Internet of Robotic Things (IoRT)

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***Abstract*—The Internet of Things (IoT) provides a robust platform for connecting objects to the Internet, facilitating Machine-to-Machine (M2M) communication and data transfer through network standards. The rapid growth of IoT is evident, with billions of devices already interconnected. In various fields such as healthcare, industry, military applications, robotics, nanotechnology, the IoT is being adapted for advanced solutions. This research focuses on integrating the Internet of Things with robotics, resulting in the Internet of Robotic Things (IoRT). IoRT is a combination of technologies such as IoT, Cloud Computing, Robotic Cloud, etc. It explains what the Internet of Things is, what robotics is, their integration, the role of the cloud, and some applications of IoRT, aiming to enhance understanding of these concepts.)**

Keywords—Internet of Things, Robotics, Internet of Robotic Things.

I. Introduction

The Internet of Things (IoT) is a collection of sensors and actuators connected through networks to software, capable of monitoring and managing connected objects, machines, and even living beings[1]. The devices in this collection can be interconnected with each other and/or to the cloud, either on the internet. The communication between these devices is achieved using protocols such as TCP/IP. The Internet of Things continues to gain ground steadily, with experts suggesting that by 2023, there are approximately 15.14 billion connected IoT devices, with estimates projecting an increase to 25 billion devices in the next seven years[2].

According to Cambridge, a robot is a machine controlled by a computer and used to perform various tasks automatically. Robotics is increasingly prevalent in our daily lives, infiltrating almost every sector, bringing significant changes to the standard of living for humanity. For instance, in the global industry, as reported by the European Commission, there were over 3.5 million robots in 2022, and this number is constantly rising. In the healthcare sector, there were 826 surgical robotic systems in 2017, and it is estimated that there will be 2,112 by 2025[3][4].

According to the IEEE Society of Robotics and Automation Technical Committee of Network Robotics[5], network robotics is defined as a robotic device connected to a communication network, such as the Internet or a local network, using network protocols such as TCP, UDP, or 802.11. The committee identifies two categories of networked robots:

Teleoperated: Robots located in remote locations and controlled by humans using commands. Teleoperated robotics is mainly used in research, education, and public use.

Autonomous: Robots embedded with intelligent sensors operating in the network, exchanging information. Sensor technology expands the functionality of robots, allowing them to communicate over longer distances to perform tasks in a highly coordinated manner.

The Internet of Robotic Things (IoRT) is a scenario presented by ABI Research, referring to the integration of robotics with the Internet of Things. Specifically, it involves the use of properties and sensors that a robotic system can possess. On the other hand, robotic systems will have access to every piece of information they need via the internet and information collected from other corresponding robotic systems. This way, they become more efficient and well-informed in real-time. The Internet of Robotic Things in robotics will also facilitate immediate remote use, control, improvement, and updates related to the system connected to the Internet of Things, equipped with the appropriate sensors for controlling the system itself and its surrounding environment or the task it performs..

II. Cloud IoRT

A. Cloud robots

In 2010, James Kufner introduced a new approach to robots that would have the advantage of utilizing internet sources while simultaneously enhancing them with a system of parallel computation and information transmission[6]. Cloud robots represent a field in robotics that combines cloud technologies such as cloud computing, cloud storage, and other internet-based technologies, focusing on the benefits of converging infrastructure and common services for robotics. By connecting robots to the internet, communication and interaction among robots and other objects connected to the Internet of Things are achieved.

Specifically, the cloud consists of database clusters where all data is stored. These clusters communicate with the servers of the cloud, where data is processed, and interact with OpenFlow Interactive devices, acting as intermediaries for communication between robots and the cloud. In this way, the cloud stores and processes the data used by robots

while simultaneously being fed with new data provided by the robots through the data collection they perform, including their sensors, processing results, and more[7].

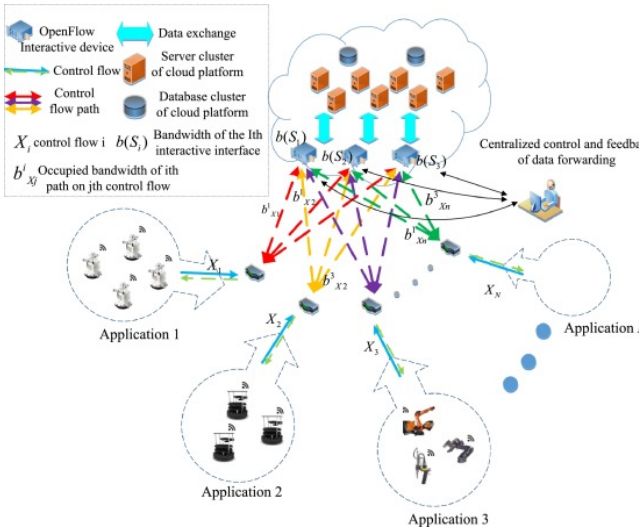

Image 1:Yan, H., Hua, Q., Wang, Y., Wei, W., & Imran, M. (2017). Cloud robotics in Smart Manufacturing Environments: Challenges and countermeasures. Computers & Electrical Engineering, 63, 56–65.

