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# Deep Learning in Robotics

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## ABSTRACT

A robot acts through a continuous loop: it senses the environment, interprets what it senses, selects an action, executes that action, and observes the result. Traditionally, designers specified how a robot should interpret sensor readings, estimate its position, plan a path, and execute a movement. This approach becomes difficult to maintain when a robot must operate in an unstructured environment. Deep learning addresses this difficulty by allowing multilayer neural networks to learn useful representations directly from images, audio, tactile signals, demonstrations, and experience. The central contribution of deep learning to robotics is not simply better classification. It is the ability to connect complex sensory input with decisions and physical actions. Deep learning gives robots powerful tools for extracting patterns from high-dimensional data and learning behaviors that are difficult to program manually. It is consequently becoming a general component of robotic autonomy. In this paper, we will explore the applications, benefits, and challenges of deep learning in robotics.

***KEYWORDS:*** *Deep learning, DL, deep machine learning, robotics, robots, deep learning in robotics.*

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## INTRODUCTION

Robotics has traditionally depended on carefully designed mathematical models, explicit rules, and task-specific software. This approach works well in controlled environments, such as factory production lines, where objects, motions, and operating conditions can be specified in advance. It becomes less effective when a robot must function in a changing home, warehouse, hospital, farm, or public space. In such settings, the robot must interpret incomplete sensory information, respond to unfamiliar situations, and coordinate perception with physical action. Deep learning has emerged as a powerful way to address these problems because it allows a machine to learn useful representations and behaviors from data rather than relying exclusively on manually programmed features. It is especially valuable for perception, manipulation, navigation, and human–robot interaction. Its long-term significance lies in the possibility of creating robots that can transfer knowledge across tasks and adapt to the complexity of the physical world [1].

## WHAT IS DEEP LEARNING?

Deep learning is a branch of machine learning that uses artificial neural networks with multiple processing layers to discover patterns in data. Its importance lies not merely in the size of its models, but in their ability to learn useful representations directly from raw or minimally processed information. Earlier machine-learning systems often depended heavily on experts to decide which features of an image, sound, document, or transaction should be measured. Deep-learning models can instead learn increasingly abstract features during training, enabling one general family of methods to work with images, speech, text, video, biological sequences, sensor readings, and other complex data. This capacity has made deep learning a central technology in contemporary artificial intelligence [2]. Figure 1 shows how deep learning is a subset of machine learning and how machine learning is a subset of artificial intelligence [3].

Deep learning may be regarded as a feature learning technique. Different applications employ different deep learning models. Deep learning has matured from being a special purpose machine learning technique to a general purpose machine learning tool. It has become a big wave of technology trend for big data and artificial intelligence. It has enjoyed success

in various applications such as automatic speech recognition, image recognition, computer vision, object detection, bioinformatics, and other areas such as drug discovery and information retrieval.

Fundamentally, deep learning refers to a class of machine learning algorithms in which a hierarchy of layers is used to transform input data into a progressively more abstract and composite representation. The word "deep" in "deep learning" refers to the number of layers through which the data is transformed. Neural network consists of layers of interconnected nodes or neurons that collaborate to process input data. In a fully connected deep neural network data flows through multiple layers where each neuron performs nonlinear transformations, allowing the model to learn intricate representations of the data. In a deep neural network the input layer receives data which passes through hidden layers that transform the data using nonlinear functions. The final output layer generates the model's prediction [4].

Deep learning models are complicated artificial neural networks designed to mimic the human brain. Figure 2 shows a deep learning neural network [5], while Figure 3 shows the key components of deep learning [6]. Deep learning is behind many technologies we use every day like voice assistants and medical tools. It is especially valuable when working with large quantities of unstructured data. Conventional databases organize information into clearly defined rows and columns, but much of the world's information exists as photographs, recordings, documents, and videos. Deep neural networks are well suited to extracting patterns from these formats. Its greatest promise, however, emerges when technical capability is combined with responsible design.

Deep learning is not just a technological advancement. It is a reflection of human intelligence, scaled, accelerated, and embedded into systems around us. It is most commonly used where there is massive data and a need for intelligent interpretation. Hence, its strongest areas of applications include language processing, image recognition, predictive analytics, and automation [7].

