Application of autonomous navigation in robotics

Wenshuai Ju
School of Mechanical & electronic Engineering, Shandong University of Science and Technology, Shandong, China
justinguo@xyzrgroup.com

Abstract. In recent years, the robot industry has made great progress, and has been widely used in automobile manufacturing, machining, transportation agriculture, medical treatment, food and other aspects. The autonomous navigation is a key technology in the development of robot intelligence. Therefore, this paper extensively investigates the applications of autonomous navigation technology in the transfer robot, the medical robot and the agricultural robot. And we analyze and summarize the developments and applications of autonomous navigation related basic technologies, such as autonomous positioning technology, sports planning technology and 5G communication technology. Finally, the future development prospect of robot technology and the autonomous navigation technology is given.

1. INTRODUCTION
The robot technology had applied in in many fields after 2000, such as industry, agriculture, national defense, scientific experiments and service [1]. ISO defined the robot that an automatically controlled, reprogrammable, multipurpose manipulator, which can be programmed in three or more axes and fixed in place or mobile for use in industrial automation applications. With the changes of industrial production, the robot also promotes chip technology, bioengineering, medical technology etc. In last 10 years, robots have been developing in the direction of intelligence with stronger perception, decision-making capabilities and human-computer interaction. Robots obtain powerful strength to detect production status of parts and product components, estimate the emotional and psychological state of production personals [2].

With the processing of continuous development in the field of robotics, puts forward more requirements for robot intelligence. The progress of autonomous navigation technology is a significant way to improve the robot intelligence. Autonomous navigation technology cooperates with each other through a variety of sensors to independent planning of the way forward such as AGV and to give a concept feed rate to itself parts, such as CNC. Autonomous navigation technology is of great significance to the current industrial production and industrial engineering.

2. APPLICATIONS OF AUTONOMOUS NAVIGATION TECHNOLOGY

2.1. Transfer robot
Transfer robot is an industrial robot that can carry materials automatically [3]. The earliest transfer robot appeared in the United States in 1960. After decades of development, transfer robot is widely used in all walks of life, including but not limited to industry, commerce, medical industry, agriculture and so on. Part of the material transfer robots take the manipulator as the carrier to carry and transfer the materials, which can widely replace the manual work, reduce the cost and greatly improve the
security, as shown in Fig. 1. For the high-precision target capture and sorting of the transfer robot, Wang et al. [4] proposed a method to reduce the influence of scale, material deformation and light on the target, which improved the flexibility of the transfer robot. Gürel [5] can reduce the energy loss by adopting the speed control strategy for the transfer robot. For autonomous handling in complex scenes, different from the manipulator widely used in factories and warehouses, the handling robot needs to have the ability of autonomous navigation, autonomous positioning, autonomous obstacle avoidance and path planning.

![Fig. 1 Application of multi-scene material handling robots in anti-pandemics](image)

In addition to the manipulator, there are AGV robots commonly used in industrial production. AGV robots have a high degree of automation, which can realize the transportation and charging automation of auxiliary materials between workshops, even can help transport medical supplies, as shown in Fig. 2(a) and Fig. 2(b). The guidance methods usually include electromagnetic induction guidance, laser induction guidance, position push-off guidance and inertial guidance. Electromagnetic induction guidance means that the electromagnetic sensor at the bottom of the AGV vehicle can recognize and realize automatic driving through the magnetic nails laid on the ground or buried wires underground. The route is fixed, and a modification of the system will have a great impact on the whole path. Laser induction guidance is to determine its own coordinates through the laser scanner to a number of specific objects or signs within the scope of action of the robot, so as to run autonomously according to the program. This method has strong adaptability to the environment and high positioning accuracy, but the cost is high and the algorithm is complex, which is easy to produce signal interference. Position inference guidance is based on the encoder of the wheel to get the movement distance of the robot, and then get the deflection angle through the motion model, and finally get the position and pose relative to the initial position. This method has good flexibility, low cost, but poor accuracy and integration error. Inertial guidance uses inertial measurement unit to obtain the acceleration and angular velocity of the robot, so as to obtain the position and pose relative to the reference point, and compare with the planned path, so as to carry out autonomous navigation. This method has high accuracy and strong flexibility, but it will produce integration error. Because the inertial components are easily affected by the external environment and vibration, it is not suitable for long-time operation, and it also needs frequent calibration accurate [6, 7].
2.2. Medical Robot

