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Artificial intelligence, machine learning and deep learning in advanced robotics, a review

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ABSTRACT

Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL) have revolutionized the field of advanced robotics in recent years. AI, ML, and DL are transforming the field of advanced robotics, making robots more intelligent, efficient, and adaptable to complex tasks and environments. Some of the applications of AI, ML, and DL in advanced robotics include autonomous navigation, object recognition and manipulation, natural language processing, and predictive maintenance. These technologies are also being used in the development of collaborative robots (cobots) that can work alongside humans and adapt to changing environments and tasks. The AI, ML, and DL can be used in advanced transportation systems in order to provide safety, efficiency, and convenience to the passengers and transportation companies . Also, the AI, ML, and DL are playing a critical role in the advancement of manufacturing assembly robots, enabling them to work more efficiently, safely, and intelligently. Furthermore, they have a wide range of applications in aviation management, helping airlines to improve efficiency, reduce costs, and improve customer satisfaction. Moreover, the AI, ML, and DL can help taxi companies in order to provide better, more efficient, and safer services to customers. The research presents an overview of current developments in AI, ML, and DL in advanced robotics systems and discusses various applications of the systems in robot modification. Further research works regarding the applications of AI, ML, and DL in advanced robotics systems are also suggested in order to fill the gaps between the existing studies and published papers. By reviewing the applications of AI, ML, and DL in advanced robotics systems, it is possible to investigate and modify the performances of advanced robots in various applications in order to enhance productivity in advanced robotic industries.

1. Introduction

Artificial intelligence (AI), machine learning (ML), and deep learning (DL) are all important technologies in the field of robotics [1]. The term artificial intelligence (AI) describes a machine's capacity to carry out operations that ordinarily require human intellect, such as speech recognition, understanding of natural language, and decision-making. Robots can detect and interact with their surroundings, make judgments, and carry out difficult tasks with the aid of AI. [2]. A branch of AI known as "machine learning" uses algorithms to give robots the ability to learn from data and get better over time [3]. It's possible to program robots to carry out certain jobs in robotics, such as grasping, object identification, and path planning. Artificial neural networks are used in deep learning, a

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type of machine learning (ML), to help computers learn from massive volumes of data [4]. DL has been particularly useful in robotics for tasks such as image and speech recognition, natural language processing, and object detection. Together, these technologies have enabled the development of robots that can perform a wide range of tasks, from simple pick-and-place operations to complex manipulation and navigation in unstructured environments [5]. The application of AI, ML, and DL in robotics has the potential to transform the field, enabling robots to become more intelligent, autonomous, and effective in a wide range of applications. Robotics is a rapidly evolving field, and the use of AI, ML, and DL is likely to continue to play a key role in shaping the future of robotics [6].

In advanced robotic systems, AI is used to create robots that can perceive, reason, and act autonomously in complex environments. Machine Learning is used to enable robots to learn from their experiences and improve their performance over time. Deep Learning is used to solve specific problems that are difficult to solve with traditional Machine Learning techniques, such as image and speech recognition. By combining these technologies, advanced robotics systems can be designed to perform complex tasks that were once thought impossible. The relationship between them are inclusive in terms of analysis and modification of advanced robotic systems. These are just a few examples of how AI, ML, and DL are used in robotics. Here are some examples of how they are used in different robotic systems as,

1. Object Detection and Recognition: Object detection and recognition are critical tasks in robotics that have become possible thanks to deep learning. By training neural networks with massive amounts of labeled data, robots can identify and classify objects in their environment with high accuracy [7].
2. Predictive Maintenance: Predictive maintenance is a maintenance approach that uses AI and ML to detect potential issues before they occur. By analyzing data from sensors and other sources, predictive maintenance algorithms can predict when a robot's components may fail, allowing for proactive repairs or replacements [8].
3. Gesture and Speech Recognition: Gesture and speech recognition are also important applications of AI and ML in robotics. For example, robots like Pepper can recognize and respond to human gestures and speech, making them useful in a variety of contexts such as customer service or healthcare [9].
4. Robotic Surgery: Robotic surgery is a field where AI and ML are revolutionizing the way operations are performed. By using advanced algorithms, robotic surgeons can assist human surgeons during complex procedures, reducing the risk of complications and improving outcomes. Surgical robots use AI, ML, and DL to aid surgeons in performing complex operations with greater precision and accuracy [10].
5. Medical applications: DL techniques are particularly useful in analyzing medical images due to their ability to recognize patterns and features that are not easily identifiable by humans [11]. This can help doctors to identify subtle changes in the images that may indicate the presence of disease [12]. Machine learning models used in drug delivery for infectious disease treatment is shown in the Fig. 1 [13]. Ensemble algorithm, decision trees and random forest, instance based algorithms and artificial neural network are used to enhance drug delivery of infectious diseases.
6. Military robotics: Robotics is used in military operations for tasks such as reconnaissance, surveillance, and bomb disposal. AI and ML algorithms are used to analyze data and make decisions based on the information gathered [14].
7. Agriculture: AI and ML are being used to develop robots that can autonomously navigate and manage crops, increasing efficiency and reducing labor costs. Robotics is used to automate tasks in agriculture, such as planting, harvesting, and spraying. AI and ML algorithms are used to optimize the farming operations, such as predicting weather patterns, optimizing water usage, and monitoring crop health [15].
8 Service robotics: Robotics is used to provide services to humans, such as cleaning, food delivery, and customer service. AI and ML algorithms are used to enable robots to interact with humans and understand their needs and preferences [16].
9 Autonomous driving: AI and ML are used to help cars navigate roads and make driving decisions on their own. For example, self-driving cars use computer vision to detect and recognize objects on the road, and ML algorithms to learn and adapt to new situations and road conditions [17]. For instance, robots like self-driving cars use AI to detect obstacles and predict traffic movements. Meanwhile, ML algorithms use data from sensors, cameras, and GPS to make navigation decisions [18].
10. Robotics manufacturing: Robotics is used to automate tasks in manufacturing plants, such as assembly line tasks, painting, and welding. AI and ML algorithms are used to optimize the robotic operations, such as improving the efficiency and accuracy of movements [2].

There are various applications of Artificial Intelligence (AI), Machine Learning (ML) and Deep Learning (DL) in analysis and modification of advanced robotics. Some of the performance data of these methods in advanced robotics are discussed below:

1. Object Recognition: Object recognition is a crucial task in robotics, and it is essential for autonomous navigation and manipulation. Deep learning techniques such as Convolutional Neural Networks (CNN) have achieved impressive results in object recognition.
2. Motion Planning: Motion planning is a key task in robotics that involves finding a collision-free path for a robot to move from one point to another. Reinforcement Learning (RL) is a powerful machine learning technique that has been used to achieve impressive results in motion planning. For example, the Deep Deterministic Policy Gradient (DDPG) algorithm has been used to generate smooth and efficient paths for robotic manipulators.
3. Control: Control is another important task in robotics, and it involves regulating the movement of robots. Deep Reinforcement Learning (DRL) has been used to achieve impressive results in control tasks. For example, the Proximal Policy Optimization (PPO) algorithm has been used to train a robotic arm to grasp and move objects.
4. Localization: Localization is the process of determining the position of a robot in its environment. Machine Learning techniques such as Support Vector Machines (SVM) and Random Forests have been used to achieve impressive results in localization tasks. For example, a Random Forest-based method achieved an accuracy of 98.8% in a robot localization task.