## FUNDAMENTALS OF ROBOTICS

The word "robot" was coined by Czechriter Karel Čapek in his play in 1920. Isaac Asimov coined the term "robotics" in 1942 and came up with three rules to guide the behavior of robots and later added the zeroth law [8]:

- Law 0: A robot may not injure humanity or through inaction, allow humanity to come to harm.
- Law 1: Robots must never harm human beings,
- Law 2: Robots must follow instructions from humans without violating rule 1,
- Law3: Robots must protect themselves without violating the other rules.

Robots are becoming increasingly prevalent in almost every industry, from healthcare to manufacturing.

Although there are many types of robots designed for different environments and for different purposes/applications, they all share four basic similarities [9]:

1. All robots have some form of mechanical construction designed to achieve a particular task;
2. They have electrical components which power and control the machinery;
3. All robots must be able to sense its surroundings; a robot may have light sensors (eyes), touch and pressure sensors (hands), chemical sensors (nose), hearing and sonar sensors (ears), etc.
4. All robots contain some level of computer programming code.

Programs are the core essence of a robot since they provide intelligence. There are three different types of robotic programs: remote control, artificial intelligence, and hybrid. Some robots are programmed to faithfully carry out specific actions over and over again (repetitive actions) without variation and with a high degree of accuracy.

Robotics is an interdisciplinary field that involves the design, construction, operation, and use of robots. It is a branch of engineering and computer sciences that includes the design and use of machines that are capable of performing programmed tasks without human involvement. The field develops machines that can efficiently carry out various tasks, can automate tasks, and do various jobs that a human might not be able to do. Robots could someday be our drivers, companions, collaborators, teachers, specialists, and exploration pioneers [10]. Figure 4 shows a cloud word for robots [11], while Figure 5 shows a typical robot [12].

## DEEP LEARNING IN ROBOTICS

Robotics has traditionally depended on carefully engineered rules, explicit mathematical models, and controlled working conditions. In robotics, the network may map camera images to object locations, tactile signals to estimates of contact, language instructions to goals, or sensory observations directly to motor commands. Earlier robotic systems often separated perception, planning, and control into modules with interfaces designed by engineers. Deep

learning addresses this limitation by using multilayer neural networks to learn useful patterns and representations from data. Deep learning, a subset of machine learning, has revolutionized various fields, including robotics. It can improve an individual module or connect several modules in an end-to-end policy that learns a direct relationship between observations and actions. As a result, deep learning expands what robots can perceive, learn, and accomplish in complex environments [1]. The integration of deep learning in robotics has enabled robots to perceive, learn, and interact with their environment in a more sophisticated manner.

The application of deep learning in robotics dates back to the 1990s, when researchers began exploring the use of neural networks for robot control and navigation. However, it was not until the 2010s that deep learning started to gain significant traction in the robotics community, with the development of more powerful computing hardware and larger datasets. Today, deep learning is a crucial component of many robotics applications, including autonomous vehicles, robotic arms, and humanoid robots [13].

## APPLICATIONS OF DEEP LEARNING IN ROBOTICS

Deep learning is transforming robotics by enhancing capabilities and adaptability. Neural networks can recognize objects, estimate poses, interpret language, predict actions, and learn control policies from demonstrations or trial and error. These capabilities have supported impressive advances in perception, manipulation, navigation, locomotion, autonomous mobility, computer vision, natural language processing, predictive maintenance, and human–robot interaction. The integration of deep learning in robotics is expected to grow, leading to more sophisticated autonomous systems capable of performing complex tasks in diverse fields such as manufacturing, agriculture, and medicine. Common applications of robotic deep learning include the following [1,13,14]:

