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Artificial General-Internet of Things (AG-IOT) for Robotics of Automation

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Abstract

The idea of the Internet of Things (IoT) is quickly developing and influencing new advancements in a variety of application domains, including the Internet of Mobile Things (IoMT), Autonomous Internet of Things (A-IoT), and the Internet of Robotic Things (IoRT), among others. The IoT influence presents new design and implementation challenges in various fields, including seamless platform integration, context-based cognitive network integration, new mobile sensor/actuator network paradigms, and architectural domains for smart farming, infrastructure, healthcare, agriculture, business, and commerce. Applications for automation in the IoRT are numerous and are developing quickly. IoRT blends the strength of robots and the IoT, resulting in creative solutions for a range of sectors. As we ensure the authenticity of the content in this introduction, we shall investigate the wide range of IoRT automation applications. IoRT automation refers to a broad range of endeavors that use connected gadgets, sensors, and autonomous machinery to improve production, efficiency, and safety across various industries. These regions are general categories into which these programs can be placed; Industry 4.0 and manufacturing, IoRT enables automated manufacturing where robots and IoT gadgets work together without issues.

While sensors keep an eye on the condition of the equipment and improve manufacturing processes, robots can carry out activities like assembly, quality checking, and material handling. Medical field: IoRT automates procedures, including surgery, patient surveillance, and drug delivery, increasing accuracy and lowering human error. Robotic prostheses and exoskeletons improve rehabilitation and mobility. Agriculture: IoRT supports precision farming by using robots and drones that can operate autonomously to check crop health, administer pesticides, and harvest crops. Decisions are made more accessible by real-time sensor data on weather and soil conditions. Logistics and warehousing: By autonomously moving items and improving inventory management, Automated Guided Vehicles (AGVs) and robots optimize warehouse operations. IoRT helps to manage traffic, monitor air quality, and enhance public safety in smart cities by utilizing autonomous cars and advanced infrastructure. Retail: IoRT improves customer experiences in the retail industry with autonomous grocery carts, robotic inventory managers, and data-driven targeted marketing. Environmental Tracking: IoRT devices gather information in hazardous or remote locations, such as monitoring ocean pollution levels or harshly weathering infrastructure inspections. Power and utilities: IoRT uses robotic inspections and proactive maintenance to help maintain electric grids, pipelines, and projects involving renewable energy. Education and Exploration: IoRT is helpful for research and education since it enables scientists and students to experiment remotely with robotic systems and learn more about automation technology. Home automation: IoRT equipment is increasingly integrated into smart homes to provide security and convenience through linked appliances, security cameras, and personal assistants. As technology develops, the range of IoRT automated applications also keeps growing. It can transform industries, enhance the standard of life, and tackle challenging problems. This overview offers a glimpse into the intriguing and diverse world of IoRT automation.

Keywords: IoRT, AGV, Industry 4.0, A-IoT, IoT, Manufacturing.

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1 | Introduction

1.1 | Artificial Intelligence

IoT and autonomous operations have shown great potential with the emergence of Internet of Robotic Things (IoRT) technology. Communication-centered robots that connect to wireless sensors and other network resources are becoming increasingly popular in robotics. These robots can easily integrate with wired or IoT networks, seamlessly utilizing IoRT's autonomous functions in this field. The IoRT technology has shown promising results in IoT and autonomous operations. The latest trend in robotics is centered around.

Communication-oriented robots that can connect with sensors and other network resources wirelessly. These robots can integrate with wired or IoT networks, and the self-sufficient operations of the IoRT technology can be seamlessly leveraged in this industry. Incorporating cutting-edge sensing, actuating, communication, and computing technologies elevates the original concept of IoT to new heights. It enhances operational efficiency, enabling businesses to uncover fresh prospects and predict potential hazards. These advancements present unprecedented opportunities for consumers and IoT and robotics solutions providers. Some applications of IoT are shown in *Fig. 1*.

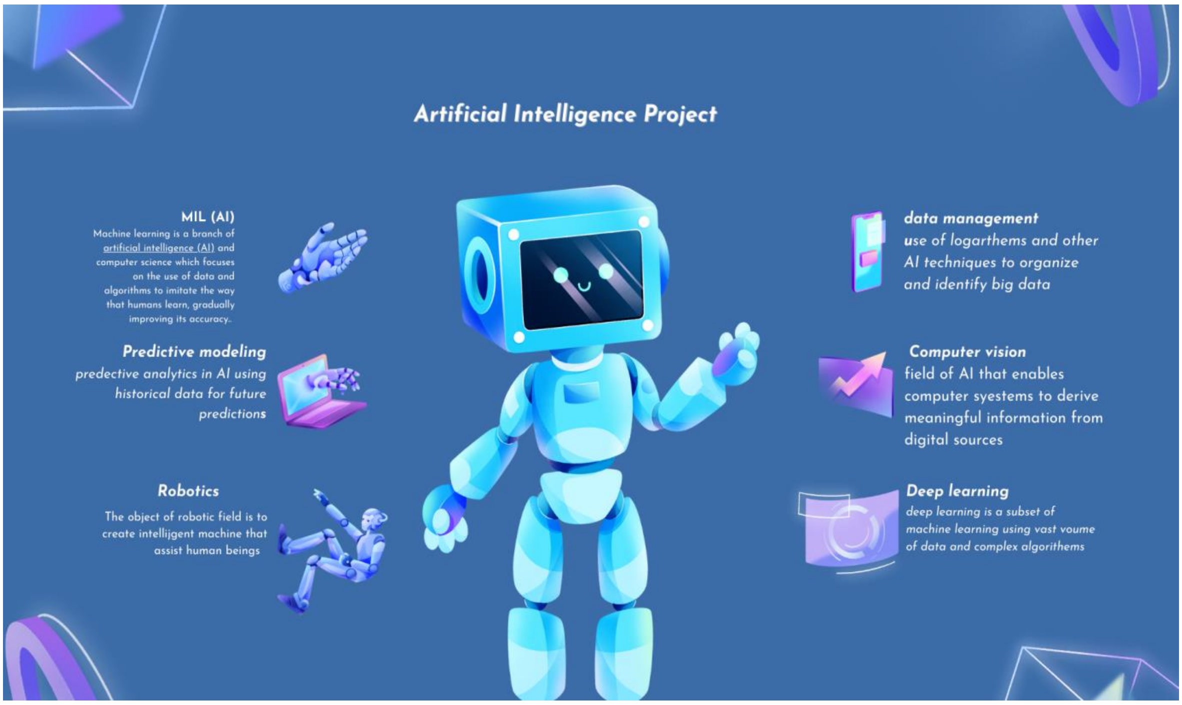

Fig. 1. Applications of IoT.

