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Sensors and Path Planning Algorithms in Robots

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Abstract. Robots are frequently used in many fields, such as agriculture, cleaning and supermarkets. These kinds of robots can help a lot in daily life, making lives much more convenient and efficient. Robots can also reduce people's workload and keep them safe. Almost all robots nowadays use sensors and algorithms. Sensors and algorithms can make the robot move automatically. This paper mainly focuses on the three kinds of sensors, including the camera, lidar sensor, temperature sensor, and three types of path-planning algorithms, including Dijkstra, A*, and RRT algorithms. This paper concentrates on the benefits, drawbacks, principles, characteristics, limitations, and uses of each type of sensor and path-planning algorithm. Then, this paper primarily discusses the difficulties and problems the sensors encounter when path-planning algorithms combine with the sensors. Comparison of machine learning with traditional methods conducted after forwards. It is found that although the sensors and the robots' algorithms are widely used, there is still much room for improving the limitations and disadvantages. Finally, prospects for future research are presented and some suggestions are proposed.

Keywords: Path planning, sensor, algorithms.

1. Introduction

Robots are machines that are capable of carrying out repetitive and complicated tasks performed by humans physically and mentally. They are commonly used in various areas, such as automatic driving, medical, and industrial. Some robots are automatic, while others are under human control. They can help reduce workload and keep people safe in industrial areas. Using robots can also increase work efficiency and accuracy. Robots can help doctors perform surgery much more accurately in the medical field. In this way, patients will be much safer. They can also help the patients recover. In addition, robots can help deliver food, drugs, and goods, especially during the pandemic, which can help people avoid unnecessary close contact with each other. Robots can also make lives much more convenient and comfortable. For example, cooking robots can help cook food after putting the ingredients into it. Sweeping robots can help clean the places people cannot reach, such as the rubbish under the bed. In automatic driving, robots can let people release their hands.

Sensors and algorithms are now used on almost every robot. They often work together to make the robot more productive and aptitude. There are a variety of sensors and algorithms nowadays. The camera can monitor the location and the position of the robot. The lidar sensor can detect obstacles by receiving the laser's echoes to measure the distance around the robot to prevent it from bumping against them. The temperature sensor can measure the temperature in the environment. Algorithms can let the robot move without human control. Path-planning algorithms, including Dijkstra, A*, and RRT algorithms,

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use different methods to help the robot navigate all environments. They have different characteristics and drawbacks and are used in different conditions. Sensing algorithms such as image processing can help the robots to perceive the environment. Some algorithms can combine with machine learning to let the robot work much more effectively and automatically.

However, robots still face some challenges, including sensors and algorithms. For example, it will be hard for the robot to grab soft objects like clothes [1]. Some sensors cannot adapt to extreme environments, so they cannot accurately collect the needed data. Also, some sensors have a limited measuring distance. In addition, some path-planning algorithms have problems planning the shortest path from the beginning to the destination. For example, they may require much time and effort to calculate the shortest route.

The following paper reviews three kinds of sensors: camera, lidar sensor, temperature sensor, and path-planning algorithms, which are Dijkstra, RRT, and A* algorithm. It introduces the advantages and disadvantages of each and their principles, characteristics, uses, and limitations. It then analyses the difficulties when the sensors combine with the algorithms and how to solve them. For example, the disadvantages of the sensors and algorithms will affect their combinations. It also introduces the advantages of integrating machine learning with algorithms. This paper concludes and gives some advice on improving these problems.

2. Sensors

2.1. Camera

The camera is one of the most common vision sensors on a robot. It monitors the robot's location and position in the environment. It converts images into electronic signals the robot can understand by gathering visual input from the environment [2]. Two kinds of cameras are commonly used: single-camera and multi-camera. Compared with a single camera on the robot, a multi-camera can more accurately monitor the location and position. Therefore, a multi-camera is used much more often than a single one.

Cameras are now used on various robots, such as construction, medical, and unmanned robots. For construction robots, cameras can primarily increase safety and productivity [3]. For medical robots, cameras can help doctors in surgical operations, improving precision and success rates. For unmanned robots, cameras can help monitor the environment around the robot to realise path planning and autonomous driving.

However, the use of cameras still faces significant challenges. The camera will have limited performance in dim light environments. In this situation, the camera cannot capture clear images around the robot, affecting the robot's performance and the implementation of the algorithms. In addition, it is still challenging for the mobile robot to navigate and localise in a random environment [4]. The camera also has limited vision, so its position will affect it.