- *Perception*: Perception is one of the most mature applications of deep learning in robotics. Robots must identify objects, estimate their positions, segment free space, recognize people, and infer properties such as shape or graspability. Convolutional networks and vision transformers can learn these capabilities from examples, often handling visual variability better than pipelines based solely on fixed features. Perception models also support autonomous driving, agricultural inspection, medical robotics, and industrial quality control. Nevertheless, their predictions depend on the data used for training. A model that performs well under familiar lighting or camera viewpoints may make serious mistakes when conditions change.
- *Manipulation*: Manipulation requires perception and control to remain tightly coordinated. A robot must locate an object, select a grasp, move without collision, detect contact, compensate for error, and revise its plan when the object shifts. In robotic manipulation, a machine must decide not only where an object is but also how to approach, grasp, move, and release it. These actions depend on uncertain factors such as friction, object shape, contact forces, and sensor noise. Programming a separate rule for every possible combination is impractical. Deep learning is useful because many of these relationships are difficult to describe with fixed rules. Learned grasping systems estimate which hand pose is likely to succeed, while imitation-learning systems acquire movements from teleoperation or human demonstrations.
- *Navigation*: Navigation and locomotion provide another major application. Mobile robots use learned perception to recognize traversable terrain, detect obstacles, and estimate where they are. Legged robots can use deep reinforcement learning to acquire coordinated gaits and recover from disturbances. Recent surveys conclude that deep reinforcement learning has achieved genuine real-world successes, but they also emphasize the continuing need for more stable, sample-efficient, and principled methods. Learned components therefore often operate alongside classical localization, mapping, trajectory optimization, and feedback control rather than replacing them entirely. Outdoor navigation, multimodal fusion, and multi-robot collaboration remain less mature than controlled indoor navigation.
- *Autonomous Mobility*: Mobile robots must determine where they are, where they can move, and how they should respond to changing hazards. Deep learning contributes to visual odometry, semantic mapping, place recognition, traversability estimation, obstacle detection, and path planning. Deep reinforcement learning can train policies that select movements from camera or range-sensor observations. The applications include autonomous mobile robots in factories, delivery platforms in hospitals, inspection robots in hazardous facilities, field robots on farms, and aerial or underwater vehicles. Semantic perception also improves planning: a service robot should treat a doorway, a staircase, and a person differently even if all three occupy space on a geometric map.

- *Human–robot Interaction*: Deep learning also improves human–robot interaction. Robots increasingly work in spaces shared with people. Deep learning can make these interactions more natural by improving speech recognition, gesture interpretation, activity recognition, and language understanding. Language models and vision-language systems allow a person to state goals in ordinary language instead of issuing low-level commands. A robot might be asked to "put the fruit in the bowl" and then use visual information to identify both the relevant object and destination. A robot equipped with these abilities may respond to spoken requests, infer which object a person is indicating, or adapt its assistance to a user's behavior. This capability is especially valuable in healthcare, education, logistics, and domestic service, where rigid command languages can be inconvenient. Although deep learning improves the interface between people and robots, it must be paired with clear feedback, privacy protections, conservative behavior, and ways for a person to interrupt or correct the system.
- *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. Robots that work with people need more than mechanical competence. They must infer intent, communicate uncertainty, respect social space, and adapt to individual abilities. Deep learning supports speech recognition, natural-language understanding, gesture detection, face and body-pose analysis, activity recognition, and affect estimation. In collaborative manufacturing, these capabilities allow a robot to anticipate a worker's next action and coordinate a handover. In homes and hospitals, they enable a service robot to follow spoken instructions, locate requested objects, monitor activity, or provide physical assistance. The stakes are also high. A model that misclassifies an image can generate an inconvenience; a robot that misreads a gesture can create a physical hazard. Effective service robots therefore need calibrated uncertainty, understandable feedback, privacy protections, and a reliable way to yield control to a person. Social acceptability depends not only on accuracy but also on whether users can predict and correct the robot's behavior.
- *Collaborative Robots*: 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. 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.
- *Robotics 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. 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. In the case of robotics drones, machine learning can be used to improve the accuracy of object recognition, object tracking, and obstacle detection. Drones can carry out difficult tasks like autonomous navigation and mapping using deep learning. Deep learning may be used to teach drones how to detect and avoid obstacles in real-time. Figure 6 shows the application of ML in autonomous navigation of drones [14].
- *Computer Vision*: Deep learning is widely used in computer vision and object recognition, enabling robots to perceive and understand their environment. Techniques such as convolutional neural networks (CNNs) are used for image classification, object detection, and segmentation. CNNs are a type of neural network that are particularly well-suited for image processing tasks. They are widely used in robotics for tasks such as object recognition and image classification. For example, a robot can use a CNN to recognize objects in its environment and grasp them using a robotic arm. Figure 7 shows a robotic system that grasps and moves objects [15]. Some of the key applications of computer vision and object recognition in robotics include object detection and tracking, image classification, scene understanding, and robot vision.
- *Manufacturing*: In manufacturing and logistics, deep learning makes automation more flexible. Vision systems can inspect products, localize randomly arranged parts, and guide robots through variable assembly operations. Learned models can also detect anomalies in vibration, sound, temperature, or motor-current data. This allows maintenance to be scheduled before a breakdown. In warehouses, deep perception and grasp planning help robots handle diverse