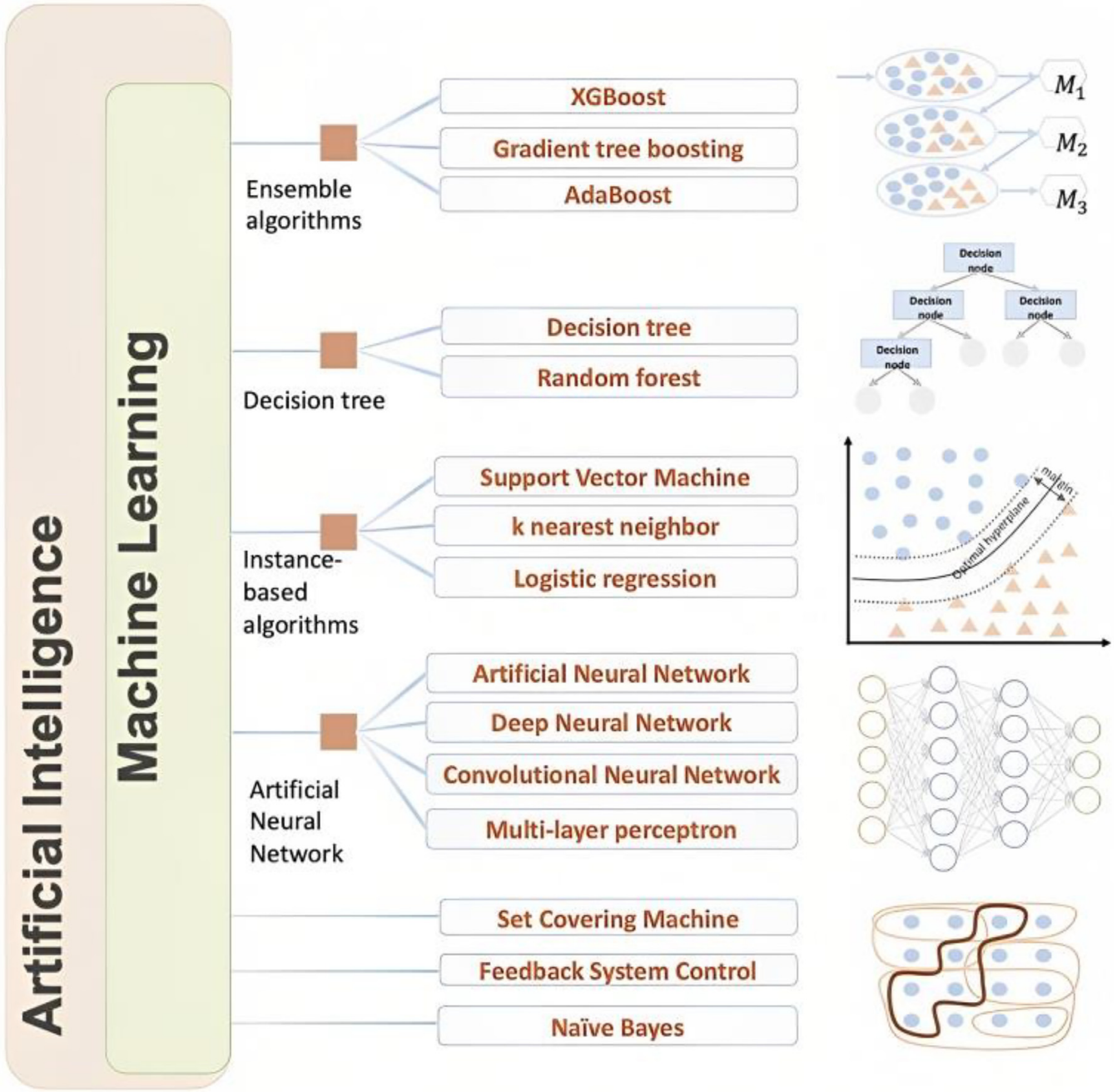

Fig. 1. Drug delivery using machine learning algorithms is utilized to treat infectious diseases [13].

5. Object Detection: Object detection is the process of detecting and localizing objects in an image. Deep Learning techniques such as Faster R-CNN and YOLO have achieved impressive results in object detection tasks.

AI in robotics can be used to enable robots to recognize objects, navigate complex environments, and even make decisions based on real-time data. ML can be used to teach robots to learn from experience and adapt to changing situations. DL can be used to enable robots to perform complex tasks that would otherwise be impossible using traditional programming methods [19]. There are many programming languages used in Robotics, such as Python, C++, MATLAB, and ROS (Robot Operating System). These programming languages have various libraries and tools that make it easier to incorporate AI, ML, and DL into robotic systems [20]. For example, TensorFlow and PyTorch are popular deep learning frameworks which can be used in robotics programming applications. Tesla machines use AI, ML, and DL in a variety of ways. For example, Tesla's Autopilot system uses AI and ML to enable semi-autonomous driving, and to recognize and respond to traffic conditions. Tesla's manufacturing processes also use AI and ML to optimize production efficiency and quality [21].

CNC machining is a crucial technology in the development and maintenance of advanced robotics, allowing for the creation of highly precise and complex parts and components that are essential for the performance and reliability of robots. CNC machining is used in the maintenance and repair of robots. When a robot component fails, it is often necessary to create a replacement part that fits precisely and functions correctly. CNC machining makes it possible to quickly produce replacement parts that meet the required specifications, reducing downtime and ensuring the robot is back in operation as soon as possible.

To evaluate and enhance CNC machining in virtual environments, Soori et al. proposed virtual machining approaches [22–26]. To examine and improve efficiency in the process of component manufacture using welding processes, Soori et al. [27] proposed an overview of recent advancements in friction stir welding techniques. Soori and Asamel [28] investigated the utilization of virtual machining technologies to lessen residual stress and deflection error during turbine blade five-axis milling operations. In order to evaluate and lower the cutting temperature during milling operations of difficult-to-cut components, Soori and Asmael [29] developed applications of virtualized machining systems. To enhance surface qualities during five-axis milling operations of turbine blades, Soori et al. [30] presented an enhanced virtual machining technique. In order to minimize deflection error during five-axis milling procedures of impeller blades, Soori and Asmael [31] developed virtual milling procedures. In order to analyze and enhance the parameter optimization approach of machining operations, Soori and Asmael [32] offered a synopsis of current advances from published works. In order to increase energy usage effectiveness, data quality and availability throughout the supply chain, and precision and reliability during the component production process, Dastres et al. [33] conducted a research of RFID-based wireless manufacturing systems. In order to increase efficiency and added value in component production processes utilizing CNC machining operations, Soori et al. [34] examined machine learning and artificial intelligence in CNC machine tools. To measure and reduce residual stress during machining operations, Soori and Arezoo [35] provided a review in the subject. Soori and Arezoo [36] described optimal machining settings utilizing the Taguchi optimization technique to reduce surface integrity and residual stress during grinding operations of Inconel 718. Soori and Arezoo [37] investigated several tool wear prediction techniques to lengthen cutting tool life during machining processes. In order to increase efficiency in the component production process, Soori and Asmael [38] studied computer assisted process planning. In order to provide decision - making support systems for data warehouse operations, Dastres and Soori [39] discussed advancements in web-based decision support systems. In order to develop the implementation of artificial neural networks in performance enhancement of engineering products, Dastres and Soori [40] presented a review of recent research and uses of artificial neural networks in a variety of disciplines, including risk analysis systems, drone control, welding quality analysis, and computer quality analysis. To minimize cutting tool wear in drilling operations, application of virtual machining system is developed by Soori and Arezoo [41]. To enhance quality of prodcued parts using abrasive water jet machining, residual stress and surface roughness are minimized by Soori and Arezoo [42]. Dastres and Soori [43] discussed using information and communication technology in environmental conservation to lessen the impact of technological progress on natural disasters. Dastres and Soori [44] proposed the secure socket layer in order to improve network and data online security. In order to create the methodology of decision support systems by assessing and recommending the gaps between presented methodologies, Dastres and Soori [45] analyze the advancements in web-based decision support systems. Dastres and Soori [46] provided an assessment of current developments in network threats in order to improve security measures in networks. Dastres and Soori [47] analyze image processing and analysis systems to expand the possibilities of image processing systems in many applications.

AI, ML and DL are transforming the field of advanced robotics by enabling the development of intelligent machines that can perform complex tasks with high accuracy and efficiency. A review in recent development of AI, ML and DL in advanced robotics system is presented and different applications of the systems in modifications of robots are also discussed in the study. The gaps between the published research works in the applications of AI, ML and DL in advanced robotics system are also suggested as future research works in the interesting research field. As a result, performances of advanced robots in different applications can be analyzed and modified by reviewing the applications of AI, ML and DL in advanced robotics system in the study. Thus, accuracy as well as productivity in applications of advanced robots can be enhanced.

