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Path Planning Strategy Design of Autonomous Mobile Robot Based on Fuzzy Control

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At present, various parts of my country have begun to build a deeply intelligent industrial chain, which has not only increased the research and development efforts on key technologies such as computer vision and natural language processing, but also invested a lot of human and material resources in the research and development of robotics technology. In the current information age, robot technology is a comprehensive high-tech development which combines many technologies such as computer, bionics, and artificial intelligence (AI). With the deepening of research, subsequent results and advancements have been widely applied in many fields. The application of robot technology in many fields in reality is not a simple and inadequate substitute for humans engaged in repetitive work. By imitating human intelligence or skills, robot technology combines the advantages of human beings with the advantages of mechanical devices. This technology enables the robot to analyze and judge the working environment and tasks quickly, and at the same time it provides the advantages of having a machine execute long-term and high-precision work. Therefore, robot technology can be said to be an important production and service equipment in the industrial field, which can provide better automation devices for advanced manufacturing technology in different regions. In the research and development of robot technology, the path planning of an autonomous mobile robot is also the focus of the current research and development of robot technology. At present, through computer technology and autonomous mobile robot path planning strategies, the robot's motion path in various complex scenarios can be simulated and optimized more accurately. The current fuzzy control technology can better improve such problems. Fuzzy control is a non-linear control technology which can better complete the dynamic description of complex and variable-rich systems through the application of the theory of fuzzy mathematics. Firstly, this study determined the feasibility of applying fuzzy control technology to the path planning strategy of an autonomous mobile robot, and proposed a new path planning strategy based on fuzzy control. The simulation results showed that the performance of this new path planning strategy in many respects was about 7.4% better than the existing path planning strategies.

Keywords: robot technology; path planning strategy; fuzzy control; data mining

1. INTRODUCTION

Robot technology has become an important research field in many areas. Its development and application are related to the industrial development and overall technical level of a region. At the same time, the problem of path planning for autonomous mobile robots is also a very interesting issue in the field of robot technology. The formulation of a path planning strategy involves many different disciplines. An appropriate path planning strategy will not only assist a robot to execute a wider range of activities; it also plays a role in a great number of industries and domains.

Several researchers in the field of robot technology have conducted extensive research on the development of robot technology, in order to determine the reasonable development direction of such technology. A study explored the present situation and future development prospects of the research and development results of robot technology in various rescue

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activities. By investigating several current requirements and risks of rescue work, he identified some advantages of robot technology in rescue activities [1]. Some researchers have explored in depth the relationship between robot technology and the development of enterprises in a specific region. Through the investigation of the current development status and application scenarios of robot technology, he determined that robot technology can drive the high-quality development of enterprises, and assist enterprises to achieve a competitive edge [2]. In the specific field of nursing, the application of robotics has been widely explored. By investigating the various aspects and task characteristics of the nursing industry, it is found that robotics can play an important role in this industry by improving the efficiency and effectiveness of nursing work [3]. A researcher has explored the feasibility and reliability of a human resource management system which combined AI technology, robots and various advanced technologies. He found that a review of the application of robot technology in human resource management system was required [4].

Other researchers have investigated the role of robot technology in society in general. One explored a variety of ways to use robot technology during the Covid-19 pandemic. He concluded that robot technology can be widely used in many fields, especially in dealing with major public health emergencies, to help people do all kinds of necessary work without contact [5]. Others investigated the application of robot technology in a certain region and its future development prospects. A comprehensive analysis of the situation and the status of robot technology in the region was carried out. It was determined that robot technology could be used in many of the local industries. At the same time, the economic development of the region in the context of robots was investigated in conjunction with relevant socio-economic data. The researcher concluded that robots can play a role in the development of the social economy [6]. Another researcher investigated the widespread application of robot technology in a region to investigate the changes in unemployment risk of low-level workers in industry or manufacturing. He concluded that there was a strong correlation between the use of robots and the greater risk of unemployment [7]. Most of these researchers investigated and analyzed some theory or history of robots to determine the development status of robot technology.

Others in the field researched ways to make robot technology better, more efficient, and more widely applicable. Some have explored the path planning strategies of a mobile robot navigation system. By investigating the existing path planning strategies in multiple environments, it was determined that the existing path planning strategies had both unique advantages and disadvantages. Finally, the navigation performance of the different strategies was compared through simulation experiments [8]. Other scholars have discussed the problem of path planning for a multi-robot based on deep reinforcement learning in AI technology. By analyzing the shortcomings of existing path planning for mobile robots, several points needing attention in the path planning strategies were identified [9]. Other scholars have explored an autonomous path planning algorithm for mobile robots. By analyzing the operation mode and structure of the mobile robot, he determined which aspect of data the autonomous path planning algorithm needed to collect and process, and gave the specific operation model of the mobile robot [10].