packages rather than a single standardized item. Collaborative robots use human-pose estimation and action prediction to work safely beside employees.

- *Agriculture:* Agricultural robots face unstructured terrain, weather variation, occlusion, and large biological differences among plants. Deep networks are used to detect fruit, classify disease, estimate crop maturity, identify weeds, guide selective spraying, and support autonomous harvesting. In cotton cultivation, reported applications include crop–weed discrimination, robotic weeding, targeted spraying, irrigation support, and harvesting. The literature notes persistent problems involving crop-specific training, costly annotation, environmental adaptability, navigation, energy use, and limited generalization. These constraints show that agricultural intelligence must be designed for rugged field deployment rather than evaluated only on curated images.
- *Medicine*: In medicine, deep learning can enhance robotic surgery and rehabilitation. Surgical systems use learned vision to improve images, segment instruments, distinguish tissue, overlay anatomical guidance, and automate tightly defined subtasks. One reviewed system used deep networks to delineate instruments during robot-assisted kidney transplantation, while other systems supported automated camera positioning and suturing steps. Rehabilitation robots can adapt assistance to a patient's movement, and assistive robots can recognize activities or interpret multimodal commands. Because errors may directly affect health, clinical deployment requires rigorous validation, human oversight, data governance, and clearly bounded autonomy.
- *Simulation*: Simulation will be especially important. A simulated robot can attempt a task millions of times, experience dangerous failures without physical consequences, and train in environments whose textures, lighting, friction, and geometry are automatically varied. Physical robot learning is expensive because real-world experiments consume time, energy, and hardware life. Failures can also damage objects or create hazards. Deep learning allows developers to take greater advantage of synthetic data and simulation. A robot can practice many variations of a task in a virtual environment before limited fine-tuning on real hardware. Experience can also be pooled across a fleet, so data collected by one machine contributes to the improvement of others. Simulation, uncertainty estimation, human oversight, and extensive real-world testing can reduce risk.
- *Hybrid Intelligence*: Some research pursues end-to-end learning, in which one model maps sensory inputs directly to motor commands. This design can be powerful because all components are optimized together. It can also be opaque and difficult to verify. In a hybrid architecture, a foundation model may interpret the user's request and propose a plan. Specialized perception networks may estimate object positions and human motion.
- *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. Their combination has the potential to make robotics taxi services safer, more efficient, and more enjoyable for passengers. 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. Figure 8 shows intelligent cab service system using the AI based on predictive analytics [14].

## BENEFITS

Deep learning benefits robotics by improving perception, enabling flexible manipulation, supporting adaptation, reducing dependence on handcrafted rules, and creating more natural forms of human–robot interaction. Other benefits of robotic deep learning include the following [1,14]:

- *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.
- *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 (you only look once) have achieved impressive results in object detection tasks.
- *Generalization:* Another benefit is the possibility of generalization, which means applying learned knowledge to situations that differ from the training examples. The central idea is that experience gathered by one type of robot may contain patterns that benefit another, even when their bodies and sensors differ. Robots encounter

long-tail events that are individually rare but collectively important: an unusual object, an occluded obstacle, a damaged sensor, an ambiguous instruction, or an unexpected human action. Neural networks can also produce outputs that are difficult to interpret. This opacity complicates diagnosis and certification because engineers need to know not only whether a policy usually succeeds, but also how it fails and whether it can detect uncertainty before acting.