2. Advantages of AI, ML and DL applications in advanced robotics

AI (Artificial Intelligence), ML (Machine Learning), and DL (Deep Learning) applications have brought about significant advancements in the field of robotics [48]. Some of these advantages of AI, ML and DL applications in advanced robotics include:

1. Automation: AI, ML, and DL can automate many repetitive and mundane tasks in robotics, freeing up human resources to focus on more complex tasks [49].
2. Enhanced accuracy: These technologies can improve the accuracy and precision of robotic systems, reducing errors and improving overall performance.
3. Adaptability: AI-powered robots can adapt to changing environments and tasks, making them highly versatile and useful in a range of industries and applications [48].
4. Predictive Maintenance: Machine learning algorithms can help robots to predict when maintenance or repairs are required, leading to reduced downtime and cost savings [50].
5. Improved Decision Making: AI and ML algorithms can analyze large amounts of data and make informed decisions based on that data, allowing robots to make better decisions and take appropriate actions [51].
6. Improved efficiency: By optimizing processes and reducing waste, AI, ML, and DL can improve the overall efficiency of robotics systems, resulting in cost savings and increased productivity.
7. Better decision-making: AI, ML, and DL can enable robots to make better decisions based on data analysis and pattern recognition, leading to improved performance and outcomes [52].
8. Adaptability: These technologies can enable robots to adapt to changing environments and situations, making them more versatile and capable of handling a wider range of tasks [53].
9. Increased safety: By automating hazardous or dangerous tasks, AI, ML, and DL can improve safety in the workplace, reducing the risk of accidents and injuries.

10. Cost Reduction: The implementation of AI and ML applications in advanced robotics can significantly reduce costs associated with labor and maintenance [54].
11. Improved Decision-making: By using AI and ML algorithms, robots can make informed decisions based on data analysis, resulting in better overall performance [55].

Overall, the use of AI, ML, and DL in robotics has the potential to revolutionize the field and unlock new levels of performance, efficiency, and safety.

3. Challenges of AI, ML and DL in robotics applications

While these technologies offer many benefits, they also pose significant challenges. One of the biggest challenges is the need for large amounts of high-quality data to train AI and ML algorithms. However, data collection, labeling, and annotation can be expensive and time-consuming, and the data may be noisy or biased, which can affect the accuracy and reliability of the models [48]. This can be particularly challenging in robotics, where data can be difficult to obtain and may be subject to noise and uncertainty. In addition, robotics applications often require real-time processing, which can be computationally expensive and may require specialized hardware [56]. Furthermore, in order to analyze massive volumes of data, build models, and make predictions in real-time, AI/ML/DL systems need a lot of processing power. This can be difficult in robotics applications since robots are constrained by energy and computing power limitations [57].

Robotics applications often require robots to operate in dynamic and changing environments which need adaptability in operations [58]. AI/ML/DL models must be designed to adapt to new situations and learn from experience, which can be challenging. Another challenge is the need for robots to be able to operate safely and effectively in a wide range of environments [15]. As robots become more autonomous and interact with humans, ensuring their safety becomes a critical challenge. AI/ML/DL algorithms must be designed to prevent accidents, detect and respond to potential hazards, and avoid collisions with humans and other objects [59]. This requires the development of robust AI and ML algorithms that can handle unpredictable situations and adapt to changing conditions. It also requires the development of sensors and other hardware that can provide accurate and reliable data about the robot's surroundings [60]. In addition, there are ethical and societal challenges associated with the use of AI and robotics. For example, there are concerns about the impact of automation on jobs and the potential for AI systems to be biased or to perpetuate existing inequalities. There are also concerns about the potential for robots to be used for harmful purposes, such as military applications or surveillance [61].

Overall, while AI, ML, and DL offer many opportunities for robotics, there are also significant challenges that must be addressed in order to realize their full potential. Researchers and engineers in this field must work to develop robust algorithms, hardware, and ethical frameworks that can support the safe and effective use of these technologies.

4. Applications of AI, ML and DL in advanced industrial robots

There are many potential applications of artificial intelligence (AI), machine learning (ML), and deep learning (DL) in advanced manufacturing robots. AI and ML can be used to analyze production data and optimize production planning. AI and ML can be used to perform quality control checks on manufactured products [62]. AI algorithms can identify defects in products and alert the production team to make necessary adjustments in real-time. This helps manufacturers to identify and eliminate bottlenecks, reduce waste, and increase productivity [63]. Some of these applications include:

1. Quality Control: AI, ML, and DL algorithms can be used to monitor the manufacturing process in real-time and identify defects or anomalies in the products being produced. This can help improve the quality of the products and reduce the need for human intervention in the quality control process [64].
2. Predictive Maintenance: When industrial equipment is predicted to fail, maintenance may be carried out before a breakdown happens thanks to the usage of AI and ML. By doing so, downtime may be decreased and overall productivity can rise [65].
3. Autonomous Robots: Advanced manufacturing robots can be equipped with AI and ML algorithms that enable them to operate autonomously. This can be particularly useful in situations where human intervention is not practical or safe, such as in hazardous environments or in situations where precision is critical [66].
4. Assembly robots: AI, ML, and DL technologies are enabling robots during assembly process to work smarter, faster, and more efficiently than ever before, and are helping manufacturers to improve quality, reduce costs, and increase productivity [67]. AI can be used to control and optimize robotic assembly processes [68]. It can enable robots to adapt to changing conditions, work collaboratively with human operators, and learn from past experiences to improve future performance. Also, AI can be used to improve the safety of assembly robots by monitoring their movements and identifying potential hazards [69]. This can help to prevent accidents and reduce the risk of injury to workers. Moreover, AI can be used to optimize the workflow of assembly robots, by analyzing data on the production process and identifying areas where efficiency can be improved [70].
5. Process Optimization: AI, ML, and DL can be employed to determine the most effective way to make a product in order to improve the manufacturing process. This can save waste and boost overall effectiveness. [71].
6. Supply Chain Optimization: AI and ML can be used to optimize the supply chain by predicting demand and ensuring that the right materials are available at the right time. This can help reduce inventory costs and improve overall efficiency [72].

