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AI In Manufacturing And Robotics: From Automation To Autonomous

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Abstract:- Recent manufacturing systems are becomes increasingly dynamic, connected and complex. The company's operations and functions may face challenges due to many uncertainties, stochastic behaviour and existed interdependencies. Hence advanced development in AI shows higher potential to transform manufacturing companies through latest analytics tools for more manufacturing processing works and generated data. Therefore this review focuses on AI in manufacturing and robotics based on automation and autonomous which identifies challenges and opportunities, also impacts the future development of recent technological innovations which can meet the manufacturing operation's needs. In doing so this paper discusses about the AI in robotics across industries, specifically AI in manufacturing and robotics, AI in manufacturing and robotics: automation and autonomous in examining the examples of robotics.

Keywords: AI, Robotics, manufacturing, automation, autonomous.

1. Introduction

In globalisation era, the industries are dealing with increasing innovations dynamics, diversification of product range and shortened product lifecycles. Similarly, they are in pressure due to the high skilled workers cost and shortage. Hence industrial robots based on different types, automation and effectiveness are considered as better solution for both flexibility and productivity. Yet the industrial robotic system programming for specific application is highly complex, expensive and time-consuming. AI driven methodologies are recently becomes highly upgrading the industrial robotic system and its easier for factories and industries to implement the robotic system easily and inexpensive. Nowadays several nations focusing on Industry 4.0 development to promote the upgrade and transition of their respective sector, for e.g. manufacturing sector. It is considered as 4th industrial revolution and its major aim is to realize the flexible, personalized and intelligent process of manufacturing based on AI driven methodologies (Gihleb, Giuntella, Stella, & Wang, 2022; Grover & Ashraf, 2023; Koch, Manuylov, & Smolka, 2021).

The establishment and utilization of them are highly enhanced and it is increase the productivity of industries with more advancement in sensors and devices, automation and information technologies in recent years. Several functions like multi-objective criteria have been developed in several fields like welding, material transportation, mechanical processing and assembly in manufacturing industries. Sensors get the details and used to make decisions of industrial robots, external environment and assisting in regulate the robots for executed functions (Bonci, Cen Cheng, Indri, Nabissi, & Sibona, 2021; Lai, Lin, & Wu, 2018; Mikolajczyk et al., 2022). Hence this study focuses on reviewing the classification of robots, types in different fields, robots across industries, their challenges have been discussed. Finally the conclusion has been drawn based on the discussion.

2. AI in Robotics across Industries

According to (Aizat, Azmin, & Rahiman, 2023; Murphy, Gandudi, & Adams, 2020), robots are used by individuals and businesses which enable humans to pursue education and job which minimizes the influence of productivity on ill employees, keeps social relationships and supports living facilities and safeguarding at-risk populations. Several exciting developments in past decades in robotic grippers fields are comprising with magnetic grippers, pneumatic grippers, suction grippers, electric grippers and vacuum and Bernoulli grippers. Different grippers are mounted on agricultural robots which offers robotic grasping of agricultural products and food in the past decades. In actuator technology, AT control techniques, materials science and sensing technology, new kind of developments are made which in turn enhances the performance and function of robotic grippers. (Zhang, Xie, Zhou, Wang, & Zhang, 2020).

Nowadays, Industrial robotic arms are general and there exists several factories and industries which are running to build a lightweight robotic arm which shows greater payload and similarly with broad motion range. Hence if arm's payload increase, there is an increase in mechanical weight and it ended up in expensive arm(Almurib, Al-Qrimli, & Kumar, 2012). On the other hand, there are many conventional solutions provides economically attractive lightweight robots which may be moved easily from one industrial process to another based basic reprogramming as requirement if it needed. User-friendly robotic solutions are not needs workers to exhibit technical innovation on robots. For industrial robotic technology, better prospects are foreseen. New materials and energy efficiency are invited by robots use. Customized elements' faster production at competitive prizes shows better encouragement to use this technology. Certain markets are predicting the demands increasing like plastic, beverage and foods, rubber, machinery and metal industries. The electronics and electrical industries are also showing greater demands for robots. Hence all these requirements encourages as major robotized manufacturing process increment in mid and short term, for SMEs and larger companies, shows the possibility in attaining the trend competitiveness for creative robotic solutions(Grau, Indri, Bello, & Sauter, 2020; Rodríguez-Guerra, Sorrosal, Cabanes, & Calleja, 2021).

