The Variety and Scope of Recent Developments in Industry and Robotics 4.0 in the Fields of Manufacturing, Medicine, Fire Fighting and Agriculture: A Review

Aditya. K[1], Akash. S[2], Gautam R[3]

[1-3]*Student, Department of Mechanical Engineering, SSN College of Engineering, Kalavakkam*

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Abstract: *Robotics 4.0 is the collaboration of the principles of Industry 4.0 by integration of intelligence, IoT and robotics. This paper reviews all the advancements made in various fields since the emergence of Robotics 4.0. IoT induced industrial robots are capable of self-maintenance and autonomous job completions. Feedback loops are employed to provide increased precision and accuracy of movement. It has revolutionized Healthcare by allowing for around the clock personalized monitoring and systems to immediately inform the doctor in the case of an emergency. Robotic surgery is a completely new field born from the ashes of conventional treatment procedures. With the development of Industry 4.0, the said robots have grown to be very dependable. Fire Fighting is another field impacted by the revolution. Improved real time mapping techniques and assisted drone help has proved to be a boon to fire fighters. Agriculture has also seen gargantuan changes since the advent of Agriculture 4.0. With "intelligent" machines taking care of every aspect of the process, the efficiency of the soil is improved and the land is used to its full potential. Our paper delves deep into each one of these topics to identify notable instances of developments that have played a key role in the revolutionizing of the world.*

Keywords: Robotics 4.0, Industry 4.0, Industrial Robots, Healthcare, Fire Fighting, Agriculture

1. INTRODUCTION

In the past two decades, the development of new technologies and their application in manufacturing industry has led to a large development in the production industry. The term "Industry 4.0" originated in 2011 from a project in the high-tech strategy of German government. Industry 4.0 or the Fourth Industrial Revolution deals with the automation of the production processes, using the available modern technologies. The digital technologies like 3D printing, sensor technologies, cloud computing, information and communication technology (ICT) and advanced robotics aids in the automation of the manufacturing processes. The application of sensor and ICT technologies in the robots leads to the invention of industrial robots that could cooperatively work with the workers [1]. The development in robotic technology also helps to increasingly employ industrial robots in the shop floor. The implementation of robots in the factories is increasing rapidly year by year [2]. Industrial robot is the base for the fourth industrial revolution. There are two main reasons for this. Firstly, the industrial and service robots are capable of making independent decisions based on the data received by it with the help of sensors. Secondly, the robots can produce goods at a quicker pace and also ensure that they are defect-free. Lastly, these robots are capable of working together with the factory workers. This indeed helps to increase the productivity of the company. In the initial stages i.e Robotics 1.0 era, robots were mainly used to perform tedious, repetitive and monotonous tasks in isolated environment. The robots were not capable of understanding the surrounding environment. The robots were preprogrammed to perform some commands to complete the task. Also, these robots were to be separated from the workers involved in production process to ensure that the robots would not harm them [3]. Later on in Robotics 2.0 era, the development of sensors, internet and other data acquisition systems helped in the employment of robots for other manufacturing applications. In the Robotics 3.0 era, the robots were able to communicate with the human beings using natural language processing (NLP). In addition to that the Raspberry-pi and deep learning algorithms were adopted to make the robots more intelligent [4]. Currently, in the Robotics 4.0 era, the advancement in Artificial Intelligence, cloud computing and integration of robot cognitive skills is used to integrate the robots into the factories to create "Smart Factories". Figure 1. shows this evolution in the form of a flowchart.

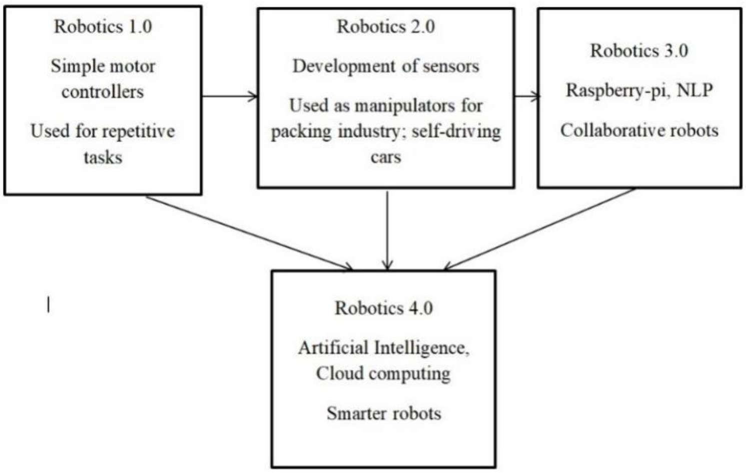

Fig.1. Evolution of Robots [4]