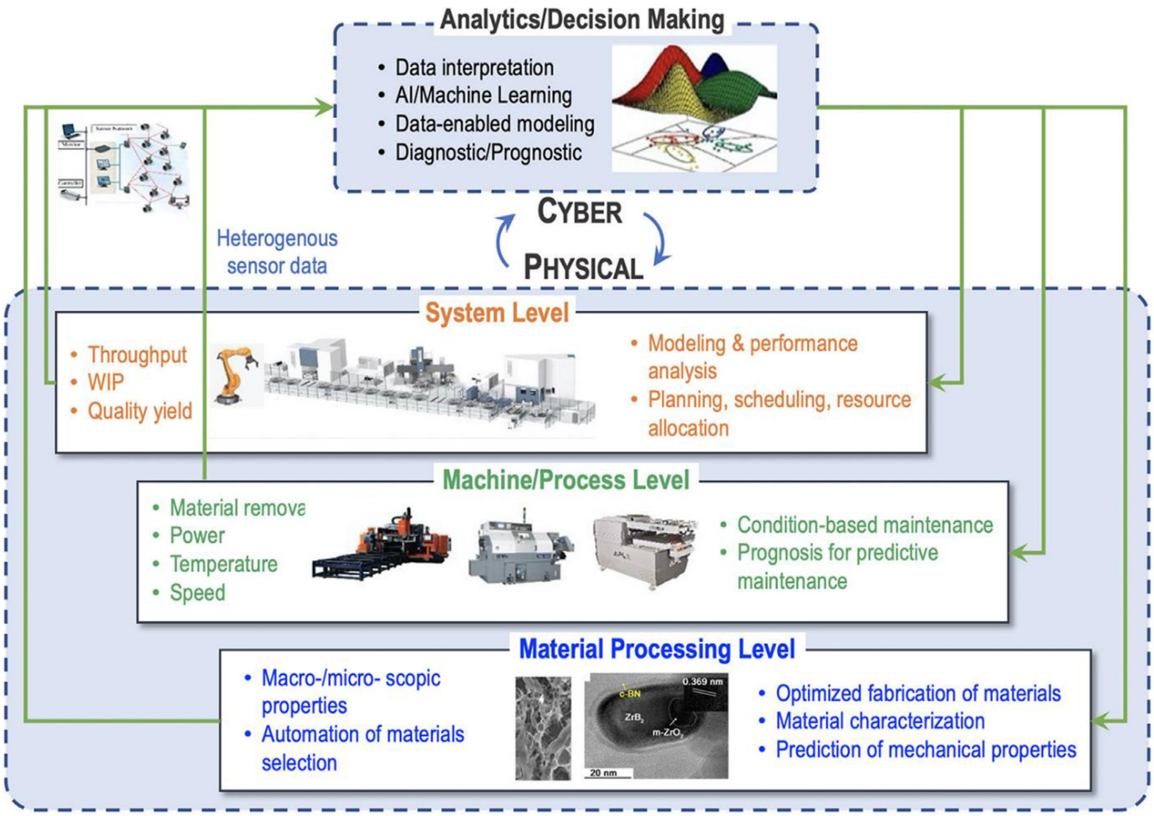

Fig. 2. Application of AI in DL in advanced manufacturing process and robots [5].

7. Collaborative Robots: AI and ML can be used to enable robots to work alongside human workers in a collaborative environment. This can help improve productivity and safety by allowing robots to perform repetitive or dangerous tasks while humans focus on more complex tasks [73].

AI, ML, and DL have a wide range of applications in advanced manufacturing, including in robotics and automated guided vehicles (AGVs) [74]. The technologies are essential for optimizing the performance of advanced manufacturing robots and AGVs, allowing them to work more efficiently, accurately, and safely in a variety of settings [75]. Some examples of these applications include:

1. Object detection and recognition: AI and ML algorithms can be used to identify and recognize different objects in a manufacturing environment. This can be useful for robots and AGVs to navigate and interact with their surrounding [76].
2. Real-time decision making: AI algorithms can enable robots and AGVs to make real-time decisions based on sensor data, allowing them to adapt to changing conditions in a manufacturing environment [77].
3. Path optimization: AI algorithms can be used to optimize the path that a robot or AGV takes through a manufacturing facility, reducing travel time and increasing efficiency [78].

Application of AI in DL in advanced manufacturing process and robots is shown in the Fig. 2 [5]. This flowchart explains a crucial idea from the viewpoint of system requirements when assessing the applicability of any AI technology to guarantee that overall objectives are satisfied and sub-optimization is avoided.

Overall, by increasing productivity, cutting costs, and raising product quality, the employment of AI, ML, and DL in advanced industrial robots has the potential to completely transform the manufacturing sector.

5. Applications of AI, ML and DL in advanced transportation systems

Artificial intelligence (AI), machine learning (ML), and deep learning (DL) are increasingly being used in advanced transportation systems to improve safety, efficiency, and convenience [79]. Here are some of the most notable applications of these technologies in transportation:

1. Intelligent Transportation Systems (ITS): AI-based ITS can help improve traffic flow, reduce congestion, and enhance safety on roads. ML algorithms can analyze traffic patterns and optimize signal timings at intersections, while DL algorithms can identify potential hazards and alert drivers in real-time.

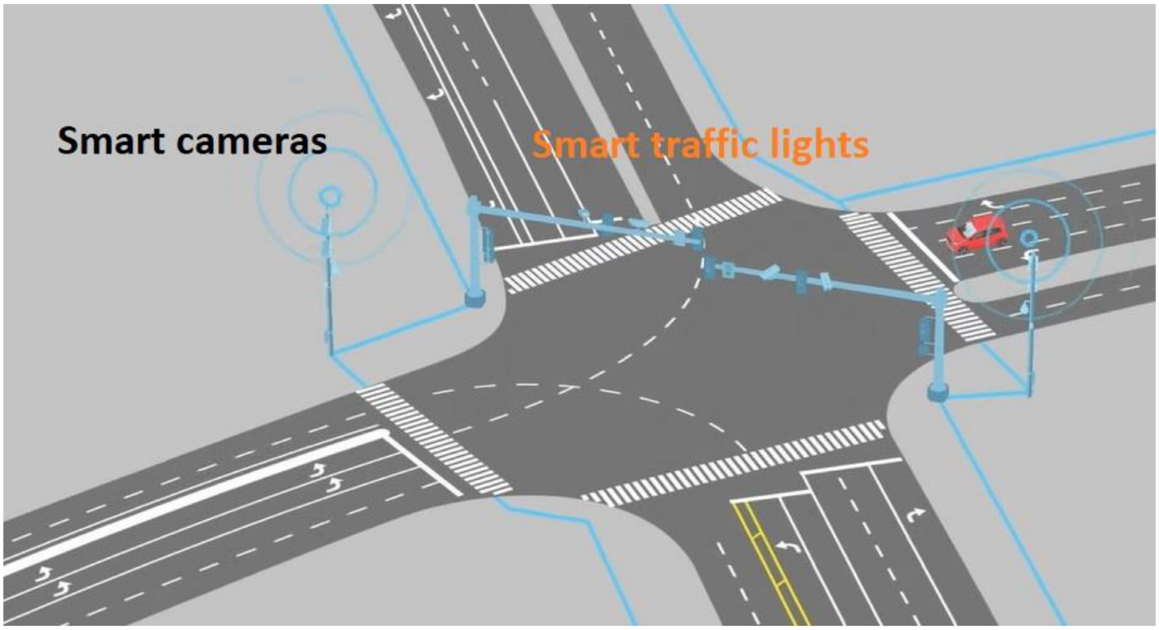

Fig. 3. Applications of AI in intelligent traffic management.

2. Traffic Management: AI, ML, and DL techniques are used to monitor and analyze traffic patterns. This helps in optimizing traffic flow and reducing congestion [80]. Applications of AI in intelligent traffic management is shown in the Fig. 3. Smart cameras and traffic lights which are controlled by using the AI can monitor and analyze traffic patterns in order to increase the performances of traffic management systems.
3. Autonomous Vehicles: AI, ML, and DL are essential components of autonomous vehicles. These technologies enable vehicles to perceive and interpret their surroundings, make decisions based on data, and navigate roads safely without human intervention [81].
4. Intelligent Transportation Systems (ITS): AI, ML, and DL algorithms are used to develop ITS. ITS includes technologies like smart traffic signals, electronic toll collection systems, and intelligent parking systems, which help in optimizing the transportation system [82].
5. Predictive Maintenance: ML algorithms can analyze data from sensors installed on vehicles and predict when maintenance is needed, allowing for proactive repairs and reducing downtime. This can be especially useful in large fleets of vehicles, such as those used in public transportation [83].
6. Smart Parking: AI-based parking systems can help drivers find available parking spots quickly and reduce congestion in busy areas. ML algorithms can analyze parking data to optimize parking space usage, while DL algorithms can recognize license plates and enforce parking regulations [84].
7. Route Optimization: ML algorithms can optimize delivery routes for logistics companies, reducing travel time, and improving fuel efficiency. This can result in cost savings and a reduced environmental footprint [85].
8. Road Safety: AI, ML, and DL can be used to improve road safety by analyzing traffic patterns and identifying areas prone to accidents. Algorithms can be used to predict and prevent accidents by alerting drivers of potential hazards and suggesting safer routes [86].
9. Intelligent Public Transportation: AI and ML can be used to optimize public transportation schedules and routes, providing passengers with more convenient and efficient services. DL algorithms can also be used to monitor passenger behavior and detect potential safety issues [87].

AI applications in collision avoidance and road hazard warning is shown in the Fig. 4 [88].