Today, with the rapid development of medical field, it has become a hot research direction to integrate robots into accompany and assistance. With the assistance of medical robots [8], it can provide patients with better medical services. According to FDA and CDC data, 70% of US citizens are taking at least one prescription drug and 15% are taking at least two. However, 40% of these people are elderly. [1] Therefore, it is particularly important to accompany the elderly in medical treatment. However, sticking to medication has always been a difficult problem hindering effective treatment. The accompanying robot can replace the manual to monitor the elderly, monitor their health status, and timely report abnormal conditions such as falls and faints. Surgical robot (Fig.3) can assist doctors in surgery, and its stability and accuracy are higher than that of manual, which plays an important role in precision surgery. [8]

![Surgical robot](image)

The large-scale outbreak of COVID-19 in 2020 has made disinfection a difficult problem[9]. If robots are used to replace artificial labor to disinfect various occasions, the safety of medical staff will be greatly improved, as shown in Fig.4. Compared with manual operation, disinfection robot can carry more disinfectant, work longer and work wider. Ultraviolet disinfection robot and hydrogen peroxide steam disinfection robot can be used for disinfection and sterilization in hospital scene. We developed an ultraviolet robot applied in the operating room or ward, which can achieve autonomous obstacle avoidance and all-round disinfection, and the experiment proved that the robot can kill Staphylococcus aureus and other samples 35mm away from the robot in 8s. The disinfection robot used in public places needs high flexibility and precision, and can move and complete tasks autonomously in a relatively complex environment. It needs the robot to have the ability of autonomous positioning, autonomous obstacle avoidance, intelligent navigation and so on. It can carry out comprehensive disinfection of public places without human participation. Generally, the crawler robot is used as the carrier, and there

![Surgical robot](image)

Fig. 3 Surgical robot
are also disinfection robots with UAV as the carrier. Compared with the crawler robot, the disinfection efficiency of UAV is obviously higher.

![Ultraviolet robot](image)

**Fig. 4 ultraviolet robot**

### 2.3 Agricultural robot

With the help of agricultural centralization, mechanization and automation, agricultural productivity has been significantly improved. Although agricultural automation needs a lot of money to purchase automation equipment and train skilled workers, the benefits brought by agricultural automation can make up for the initial cost. The current agricultural robot not only reduces the labor cost, but also plays an important role in improving the yield and the quality of crops. Agricultural robot can improve the average size and even maturity of the plant by scientific and reasonable way. Precise Fertilization of crops by agricultural robot can significantly improve the fertilizer utilization rate of crops and reduce the cost. The weeding robot [10] used in the field uses GPS computer technology to locate and record the coordinates of weeds in the field, as shown in **Fig.5** and then carries out accurate weeding on the recorded coordinates.

![Weeding robot](image)

**Fig. 5 Weeding robot**

But at present, the development of agricultural robots is also facing important challenges. The process of farming and agricultural production is complex and diverse, and the labor intensity is very high. For a single crop, its production process is often unique and unique, and its production process will change according to different places of production and different production seasons. At the same time, there are few widely used robots in horticulture, which still need a lot of manual work.

At present, robots can be divided into four categories: I) environment and object are structured; ii) environment is unstructured and object is structured; iii) environment is structured and object is unstructured; IV) environment and object are unstructured. But agricultural robots do not belong to these four categories. Avital Bechar et al [10]. Explained the influence of sunlight direction and
illumination on the visibility of pepper rows in greenhouse, and because of the high uncertainty of shape, color, size and height when processing fruit branches and leaves, most of the production tasks of fruits, vegetables and flowers are still completed manually, which makes it difficult for agriculture to get rid of labor-intensive industries. The commercialization of agricultural robots needs to seek in this direction. Further breakthroughs. At the same time, the use of agricultural robots must consider the following points: 1. The cost of using robots cannot be higher than other ways; 2. Robots can help agricultural production to improve the yield and quality of agricultural products; 3. Agricultural robots can help planting production to reduce uncertainty and reduce product differentiation. 4. Compared with other production methods, it can help farmers make more reasonable production decisions and improve the output and quality of agricultural products.