- *Transfer Learning:* Transfer learning strengthens generalization. A model trained on a broad dataset can be adapted to a narrower robotics task using a smaller amount of specialized data. Knowledge may also be transferred between related tasks, robots, or simulated and physical environments. The transfer is not automatic, because differences in sensors, hardware, and environmental physics can create a reality gap. Nevertheless, the ability to reuse learned representations can reduce development time and make robotic systems easier to extend.
- *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. 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.
- *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.
- *Adaptability*: AI, ML, and DL can enable robots to adapt to changing environments and situations, making them more versatile and capable of handling a wider range of tasks Robots can adapt to new tasks without extensive reprogramming, learning from experience instead. AI-powered robots can adapt to changing environments and tasks, making them highly versatile and useful in a range of industries and applications. AI/ML/DL models must be designed to adapt to new situations and learn from experience, which can be challenging.

## CHALLENGES

While deep learning robotics offers many benefits, it also poses significant challenges that must be addressed in order to realize its full potential. Data quality, limited interpretability, transfer failures, and safety concerns remain challenges. The decisive barrier to widespread adoption will not be whether a robot can succeed once. It will be whether it can behave acceptably across millions of interactions. Other challenges of robotic deep learning include the following [1]:

- *Data Quality*: Data quality becomes as important as mechanical design. Robotics faces a data problem that language modeling did not face in the same form. A model may fail when lighting, sensors, objects, or human behavior differ from its training distribution. Simulation can generate large datasets, but differences in physics, appearance, and sensor noise create a sim-to-real gap. Collecting real-world data is costly and sometimes dangerous. Rare events are difficult to represent, even though these events may matter most for safety. Responsible deployment therefore requires several layers of protection. Training data should represent realistic operating conditions and known edge cases.
- *Safety:* Errors in digital classification are often inconvenient; errors in robotic control can cause physical harm. Safety must therefore hold during learning as well as after deployment. Safe reinforcement learning is commonly defined as learning policies that optimize performance while maintaining reasonable behavior or respecting constraints during training and operation. Safety must be designed at the level of the whole robotic system. Practical designs can constrain learned policies with collision checking, force limits, emergency stops, verified controllers, uncertainty estimates, and human oversight.
- *Interpretability*: Interpretability presents another problem. Deep policies can be difficult to audit because their decisions emerge from many learned parameters. Testing every possible physical situation is impossible. High-capacity models also demand memory, energy, and computing power that may not fit on a mobile platform. Cloud inference introduces latency, connectivity, cybersecurity, and privacy risks. These concerns are particularly serious in healthcare, public spaces, and workplaces.
- *Partial Observability:* A robot never observes the complete state of its environment. Cameras suffer from occlusion and changing illumination. Depth sensors fail on reflective or transparent materials. Objects move between observations, and people act according to intentions that cannot be measured directly. The robot must infer hidden

state from incomplete, noisy, and asynchronous signals.

- *Continual Learning*: Robots operate in environments that change after deployment. New tools appear, rooms are rearranged, mechanical parts wear, and users introduce new preferences. A useful robot should adapt without being retrained from the beginning. Standard deep networks, however, often suffer from catastrophic forgetting: learning from a new data distribution rapidly degrades performance on previously learned tasks. Methods based on replay, regularization, specialized optimization, or context-dependent processing can preserve old capabilities, but they introduce costs.
- *Reproducibility*: Robotics experiments are difficult to reproduce because outcomes depend on hardware tolerances, calibration, control frequency, room layout, object placement, and software timing. A policy that works on one laboratory's robot may fail on another nominally identical platform. Small evaluation sets can conceal rare but serious failures, while average success rates can conceal unsafe variance.

## FUTURE OF DEEP LEARNING IN ROBOTICS

The most credible future is not a single neural network operating without constraints. It is a hybrid architecture in which learned models provide flexible perception, prediction, task interpretation, and skill selection, while structured planning and control enforce physical requirements. Progress in deep-learning robotics will depend on improvements in data, algorithms, hardware, and evaluation. Better shared datasets can increase task diversity, but data collection must record failures and environmental variation rather than only successful demonstrations. The strongest future systems will not rely on deep learning alone. The most credible path forward combines better learning methods with disciplined robotics engineering. Robots will move from isolated, task-specific models toward generalist systems that combine vision, language, action, and prediction.