Overall, AI, ML, and DL are becoming increasingly important in the development and operation of advanced transportation systems, helping to improve efficiency, safety, and sustainability. The applications of AI, ML, and DL in advanced transportation systems have the potential to revolutionize the way we travel, making transportation safer, more efficient, and more sustainable.

5.1. Drones

Artificial intelligence (AI), machine learning (ML), and deep learning (DL) are all important technologies that can be applied to the field of robotics drones. Unmanned aerial vehicles (UAVs), usually referred to as advanced drones, are being utilized more frequently in a wide range of industries, including agriculture, construction, mining, search and rescue, and military activities [89]. The use of

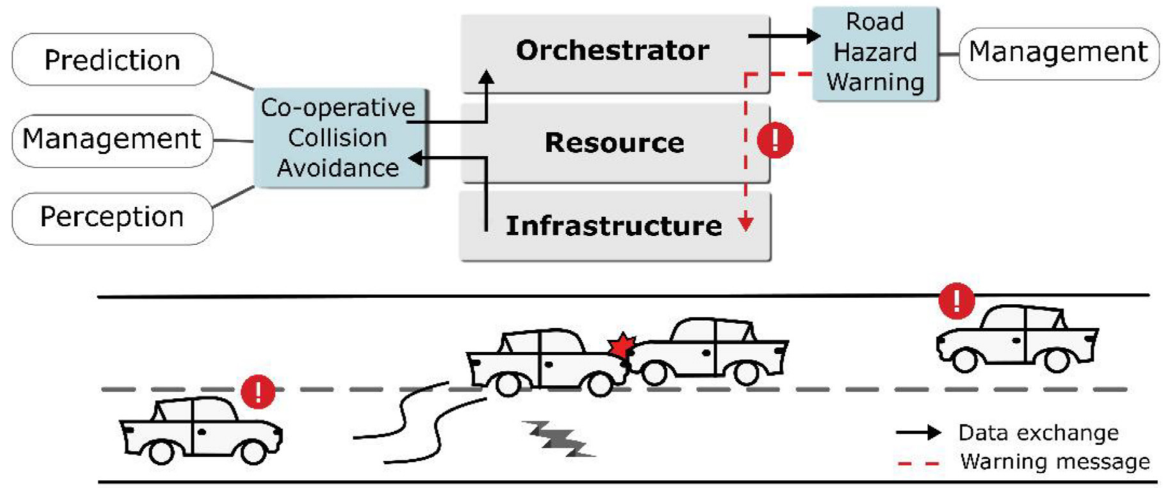

Fig. 4. AI applications in collision avoidance and road hazard warning [88].

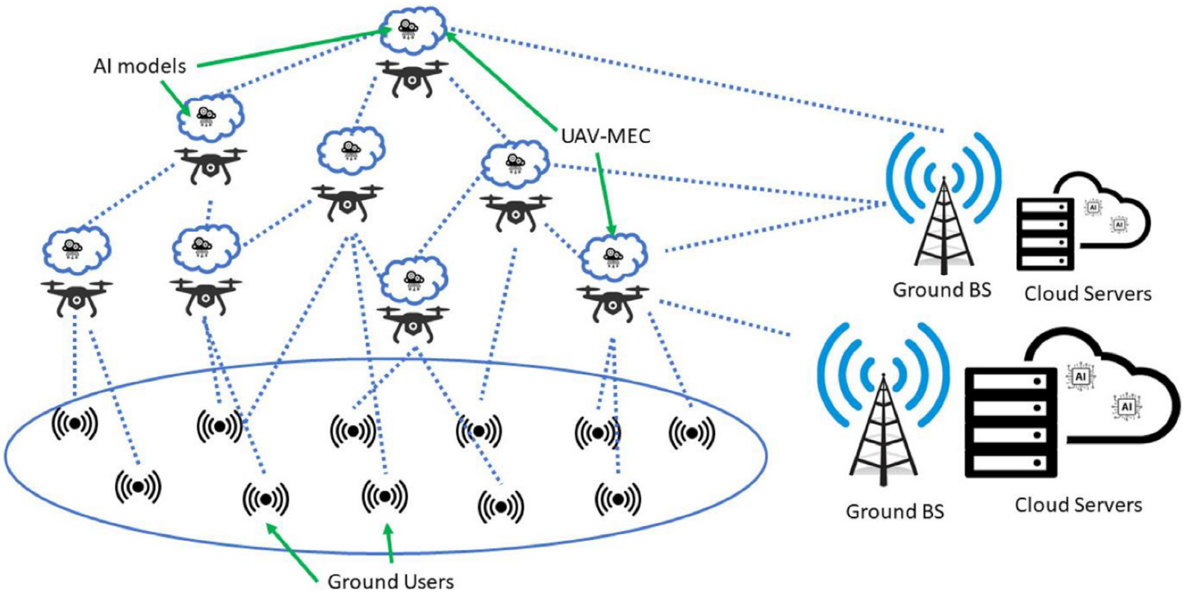

Fig. 5. Mobile edge computing and AI in drone navigations [94].

AI, ML, and DL in advanced drones has expanded their capabilities and made them more efficient and effective in performing various tasks of different drones [90]. Here's how:

1. AI in Robotics Drones: AI can help drones to perform complex tasks by using algorithms to analyze data from sensors, cameras, and other sources. With AI, drones can make decisions on their own based on the data they collect. For example, AI can be used to identify and track objects, detect obstacles and avoid collisions, and optimize flight paths for maximum efficiency [91].
2. Machine Learning in Robotics Drones: Machine learning is a subset of AI that involves training algorithms to recognize patterns in data. In the case of robotics drones, machine learning can be used to improve the accuracy of object recognition, object tracking, and obstacle detection. For example, drones can be trained to recognize different types of objects, such as vehicles or people, and respond accordingly [92].
3. Deep Learning in Robotics Drones: Deep learning is a subset of machine learning that processes massive quantities of data using neural networks. Drones can carry out difficult tasks like autonomous navigation and mapping using deep learning. Deep learning, for instance, may be used to teach drones how to detect and avoid obstacles in real-time [93]. Mobile edge computing and AI in drone navigations is shown in the Fig. 5 [94]. The Unmanned Aerial Vehicles (UAV) receives divided the task from an IoT device and transmits the results back after the assignment has been completed. Additionally, in the event that complicated processing needs exceed the capacity of the onboard cloudlet, the UAV might forward the collected data to the closest ground servers. The

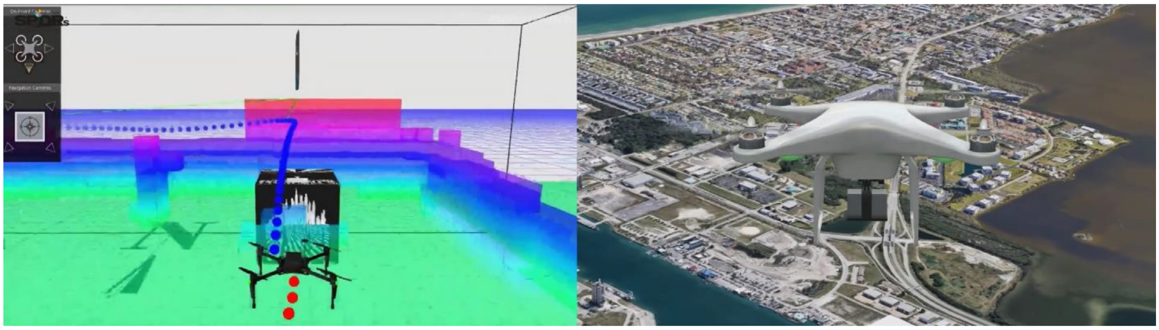

Fig. 6. Application of ML in autonomous navigation of drones.

system may incorporate a number of UAVs that support a vast array of deployed Internet of Things devices, such as smartphones, sensors, cars, and robots. With the use of AI, onboard cloudlets examine and process the user-generated data.