The industrial robots have many applications. Initially, they were used for traditional applications like spot welding, spray painting, Metrology, assembly operations and machining [5]. Currently, they are employed in the fields of Manufacturing, Medicine, Fire Fighting and Agriculture

2. INDUSTRIAL ROBOTS AIDED BY INDUSTRY 4.0

The onset of industry 4.0 has led to the introduction of robots in various industries. Robots can perform precise, accurate and repetitive motions without much variation. Baris Bayram et al, 2018 states that lack of variation can lead to better productivity and more efficient processes [6]. There are many robots available in the market, some of which are shown in Table 1.

TABLE - 1. Different Robots available in Current Market

S. no	Robot name	Company	Details
1	Sawyer	Rethink Robotics	Used for precise tasks such as circuit board testing, machine tending etc.
2	Baxter	Rethink Robotics	Used for packaging applications
3	Fanuc	LR Mate 200ic	Tabletop robotic arm for material handling
4	Flexarc	ABB	Used for metal welding

2.1. Tool handling

In industrial settings, there are a lot of constraints posed on the movement of robots. Wired robots can get entangled if not design properly. An entanglement quantification method can be used to properly plan tool motion [7]. The proposed method takes into account the cable tension, position to keep a track of degree of entanglement.

2.2. Human-Robot collaborative manufacturing

The cost problems in completely automated plants lead to the idea of human-robot collaborative manufacturing. Integration of industrial robots and human workers can be more productive. However, collaborative working in complex assembly lines may pose a safety threat to the human workers [6]. Lenz et al, designed a smart factory concept for Human-Robot cooperation [8]. It uses a hidden Markov model to capture the position of human joints and sensors to capture the position of robots. Another important part for smooth functions is to transfer the information of where the humans are to the robots through a shared network [9].

2.3. Maintenance

In industries, proper and regular maintenance is needed to avoid machine failures and downtimes. Even though conventionally humans are used for such activities, new technologies are on the rise. PHM is field of engineering focused on health assessment, prediction and management of machineries [10]. Biggio Luca et al, emergence of deep learning and machine learning techniques have increased the progress of data driven PHM methods [11]. With these new additions, robots can have a sense of self maintenance. Pedersen et al. 2016 showed that a factory worker's knowledge can be transferred to robots to develop a self-asserting ability [12]. Jaber et al designed a system that can diagnose failure due to cracking, pitting, fatigue and fracture in gears used in industrial robots by using Discrete Wavelet Transform and Artificial Neural Networks [13].

3. HEALTHCARE AIDED BY INDUSTRY 4.0

In the past few years, Surgical robots have been used in various medical fields from general surgery to urology. Surgical robots are classified as active telesurgery robots such as Flex, DaVinci etc. and passive assistance systems such as Soloassis, Cirq [14]. Different applications of robotics 4.0 in medical field are shown in Figure 2.

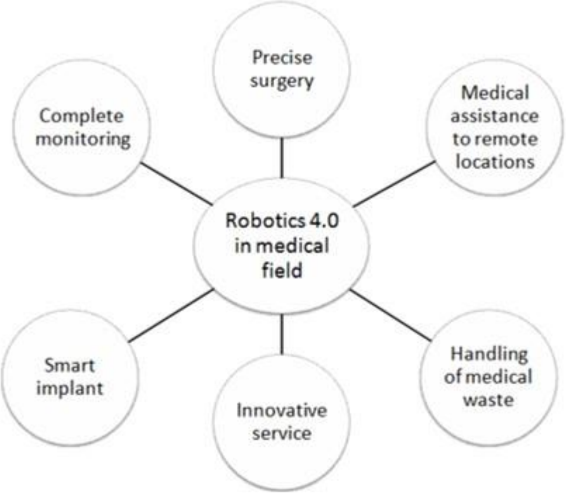

Fig 2. Applications of robotics 4.0 in medical field [15]

3.1 Robot assisted surgery (RAS):

Autonomous robots are not used in medical fields due to constant safety issues. But Robot assisted surgery has been used in fields of gynaecology, visceral surgery etc. by increase in precision of surgeon, the outcome of surgery is improved and even post-surgery hospitalization is reduced [14]. Boehm at al shows that with current technological improvements robots can be used in surgery of difficult to access areas of the human anatomy [15]

3.2 Transoral Robot Assisted Surgery

In few hospitals, oropharynx tumours in early stages have been removed in last couple of years. Post-surgery analysis has shown good organ function and increased survival rates.[16]. Park et al compared post-surgery reports of TORS to open transcervical surgery and found that TORS patients needed lower recovery time and survival rate was same for both procedures for the first 5 years [17]. Precise insertions and sealing have led to the avoidance of visible scars.