B. *Internet of Things and Cloud*

The Internet of Things, as previously mentioned, is an extensive network of interconnected devices. These devices are equipped with sensors that gather information and data. Subsequently, this data is transferred to the cloud where it is stored and processed. The data that is stored or generated in the cloud, through the processing that takes place, is then fed back to the devices, humans, or robots [8].

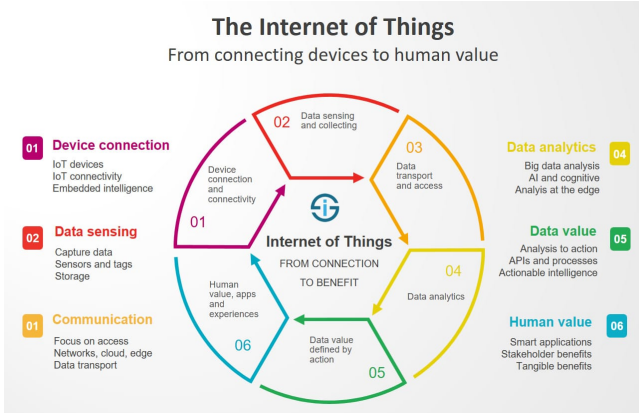

Image 2: IoT circle
https://www.i-scoop.eu/internet-of-things-iot/internet-of-things-what-definition/

For a better understanding of the connection between the Internet of Things and the cloud, we need to comprehend how cloud computing operates. Cloud Computing is a way of using computer services, such as storing information or running programs, over the Internet without relying on our own machines or equipment. This facilitates people's access to data from anywhere in the world.

Cloud Computing services are divided into three main types:

- Infrastructure as a Service (IaaS) - Companies rent virtual hardware for processing power.
- Platform as a Service (PaaS) - Allows developers to create applications using tools provided by the platform.
- Software as a Service (SaaS) - Provides users with access to software applications through subscription models.

The Internet of Things (IoT) technology and Cloud Computing are closely interconnected technologies, with IoT data storage and management in the cloud, and cloud computing power playing a crucial role in enabling IoT. The enormous volume of data generated daily by IoT devices, can be stored and managed in the cloud. This leverages the scalability, flexibility, and cost-effectiveness of the cloud. With analysis tools ranging from artificial intelligence, valuable insights can be derived from this raw data within the cloud [9].

C. *Internet of Robotic Things in cloud*

If we combine the relationship of IoT with the Cloud and the relationship of robotics with the Cloud, we observe the relationship of IoRT (Internet of Robotic Things) with the Cloud. More specifically, devices, humans, and robots send data to the IoT network. As mentioned earlier, the use of the cloud is crucial for storing and processing this data, both for robots and the Internet of Things. Subsequently, robots are fed back with data from the Internet of Things stored in the cloud to enhance their ability to perform assigned activities more effectively.

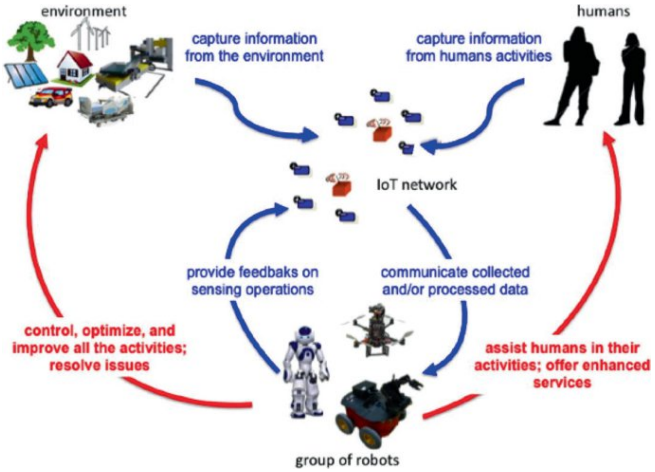

Image 3:Circle of IoRT.

III. APPLICATIONS OF THE INTERNET OF ROBOTIC THINGS

The combination of robots with the Internet of Things has brought about significant and radical changes in the way of life we have known so far. The solutions introduced by the Internet of Things are transforming how we address problems. Smart homes, everyday-use accessories (such as smartwatches), smart cities, and the integration of the Internet into industries have led to profound changes, with

interconnected cars, smart agriculture, and advancements in healthcare being just a few areas where the Internet of Things and robotics are applied in conjunction.