The Technical Committee on Networked Robots of the IEEE Robotics and Automation Society defines two types of networked robots:

I. Remote-operated robots: networked systems make it simple for human managers to issue directives and get feedback, boosting the availability of crucial resources for study, instruction, and public awareness. This connectivity between robots and humans significantly impacts shared responsibilities, including teleoperation and human-robot interaction. The ability to reprogram and adapt robots on the network is also affected. These technologies are now widely available for remote meeting assistance and telepresence medical equipment. Cloud robotic systems allow robots to exchange knowledge and learn from each other, while cloud infrastructure provides elastic resources to help robots overcome limitations in networked robotics.

II. Automated robots: In highly advanced systems, robots and sensors can communicate with one another with minimal human intervention. This network of sensors expands the robots' sensing abilities, enabling them to interact over long distances and plan their actions accordingly. Robots can deploy, repair, and maintain the sensor network to prolong its lifespan and usefulness. However, a significant challenge in networked robots is establishing a scientific foundation connecting communication to control and enable new capabilities. Whether remotely or locally, updating functionality and operations typically requires specialized knowledge and more extended maintenance periods in closed systems without open interfaces or communication channels.

By utilizing open interfaces, security and efficiency can be guaranteed through this approach. Wireless networks are essential for networked robots to share information among themselves and with powerful workstations used for intensive offline processing. These technologies encounter a number of technological obstacles, including installation, inspection, safety, the localization of operations sensor and actuators fusion, networking noise, trustworthiness, congestion, latency, stability, and range and power constraints.

The IoRT is a complex field that requires careful consideration of these issues. Fortunately, new hardware, software, and communication standards are emerging, providing new capabilities and possibilities.

IoT technologies and applications fundamentally change people's and society's perspectives on technology and business. It is vital to incorporate new IoT concepts, designs, and techniques into the conception and creation of open IoT platforms to support future advancements where IoT services and infrastructure collide with artificial and autonomous system technologies. It will make new apps, increased functionality, new business models, and investment opportunities possible [1].

1.2 | Converging Sensing/Actuating Information Network

A wide variety of products differ in their level of intricacy, sensing and acting capabilities, communication, processing power, intelligence, mobility, and platform compatibility. When we use the term "robotic," we refer to a subset of these highly advanced, intelligent, and self-governing products. These robotic devices rely on edge computing and cloud IoT platforms, incorporating cutting-edge robotics and Artificial Intelligence (AI) techniques to function.

To provide specialized solutions for specific jobs, the IoRT is a sophisticated network of devices that uses path, motion planning, and motion control. This autonomous system architecture is integrated into the larger IoT architecture and is defined by six fundamental characteristics:

I. Sensing: in the realm of IoT and robotics, the term "sensing" is frequently utilized to describe the capacity of devices or "Things" to communicate with other IoT devices and individuals. This communication is typically unidirectional, from the device to the human, which empowers people to participate in the IoT ecosystem based on their own IoT concept or service paradigm. Thanks to extensive research into the flexibility of this feature, "Sensing-as-a-Service" has been integrated into numerous IoT solutions.

II. Actuating: while it is widely recognized that actuating based on a comprehensive approach is a valuable aspect of IoT verticals, it has yet to be made available in the open market. This feature empowers devices to take action in response to physical and/or virtual activities. To ensure that actuating is both reliable and secure, services must be established to support the open, multi-vendor development, deployment, and operation of IoT applications. Through extensive research, the concept of "actuation has emerged as a new prototype for IoT, providing a user-friendly experience that encourages acceptance and engagement for managed IoT devices. Innovative installations are necessary to enable actuating and bring this technology to life.

III. Control: this is a structured set of activities, mainly at the application layer, that operates in a loop or series of loops, referred to as control loops, which define the functions and services. The architecture's comprehensive security concepts must be reflected in the interface definitions to ensure proper sequencing mechanisms. These interfaces are crafted to grant access to sensing data and control mechanisms. Various entities, such as applications and cloud services can be integrated within the control loop.

IV. Planning: the orchestration feature plays a crucial role in streamlining the logic that interconnects various internal components of the platform, enabling seamless completion of service requests. It guarantees that high-quality standards are upheld throughout the entire lifecycle of the IoT application. The planning process employs a robotic sequence engine based on logic to ensure that service requirements are in accordance with processed data and knowledge entities as well as platform-specific representation. Recording user-defined representations of data and resources by the orchestration logic facilitates the server definition process.

V. Perception: the interdisciplinary field of robotics involves integrating sensor data with knowledge modeling for enhanced functionality. Robots use a variety of techniques, including human-interface layout, software development, cloud-based architectures, analytics of data, multiple-agent systems, machine sensing systems, and occasionally AI, to build seamless contact between themselves and people. Robots may identify and understand their surroundings through perception, freeing people to perform specialized activities.

VI. Cognition: this feature equips the robot with monitoring and sensing capabilities, allowing it to gather sensor data from various sources and utilize local and distributed intelligence. It demonstrates the device's impressive capabilities, as it can analyze data from observed events, often employing edge or fog computing. These foundational elements support the device's third capability, which involves autonomous decision-making for actions such as physical manipulation or control in the real world. The device can navigate and operate in its designated physical environment and notify or alert based on physical event analysis. The following subsections offer an overview of the IoRT technologies utilized in creating, using, and deploying IoRT applications [1].

1.2.1 | Sensors and actuators

IoT and robotics rely on two fundamental technologies: 1) sensors, and 2) actuators. These components are crucial for IoRT systems to function correctly, as they provide essential functionalities and well-defined interfaces for identification and reaction. In contrast to IoT, the practical functionality of IoRT building blocks is based on sensors and actuators. Robotic Interaction Services (RoIS) define HRI functions and the usage of external building blocks, as well as abstracting the hardware in service robots. HRI functions, such as facial recognition and wheel control, rely on sensors and actuators like radar, lidar, cameras, and microphones. These components are physically implemented on the robot or in the environment, enabling logical functional aspects such as person detection and identification. This standard allows for the development of HRI apps that can be used on devices and gateways. Actuation is a crucial aspect of robotics that enables the manipulation of items, the movement of people and products, and even the functioning of automated doors. Numerous actuation approaches, including automated strategy and execution by multiple robots, have been developed in robotics.