3.3 Health monitoring

According to a survey by the World Health Organization (WHO); by 2030, 66% of the population will have chronic diseases like diabetes and Parkinson's [18]. This leads to an increase in the no. of patients per doctor, creating a need for new methodologies.

Health monitoring systems are made of 5 layers namely Device Layer, Gateway Layer, Service Platform Layer and Core Network [19]. Sensors that support standards such as Z-Wave, Zigbee that define wireless communication protocol stacks are located in the Device layer. The sensors themselves vary based on the specific application they are intended for. The sensors are securely to the Administration Stage through the gateway layer. The Core Network is an IP based system that facilitates data trade between the layers.

4. CONTRIBUTIONS OF INDUSTRY 4.0 TO MOBILE ROBOTICS

Robotics 4.0 is not a field constrained to industry robots alone. In contrast, it is a general term that encompasses all inclusions of IoT in Robotics. Conventional mobile robots suffer from the limitation that it requires human operators to configure and pre-program the sensors to facilitate the motion planning of the robot. The need for a more adaptive infrastructure brought about the inclusion of Industry 4.0 concepts into robotics to intelligently configure the sensors, actuators and controllers in real time by comparing its desired output with actual output at regular time intervals [20].

Nicolas et al. are one among many who have explored the possibilities of integrating smartphones in Robotics [21]. The smartphones act as a remote controller unit while also acting as a neural cloud that the robot uses to comprehend the world around it. Moreover, the smartphone sensors can also be used by the robot to as a computing and interface device. Figure 3 represents the basic framework of the Android based control system that Nicolas et al. implemented in their project. Similar to the open source IOIO board, there exist several other platforms to connect android devices with robots, as expressed by Stephan et al. in his paper, such as LEGO Mindstorms NXT and LEJOS for NXT among others [22].

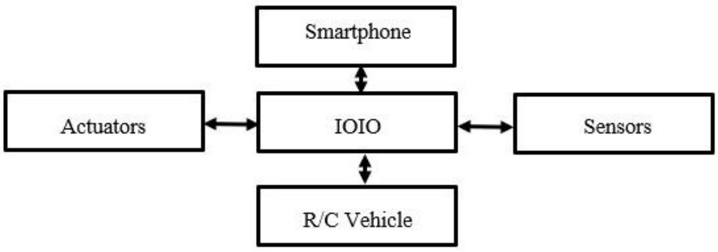

Fig 3. Android Based Robotics Framework [21]

This very technology has found root in many modern-day applications that have revolutionized several fields as explained below.

4.1 Fire – Fighting Aided by Industry 4.0

Valerio proposed a system to fight fires on small ships by optimising the hybrid propulsion technology to suit the particular need [23]. He focused on trying to reduce the chance of explosion of the Li-Po batteries used in small ships. It used intelligent sensors to cool down the battery by soaking the exterior in water. Radhya et al. proposed a system to continuously monitor weather conditions in real time using a concept of static window sizing to predict possible forest fires [24].

Vijayalakshmi and Muruganand [25] proposed a generic structure for an IoT based fire monitoring system. The sensing layer consists of flame sensors which transmits the signal to the service layer for storing via a transport layer consisting of Internet, LAN and mobile networks. The information is further extracted and analyzed in the application layer.

Vergin et al. built a drone equipped with a flame sensor, an inbuilt camera, an Arduino UNO board and a Wi-Fi module for detecting and transmitting the location of the fire to the respective authorities [26].

Kinaneva et al. proposed a system of fixed wing medium altitude UAVs and rotary wing low altitude UAVs working in coordination for early detection of Forest Fires [27]. In contrast to the rotary wing UAVs that fly between 10 and 350m of ground level, the fixed wing UAVs, much like an airplane, fly between 350 and 5500m. The UAV that flies higher is used to map out larger areas with lower precision, while the other is used to account for false fire alarms and give a reading closer to ground reality. Figure 4 represents the proposed fire detection mechanism.