Likewise in case of agriculture, the adopted technologies advance later in industries which follow the intelligent factories ideas and establish the concept of intelligent farm. (Gonzalez-de-Santos et al., 2020) evaluates the features the agricultural robots must attains from industrial robots in achieving concept of intelligent farm focusing on functionalities and robot structures with computing, data management and communication. Outdoor farm robotics evaluates various mobile robot structures and manipulators with advanced technologies used in innovative industries with goals of advancing the robotics characteristics for intelligent farms in future. Service robots are shown beneficial according to (Holland et al., 2021) and they minimizes human error, spread of infection prevention and permits front line workers to minimize the direct contact and concentrating on their attention on greater priority works and making the isolation to prevent direct exposure. Hence these robots are highly advantageous in healthcare especially during covid-19 pandemic and highly beneficial to healthcare workers, organisations, patients and customers (Vallès-Peris, Barat-Auleda, & Domènech, 2021). In addition it is useful for patients and supplies logistics and effective cleaning process, resource quality in hospitals, remote monitoring of patients, efficiency and increase system capacity and associated with healthcare environments like (Andtfolk, Nyholm, Eide, & Fagerström, 2022) discussed about humanoid robots helps for elderly persons care.

3. AI in Manufacturing and Robotics

In most of the day to day manufacturing operations the major driving aspects across different operations are expected to meet quality, safe working environment, cost objectives and throughput. But to attain these goals it becomes challenging with several demands reducing from process difficulty, greater variability, progressing product in customer preferences and demand along with persistent competitive pressures from outside market places which said to be profitable. From the positive side most of the manufacturers offer chances for unique capabilities of AI compared with traditional approaches and tools. Specifically, the general problem solving activity includes searching for root leads to AI tools which capable in recognizing and classifying the non-linear and multivariate patterns in performance and operational data which are not shown to plant engineer.

Recently greater amounts of continuously generated data are formed by ambient sensors, labor records, machines, and controllers and so on. The data can be divided as i) process data collected from sensors on process machines or stations, e.g., machining and grinding coolant temperatures, power, and heat treat temperature/energy, ii) production operation data recorded in controller systems, e.g., timestamps or elapsed time of each part in each operation station, machine downtime, starvation/blockage, idle time, and shift scheduling, iii) environmental data collected from ambient sensors, e.g., room temperature and humidity, and iv) measurement or check data from product quality inspections, e.g., product diameter, form, and balance. AI focused on higher dimensional data and offers the ability in transform greater amounts of complex manufacturing data which becomes used in factories recently into insightful and actionable information (Arinez, Chang, Gao, Xu, & Zhang, 2020; Sharp, Ak, & Hedberg Jr, 2018).

AI practical implementation in manufacturing

Here the AI's most of the studies has been performed in laboratory environment like using test rigs and organisation or companies have started to implement and adapt the conventional into everyday operations to enhance flexibility, minimize cost and production efficiency. For e.g. in 2018, technical report published explained the DCNN- Deep Convolutional Neural Network as solution of machine vision to enable earlier diagnosis and defects classification like staining epoxy, excursion associated to ball application in wafer production line. The system comprises of classification inference cluster for assisting model building unit and larger scale production which establishes and refines DCNN approach. In addition, it is identified that AI based model can automatically and accurately detect and classify the defects which may otherwise needs manual procedure and may minimizes 80% entire time of workers. In another case vision based model established for fabric texture recognition and executed in organisation which produces automotive interior parts. The unstable illumination positions relatable challenges in implementing conventional image classification approaches in industrial environment. Using Laws and Sobel filters the pre-processing are performed and suitable classifier based on machine learning or deep learning techniques performed classification and reduced computational tome in massive production setting. More efforts is required to promote AI techniques from the industrial perspective and enables the wider acceptance of AI approaches(Arinez et al., 2020).

