following journals devoted to robot-related issues:

- Robotica
- Robitics and Autonomous Systems
- Robotics Research
- Frontiers in Robotics and AI
- Robotics and Computer-Integrated Manufacturing,
- Advanced Robotics
- Autonomous Robots

- Journal of Robotics
- Journal of Robotic Systems
- Journal of Robotic Surgery
- Journal of Robotics and Mechatronics
- Journal of Intelligent & Robotic Systems
- Journal of Mechanisms and Robotics-Transactions of the ASME
- Journal of Automation, Mobile Robotics and Intelligent Systems
- Intelligent Service Robotics
- IEEE Journal on Robotics and Automation
- IEEE Robotics & Automation Magazine
- IEEE Robotics and Automation Letters
- IEEE Transactions on Robotics
- International Journal of Medical Robotics and Computer Assisted Surgery
- International Journal of Robotics Research
- International Journal of Social Robotics
- International Journal of Humanoid Robotics
- International Journal of Advanced Robotic Systems
- ISRN Robotics
- Recent Trends in Mobile Robots
- Science Robotics

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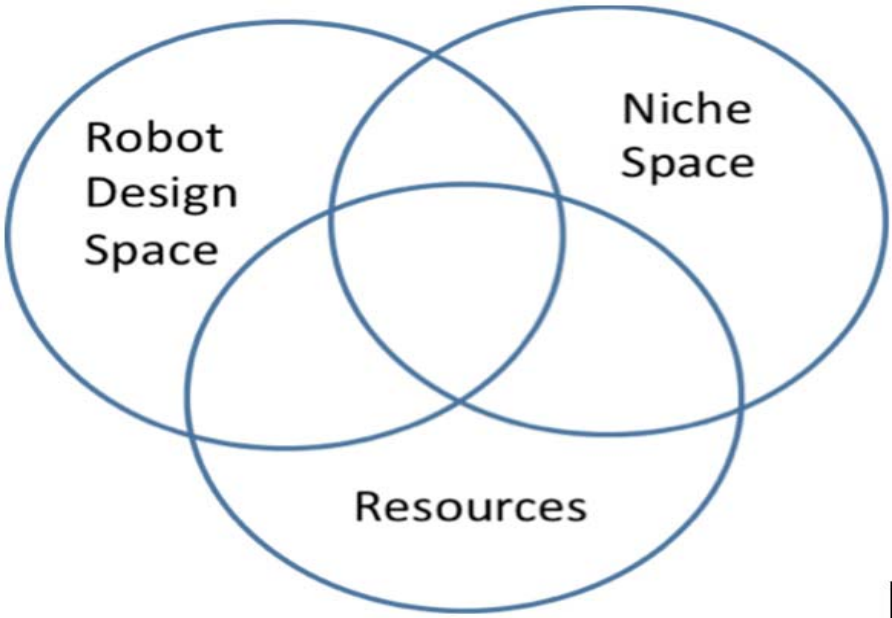

Figure 1 The design space of robots [7].

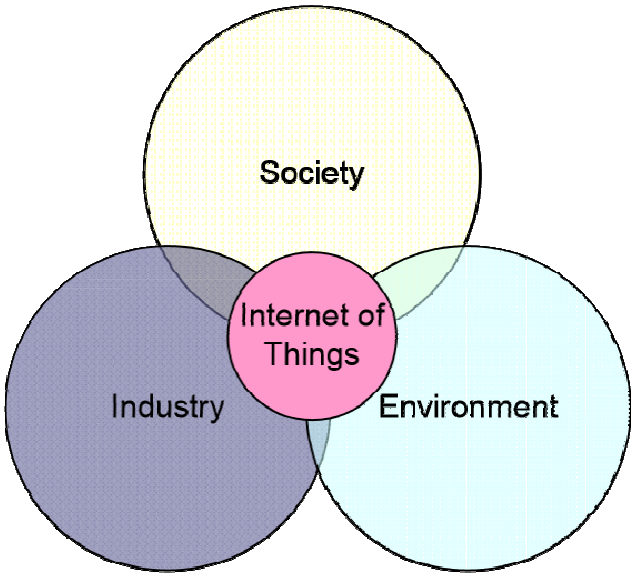

Figure 2 The main application domains of IoT [9].