1.2.2 | Emerging IoRT technologies

Cost-effective solid-state semiconductors or Complementary Metal-Oxide-Semiconductor (CMOS) photographic sensors with proactive illumination are needed for IoRT applications to operate correctly in various weather situations, including sunlight, darkness, rain, fog, and dust. These sensors must have high accuracy and resolution for vertical object identification and horizontal road surface scanning. Most sensors now only provide 2D sensing data; therefore, sensor fusion is primarily concerned with 2D representation. However, more height data, 3D visualization, and combining actuators and sensors are needed to better future IoRT activities. Robotic objects require a customized environment model that utilizes existing and new sensor technology to generate an ideal 3D environmental model that balances resource consumption and maximizes performance. LIDAR systems, which use a revolving, scanning mirror to provide a complete picture, give autonomous robotic objects and cars 360-degree vision. For self-driving, autonomous robotic things, LIDAR systems provide precise 3D data on the immediate surroundings that can be utilized for obstacle avoidance, motion vector analysis, object recognition, and collision prediction. However, LIDAR systems are ineffective for close-range control, so radars must be added to autonomous robotic objects and vehicles. The 76-81 GHz frequency range is typically used for radar because of its RF propagation characteristics and necessary resolution. The radar equipment is small, emits less power, and has a lower risk of mutual interference, making it an effective method for collision avoidance in conditions such as smoke, dust, or other weather conditions.

IoT devices around the world are taking over non-IoT devices. *Fig. 2* illustrates the annual trend in the transition from non-IoT to IoT devices between 2010 and 2025. The US, China, and developed countries in the European Union and the Asia Pacific region are leading IoT markets. The area is predicted to lead in expenditure and uptake in the worldwide market, which aligns with other APAC-related trends. According to market predictions, China will account for two-thirds of the industrial IoT market in the APAC region by 2025.

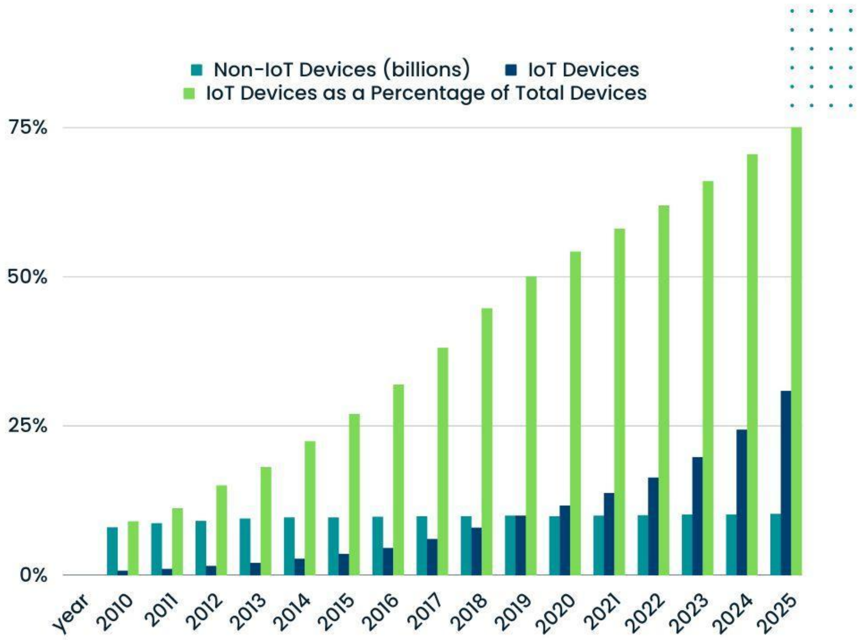

Fig. 2. Yearly shift from non-IoT to IoT devices.

1.2.3 | Communication technologies

The communication infrastructure of IoRT necessitates novel methods to allow the virtualization of operations on current computing engines and facilitate the usage of such infrastructures in diverse fields. These strategies should enable exchanging data streams (important for 3D awareness and imaging systems), communicating internally, and using edge computing. Time-critical communication is essential for collision avoidance, significantly lowering accidents and collisions. IoRT commonly operates local robots using networking technology and remote robots using designated white spectrum frequencies. IoT employs machine-to-machine communication and implements emerging protocols like LoRa and SIGFOX, as well as 4G, WiFi, and Bluetooth. However, this level of interoperability and service development is more challenging and requires semantic data from other disciplines. Due in part to the dynamic nature of IoRT conditions and their dependence on applications, contexts, and use cases, the ability to discover and classify services of objects often presents significant challenges. IoRT systems are built on communication protocols, enabling network connectivity and application interaction. To exchange data over the network, edge devices, and autonomous devices use a variety of communication protocols that define the exchange of data formats, data encryption, device addressing schemes, and packet transportation from origin to destination. Various Wireless Local Area Network (WLAN) communication standards, such as 802.11a, 802.11b and 802.11g, 802.11n, 802.11ac, and 802.11ad, are included in the 802.11-WiFi protocols that are used. These standards offer communication ranges between 20 meters (indoors) and 100 meters (outdoors), with data speeds ranging from 1 Mb/s to 6.75 Gb/s. Various IoRT communication techniques can be used to achieve shared real-time computation, data exchange, and internal communication [1].

1.2.4 | Voice recognition, voice control

Nowadays, chatbots and devices with microphones are commonly used for communication. As the IoRT advances, more endpoints are created for people and robots to interact. It leads to a new digital experience where robotic objects and humans collaborate, resulting in IoRT mesh development through mutual contact between robotic entities.

People should be able to communicate with robot fleets more naturally for IoRT applications, including tour-guiding, elder care, recovery, search and rescue, monitoring, education, general support in everyday settings, workplaces, factories, and homes. When creating IoRT applications, multimodal interfaces that deal with movement detection, auditory localization, people monitoring, users (or fellow person/robot) localization, and merging different modalities are essential. Using knowledge of the robot's movements and postures, powerful noise-reduction techniques can be used for speech recognition and voice control.

To reduce background noise, the microphone's quality is crucial for automatic speech recognition. A speech recognition automation system for robots can accurately identify voices from adults as well as kids in crowded spaces thanks to the reduction of reverberation, disruption, and noise in portable multiple channels of communication technique with an outlier-robust broader side-lobe canceller method and a feature-space noise reduction criterion [1].

1.2.5 | Machine learning as enabler for adaptive

The Internet of Things (IoT) community recognizes the significance of incorporating Machine Learning (ML) techniques into IoT devices to manage network nodes' vast and diverse sensory data effectively. This integration enables IoRT solutions to adjust to different environments while IoRT apps can learn from their surroundings and experiences. The ML service must be intelligent and distributed enough to encompass every IoRT node, including those at the network's edge. Distributed and embedded intelligence can generate high-level aggregated information from the device/sensor's low-level data by performing early data fusion and predictive analyses. These forecasts might be used as inputs for an innovative learning method on an alternative network node, which would then carry out additional forecasts and data fusion operations. It would result in developing a smart network of ML algorithms to carry out progressive sensed data compilations [1].