By providing this network with the ability to access a vast array of data instantly, the response time to critical problems can be reduced, often eliminating the need for human intervention in solving these issues. Robots play a crucial role in various fields, accessing and enriching the Internet of Things directly. In many instances, robots replace humans in tasks, ensuring that human resources are not exposed to potential risks. Moreover, robots frequently perform tasks that would be impossible for humans, such as underwater explorations at great depths or space exploration. Below, we will discuss the applications of robots in conjunction with the Internet of Things in several critical and everyday sectors, including health, industry, the military, and research and rescue operations [10].

A. Applications in Healthcare

The Internet of Things is utilized in medical devices for remote patient monitoring, medication control, and the tracking of medical personnel and equipment. Wireless Body Area Networks (WBANs) are often employed to support patients. A WBAN is equipped with various measurement sensors (ECG, pulse oximeter, thermometer, etc.) for collecting signals from the human body. These measurements are then transmitted to an external device used for collecting and visualizing the data. With internet connectivity, remote patient monitoring from home has been achieved.

The use of robotics in the healthcare sector already plays a significant role. Robot-nurses can assist patients both within and outside the hospital. Robots are employed to aid in healthcare and rehabilitation, as well as to provide assistance in surgical procedures. With IoRT, a Cyber-Physical System is possible, where a massive amount of information is generated from heterogeneous equipment (medical devices, local and remote monitoring systems, body control sensors, and smart objects). Collaborating with robots that lean towards solving problems, executing tasks, and leveraging their autonomy and mobility, this system can become autonomous and efficient. However, since the healthcare sector is one of the most, if not the most, crucial areas, assistance should be supportive to the existing human workforce, which will make critical decisions..

B. Applications in Industry

The combination of robotics with the Internet of Things and its application in the industry is one of the most common integrations encountered. Automated processes, guided remotely by an operator, can be executed promptly and accurately. The use of robots in the field could reduce labor costs, increase production, and significantly decrease the chances of errors and prevent industrial accidents.

When integrated with the Internet of Things, industrial production becomes instantly informed about product movements in the market, avoiding surplus production and leading to resource savings. If the product is also connected to the Internet of Things, it can send information to the production sector, allowing robots to self-update and parameterize. This results in higher-quality production, minimizing factory errors, and preventing future issues as much as possible.

C. Applications in the Military

The Internet of Robotic Things in the military has a broad range of applications. One usage is the detection of various elements such as chemicals, signals, radiation, etc., through photovoltaic, laser, acoustic, and other sensors. It is employed to unveil hazardous zones, identify enemy movements, and establish security zones in sensitive areas. On the other hand, the military commonly utilizes robots for aerial and underwater coverage to avoid endangering human personnel. The combination of the Internet of Things with robotics has introduced new technologies to the military sector, with Unmanned Aerial Vehicles (UAVs) being one of them. UAVs are unmanned aircraft remotely controlled for purposes such as area surveillance, target neutralization when necessary, and creating secure zones for the safety of soldiers. They typically feature sensors for environmental recognition, GPS, various types of cameras, sound sensors, electromagnetic field sensors, etc. The sensors collect data, and with the help of systems, perform the required recognitions. All this data is transmitted to the operator, who takes the necessary actions [11][12].

D. Applications in Rescue Operations

Rescue operations and ensuring the safety of individuals at risk, primarily from natural or human-made disasters, are another area where the use of IoRT can prove beneficial. During a rescue operation, collecting necessary information is essential for a safer, more secure, and prompt execution. The use of the Internet for information transfer and robots is necessary to avoid endangering the lives of rescuers and to enable quicker and more extensive data collection. The combination of these two elements will facilitate smoother operation execution and enable operations in environments where humans may be unable to act. Continuous information gathering, rescuing people from challenging environments, and assisting human activities in the field of rescue make robots in combination with the Internet of Things indispensable for this sector [13].

CONCLUSION

The Internet of Things (IoT), Robotics, and Cloud Computing are considered highly advanced technologies today. With the revolution in Information Technologies, ranging from simple computing machines to smart phones, from cloud to IoT, the capability of data management has reached a new level. Robotics plays a significant role in almost every sector today. By combining robotics with the Internet of Things, we are led to the execution of complex processes almost autonomously without any human intervention.With IoT, multiple robots can be integrated for a single task, executing the job with high efficiency and coordination. In this context, we have reviewed a new concept that emerged from IoT, transforming robotics to a more advanced level – the Internet of Robotic Things (IoRT). The Internet of Robotic Things will enable robots to share, network, and disseminate information, resources, and various types of data among other robots, operating in a

common environment using a new architecture designed specifically for IoRT.IoRT will provide a robust foundation for opening broader opportunities for the application of robotics in various fields.

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