Here are some applications of AI, ML, and DL in advanced drones:

1. Object detection and recognition: AI and ML algorithms can be used to identify and classify objects in drone imagery. This can be particularly useful in search and rescue missions, where drones can quickly scan a large area and identify objects of interest such as people, vehicles, or buildings [95].
2. Autonomous navigation: DL algorithms can be used to enable drones to navigate autonomously without the need for human intervention. This can be particularly useful in industrial applications where drones need to fly in and around obstacles or structures [96]. Application of ML in autonomous navigation of drones is shown in the Fig. 6.
3. Precision agriculture: Drones equipped with AI and ML algorithms can be used to collect data on crop health, moisture levels, and soil conditions. This data can then be used to optimize crop yields and reduce waste [97].
4. Surveillance and security: Drones equipped with AI and ML algorithms can be used for surveillance and security applications, such as monitoring borders, detecting intruders, and identifying potential threats [98].
5. Disaster response: Drones equipped with AI and ML algorithms can be used in disaster response efforts to quickly assess damage and identify areas where help is needed. This can help first responders prioritize their efforts and resources [99].
6. Delivery services: Packages and supplies can be delivered to far-flung or difficult-to-reach regions using drones with AI and ML algorithms. When drones are delivering packages, these algorithms can guide them and assist them avoid obstacles [100].

Overall, AI, ML, and DL are all essential technologies in the development of robotics drones. They can help to improve the accuracy, efficiency, and autonomy of drones, making them more useful in a variety of applications. The use of AI, ML, and DL in advanced drones has expanded their capabilities and made them more efficient and effective in performing various tasks. As these technologies continue to evolve, we can expect to see even more applications of AI, ML, and DL in advanced drones in the future.

5.2. Ship navigation

Artificial intelligence (AI), machine learning (ML), and deep learning (DL) are increasingly being used in robotics, particularly in ship navigation [101]. These technologies can help ships navigate more efficiently, accurately, and safely [102]. Here's a brief overview of how AI, ML, and DL are being used in ship navigation:

1. Artificial Intelligence (AI): AI can be used in ship navigation to identify patterns and make decisions based on those patterns. For example, AI algorithms can be used to identify potential hazards or obstacles in a ship's path and make course corrections to avoid them [103]. AI can also be used to optimize ship performance, such as fuel consumption and speed, based on environmental conditions.
2. Machine Learning (ML): ML is a subset of AI that involves training algorithms on data to make predictions or decisions. ML can be used in ship navigation to learn from past experiences and improve navigation in real-time [104]. For example, ML algorithms can learn from previous ship routes and weather conditions to make more accurate predictions about future routes.
3. Deep Learning (DL): DL is a subset of ML that uses neural networks to learn from data. DL can be used in ship navigation to analyze large amounts of data, such as sonar or radar images, to identify potential hazards or obstacles. DL can also be used to improve ship performance by optimizing engine settings or predicting equipment failures before they occur [105]. Applications of AI in ship navigation systems is shown in the Fig. 7 [106]. First, in the requirements collection stage, navigation practices in the open sea, restricted waters, and two-ship and multi-ship interactions are collected and categorized. Second, in the requirements extraction stage, the collected navigation practices are linked to COLREGs part B to extract the primary rules and keywords on the topic of collision avoidance. Finally, in the requirements analysis step, the requirements to generate the optimal local path are analyzed and specified according to the categories identified during the requirements collection and the rules and keywords defined in the extraction step [106].

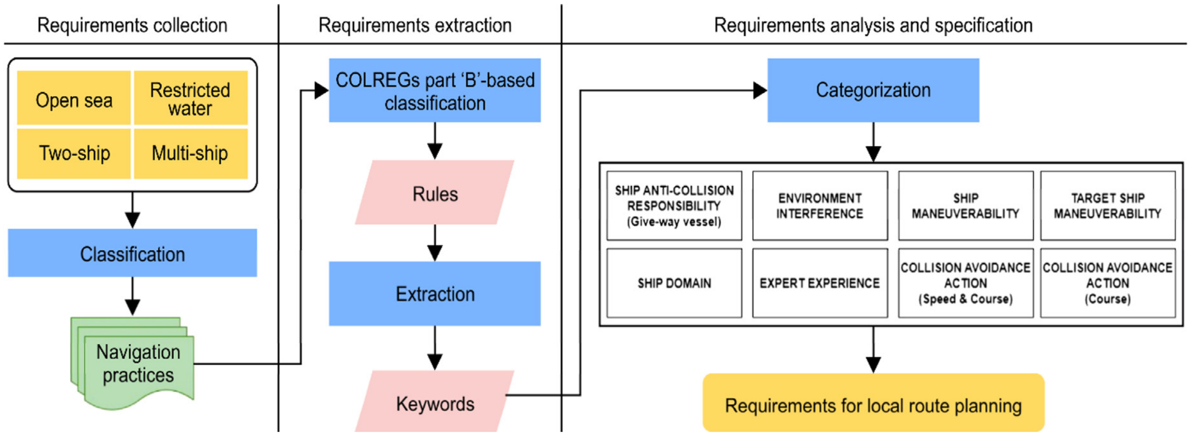

Fig. 7. Applications of AI in ship navigation systems [106].

Some applications of these technologies in ship navigation include:

1. Autonomous navigation: AI and ML algorithms can be used to create autonomous navigation systems that can pilot ships safely and efficiently without human intervention.
2. Collision avoidance: ML models can be trained on historical data to predict potential collisions and provide real-time recommendations to avoid them [107].
3. Route optimization: AI and ML can be used to analyze weather patterns, currents, and other factors to optimize ship routes for speed, fuel efficiency, and safety [108].
4. Predictive maintenance: By analyzing sensor data and forecasting equipment breakdowns beforehand, DL algorithms enable proactive maintenance and save downtime.
5. Weather routing: AI and ML algorithms can be used to analyze weather data to identify the safest and most efficient routes for ships to take, taking into account factors such as wind speed, wave height, and water currents [109].
6. Autonomous mooring: AI and ML can be used to develop autonomous mooring systems that can safely and efficiently dock ships without human intervention.

Overall, the application of AI, ML, and DL in ship navigation has the potential to greatly improve safety, efficiency, and sustainability in the shipping industry [103].

5.3. Aeronautical industry and aviation managements

The use of AI, ML, and DL in robotics autopilot systems has the potential to improve the reliability and safety of autonomous vehicles, making them a promising technology for the future of transportation. In robotics autopilot systems, these technologies can be used to improve the accuracy, efficiency, and safety of the system. For example, AI can be used to enable the autopilot system to make decisions based on real-time data from sensors and cameras [110]. ML can be used to train the system to recognize and respond to different situations, such as changing weather conditions or unexpected obstacles. DL can be used to enable the system to learn from past experiences and make more accurate predictions about future events. Artificial intelligence (AI), machine learning (ML), and deep learning (DL) are all crucial technologies in the field of robotics, and they can play a significant role in improving the efficiency and safety of cargo handling at airports. The creation of intelligent computers with the capacity to carry out activities that traditionally require human intellect, such as decision-making, natural language processing, and picture recognition, is known as artificial intelligence (AI) [111]. In the context of airport cargo handling, AI can be used to automate tasks such as cargo tracking, inventory management, and customs processing. ML is a subset of AI that focuses on building algorithms that can learn from data and make predictions or decisions based on that data [112]. ML algorithms can be used to identify patterns in cargo data, such as shipping routes, handling times, and delivery destinations, which can be used to optimize cargo handling processes [113]. DL is a subset of ML that is based on artificial neural networks, which are designed to simulate the structure and function of the human brain. DL algorithms are particularly effective at processing complex data, such as images and video, and can be used to identify cargo types and detect anomalies, such as damaged or dangerous cargo [114]. In the context of airport cargo handling, robotics systems can use AI, ML, and DL technologies to perform tasks such as cargo sorting, packing, and transportation. For example, robotic cargo handlers can use DL algorithms to identify and sort cargo based on size, weight, and destination, and they can use ML algorithms to optimize their movements and avoid collisions with other cargo handling equipment [115]. Application of AI in different sections of aeronautical industry and aviation managements are shown in the Fig. 8.