2 | Marketplace for an IoRT Ecosystem

Mechanisms for monetizing service components and data are required to encourage participation and the development of an IoRT ecosystem. A marketplace must be established as the center of an IoRT ecosystem. A marketplace facilitates registration and the discovery of offerings and the data or attributes services provide. These services may act on robots or objects directly or as separate components accessible through IoRT platforms. Selling and buying products and services occur in the marketplace, which acts as a central location for transactions.

Offering authentication, where a supplier of an offering can provide a metadata description for the marketplace to ingest and index to help with discovery.

Offering discovery, where a customer searches for offerings using a marketplace search interface. Common ontologies for the semantic description of data must be established to facilitate data registration and discovery.

Role and privileges management could be used to secure access to the market. Authentication and authorization can also be used to ensure access to the marketplace.

Reputation management involves consumer evaluations of suppliers and their goods; these evaluations may be considered when selecting search outcomes and during investigation. Auditing and accounting, wherein a customer's service use is monitored, providers can charge a fee at their discretion. This function is crucial for making IoRT monetization possible and giving the ecosystem's growth drive. The management of different data-providing licenses is closely related to it [1]. *Fig. 3* shows advantages of using artificial intelligence.

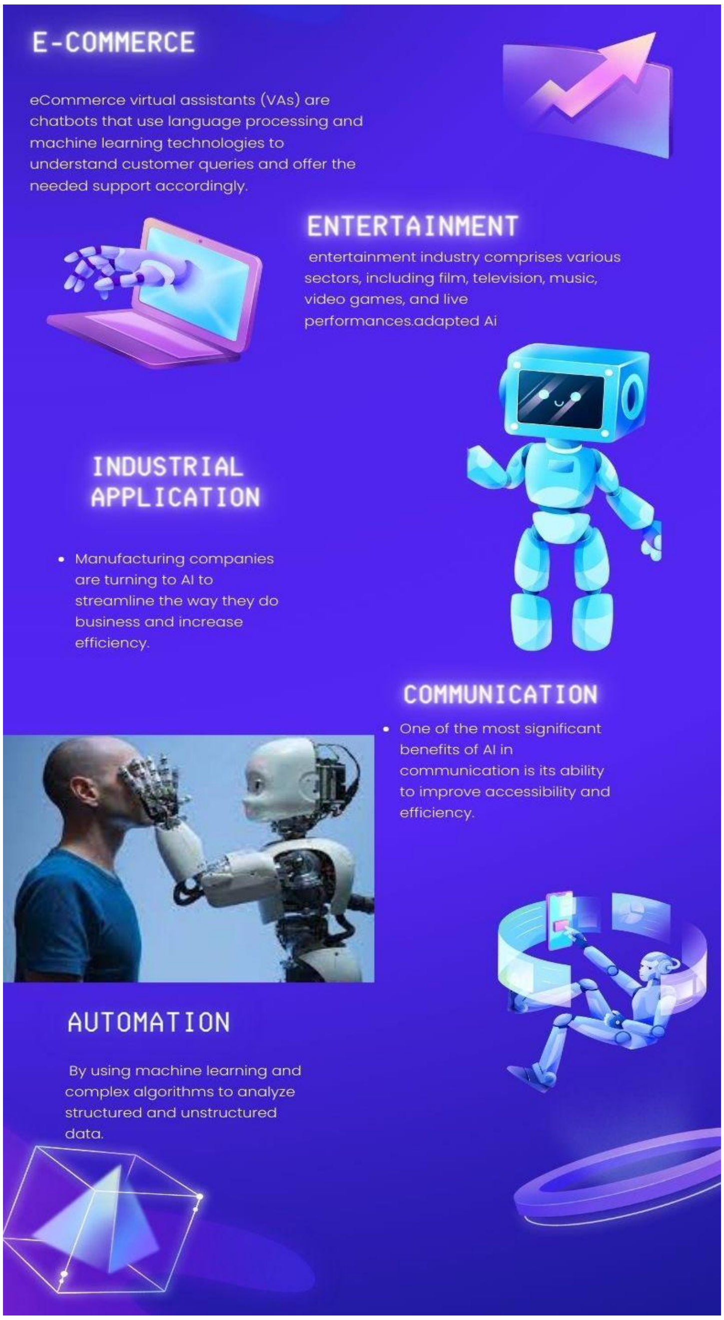

Fig. 3. AI advantages.

2.1 | Orchestration

Supporting composition generation, instantiation, maintenance, and dissemination. This feature of an online marketplace fosters the reuse of enrolled offers since it permits their use in other processes, even if it is not required. Due to orchestration, a customized manufacturing procedure might be represented as a cooperation of numerous robotic item functions, for instance [1].

2.2 | The Applications in Warehouse and E-Commerce

IoRT was developed in reaction to the growth of e-commerce, where human warehouse workers and autonomous robots coexist. Collaborative robots can help logistics organizations by alleviating some staffing shortages and the demanding nature of the work. One typical use for IoRT is the delivery of goods by fleets of autonomous robots within a range of between three and five kilometers, carrying loads as large as ten kilos at speeds of eight to ten kilometers per hour. Robots may be controlled and monitored remotely if circumstances prevent them from traveling autonomously [1].

3|IORT Practical Applications in Commerce

Amazon has assembled a team to examine possible uses for autonomous technology inside its expanding logistics network. The company won't be building self-driving cars; instead, it will act as a think tank to help the most prominent online retailer in the world incorporate automation into its logistical plan. Amazon may reduce delivery costs by further automating administrative tasks, giving them a vital competitive edge.

Automated forklifts, for example, might save labor costs in the company's operations; the Kiva robots have demonstrated 20% lower operational costs.

3.1|Both Amusement and Well-Being

Telepresence robotics enables more complex human-robot interaction by fusing communication technologies with robot sensing abilities. It allows people to virtually roam and gaze around distant areas, participate in business meetings, and keep a watch on patients or elderly individuals at residences or in medical institutions. Cinemas, theaters, and retail environments provide creative and exciting venues to integrate modern technologies. Since the ability to move around and live in social and natural surroundings is necessary for a normal lifestyle, communal and open spaces will get more attention as locations for technology in the future. Service robots are employed in various social tasks, such as grocery shopping, outdoor cleaning, and visiting historical sites [1].

3.2|Coordination

Robot collaboration must be correctly considered to achieve the IoRT's collective optimization goals. When these problems develop in multimodal robot networks outfitted with a range of actuators, sensors, onboard computing systems, etc., to accomplish the required tasks effectively, the implementation and the design of MRS synchronization pose substantial hurdles. The difficulty of the assigned job must be considered when estimating the complexity of the assignments the collaborative MRS must develop, which leads to an estimate of a reasonable number of robots to carry out that assigned task. Another alternative is to divide the task among several robot subgroups.