2.2. Lidar sensor

The Lidar sensor, which detects light and ranges, is also commonly used on robots. It uses a pulsed laser and receives its echoes to measure the distance around it [2]. The main components of a radar sensor include the antenna, transmitter, receiver, duplexer, and signal processor.

Lidar sensors are often combined with other kinds of sensors used on robots. They are commonly used in various areas, such as automatic driving, agricultural, and industrial automation. The primary use of the lidar is to generate real-time maps of the environment, enabling precise positioning and path planning for the robot. For automatic driving, lidar sensors can help vehicles detect obstacles, such as pedestrians and other vehicles, to ensure the safety of the people in the car. For agricultural robots, lidar sensors can locate and target ripe fruits and vegetables to help the farm robot automatically pick the fruits and vegetables. Lidar sensors can also help forecast soil properties in agricultural areas [5]. For industrial robots, lidar sensors can help them operate and locate accurately on industrial lines.

Despite its wide use, the lidar sensor still faces some challenges in specific areas. It has an extended measuring distance and a high cost. In the automatic driving area, the lidar sensor cannot detect accurately in terrible weather conditions [6].

2.3. Temperature sensors

Temperature sensors are another kind of sensor used on robots. They measure the object's or the environment's heat level [2]. They determine the temperature using the material's temperature dependency on electrical resistance [7].

Temperature sensors are commonly used on various robots, such as rescue, industrial, and medical robots. The temperature sensor helps rescue robots perceive the environment's temperature to keep the rescue worker from experiencing high temperatures. On medical robots, the temperature sensor measures the patient's temperature to help doctors diagnose the disease and monitor the patient's vital signs. On industrial robots, temperature sensors measure the temperature of the work environment to keep the workers and the components safe. For example, they can measure the temperature of the motor. If the motor's temperature is too high, it will destroy the motor components.

Nowadays, temperature sensors still face some challenges. For example, some applications need temperature sensors to be exact. In addition, the temperature sensor cannot adapt to extreme temperatures, which means it cannot measure the temperature accurately.

3. Path planning algorithms

3.1. Dijkstra algorithm

The Dijkstra algorithm finds the shortest path between two locations in a weighted graph. It tracks a group of nodes for which the shortest route to the source is known. Then, it chooses the nearest unprocessed node and finally updates the shortest path to its neighbours. The Dijkstra algorithm has a broad applicability. It can be used in all graphs except those with negative weights. It is now widely used in various areas, including network routing and traffic route planning.

The Dijkstra algorithm relies only on the edge's weight instead of heuristic dependence. It is always optimal and certain. This algorithm can find the shortest path no matter what kind of structure it is.

Although the Dijkstra algorithm is one of the most common and mature algorithms for finding the shortest path between two points, it requires more storage space. In addition, it will cost a lot of time and effort to find the shortest path from the beginning to the destination in specific situations [8]. Therefore, it is unsuitable for path-planning situations, such as automatic driving.

3.2. A algorithm*

A* search algorithm is a graph traversal and path-finding algorithm mainly used in computer science. It is also one of the most common path-planning algorithms. It can find the shortest path from the origin to the destination by giving a weighted graph and a code. A* algorithm is also an extension of the Dijkstra algorithm. It can also be used in path-planning situations, including video games, artificial intelligence and robotics.

A* algorithm is terminated and complete, so it can always find a solution from start to end. It is also very flexible so that it can meet the requirements of different kinds of situations. It is highly efficient, allowing it to search quickly using a heuristic function. It is suitable for complex environments because it uses the heuristic function. Based on these characteristics, the A* algorithm is widely used in situations including video games and network plans.

However, the A* algorithm still has some disadvantages. It has a shallow searching time and a quick path turn, which means it will have low accuracy [9]. In addition, it only sometimes yields the shortest path as it relies on the heuristic function and approximations to produce the path.

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3.3. RRT algorithm

Rapidly exploring random trees (RRT) is a random algorithm for planning paths. It randomly uses a space-filling tree to find space without obstacles by building a tree structure and sampling randomly. RRT is used primarily in complicated high-dimensional environments such as robot navigation, automatic driving, and drone flight.