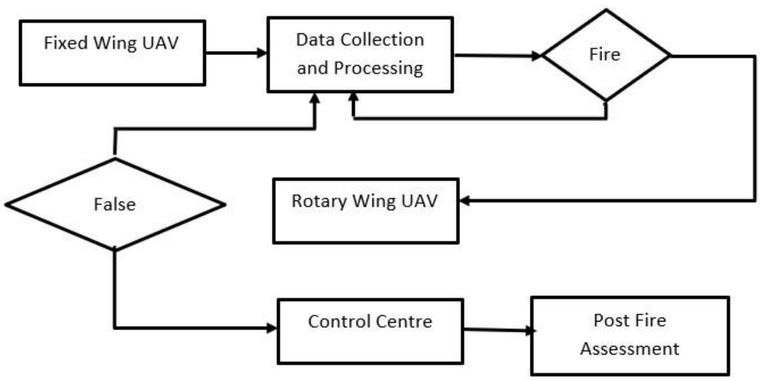

Fig 4. Framework of an Early Fire Detection System [27]

Simoes et al. proposed a system of autonomous network of Unmanned Aerial Vehicles (UAVs) to support firefighters in the case of a wildfire [28]. The UAVs collect data and relay it to the ground station through means of a Flying Ad-hoc Network (FANET).

Sathishkumar et al. proposed a system using an Unmanned Aerial System (UAS) platform and multispectral sensor to map the extent of a burned area for post fire analysis [29].

In summary, Industry 4.0 IoT tools have helped create make several changes to conventional fire-fighting approaches. UAVs are primarily used to collect and relay data, although there have indeed been few designs proposed to extinguish the fire itself using drones. V. Mangayarkarasi [30] designed a RF controlled fire-fighting robot with a water tank and a pump which senses the fire with the help of thermistor while N. Jayapandian made a UAV which delivers fire extinguisher balls to the location of the fire [31].

Smart clothes equipped withs sensors to monitor and locate the fire fighters have also been developed to further facilitate comfort and safety of fire fighters [32].

4.2 Agriculture Aided by Industry 4.0

Agriculture is a very vast field consisting of innumerable manual labourers. While robotic implements in agriculture can aid farmers greatly, they suffer the limitation of being operable on a rough terrain. Successful implementation of robots in agriculture requires precision-controlled system of robots that can aid with soil fertilization, pest control, soil management, harvesting and transportation [33].

A German company Raussendorf, in the year 2014, developed a robot entitled Cäsar. The commercially available Cäsar robot can fertilize the soil either through remote control or autonomously. It employs Real-Time Kinematic (RTK) technology for the Global Navigation Satellite System (GNSS) to precisely locate its real time position [34].

A Chinese company DJI developed several UAVs. The DJI Phantom 3 was developed in order to map out the agricultural field in advance for further action [35]. in 2016 DJI developed the octocopter AGRAS MG-1P to carry out the precise application of liquid fertilizers, pesticides and herbicides [34].

UAVs of different kinds such as Fixed Wing UAVs, Rotary Wing UAVs, Blimps, Flapping Wing UAVs and Parafoil Wing UAVs are also used in precision agriculture for the monitoring of crops [36]. Each device has its own inherent advantage that explains the need for their use. The Fixed Wing UAV is used for large scale data acquisition. The Rotary Wing UAV is capable of vertical lift off and can hover in a fixed location. Blimps are lighter than air and can stay afloat temporarily even in the case of complete loss of power. Flapping Wing UAVs provide high manoeuvrability but they are seldom used in precision agriculture due to their high-power consumption [37]. Parafoil Wing UAVs are specially designed to consume lesser power while still carrying larger payloads.

Monteleone et al. has proposed a system for Smart Water Management in Agriculture using a 5-layer architecture. The first layer consists of an assortment of sensors to detect the moisture in the soil, the height of the plant and the weather conditions such as temperature and humidity. Layer 2 consists of the data acquisition and the protocols involved while layer 3 consists of storing the data. Layer 4 consists of running traditional algorithms to estimate the water required by the plants. Layer 5 involves working the pumps to deliver the required amount of water [38].

Industry 4.0 has also revolutionized other aspects of agriculture such as harvesting and transport. Soft grippers have led to ease of harvesting without damaging the actual produce [39]. In summary, Industry 4.0 has spread its wings to all parts of agriculture starting from planting the seeds to harvesting the final crop. Several of these processes have already been mechanised and commercialized. However, the inclusion of IoT in them have led to smarter vehicles more efficient at institutionalizing the process.

5. CONCLUSION

Industry 4.0 has revolutionized various fields by improving the effectiveness of various equipment. The introduction of intelligence to equipment by means of Industry 4.0 has led to a reduction in cost while simultaneously improving the precision and accuracy. Robotics 4.0 is the inclusion of said intelligence in robots that has led to increase in productivity. In our paper we have performed a comprehensive study of several recent developments in the fields of Manufacturing, Medicine, Fire Fighting and Agriculture.

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