In this paper, AI usage and its potential for further prospects in manufacturing processes and systems across automation and autonomous levels. There exists a different degree of success and respected trials which may be identified in future. Manufacturing systems simulation is a way to knowledge based on simplicity through which training data may be generated. But this is restricted by ability of model which reflected the certainty with greater fidelity. Several AI technologies are used more which aids in communication of determined among robot and human with respect to gesture, explicit, voice, and gaze commands. Greater cognition levels of interaction concentrated on shared work piece activities which needs more researches to develop robots with reliable and feasible models based on human counterpart which generate motion adaptive human behaviour dynamically. Hence with considering the aspects of diagnostics, prognostics and monitoring the process the AI tools deployment shows higher extensive due to the higher data stream originating from sensors, equipment and processes. Machine learning methods depend on greater quality data in extracting relevant features. Hence AI based diagnosis has identified popular usage in expressing classifications and related data in respected severity levels and fault types. AI has also used in predicting experimental results and material properties used in manufacturing process in fraction of time. Such material properties prediction applies to both micro and macro levels in which the properties like hardness and melting point identified based on simulation experiments(Arinez et al., 2020).

4. AI in manufacturing and robotics: automation

Digital industrial technology is also refer as Industry 4.0., which is entirely a new phase in Market Revolution which concentrates on real time data, machine learning, robotics and automation. Robotics in Industry 4.0 is said to be smart machines market like autonomous robots, digital assistants and expert systems. According to Technavio research recent report in Robotics which is progressing day by day in higher part due to the Industry 4.0 arise. The major goal of advanced industrial applications is significantly develop smart industries in which the products can identify their own way through production and generate alternatives for any disturbances, through Internet of Things- IoT. Example for Intelligent factory or automation shown in following figure based on robotics, higher end ioT chips, big data and all of them is based on wireless connection. Communication and control each other is possible.

Fig.1. Robotics and Industry 4.0 (Goel & Gupta, 2020)

Due to constant market changing, global competition is increasing every day. New challenges are came due to more customer requirements for manufacturers and it may impact crucial decision later. It is highly complex for manufacturer to enter into market using traditional approaches since customer needs to customize and wants advanced product in lesser cost in their fixed deadline. Is it highly impossible in satisfying all since it is more difficult and costly too. There is an increase in internet based digital technologies usage because of today's business settings. ICT technologies, robotics based sensor technologies resulted in development of new robots which may works with the employees or workers. For 4^{th} industrial revolution robotics is the foundation which further increases productivity since its used the actuators and sensors for producing strong and accurate data. However the major fact is no robot has any future except it is incorporated to latest technologies based networks. Smart factory are the future and the proofs recommended that future factories may be fully robotized and automated. These automated with robotics factories will becomes highly effective manufacturing setting with machines at various production stages and enhanced logistics systems which permanently exchange data without more human interferences. If the industrial production in reality is notably efficient then its due to updated technological innovations. At various levels the technological progress is visible and highly flexible modern production plants are seen. Also the flexible automation solutions are invokes the tailor made production and it supports to address the consumer needs and consumers.

For Industry 4.0, mass customization is said to be significant goal and it is no longer in its early stages in different sectors like shoes, furniture, jewellery, textiles, clocks and furniture. Through component management networks the production efficiency has increased. Moreover, modern industrial production attires use latest image processing systems for quality management purposes. Robotization and automation impacts the working lives of people and basically modifying the workplace. Robots are becoming highly co-operative, flexible and independent. Also they will perform with humans and communicate with one another for learning. These kind of lesser expensive robots shows higher range of capabilities compared with robots used in manufacturing recently which is shown in fig.2. robotics and computers came in entirely new manner in Industry 4.0. the uses of robots comprises with different functions like office management, production, logistics and they can be remotely controlled. Hence different robot types used in manufacturing and other industries for various purposes (Goel & Gupta, 2020).