4|Healthcare Robotics Process Automation Paradigm

Any country's medical industry generates a considerable amount of employment and cash. It includes medical insurance, clinical research, and hospital supplies. It could be challenging to compile and assess data, such as information on pharmacological qualities, scattered across several organizational factors against the backdrop of the healthcare business. Tests, laboratory tools for technological developments, outside routes, health portals, scanning diagnostics administration, sequence-dependent arranging programs, preservation offers, and improvements in human resource utilization. Healthcare organizations must rely on people to complete conventional, challenging tasks that require much concentrated work since interoperability across various systems can occasionally be challenging.

In the healthcare sector, the three main participants are patients, doctors, and health insurance. Creating a far more accurate and efficient internal process is essential to balancing the rising patient demand and the records needed for surveillance, insurance demands, etc. Alternatives to computerized testing that are based on modern science and technology, like automated robotic processes, could assist clinicians in managing details such as doctor licenses, documenting and patient incentives, healthcare provider schedules, programming, statements of billing and claim management, patient information, Medicare payment and adherence, and supplemental insurance policies to increase utility, reduce costs, and set limits on care. The benefit of robotic process automation is that it guarantees that its applications and tools have excellent visual designs that improve patient User Experience (UX). The objective is to provide a simple framework that almost anyone with a fundamental understanding of modern technology may use. To satisfy the requirements of the final consumers, it must also be thoroughly modified. It is stated that the science of computation and mechanical engineering are combined in modern robot technology. It is also extending its area of influence and communicating wisely with others. Three significant uses of automation in medicine are robotic assistants, rehabilitation tools, and medical automation. Robots are offering medical institutions an economic edge over their rivals by providing better findings, more precise availability, and higher efficacy. To make it easier for physicians to carry out their duties and deliver patients with exceptional medical treatment, several large firms and mega-specialty organizations have started up and investing in robots [2].

5|Operative Robotics

With robotic surgery, physicians can perform complex surgeries with fewer incisions. Surgery is arguably the most well-known use of robots in the healthcare sector. It allowed doctors to do accurate punctures and encouraged the creation of fresh, non-invasive methods [2].

5.1|Radiographer Robotics

Radiologists will receive training in sophisticated diagnostic imaging interpretation. In addition to earlier scans, doctors will consider a patient's complete medical history. Robotic surgeons won't tire out from doing constant surgeries all year [2].

5.2|Rehabilitating Robotics

Lightweight, portable digital exoskeletons provide solutions for flexible appendages. After chemotherapy and more procedures, a variety of robotic wheelchairs may aid with the brain's ability to reconstruct suitable connections between neurons. Robots replicating human movement are now being researched to trick the brain into reacting [2].

5.3|Software in Smooth Robots and Prosthetics

5.3.1|Smooth grippers

Thinking about the inherent flexibility and compliance of DEA synthetic muscle tissues, growing gentle grippers based on DEA synthetic muscular tissues provides a new way to grasp objects with unique shapes and brands. Various soft grippers evolved based on DEA synthetic muscle groups.

5.3.2|Vibrotactile stimulation

Recent studies have used vibrating sleeves, prosthetic sockets' pressure points, and touchscreen surface friction modulation as examples of vibrotactile feedback. The pair's ability to collaborate is improved by vibrotactile stimuli and haptic signals, which can considerably increase the information the machine provides to the user without hindering task flow. As was explained throughout the study, one-way intent transmission—from the person to the robot—has made task-specific robotic assistance conceivable. We discussed how most research conducted at pHRI treats the autonomous device as a passive spectator of human conduct and, at most, enables the robot to offer feedback on its present condition and/or intended use. Evidence that reciprocal signaling between an automated device and a person significantly enhances interaction was covered. These contacts, however bidirectional, have allowed for task negotiating or the progressive development of mutual comprehension and alignment. Through bidirectional discourse, which depends on the psychological well-being of the person interacting and the dialogue history, more adaptable cooperation may be made feasible. As a result, the robot could provide feedback on its current state and/or intended function.

6 | Estimated Usage and Success Rate of Robotics in Healthcare

The usage of robotics and automated technologies has increased in the healthcare industry and other connected companies. The market for healthcare robots is anticipated to expand quickly over the following decades, hitting 9 trillion dollars by 2024, according to the Global Association of Robots forecast. Robotics also helps healthcare professionals complete complex and exacting tasks more quickly and accurately, enhancing the efficiency of the entire medical sector.

Robot-assisted therapy may allow for therapeutic procedures that are more efficient, available, and enjoyable than conventional therapy. So far, there have been conflicting findings regarding how clinical outcome markers are impacted by robot-assisted training. Customized robot-assisted training has been demonstrated in some trials to be superior to conventional therapy, while no statistically significant differences in clinical outcomes have been found in other investigations. However, there is solid proof that patients who actively engage in therapy benefit from it. These optimistic findings spur research that reliably identifies intent and provides real-time accomplishment and effort metrics to promote patient engagement.

Significance of Robotic process automation in the healthcare sector is as follows:

I. By employing machine artificial neural networks to gain and incorporate clinical data from lab technologies quickly, third-party entry points, health insurance pathways screening imaging equipment, sequence-dependent setup, as well as additional multiple systems, we aim to lessen the difficulties faced by medical professionals when coping with the complicated layout of procedures and a volume of patient and health care facility statistical analysis.

II. Learning more about robots to improve patient care is the aim of automation in the medical sector. Building the appropriate automated machinery and working with experts are essential to accomplish that. To completely understand the importance of ML in healthcare, additional study is necessary.

III. Since people's potential for compassion is linked to their humanity or chaotic structure, further research is still needed to determine whether or not medical professionals can substitute people. Robots and ML may show empathy toward people and can also be demonstrated through preprogrammed actions.

7 | IOT in Transportation

In addition to making it easier to get from one place to another, IoT in transportation also increases safety and appropriateness. For instance, a smart car may do multiple functions simultaneously, including communication, pleasure, navigation, and more reliable, efficient transportation. Travelers may stay connected to all kinds of transportation at all times, thanks to IoT. Several wireless technologies connect the car to the internet, including WiFi, Bluetooth 3G, 4G, smart transportation systems, and even other vehicles. A more sophisticated version of geofencing has been developed in this sector. It records the coordinates of a given location along with the position of an object or device [3].

8 | Applications of IOT and AI in Agriculture Automation

By integrating better programs, an IoT environment powered by AI surprisingly can increase the control and specificity of farming operations. The potential of these most recent technological developments in farm operations is limitless because they might automate complex tasks with little manual labor.