A major emerging direction is the use of foundation models: large networks pretrained on broad datasets and adapted to many downstream tasks. This approach could reduce the need to train a separate model for every task. The future of robotic deep learning will not be secured by scale alone. Larger datasets and models may improve generalization, but dependable autonomy also requires explicit uncertainty, safety constraints, efficient computation, and rigorous evaluation. Deep learning will change the economics of robot development [1].

## CONCLUSION

Deep learning is reshaping robotics by enabling machines to learn perceptual representations, control policies, and task relationships from experience. It has produced important advances in object recognition, manipulation, navigation, locomotion, and language-guided action. Deep learning provides robotics with a powerful engine for adaptation, but disciplined system design will determine whether that power becomes useful, trustworthy, and socially beneficial. The central question is therefore not whether deep learning will replace classical robotics. It is how learning can be integrated with models, planning, control, and safety mechanisms to create dependable machines. The most successful robots are likely to combine broad learned capabilities with explicit constraints and careful human oversight.

Deep learning is a powerful tool that is revolutionizing the field of robotics. It has changed what robots can perceive and, increasingly, what they can do. It does not eliminate the core engineering challenges of robotics. It changes them. When deep learning is combined with sound mechanical design, model-based control, rigorous testing, and appropriate safeguards, it becomes a powerful component of modern robotics. Its greatest contribution is not simply that robots can perform individual tasks more accurately. It is that they can increasingly learn from experience and respond to a world that cannot be specified completely in advance. More information about deep learning in robotics can be found in the books in [16-19] and the following related journals:

- Robotica
- Robotics
- Robitics and Autonomous
- Robotics and Computer-Integrated Manufacturing,
- Advanced Robotics
- Autonomous Robots
- Automation in Construction
- Journal of Robotics
- Journal of Robotic Systems
- Journal of Robotic Surgery
- Journal of Robotics and Mechatronics
- Journal of Intelligent & Robotic Systems
- Journal of Mechanisms and Robotics-Transactions of the ASME
- Journal of Automation, Mobile Robotics and Intelligent Systems
- Journal of Future Robot Life
- IEEE Robotics and Automation Letters
- IEEE Transactions on Robotics
- International Journal of Robotics Research
- International Journal of Social Robotics
- International Journal of Humanoid Robotics

- International Journal of Advanced Robotic Systems
- Science Robotics
- Soft Robotics
- Cognitive Robotics
- Journalism
- Journalism and Media

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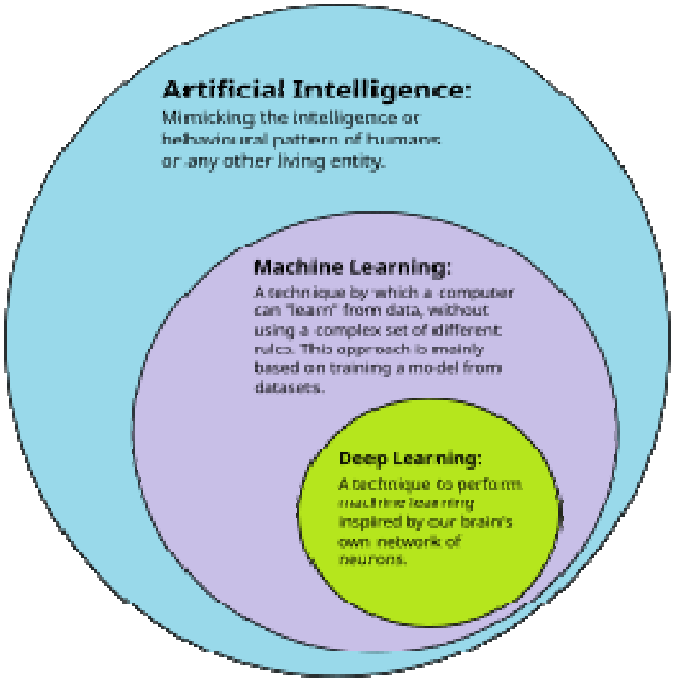



**Figure 1 Deep learning is a subset of machine learning and machine learning is a subset of artificial intelligence [3].**