Fig.2. Robots in manufacturing (Goel & Gupta, 2020)

5. AI in manufacturing and robotics: autonomous

Specifically, autonomous robots can communicate and navigate with their settings without any human intervention which is the recent research areas for many scholars. According to (Soori, Arezoo, & Dastres, 2023), machine learning algorithms can be used for robots training for identify and respond to various incentives and allows them to perform tasks like path planning, obstacle avoidance and object recognition. Progressing efficiency and flexibility needs by demands in industry and leads to robotic technologies into manufacturing works. Most of the robot co-workers in industrial companies have been reported refers majorly to manipulators team up with humans, ground robots used for exoskeletons or transportation. AGVs- Autonomous Guided vehicles and ground robots are highly used in manufacturing center for several decades. They are appropriate tools for different tasks like heavy component transportation and expert manipulation, higher density of objects based dynamic environment, and workers may limited the robotic motion and speed. Further the ground robots may disturb workers since they must concentrate on their works. Alternatively above level factories usually static and sparse and they are highly appropriate for autonomous robot navigation and certain industrial tasks may highly advantageous in using the unused space for tasks like inspection of greater structures or areas or missing items searches. Hence there exists increasing interests in drones usage also in manufacturing and warehousing operations. But most of the systems are operated manually by skilled pilots and few autonomous aerial robots are reported in earlier development stage. Only few traditional robotic systems with automated operations are validated in factories in fully operational conditions, but in certain cases the autonomous functionalities are limited to simple works and restricting their potential applications range(Perez-Grau et al., 2021).

Significantly, AGVs are based on predefined paths or tracks and needs operator oversight and freely traverse settings. These are generally used to move items and deliver materials in controlled environments like factory floors and warehouses(Søraa & Fostervold, 2021). AGVs growing popularity used in the manufacturing which has not only be the outcomes of the technical features but also from their capability to perform. Increased flexibility in production allowed by the co-operative based internal logistics. Due to AGV which are internal logistics executive part, their co-operation with manufacturing equipment and information systems is specifically significant. Greater degree of flexibility demanded by advanced production models which enables with often modifications that resulted from orders which are modified by agile production technologies, customers and lower material buffers which are attained by robotised production stations and production technology's several variants can be used(Aizat et al., 2023).

Conventional industrial robot system is doing assigned works on particular assembly stations and frequently separated from human operators and other stations using the fences like physical barriers. Collaborative and safe robots into the production systems which perform together with humans discloses the robots usages for several different tasks and allows the physical pressure to rest of production process to elevated. Robot automation enables from this option and are used by different industries and however these robots are still used by particular assembly stations. Extensive usage has attained when these collaborative robots combines with AGVs in different assembly stations. The production staff efficiency has increased further. Data fusion methods allows incorporation of collaborative robot, different sensors and AGVs which attains docking

functionality, robot and AGV recalibrated to specific assembly station. For e.g. (Moshayedi, Reza, Khan, & Nawaz, 2023) analyses in 3D unity environment in which RAZBOT and TurtleBot2i robot platforms were incorporated and controlled using ROS. Many advantages attained due to unity as simulator for robot performance, and they are greater quality of graphics and robot behaviour. Another example of AGV robotics in manufacturing is ActiveOne AGV shown in fig.3 produced by Portuguese company Active space Automation. It is said to be bidirectional AGV shown in fig with 800 kg lifting capacity and performs natural navigation with wireless communication for communication with operators and product lines and for monitoring and remote management.

Fig.3. ActiveOne AGV (D'Souza, Costa, & Pires, 2020)

6. Conclusion

In conclusion the AI based robotics in manufacturing are reviewed which unveils a landscape marked through automation and autonomous based on innovation, ethical considerations and collaboration. The future of AI enhanced robotics exhibited in-depth promise for adaptability, production paradigms transformation and efficiency. Hence, Continued innovation call and responsible deployment repeats the requirement for ethical, collaborative and forward thinking method which ensures the incorporation of AI improves not only the robotic system capabilities and also the societal well-being at higher particularly in manufacturing industries. This review suggested that in future AI and robotics seamlessly interlink with manufacturing processes which is collective venture that layouts the further industrial evolution.

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