8.1 | Smart Farm

Today's farmers use a range of farm machinery and equipment to complete several agricultural jobs. Tractors are included and regarded as the most essential and indispensable farm energy source. Tractor performance monitors gather data, take measurements, and help with remote process observation. The variables that are frequently considered include power, fuel consumption, draught, and wheel slip.

The Global Positioning System with Difference (DGPS) is a crucial part of the system that provides spatial values. As a result, the tractor-implement system may be evaluated, documented, and monitored in terms of its functions concerning the position. Given that the soil texture and land slope influence how well a tractor-implement system operates, this mapping technique is beneficial for estimating crop production costs inside the field limits.

Robotic harvesters and rice cultivators have adopted a function with efficiency nearly equivalent to that of humans. The image-collecting module was the primary element of the robotic fruit harvester prototype. It was followed by an image editing module mounted on a motorized carriage. The information was utilized to determine which fruits and vegetables might be gathered using an object identification method based on computer vision.

8.2|UAV or Drones

Drones were first utilized for military operations but have increasingly been modified for use in agriculture. Another development in agriculture is the automation of numerous agricultural operations using drones, including pesticide application and land monitoring. Uncrewed Aerial Vehicles (UAVs), characterized as airplanes without a human pilot on board, include agricultural drones in their category. A central processor unit, a GPS receiver, a laser, a radar, a camera, a gyroscope, an accelerometer, a compass, and other sensors are all included in the drone gadget. Actuators and motors are also included to carry out necessary activities. The remote control is used to interact with this via wireless communication. UAVs' integrated thermal and multi-spectral detectors allow them to survey hectares of fields in a single flight [2].

8.3|Irrigation

The "per drop more crop" strategy has been developed to ensure proper use of the limited water supplies necessary to meet our future food demands. The sensors' usage of data-transmission protocols like MQTT makes real-time monitoring possible. Data is made available to subjects in MQTT, and those enrolled in such topics are the only ones who may read the data. MQTT has the advantage of being small and simple for the network to control. The processing unit of the module is equipped with a relay and a motor and is ready to accept commands from the outside. An MQTT dashboard may view the data [2].

8.4|Fertilizers Application

Businesses now push farmers to embrace technology-enabled agricultural practices and digital farming approaches. Using IoT technologies can make fertilizer applications more sophisticated. An NPK sensor can be used to monitor the concentrations of nitrogen, phosphorus, and potassium (K). This sensor can be made using resistors, LEDs, and light-dependent resistors. The concepts of colorimetry and photoconductivity are the foundation of the sensor's operation. An on-chip processing unit receives data from the NPK sensors directly. Edge computing or cloud computing is used to conduct further research. The low-cost SPAD was developed for the field-based indirect crop leaf chlorophyll content evaluation [2]. *Fig. 4* shows evaluation of robotics in agriculture and explains the matters related to it.

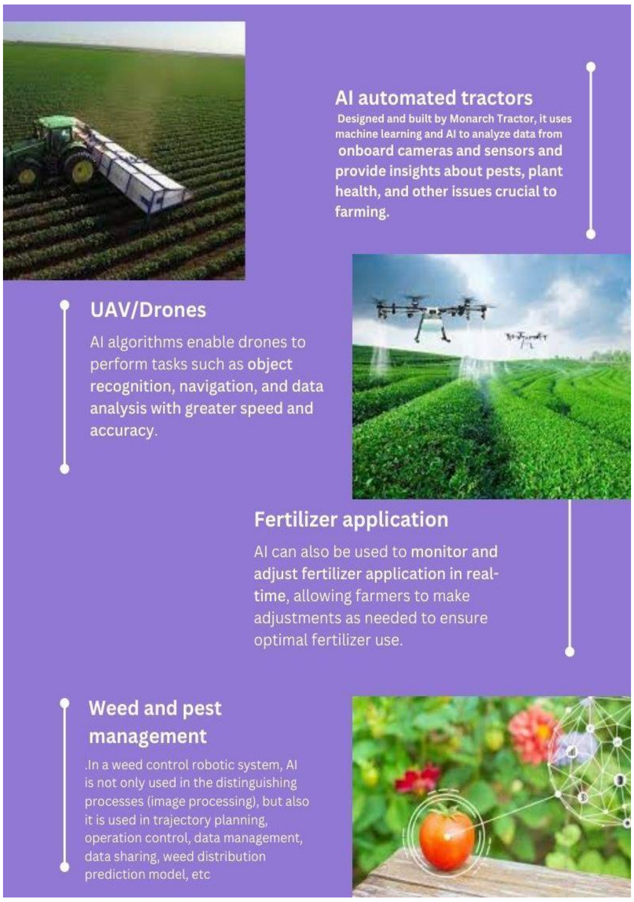

Fig. 4. Robotics in Agri industry.

8.5 | Weed and Pest Control

The application of herbicides is still challenging due to its unfavorable impacts, which include harm to the environment and human health. Additionally, conventional weeding methods uniformly spray pesticides throughout the whole field, whether or not there are weeds, which raises the price of herbicides and boosts greenhouse gas emissions. Incorporating robots, the IoT, and innovative image-processing techniques into a site-specific system effectively addresses these problems. Weeds in a field can be found using RGB and infrared imaging sensors.

Using a sprayer, imaging devices, sensors, and system-on-chips like the Raspberry Pi, systems created utilizing the IoT may manage weeds by dousing them in herbicide. An AI-based categorization method handles the critical aspect of managing weeds [2].

8.6 | Storage of Farm Products

Wireless sensor nodes are a helpful instrument for monitoring the quality of agricultural products maintained in storage containers. Moisture and temperature detectors can ensure that the storage room is kept at the ideal temperature and humidity levels. The values in the time series of sensor readings could vary slightly. Cumulative data are acquired from this to evaluate the storage system's humidity and temperature fluctuations. Each threshold is determined based on the crop kept in the storage facility. Data aggregation is done at the remote databases server, a gateway to connect sensor nodes to the World Wide Web. They are coupling the data findings with the local farmers' ongoing surveillance of the storage conditions on a local level [2].

9 | Sustainable Agriculture

Sustainable agricultural practices are anticipated to provide a number of advantages, including enhanced soil fertility, environmental protection, and a greater supply of the planet's natural resources. By following various goals, sustainable agriculture seeks to increase productive agricultural revenue. Promote effective environmental management [4].

For agriculture to be sustainable, data must be easily accessible. Smart farming enables cost-effective and sustainable agriculture through earth observation data and navigation satellites, making it easier for farmers to make informed agricultural decisions. The main types of sustainability are three:

I. Environmental sustainability assures that nature may be used regularly and without interference from various variables at the ecological level, preventing it from being used as an infinite supply of resources. Focusing on renewable energy sources, outdoor safety, and water conservation are a few examples of realistic adaptation.