Researchers have also discussed the direction of further development of robot path planning. For example, some people have conducted in-depth discussion on the current routing problem of robots. By investigating the effect of guided reinforcement learning on data analysis in a dynamic environment under a global context, it was determined that this guided reinforcement learning can enable the robot to choose an appropriate routing in each environment by using the space-time information of the environment [11]. Others have discussed an information perception network suitable for large-scale robot path planning. By studying the network structure, some advantages of this information perception network in path planning were identified, and a path planning strategy based on this network was proposed [12]. However, at present, these approaches require a great deal of computing power that is costly and makes their widespread implementation unfeasible.

In this paper, the research on existing robot technology found that there were still many deficiencies in the path planning strategy of the current autonomous mobile robot. After an in-depth analysis of the fuzzy control technology, the new path planning strategy of the autonomous mobile robot is discussed. This new path planning strategy uses fuzzy control technology enabling the robot to handle complex scenarios, as well as several offshoots of AI technology to give the robot more intelligent information sensors.

2. FUZZY CONTROL TECHNOLOGY

The current widely-used fuzzy control technology was originally proposed based on the theory of fuzzy mathematics, which advanced the development of the control field at that time. However, with the development of fuzzy control theory, modern fuzzy control technology can be applied in more industries, such as industry, high-end manufacturing and mechanical automation control, etc. [13]. One of the widely-used fuzzy control practices today is to analyze and simulate the human control experience through the rapid development of computer technology, so as to store a large amount of control experience and convert these experiences into fuzzy linear control rules [14]. Fuzzy control technology can be widely used today because the control mode theory is rule-based, and it directly uses the rules of language through the control experience of operators in related fields and a series of items of information to achieve the control of the target object.

Moreover, the existing fuzzy control technology can generally start from the qualitative understanding of industry, and can establish language type control rules at a lower cost. At the same time, this model can more easily and effectively control some complex and dynamic objects. The current fuzzy control technology is also a kind of decision rule based on heuristic knowledge or language. This decision rule can simulate the experience and manual operation, so as to further enhance the adaptability of the control system.

Generally speaking, the essence of this fuzzy control technology is a kind of non-linear control technology, which belongs to a working category of intelligent control. This type of technology also requires systematic combing and analysis of theoretical knowledge. This intelligent control technology can have a wide range of practical applications in the real world. In recent years, fuzzy control technology has made good progress both in scientific research and in the popularization of technology, and has become an important, active and efficient technology in the field of modern automation control.

3. FUZZY CONTROL ALGORITHM

The research and development of path planning strategies for autonomous mobile robots is often a complex and comprehensive undertaking that involves several cross-sectional disciplines, from robot technology to various control theories. In this paper, the feasibility of a path planning strategy for a robot based on fuzzy control algorithm was discussed, and the advantages of this strategy were determined. Path planning is generally considered to be a kind of uncertain behavior in the related scientific research field, and the uncertainties correspond to the characteristics of fuzzy mathematics in fuzzy control. In path planning, factors such as the distance and location between the robot and obstacles in the path can be collected by the robot's built-in sensors. The fuzzy control algorithm is used to analyze and judge the data gathered from the operations of vehicles. On the other hand, the path planning strategy of an autonomous mobile robot which includes the fuzzy control algorithm is a more complex system. The system also has the problem of time delay and non-linearity which is not easy to determine. Therefore, a large number of relevant experiences need to be analyzed by means of fuzzy control.

If a better description of a complex system is needed in the fuzzy control algorithm, the rules in the complex system need to be clarified first, so that the appropriate fuzzy algorithm can be used according to different rules. First, the relationship between data is defined with formula (1):

$$U = min\left[a_r(x), b_r(y)\right] \tag{1}$$

where a_r and b_r represent the deviation and variation of the fuzzy vector, respectively. x and y represent the input and output. Then, a weighted average judgment method is used to determine the influence and function of the control quantities during operation, so as to overcome the influence of these control quantities. The formula is:

$$V = \frac{\sum_{i=1}^{n} \mu(u_i)}{\sum_{i=1}^{n} \mu_i(u_i)} \tag{2}$$

where μ and μ_i are expressed as weighted weighting and weighted parameter values, respectively. The next step is to calculate the control amount of the actual output in the whole operation process, as shown in Formula (3).

$$u = \frac{y_n}{n} U \tag{3}$$

where y_n represents the parameter output value of class n. The appeal fuzzy control algorithm helps to further develop the autonomous mobile robot technology, and also enables the robot to work in more scenarios by further expanding its range of activities.