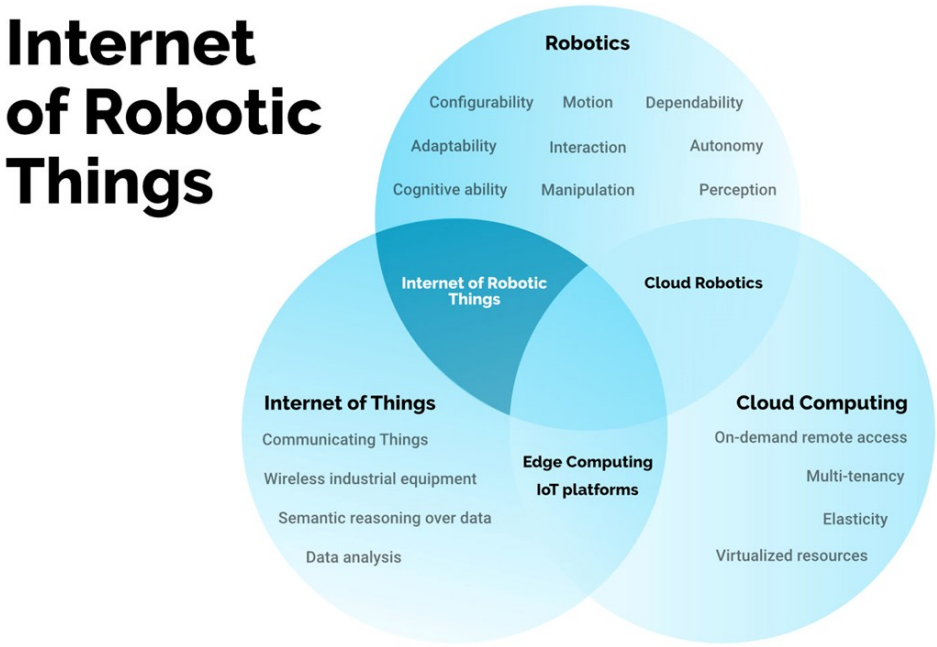

Figure 3 The concept of Internet of robotic things combined with cloud computing [14].

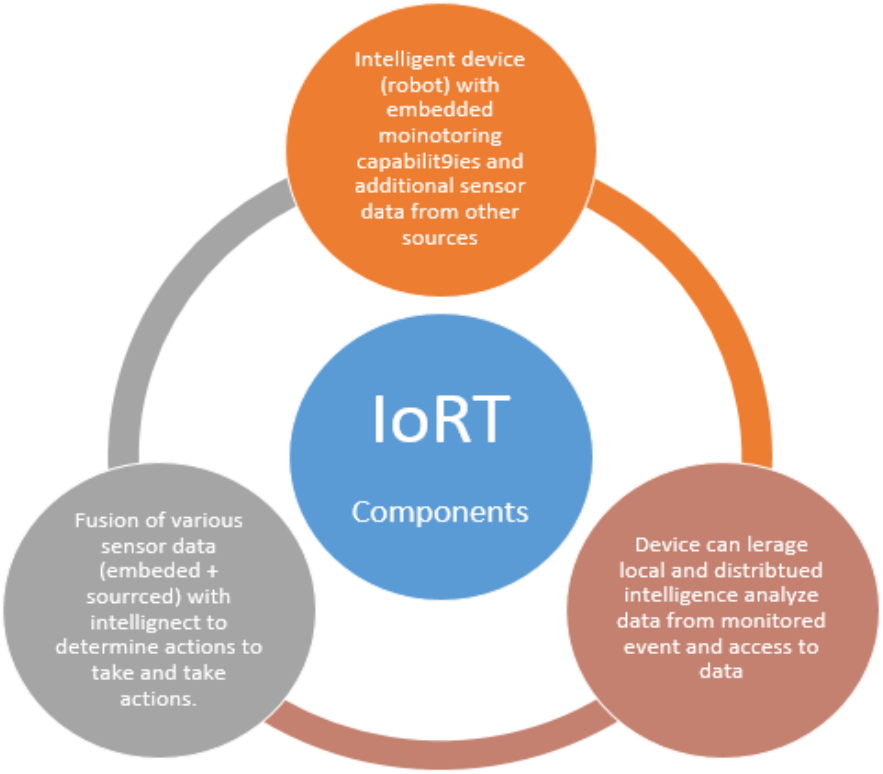

Figure 4 The components of IoRT [16].

Figure 5 IoRT-based robotic manufacturing [18].