There are a variety of applications of AI (Artificial Intelligence), ML (Machine Learning), and DL (Deep Learning) in aviation management. Here are some examples:

Fig. 8. Application of AI in different sections of aeronautical industry and aviation managements.

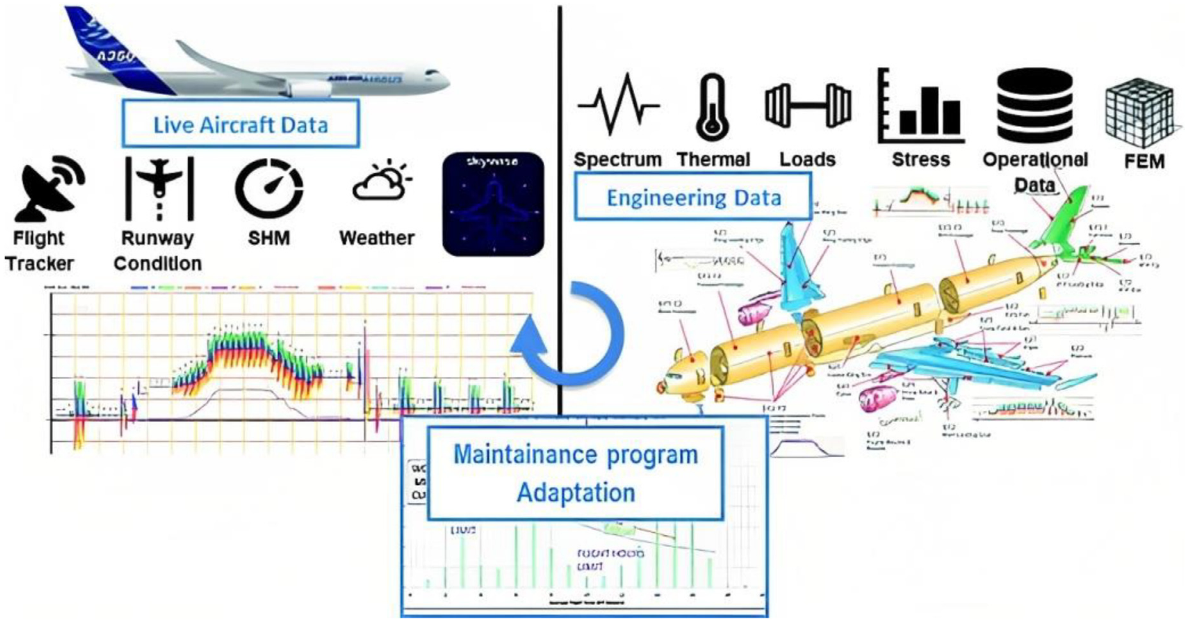

Fig. 9. ML application on aircraft fatigue stress predictions [116].

1. Predictive maintenance: AI and ML algorithms can be used to predict when maintenance is needed on aircraft components. This can help airlines to reduce downtime and minimize disruptions to their schedules. ML application on aircraft fatigue stress predictions is shown in the Fig. 9 [116].
2. Flight route optimization: AI algorithms can be used to optimize flight routes, taking into account factors such as weather conditions, air traffic, and fuel efficiency. This can help airlines to reduce fuel consumption and save money [117].
3. Passenger profiling: AI algorithms can be used to analyze passenger data to predict behavior, preferences and improve personalized service offerings. This can help airlines to tailor their services and improve customer satisfaction [118].
4. Air traffic management: AI and ML algorithms can be used to manage air traffic more efficiently, reducing the likelihood of delays and improving safety [119].

5. Baggage handling: AI algorithms can be used to optimize the handling of baggage, reducing the risk of lost or delayed luggage [120].
6. Crew scheduling: AI and ML algorithms can be used to optimize crew schedules, taking into account factors such as flight times, rest periods, and seniority. This can help airlines to improve efficiency and reduce costs [121].
7. Fraud detection: AI algorithms can be used to detect fraudulent activity, such as credit card fraud or identity theft, helping airlines to reduce financial losses [122].

Overall, the use of AI, ML, and DL in robotics systems can improve the efficiency, safety, and accuracy of airport cargo handling, which can lead to faster delivery times, reduced costs, and improved customer satisfaction.

5.4. Taxi services

Artificial intelligence (AI), machine learning (ML), and deep learning (DL) are all technologies that have the potential to revolutionize the field of robotics taxi services. These technologies can help improve the safety, efficiency, and overall customer experience of autonomous taxi services [123]. AI is the overarching technology that enables machines to perform tasks that would normally require human intelligence, such as perception, reasoning, and decision-making. Machine learning is a subset of AI that focuses on training machines to improve their performance on specific tasks by providing them with data and algorithms [124]. Deep learning is a subset of machine learning that involves the use of neural networks to analyze large amounts of data and learn patterns [125]. In the context of robotics taxi services, AI, ML, and DL can be used to achieve several goals. For example:

1. Perception: Autonomous vehicles need to be able to perceive their environment accurately to navigate safely. AI and DL techniques can be used to process data from sensors such as cameras, lidar, and radar to identify and track objects in real-time [126].
2. Route planning and optimization: Machine learning can be used to analyze historical data on traffic patterns and other factors that affect travel time, allowing the system to optimize routes and avoid congestion [127].
3. Decision-making: Autonomous vehicles need to be able to make decisions quickly and accurately in response to changing conditions. AI and DL techniques can be used to develop decision-making algorithms that take into account a wide range of factors, such as weather, road conditions, and passenger preferences [128].
4. Route optimization: DL can be used to analyze traffic patterns and optimize routes for taxi drivers. This can help them avoid congestion and take the most efficient route to their destination, which can save time and reduce fuel costs [129].
5. Customer experience: AI and DL can be used to personalize the customer experience by analyzing data on passenger preferences and behavior, and providing recommendations for entertainment, food, and other services [130].
6. Fraud detection: AI algorithms can analyze transaction data to identify fraudulent activities, such as false claims of lost property or overcharging customers. This can help taxi companies reduce losses and improve customer trust [131].
7. Chatbots: AI-powered chatbots can be used to provide 24/7 customer support and help passengers book rides, track their taxis, and get answers to their questions. This can improve customer satisfaction and reduce the workload on call center agents.
8. Safety monitoring: DL can be used to monitor drivers and passengers for safety concerns, such as distracted driving or unruly behavior. This can help taxi companies maintain high safety standards and reduce the risk of accidents [132].
9. Autonomous driving: DL is used in autonomous driving technology, which is being developed by taxi companies to reduce labor costs and improve safety. Autonomous taxis can provide a consistent level of service without the need for drivers [133].
10. Personalization: ML algorithms can analyze customer data to personalize their experience. For example, by analyzing past trips, AI can suggest preferred routes or destinations to customers, reducing their travel time and improving their overall experience [134].
11. Predictive analytics: AI and ML can be used to analyze historical data to predict future demand for taxi services. This can help taxi companies optimize their fleet management, scheduling, and pricing strategies to ensure that they are providing the right number of taxis in the right areas at the right times [135]. Intelligent cab service system using the AI based on predictive analytics to select the best cab for the demand and desire of customers and taxi service company is shown in the Fig. 10 [136]. The wireless communication network can be used to provide an advanced distributed approach in Cab booking system in order to enhance efficiency of intelligent cab service system.

Overall, the combination of AI, ML, and DL has the potential to make robotics taxi services safer, more efficient, and more enjoyable for passengers. AI, ML, and DL are transforming the taxi industry by improving efficiency, reducing costs, and enhancing customer experience.