4. ROBOT PATH PLANNING MODE UNDER FUZZY CONTROL

The further development of technology and the social economy has enabled people to have a better working environment in more fields and has helped to reduce a lot of repetitive work through robot technology and AI. A robot is an operating machine that can have numerous functions. At the same time, robot technology can also produce a customized system that can be changed by computer according to different usage scenarios. However, with the advancement of various types of science and technology, the definition of robot technology in the field of scientific research is becoming increasingly blurred. Finally, current robot technology is not capable of adapting appropriate actions to appropriate scenarios after analysis of the environment or various information.

At the same time, a type of robot that can move independently has been proposed; the technology comprises various scientific and technological features. Although this kind of autonomous mobile robot technology can broaden the range of application scenarios, there are also many problems that need to be solved by researchers in related research fields. Hence, more attention has been paid to the problem of path planning for autonomous mobile robots. Via the path planning strategy, robots are generally required to collect and analyze data about the environment around the robot through various types of sensors, and then make appropriate responses based on the results of this analysis. Most of the existing path planning strategies for autonomous mobile robots use computers to analyze a large amount of data that can be stored in the cloud server or the internal server of the robot, and situations can be quickly analyzed when the robot is facing similar scenarios.

The path planning strategy of an autonomous mobile robot combined with fuzzy control can appropriately describe the uncertainty of things using some function algorithms in the fuzzy control theory, which can provide a more accurate control mode for the path planning of the robot. On the other hand, it can also provide more efficient data analysis and processing capabilities for autonomous mobile robots' path planning strategies, which can improve their performance in many arespects. The operation flow of the autonomous mobile robot path planning strategy based on fuzzy control is shown in Figure 1.

5. EXPERIMENTAL VERIFICATION OF PATH PLANNING STRATEGY FOR NEW ROBOTS

Autonomous mobile robots often reflect the degree of development of mechatronics. They are not only one of the most popular fields of science and technology in many

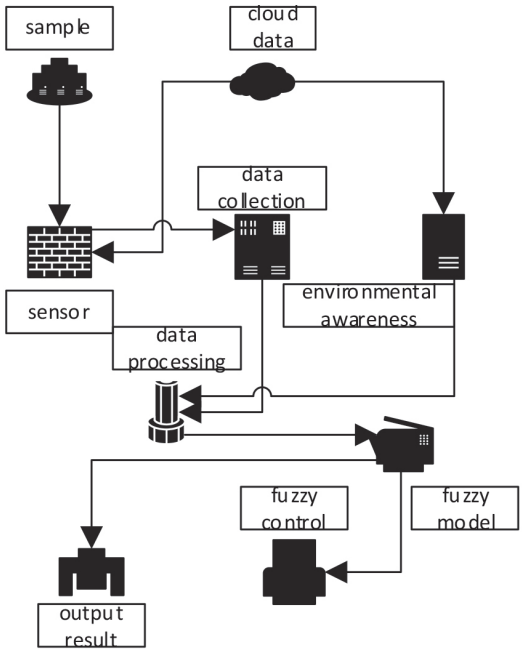

Figure 1 Operation process of path planning strategy for autonomous mobile robot based on fuzzy control.