II. Social sustainability: at the social level, sustainability may plant the seeds for the development of individuals, groups, and societies to provide realistic and isolated personal enjoyment, healthcare, and education throughout the globe.

III. Economic sustainability: business activities and the related flow of capital will support various pillars of viability for an all-around improvement [4].

10 | Machine Intelligence

The development of IoRT is greatly affected by the field of AI. Specific robotic devices are becoming more capable thanks to AI algorithms.

The sensor fusion capacities of IoRT devices are enhanced by AI technologies, such as lenses for detecting sight, chemical detectors for distinguishing smell and taste, microphones for listening, pressure detectors for feeling touch/pressure, etc.

In order to deliver analytics and insights and improve the capabilities of one's robotic toys and their cooperative behaviors as a fleet, AI techniques and approaches are applied in all kinds of IoRT platforms. Convolutional artificial neural networks, a deep neural network, are used to evaluate and extract visual properties from images. The techniques are designed to divide and de-noise monitored signals to achieve substantial variation or potential defect detection rates, enhancing the recognition function's efficacy.

In order to deliver analytics and insights and improve the capabilities of the individual automated machinery and their collaborative behaviors as a fleet, the various levels of IoRT platforms utilize AI approaches and methodology. For example, Convolutional Neural Networks (CNNs) are neural networks with deep connections used to analyze images and extract their visual characteristics. To enhance the effectiveness of the acknowledgment function by obtaining extraordinary variation or prospective defect detection rates, the procedures are made to partition and de-noise monitored signals. IoRT applications may now manage big data sets due to the transition from central computing to edge/fog nodes. This strategy is also applied, which fuses effective production inspection technologies with edge processing. Technologies for production inspection are also. By adapting a CNNs engine to the cloud computing environment, this strategy significantly increases the computational effectiveness of a verification model that can determine the type and severity of faults. Robotic machines collect video, compress video data, pre-process video images, and segment video using perception tools like cameras. Images are first processed and segmented using perceptual technologies, such as cameras. It might be possible to increase the accuracy of item recognition by working together to create an environment and scenery-aware adaption model utilizing data from different video capture equipment. IoRT equipment, servers at the edge, and the cloud must all share the same amount of DL computing. Hence, a suitable offloading method must be developed.

Fig 5. Performance of AI computing.

Significant trade-offs must be considered when assessing network health, video-encoded data, information rates/usage, power consumption, processing delay, framing rate, and the computational correctness of analytics. The potential exists for multiple distributed edge autonomous gadgets to collaborate at the edge to provide better services. Condensing the DL frameworks at the outer layer can enhance system performance through computing edge collaboration and the distribution of capabilities [5].

11 | Virtual and Augmented Reality

Immersive technology (such as Virtual Reality (VR) and Augmented Reality (AR)) may now be incorporated into interfaces for users of automated machines and for robotic tools that communicate with the interface of IoRT platform systems. It is possible because IoRT applications are becoming more cognitively capable at the edge. For IoRT systems to be more dependable, end-to-end security, electronic identities, and mobile data/knowledge security must be enhanced. This criterion is based on cognitive skills based on emerging AI algorithms. Future distributed IoRT architectures will require adaptability, end-to-end reliability, privacy, and intelligent connectivity to move away from existing centralized IoRT systems. A fluid data flow and expertise exchange across IoRT applications/services executing at the edge or in the cloud is required to support the utilization of computing at the edges, software that uses cloud computing of operations, and rule-driven policy execution while maintaining the integrity and privacy of data. Internet of Things (IoRT) applications may use VR/AR for learning, maneuvering, and support functions. While the technology known as AR supersedes information generated by computers over the actual world to retain time and space coherence and enable in-the-moment communication, VR replicates occurrences [5].

12 | Integration of Digital Twins with IOT

Digital Twins (DT) is a brilliant concept that has recently emerged. It involves creating a digital replica of a real system, as seen from the Cyber-Physical Systems (CPS) perspective. This virtual replica mimics the actual performance of the system. Throughout the entire development lifecycle, information from the virtual system, combined with that of the real system, characterizes the data from the physical system. Combining the digital and real counterparts achieves a more effective way of handling, controlling, and improving coordination when the system is operating.

DT refer to virtual models of physical objects or systems used for real-time monitoring and management. Meanwhile, IoT is a network of interconnected devices capable of data sharing and communication. When integrated, DT and IoT can produce intelligent systems that optimize performance and anticipate potential problems. AI can identify patterns and offer predictions by analyzing data collected from DT and IoT devices.

It is effectively incorporated into various applications, including medicinal systems, industry, the aviation industry, the agricultural sector, urban planning, and weather prediction [6].

13 | Biomedical Application

The industry that has profited the most from applying digital twin ideas is biomedical healthcare. Digital twin applications in biomedical fields have been made possible by new IoT, fitness, and e-health technologies. In the healthcare sector, DT technologies are used to analyze and propose medications, identify lifestyle changes, improve hospital operations, do remote surgery, and help policymakers provide healthcare to patients. In vitro, methods for forecasting how the actual organ will function in either scenario will be developed with the help of a DT virtualized biological approach by physicians as they look into how the development of DT in the medical field impacts treatment, diagnosis, and overall health.

14 | Smart Cities

Smarter features for smart cities are now being presented via digital twin advancements. Research on this topic has evolved along with IoT and communications, boosting interest in digitizing our lives. A framework for creating smart medical amenities for people in smart cities using DT is described, and a knowledge-based approach with AI is used to provide categorization and decision-making methods for managing mobility and power in a major city. DT are used to control energy in smart cities [7].

15 | Energy Management

With the ever-growing demand for energy supply, energy management is becoming a pivotal part of our life. A benchmark based on data analysis from smart meters is created to create a daily suggestion for energy building. The framework will examine how these procedures may assist in power control that is as near to actual as possible and will ascertain the differences between what is new from traditional and yearly energy assessment techniques. The paradigm is built by combining DT with information and communication technology to provide a strong promise for improving the effectiveness of catastrophe management measures [3].

16 | Intelligent Connectivity

Depending on the application, the intelligent connectivity infrastructure must operate as a continuous and compatible network to support heterogeneous devices with a range of intelligence competencies and connectivity requirements. Strong, resilient, and dependable connection networks are necessary for IoRT applications. The connection infrastructure must be flexible enough to respond to changing environmental conditions and to expected and unanticipated events and circumstances. The intelligent infrastructure for connectivity must function as a continuous and interoperable network to serve heterogeneous devices with varied intelligence features and connectivity needs, depending on the application. This is because robust, resilient, and dependable connectivity networks are necessary for IoRT applications. The linkage infrastructure must be flexible enough to respond to changing environmental conditions and to expected and unanticipated events and circumstances. To meet operational requirements and the economic viability of the vehicular networks, AI methods like ML are employed as useful tools to address the difficulties faced in 5G technology wireless technology (such as cached data, processing, and communication operations).