6. Conclusion and future research work directions

Artificial intelligence (AI), machine learning (ML), and deep learning (DL) are increasingly being integrated into robotics, providing robots with the ability to learn, adapt, and improve their performance over time. The fields of robotics and artificial intelligence (AI) are rapidly advancing and merging, with machine learning (ML) and deep learning (DL) playing an increasingly important role in the development of intelligent robots. Advanced robotics applications that use AI, machine learning, and deep learning include autonomous vehicles, drone navigation, industrial robots, healthcare robots, and search and rescue robots. These technologies are transforming the field of robotics and enabling robots to perform tasks that were once considered too difficult or dangerous for humans. DL is particularly useful in robotics because it can be used to develop algorithms that enable the robot to learn from large

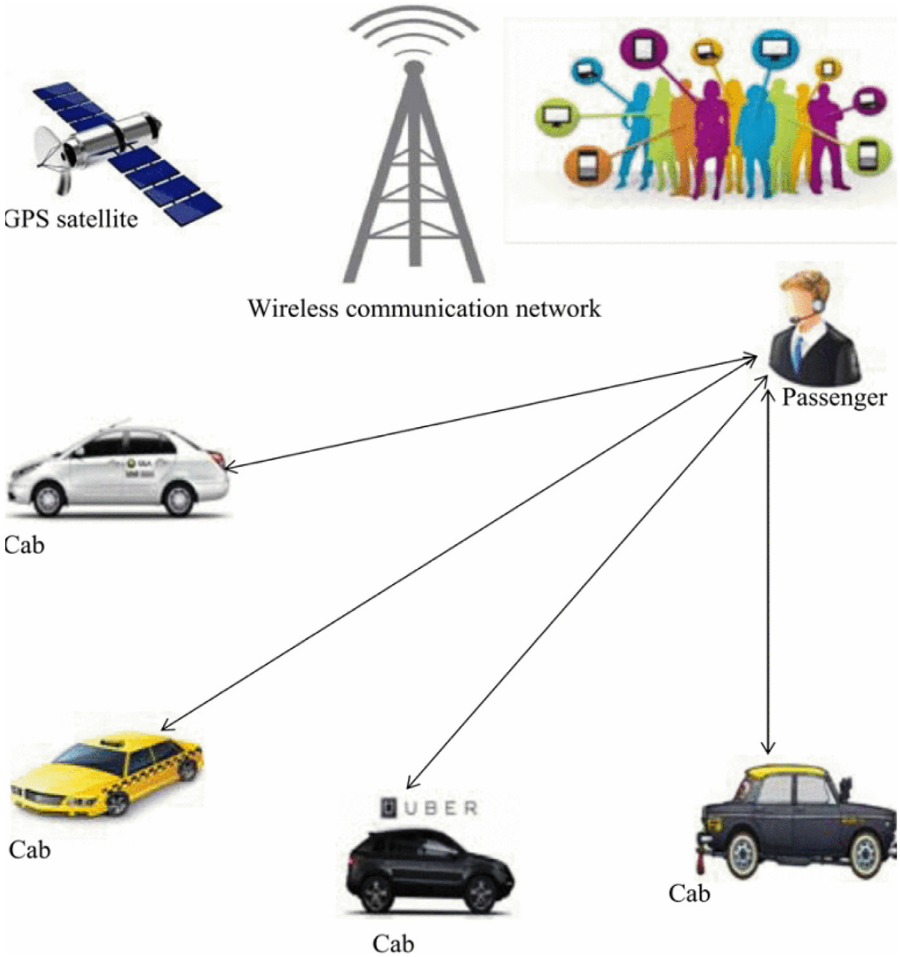

Fig. 10. Intelligent cab service system using the AI based on predictive analytics to select the best cab for the demand and desire of customers and taxi service company [136].

amounts of sensory data, such as images or audio recordings. This allows the robot to perceive and understand its environment in a way that is similar to how humans do, and to make decisions based on that understanding. In the case of Tesla machines, AI, ML, and DL are used to enable a range of advanced capabilities. For example, Tesla's Autopilot system uses a combination of cameras, radar, and ultrasonic sensors to detect and respond to obstacles and other vehicles on the road. ML algorithms are used to analyze this sensor data and make decisions about how to control the vehicle, such as adjusting its speed or steering to avoid collisions. Additionally, DL algorithms are used to improve the accuracy of object detection and recognition, enabling the vehicle to identify and track pedestrians, cyclists, and other objects on the road. As Tesla continues to develop its autonomous driving technology, AI, ML, and DL will likely play an even more important role in enabling safe and efficient self-driving cars. The integration of AI, ML, and DL into robotics is an exciting and rapidly evolving field with many potential research directions. Here are some areas of future research where these technologies could have a significant impact:

1. Autonomous robots: Autonomous robots that can navigate and interact with their environment without human intervention are an area of active research. Machine learning algorithms can be used to train robots to recognize and respond to different stimuli, allowing them to perform tasks such as object recognition, path planning, and obstacle avoidance.
2. Reinforcement Learning: Reinforcement learning algorithms enable robots to learn through trial and error, with rewards and punishments guiding their actions. Further research in this area could focus on developing more efficient and effective algorithms for training robots in complex tasks, such as navigation and manipulation.
3. Learning from demonstration: ML and DL algorithms can be used to enable robots to learn from demonstration, where a human operator shows the robot how to perform a task. This can enable robots to quickly learn new tasks and adapt to new environments.
4. Natural Language Processing (NLP): Natural language processing allows robots to understand and respond to human language, opening up new possibilities for human-robot interaction. Future research could focus on improving the accuracy and speed of NLP algorithms and developing new applications for language-enabled robots.

5. Computer Vision: Computer vision is a critical component of robotics, allowing robots to perceive and interact with their environment. Further research in this area could focus on improving the accuracy and robustness of object recognition, tracking, and scene understanding algorithms.
6. Neural networks: By using neural networks, robots can learn from experience and become more efficient over time.
7. Vision-based navigation: Vision-based navigation is a promising area of research in robotics, where robots use cameras and other sensors to navigate through complex environments. Using ML and DL techniques, robots can learn to recognize and classify different objects in their environment, which can help them to make better decisions and navigate more effectively.
8. Collaborative Robotics: Collaborative robots, or cobots, are designed to work alongside human operators, making them ideal for tasks that require a combination of human dexterity and robotic precision. Future research could focus on developing new algorithms and control strategies that enable more effective collaboration between humans and robots.
9. Human-robot interaction: As robots become more common in various settings, it becomes increasingly important to design robots that can interact with humans in a natural and intuitive way. Machine learning algorithms can be used to analyze human behavior and preferences, enabling robots to adapt to human needs and preferences.
10. Robotic vision: Robotics relies heavily on vision since it enables robots to interact and comprehend their surroundings. Deep learning algorithms have shown great success in image and video recognition, enabling robots to recognize objects, people, and activities in real-time.
11. Object recognition and manipulation: With advancements in computer vision technology, robots can now recognize and manipulate objects with a high degree of accuracy. Future research can focus on developing more sophisticated algorithms that enable robots to interact with the environment in a more natural and intuitive manner.
12. Robotics in healthcare: Robotics has the potential to revolutionize healthcare by enabling robots to assist with surgeries, deliver medications, and provide therapy to patients. Machine learning algorithms can be used to analyze medical data, identify patterns, and make predictions, enabling robots to provide more personalized care.
13. Swarm robotics: Swarm robotics is an emerging field that focuses on coordinating large groups of robots to perform tasks. Machine learning algorithms can be used to enable robots to communicate with each other, coordinate their actions, and adapt to changing environments.
14. Robot control: In robotics, control is the process of determining how a robot should move and interact with its environment. ML and DL techniques can be used to develop more sophisticated control algorithms that can adapt to changing environments and improve the performance of robots.

Overall, the combination of AI, ML, and DL with robotics has the potential to create a wide range of applications that can benefit society in various ways. The combination of AI, ML, and DL in advanced robotics is enabling the development of robots that are more intelligent, versatile, and capable than ever before. In advanced robotics, these technologies are used to create robots that can perform complex tasks and learn from experience. AI, ML, and DL can be used to improve the accuracy of autonomous vehicles, allowing robots to operate them more safely and effectively. There are many exciting research directions and applications of AI, ML, and DL in robotics, and the field is likely to continue to grow and evolve rapidly in the coming years. Continued research in this field is likely to lead to exciting new developments in the years to come.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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