3. Key Technologies of Autonomous Navigation

3.1. Environmental awareness Technology
In the process of robot autonomous navigation, the perception of the external environment is a very important research content, and the environment perception technology is the premise of autonomous navigation [3]. Environment perception collects data through sensors, and then gets effective information through computer processing, and then establishes an accurate model, which guides the robot’s autonomous positioning, movement and path planning. In order to realize the perception of the environment, all kinds of sensors are needed. Sensors can collect data, identify objects, map and express them. Common sensors are divided into noumenon / external sensors and active / passive sensors. Noumenon sensors are usually encoders, potentiometers, gyroscopes, etc., which are used to measure various data of robot noumenon, such as motor speed, joint angle, residual power, etc., while external sensors are usually sonar sensors, infrared sensors, ultrasonic distance sensors, etc., which are used to obtain the external environment or objects Information in the body. The active sensor is the corresponding part of its own emission energy measurement environment, which can interact with the environment, so it has higher requirements for sensor performance, such as sonar sensor, radar and so on. Passive sensor is to receive the energy of external environment to judge, such as temperature sensor, infrared sensor, touch sensor, etc. At present, environment sensing technology attaches great importance to multi-sensor fusion, which is the main direction of future development. Different sensors are also different in application scenarios. In recent years, machine vision is a popular research direction. The point cloud data collected by lidar is used to recognize and segment the object features, simultaneous interpreting and segmenting objects by using different cameras. A leg robot based on structured light RGB-D sensor and stereo camera is proposed to model and navigate unstructured environment, propose an improved elevation grid concept, the perception ability of the robot is improved.
3.2. Autonomous positioning technology

The precise positioning of robot depends on autonomous positioning technology, which is an important part of robot autonomous navigation. Robot autonomous localization relies on the cooperation of a variety of sensors, such as ultrasonic, GPS, lidar and so on [3]. Robot positioning technology [11] is divided into two types: relative positioning and absolute positioning. Relative positioning is that the robot calculates its own direction and distance relative to the initial position according to the direction and pose of the previous state. This method causes error accumulation due to the continuous updating of the position. Absolute positioning is to determine the environment model according to GPS or setting road signs and matching environment map, and then obtain the robot's position in the environment, but this method is difficult to apply in unknown environment. In the early stage of autonomous localization technology, Kalman filter is usually used [3]. The working principle of Kalman filter is to assume that the current state is only related to the previous state, which greatly reduces the computational memory consumption. With the improvement of computer computing power, SLAM [12] (simultaneous localization and mapping) technology is produced. SLAM technology is to generate maps by detecting unknown environment and combining sensory information. Commonly used sensors include encoder, inertial measurement unit (IMU), camera, laser rangefinder, etc. slam technology can optimize the robot's pose and improve the positioning accuracy through the robot's constantly updated pose constraints and environmental maps. In order to reduce the failure rate and improve the durability, multi robot slam has been widely used, but it increases the complexity of development and operation. Multi robot slam is that each robot integrates the local maps provided by other robots according to the local maps provided by its own reference coordinates to get the global map. Saeedi [12] proposed an improved multi-sensor fusion algorithm and tested it in the actual environment.
In advance, the distributed framework is a key. CoRoBa, the distributed framework used, is based on the TAO implementation of the communication middleware CORBA. The implementation of the framework is based on several design patterns that make the design flexible, elegant and ultimately reusable (Colon 2006). The elementary brick in CoRoBA is a component (Component-based Architecture Pattern) that exchanges data over a network, by invoking remote operations (Remote Method Call Pattern) [11], as shown in Fig. 7.

3.3. Sports planning technology
In the process of robot autonomous navigation, good motion planning can not only achieve robot autonomous obstacle avoidance, but also complete the task in a shorter time and reach the destination. Motion planning[3] is an important research content of robot autonomous navigation, which is widely used in medical treatment, safety, warehouse, logistics, ocean and space exploration, guiding vehicle of material transportation robot in workshop, etc.[12]. According to the collected environmental information, the robot obtains the optimal path by path planning technology according to the principles of minimum consumption, shortest distance, path smoothness and shortest time, and drives the robot to reach the designated position without collision[13]. Among them, the most commonly used principles are the shortest distance and the shortest time.

There are two kinds of path planning methods: classical approach and artificial intelligence (heuristic approach). The specific results are listed in the table 1. Path planning methods can be further divided into (I) analytical methods, (II) incremental methods, (III) evolutionary methods and (IV) meta heuristic methods. The analytical method is too complex for unknown environmental applications, for evolutionary methods, when the search scope is too large, this method is proved to be invalid in many cases, and meta heuristic methods are widely used in path planning. Path planning can be divided into local path planning and global path planning. In local path planning, the robot's cognition of the navigation environment is limited, while in global path planning, the robot has a comprehensive
cognition of the navigation environment and can complete the task according to the preset path. However, this way will be affected by the terrain and has poor stability.