To support new connectivity, which has developed into the enabler for the future IoRT intelligent services, wireless and cellular networks utilized for telecommunications must offer predictable/guaranteed latency.

Peer-to-peer and/or broadcast communication techniques are available for direct communication and data sharing on IoRT devices. The forthcoming 5G wireless technology will have an average latency performance ranging from 1-10 ms in contrast to the current 4G mobile technology's latency efficiency of 80-100 ms, thanks to the use of Software-Defined Networking (SDN) and the Network Function Virtualization (NFV). Applications for dispersed networks are supported to meet the stringent energy efficiency standards required to cover large outdoor regions, deep indoor or underground locations, or mobile objects moving quickly. These applications are built for the edge and the cloud. The architecture and additional functions of the 5G network are designed to fulfill the Latency, reliability, and throughput requirements for IoRT applications that are both mission- and safety-critical. Future directions in physical human-robot interaction for embodied communication

It consists of multimodal communication, assistance for emergent, unforeseen behavior, and communication during collaboration (safe operation guaranteed by autonomy while allowing continual adaptation). These goals consider how individuals and their surroundings alter over time, enabling a process of coadaptation between humans and automated systems. However, they also have one thing in common: no standardized algorithmic tools are currently available. We shall discuss this in more detail below. Therefore, datasets are needed to compare and evaluate the features of the current pHRI, test algorithmic tools relevant to the pHRI, and certify algorithms before use with people [8].

17 | Continual Adaptation with Safety Guarantees

PHRI may provide a safety risk due to the immediate mechanical contact and power exchange. As a result, enabling pHRI has placed a high priority on safety. However, how to ensure safety without restricting robot motion parameters (such as torque or velocity) and performance limits is unclear. Due to the lack of reliable alternatives, the ISO Standards 2016 point to quantifiable biomechanical restrictions, such as acceptable threshold forces or pressures for specific body regions, as a requirement for collaborative robots.

These initiatives provide a step toward offering standardized safety assurances for data-driven autonomous machines (given acceptable assumptions). Notably, only a small number of research have considered continuous or long-term adaptation. Most work has concentrated on learning within a constrained period following initial engagement. One explanation for this is that although evaluating the effectiveness and safety of data-driven approaches is difficult, doing so for constantly evolving systems is considerably more difficult. The development of methods for long-term learning facilitation and data-driven safety verification should be the main areas of research to come. While giving specifications adequate for nonstationary simulations and considering variation in humans and adaptation, we should try to provide safety assurances that, at the very least, retain states within safe sets and adhere to temporal logic criteria [8].

18 | Multimodal Dialogue

Similar to how we try to deduce pertinent assessment signals from an individual for the robot, the robot should try to provide the individual with data signals. The robot's mobility is often used in human-robot systems to provide implicit feedback to the human partner. In certain pieces, anthropomorphic cues or exaggerated robot movements strengthen the connection.

As a result of making robotic behaviors more predictable, intentional communication motion has increased engagement. It enables users to foresee the robot's motions and modify their behavior accordingly [8].

19|Industrial IOT

The expansion and use of the IoT in industrial applications and sectors are referred to as the Industrial Internet of Things (IIoT)—more credibility because of its substantial focus on big data, machine-to-machine connectivity, and ML. The IIoT is made up of numerous devices that are linked together through communications software. Without the need for human involvement, the outcomes networks can rapidly respond to information after exchanging, analyzing, monitoring, and collecting it to modify their behavior or surroundings [3].

20|IOT Fire Forcast Detectors

Scientists and engineers have created Vision-based Fire Detectors (VFDs) and sound-, flame-, temperature-, gas-, and solid-sensitive fire sensors to detect fires early. Smoke's chemical properties are detected by sensors, which activate an alarm. The YOLOv8 detection model, used by the Smart Fire Detection System (SFDS) approach, provides quick and accurate object identification without requiring a regional proposal network. The system is improved to need fewer parameters for detection, increasing its effectiveness. The SFDS automatically utilizes computer vision to detect fires in photo and video feeds [7].

21|IOT based Greenhouse Management

An IoT monitoring management device for a greenhouse is developed to achieve high-efficiency environmental data monitoring. The organizational framework of the IoT system for managing and monitoring the environment in greenhouses. The system's main parts are a remote web server and a smart gateway running an Android operating system. Using a data-collecting device, the gateway gathers greenhouse environmental data, which is then stored in a SQLite database. Meanwhile, the gateway sends the greenhouse's environmental data to the server. The control node supervises the greenhouse's equipment, including the windows, fans, and heating units. Output from the gateway is received by and managed by the server system [2].

22|IOT Architecture Domain

Smart, linked houses may be divided into two basic architectural types: 1) distributed, and 2) centralized.

22.1|Centralized Smart Home Architecture

A computer system responsible for controlling the control system is used in a centralized smart home design for collecting information from sensors, interacting with users, implementing control algorithms, and instructing actuators. In addition to performing the control function, it is responsible for connecting the smart home to the outside world through the Internet and offering services to its inhabitants.

22.2|Distributed Smart Home Architecture

The software for the control system is envisioned and developed as a distributed computing system in a distributed smart home architecture. The distributed design takes advantage of the processing power of intelligent objects to integrate software modules into the smart home network's nodes [3].

23|Emergent Interfaces

The communication agent (human or robot) must have a correct mental representation of the communication rules for the signaling model outlined above to work, and this hypothesis that the mental representation is correct is frequently static. New symbolic languages will be the foundation for communication if we move toward active nonverbal interaction between humans and technology.

We can connect with assistive technology using our kinematic, muscular, and cognitive null space—excess degree of freedom—while avoiding significant increases in cognitive burden. The developer chooses a group of vectors in the neural null space, and the operator, who is a human being, is trained to read and create them. As a starting point, the robot can specify and program languages. There is an apparent way to symbolize the connection of the continuous 2D regulated space onto the corresponding 2D action space of the robotic machine, making the language simple to learn if we are mapping joystick signals to the action space of a motorized wheelchair [8].

Author Contribution

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All data supporting the reported findings in this research paper are provided within the manuscript.

Conflicts of Interest

The authors declare no conflict of interest concerning the reported research findings. The authors have read and agreed to the published version of the manuscript.

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