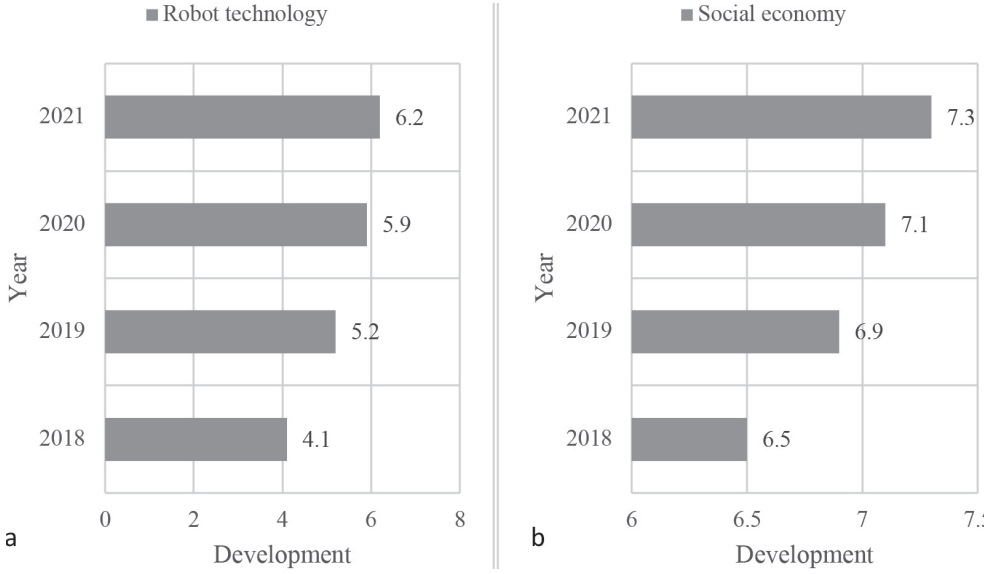

Figure 2 Development of robot technology and social economy. (a) Schematic diagram of the development of robot technology. (b) Schematic diagram of social economy development.

regions, but also one of the fields of scientific research and development that many regional management organizations consider extremely important. With the further development of robot technology, its field of application is expanding. In this paper, a type of autonomous mobile robot technology is proposed that not only expands the scope of the robot, but also greatly improves its efficiency. The focus of the research and development of autonomous mobile robots is the path planning strategy. Generally speaking, researchers consider the running environment of autonomous mobile robot as a parameter space, and the aim of the path planning strategy is to find an optimal solution within this space. Path planning strategies for autonomous mobile robots have also yielded more results with in-depth research [15–17], and these results have better applications in more areas. Robot path planning strategies can also be considered as a constrained optimization problem in the development process, which includes the modeling and analysis of the geographic environment around the robot, the path planning, the analysis and avoidance of obstacles, and so on. Therefore, the path planning strategy can be regarded as essential for the navigation and precise control of autonomous mobile robots.

In this paper, the development of robot technology and socioeconomics in a specific area over a period of time was analyzed in order to further determine the role of robot technology today, as shown in Figure 2.

In today's social environment, some of the technological achievements of robot technology research and development

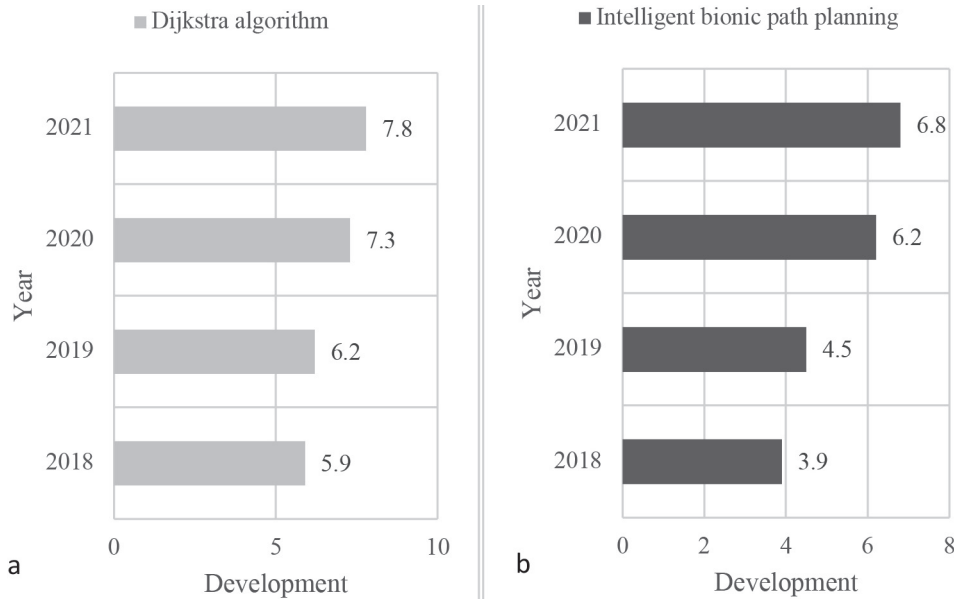

Figure 3 Schematic diagrams of the development and application of different types of path planning algorithms in a certain period of time. (a) Schematic diagram of the development and application of Dijkstra algorithm (b) Schematic diagram of the development and application of intelligent bionic path planning.

have been applied in many industries, and have a greater impact on the growth of these industries. In modern society, robots not only help people to accomplish repetitive and time-consuming tasks, but also help a particular region to improve its technology and productivity. Therefore, robot technology has become a high-end technology which is inseparable from social economy development. This technology helps society to make the transition from the information age to the intelligent age. With the rapid development of AI technology, current robots also have greater capabilities. The combination of AI technology and robot technology has rapidly improved the intelligent standard of robots, helping them to have a variety of perceptual sensors that mimic the sensory organs of human beings, including visual, auditory and speech functions, as well as a variety of capabilities for intelligent analysis.