### TABLE I. Different Path Planning Approaches[13].

| Classical                              | AI                                    |
|----------------------------------------|---------------------------------------|
| 1. Potential Field. (1979)             | 1. Neural Network Technique. (1943)   |
| 2. Roadmap Cell Decomposition. (1987)  | 2. Fuzzy Logic Technique. (1965)      |
| 3. Grid Based. (1988)                  | 3. Genetic Algorithm Technique. (1989) |
| 4. PRM (Probabilistic Roadmap). (1996) | 4. Ant Colony Optimization Technique. (1992) |
| 5. Rapidly Exploring Random Tree. (1998) | 5. Particle Swarm Optimization Technique. (1995) |
| 6. Virtual Impedance Method.           | 6. Bacterial Foraging Optimization. (2002) |
| 7. Convex Hull and Local Search Method. | 7. Bee Colony Optimization Technique. (2005) |
| 8. Divide and Conquer Method.          | 8. Firefly Algorithm Optimization Technique. (2008) |
| 9. Grey Wolf Optimization.             | 9. Grey Wolf Optimization. (2014)     |

#### 3.4. 5G communication technology

5G communication technology is becoming more and more mature. Compared with 4G network, 5G has higher spectrum utilization and energy efficiency, and can provide faster transmission rate and resource utilization. It can not only meet the higher transmission rate requirements, but also enable the communication system to obtain the ability to interact with the environment, greatly improving the communication ability of the robot. In 2014, You Xiaohu and others[14] reviewed 5G communication technology and its key technologies. In 2018, they sorted out 5G key technology and its frontier research direction again[15], and proposed a variety of optimization design patterns.

![Fig. 8 Communication requirements of a telesurgery robot for the 5G tactile Internet](image)

The traditional communication mode of robot is generally divided into wired communication and wireless communication. Generally speaking, the communication of robot is networking by wireless way. The rapid development of 5G technology has brought more possibilities for robot communication. The application of 5G technology can greatly improve the communication distance and shorten the communication time, which brings great convenience to multi robot cooperation and information transmission Autonomous navigation provides a better environment. In the situation of high communication requirements, such as security investigation, emergency rescue and so on, the robot can have the advantages of stable signal transmission, low delay and high transmission rate by using 5G communication technology, and has stronger adaptability in the process of task, and can transmit all kinds of effective data in real time. The communication requirements of the robot for multi-modal sensing data transmission through the 5G tactile Internet in the telesurgery are shown in Fig. 8, directly representing the characteristics of the telesurgery, i.e., high reliability, low delay[16-18], and high data transmission rate. The interaction between the master control terminal and the controlled terminal through the tactile Internet is shown in Fig. 9[19, 20]
3.5. Self-control and End tools

Robot autonomous control technology is a technology that combines the perception, decision-making, cooperation and action ability of autonomous control system in unstructured environment under the condition of unmanned control or command, and makes self-decision, and continuously works and executes tasks to complete the scheduled tasks[3]. It is one of the key technologies of autonomous navigation. This technology needs to be realized through a variety of perception systems, such as visual system. Through autonomous control technology, the safety and reliability of robot autonomous navigation can be further improved. Saadatmand[21] proposed a Q-learning controller based on artificial intelligence to realize the optimal control of robot.

The use of end tools is also an indispensable part of autonomous navigation. Through the rational use of end tools, it can help the robot to better complete the scheduled task, or assist the robot to plan the path and remove obstacles in the path in the process of autonomous navigation. For example, the robot used for safety investigation usually runs in bad environment, through the configuration of end tools In addition, it can overcome the obstacles in the path and greatly improve the adaptability of the robot to the environment, and the same manipulator can complete different tasks such as handling and welding by installing different end tools, as shown in Fig.10. Park et al[22]. put forward a design scheme of terminal tools suitable for various first aid work, and designed the injection end device in detail[23].

Fig. 9 The interactive mode of a telesurgery robot
4. CONCLUSIONS

Nowadays, with the rapid development of computer technology and the maturity of 5g communication technology, robot technology has penetrated into many aspects such as industry, medical treatment, transportation, food and so on. The application of reasonable navigation mode to robot can greatly improve the work efficiency and control cost of robot. This paper discusses the application of autonomous navigation in transport robot, medical robot and agricultural robot, and introduces the corresponding robots. Then, it introduces the key technologies of autonomous navigation: environmental awareness technology, autonomous positioning technology, sports planning technology, 5g communication technology, self-control and end tools.

In the future, with the further exploration of robot, the renewal and iteration of key technologies and the maturity of emerging technologies, robots will be more intelligent and provide more convenience in production and life; the progress of autonomous navigation technology will bring more functions, lower cost and more accurate control to robots.

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