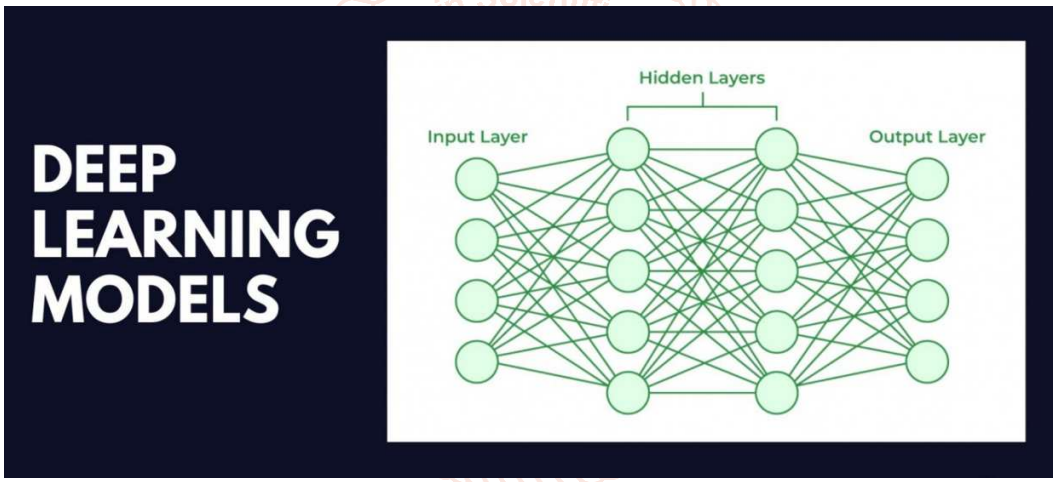



**Figure 2 A deep learning neural network [5].**

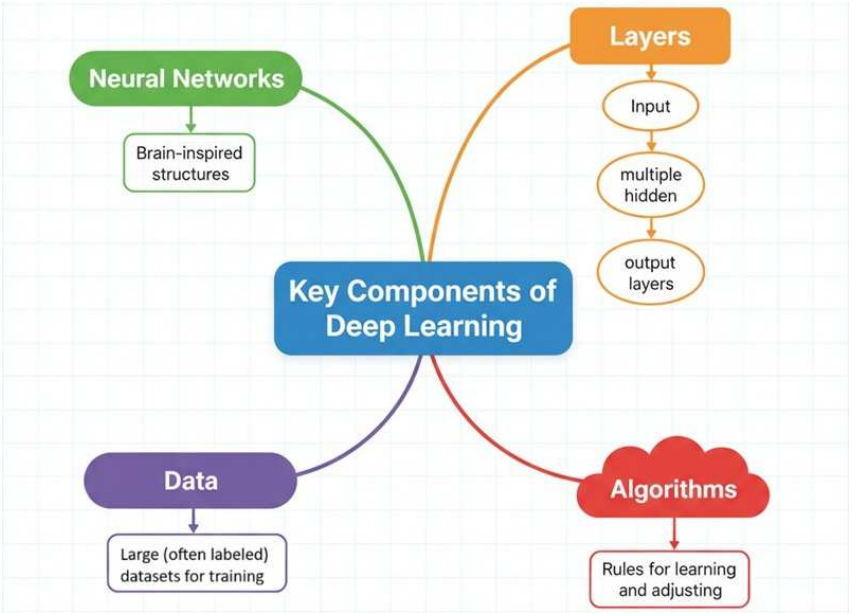



**Figure 3 The key components of deep learning [6].**




**Figure 4 A cloud word for robots [11].**



**Figure 5 A typical robot [12].**

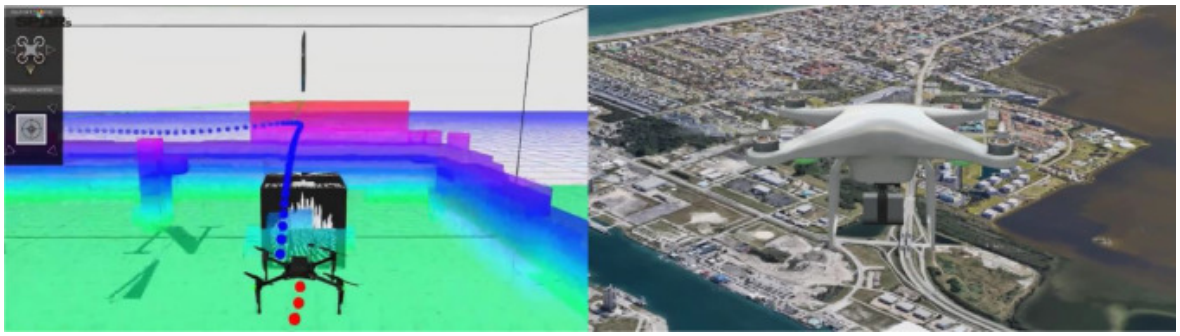