RRT is suitable for complex surroundings and high-dimensional space exploration. It also has strong obstacle avoidance and can cover a lot of ground in a short time by exploring the area randomly. Compared with other algorithms, the RRT algorithm is also straightforward, mainly relying on random sampling and simple collision detection. RRT algorithms are now commonly used in a variety of areas, such as automatic driving and drone flight.

Although the RRT algorithm has many advantages, it also has some drawbacks. Finding the best solution takes a lot of time, so it needs to use a lot of memory and storage. It is very important to find the best solution quickly in some specific areas, like automatic driving [10].

4. Optimisation and recommendations for intelligent mobile robot path planning schemes

4.1. Sensors

The robot uses various sensors. In addition to the camera, lidar sensor, and temperature sensor, other kinds of sensors, such as gas, force, and proximity, are also widespread. Although these sensors can significantly help the robot, they face some challenges.

One of the biggest challenges is that the sensors cannot adapt to various environments. In some extreme environments, the sensors may not correctly measure the data. They will also be affected if there is any noise around them. Furthermore, the maintenance cost of some high-performance sensors, including a 3D camera, is very expensive, influencing the robot's operation and limiting the use of these sensors. Some sensors must deal with a large amount of data simultaneously so some delay will affect the robot’s decision. When the sensors are combined with the algorithms, a severe delay will cause the robot to get stuck.

To solve these challenges, multi-sensor data fusion techniques can be used on the robot to reduce uncertainty. Using several sensors together can also increase accuracy and reliability [4].

4.2. Algorithms and sensors

The algorithms are often combined with the robot's sensors, allowing robots to move more efficiently. Sensors can collect data and then give it back to the algorithm. The algorithm will let the robot move automatically according to the data collected. However, this combination also has some difficulties that need to be solved.

The challenges of the sensors will also affect their use in path-planning algorithms. The sensors must detect the obstacles around them quickly and accurately and then return the data to the robot in time. If not, the robot will be in trouble. Furthermore, the data collected by the sensors will inevitably have errors, which may affect the path-planning algorithm. To improve this, several sensors can be used to reduce the error.

In addition, the difficulties caused by the algorithms will also influence the combination. The algorithm's function is restricted when the robot is in a highly complicated environment. To improve this, the path-planning algorithm can be integrated with environment modelling technology to allow the algorithm to adapt to the complex environment [11].

4.3. Machine learning and path planning algorithms

The path-planning algorithm can be integrated with machine learning in various situations and help solve some challenges. Compared with traditional methods, the path-planning algorithm used by machine learning is much more efficient at discovering the hidden goal in a complex and unknown environment [12].

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Machine learning can be used in various scenes, including smart homes, medical robots, and intelligent transport. Machine learning can help doctors analyse images to diagnose diseases like cancer in medicine. In addition, it can help researchers predict the drug's effectiveness before use to ensure its safety. For intelligent transport, machine learning can help predict road congestion and optimise the traffic lights to keep the traffic moving. Machine learning can help control smart home equipment to improve comfortability. Without machine learning, it will be tough for the traditional method to find the target in an unknown environment. Therefore, machine learning can make life much more comfortable and efficient.

5. Conclusion

This paper finds that although robot sensors and path-planning algorithms are commonly used nowadays, there is still much room for improvement. There is still much work to be done to increase the accuracy and efficiency.

Most sensors, including camera and temperature sensors, cannot adapt to extreme environments, so they cannot collect data accurately in this condition. Some lidar sensors have limited measuring distance and high cost. These drawbacks of the sensors will affect their use. To solve the problem, several sensors can be used together to increase the accuracy of the data. Multi-sensor data fusion techniques can also be used to reduce data errors.

Some path-planning algorithms, including the Dijkstra algorithm, need a large amount of storage space to find the shortest path from the start to the end so that they will take a lot of time. A* algorithm has low accuracy because of its long searching time and fast path turn. RRT algorithm has difficulties in automatic driving because it takes a long time to find the shortest path. Furthermore, when the algorithm is combined with the sensors, the accuracy of the data collection in complex environments and the long search time will influence the algorithm's execution. Combining environment modelling technology with path planning algorithms can improve the situation.

Future research can focus on how sensors can adapt to all kinds of environments and increase the accuracy of data collection. For the algorithm, future research can concentrate on improving the efficiency and effectiveness of the path-planning algorithm. The processing time and the storage space also need to be reduced when the algorithm is executed. Furthermore, machine learning and deep learning models can also be applied to the algorithm to increase its efficiency and speed.

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