Figure 2a shows that over a period of four years, robot technology had a good development trend in this area, and the analysis of the growth trend also confirms that the robot technology is developing steadily and has good future potential. Also, the development of the social economy of the area is depicted in Figure 2b. Firstly, an analysis of the data indicates that the social economy of the area of interest has improved over the four years although the overall growth of the social economy remained relatively stable. It can be concluded that the positive development of robot technology can contribute to the development of the local social economy to a certain extent.

Then, the development and application of different types of path-planning algorithms over a period of time in a region were analyzed to determine the development and advantages of these algorithms, as shown in Figure 3.

Nowadays, robot technology is a comprehensive and complex subject that is multidisciplinary. At the same time, with the increasing level of science and technology, robots have become an indispensable and important tool in for social development. At present, robot technology plays an important role in the field of industry and manufacturing, and from a fixed position, a robot can manipulate many kinds of objects in industrial production. However, autonomous mobile robot technology has been proposed, which can expand the range of tasks undertaken by a robot. However, autonomous mobile robot technology still has many problems, among which the research and optimization of path planning strategies for autonomous mobile robot technology are of the most concern.

After analyzing the development and application of the Dijkstra algorithm in the current robot path planning strategy (Figure 3a) over the last four years in this area, it can be determined that this Dijkstra algorithm has developed well in the past four years, but its growth rate is relatively slow mainly because this algorithm is inefficient. On the other hand, the development and application of the intelligent bionic path planning algorithm (Figure 3b) has advanced in the past four years and has been applied in more and more fields.

Then, the development and application of fuzzy control algorithm in a certain area for a period of time were analyzed, and the status of fuzzy control algorithm was determined, as shown in Figure 4.

Fuzzy control is an intelligent optimization method that can establish a more precise model for the controlled object within a specified range. The related aspects of AI technology are used to convert this model into a mathematical problem that can be solved by applying the fuzzy mathematics theory. This solution can play a valuable role in solving linear and non-linear planning problems. For relatively complex systems, fuzzy control algorithms generally need to establish a variety of parameters to optimize the stability and accuracy of the system so as to obtain a better operation model. Fuzzy control is widely applied many industries today, and plays a positive role in the high-quality development of the control field.

Figure 4a indicates that the development of this fuzzy control algorithm was relatively good, and the growth rate of the developer during the same period of time tended to be a stable numerical value. This also shows that the fuzzy control

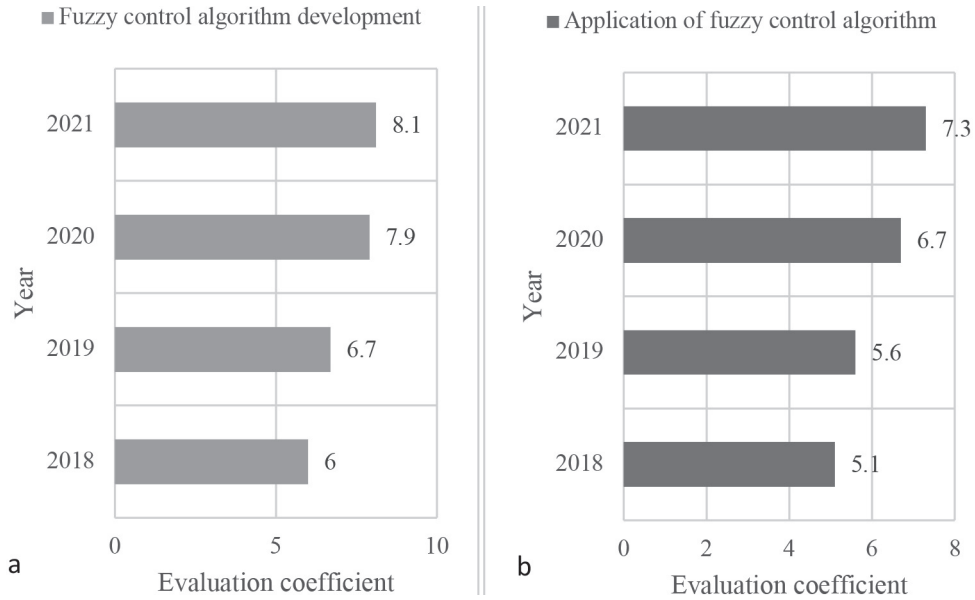

Figure 4 Schematic diagrams of the development and application of fuzzy control algorithm. (a) Schematic diagram of the development of fuzzy control algorithm (b) Schematic diagram of the application of fuzzy control algorithm.