**Figure 6 Application of ML in autonomous navigation of drones [14].**



**Figure 7 A robotic system that grasps and moves objects [15].**

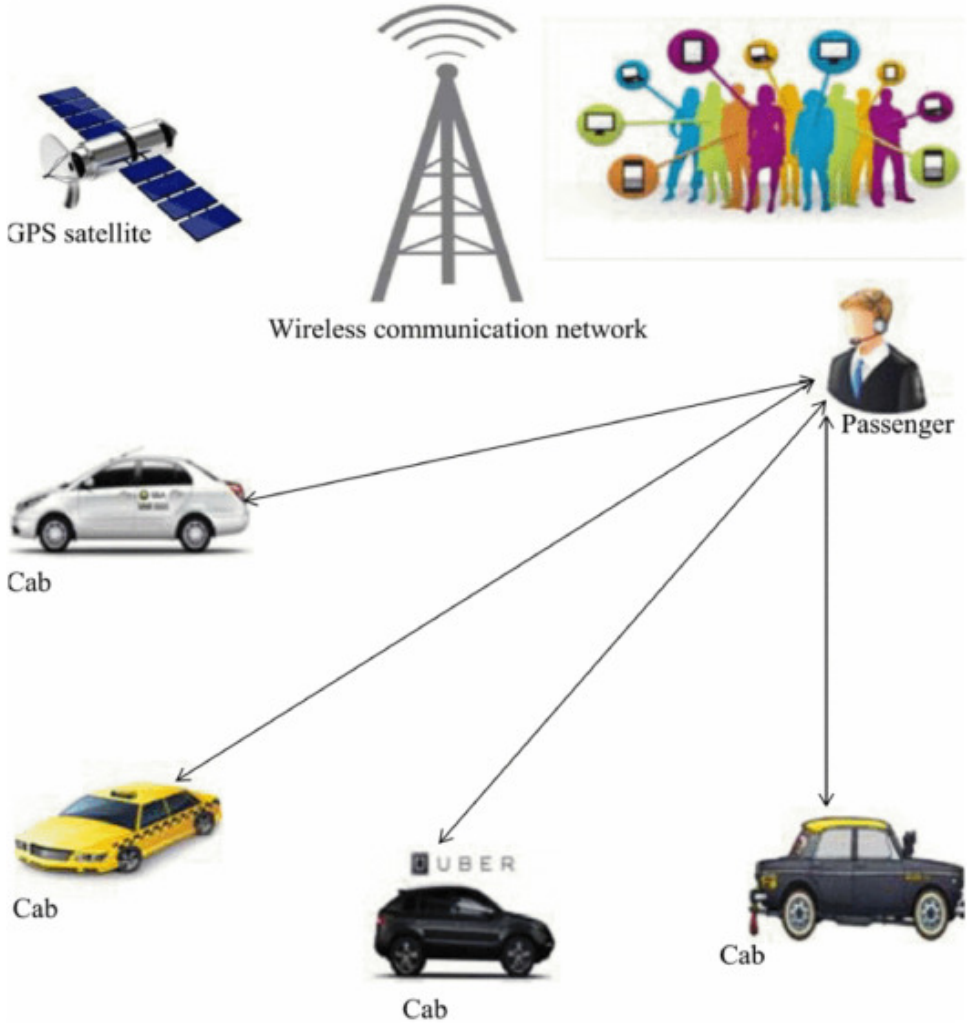



**Figure 8 Intelligent cab service system using the AI based on predictive analytics [14].**