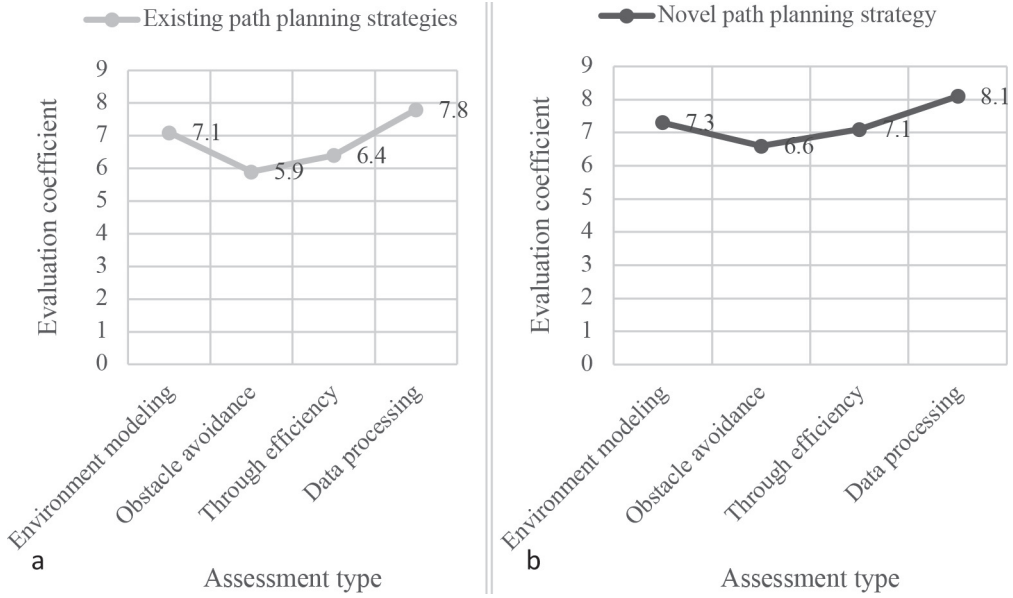

Figure 5 Schematic diagrams of the performance of novel path planning strategy and existing path planning strategies in multiple aspects. (a) Schematic diagram of the performance of existing path planning strategies (b) Schematic diagram of the performance of novel path planning strategy.

algorithm is still a hot topic in the field of scientific research. On the other hand, after analyzing the application of the fuzzy control algorithm for four years (Figure 4b), it is also evident that this algorithm has been applied more extensively, and the degree of integration with multiple fields is also stronger and broader.

Finally, the performance of the autonomous mobile robot path planning strategy proposed in this paper combined with fuzzy control was analyzed in terms of environment modeling, obstacle avoidance, efficiency and data processing as shown in Figure 5.

People hope to develop a strategy that enables autonomous mobile robots to develop their own path planning and obstacle avoidance strategies based on analysis of the surrounding environment. However, most of the existing path-planning strategies are based on the analysis of a large amount of data, and then a prescribed path-planning strategy is formulated for autonomous mobile robots. However, these strategie cannot adapt to changes in the environment and subsequently alter the original path-planning strategy.

Figure 5a shows that the existing path planning strategies of autonomous mobile robots performed relatively poorly in terms of obstacle avoidance and efficiency. On the other hand, as shown in Figure 5b, the proposed path-planning strategy that includes fuzzy control improves all the four aspects being tested, verifying the feasibility of including the fuzzy control algorithm in the path planning strategy. Finally, results show that the performance of this novel path planning strategy was about 7.4% higher overall than that of the existing path planning strategies.

6. CONCLUSION

With the development of the social economy, an increasing number of enterprises are seeking intelligent machines to do daily, repetitive tasks in the workplace. Hence the emergence and ongoing development of robotic technology. At the same time, because the research and development or progress of robot technology generally requires a large number of high-end technology achievements for support, the status of robot technology in a particular region is an indicator of its level of scientific and technological innovation and the development of high-end manufacturing. Currently, the field of robot technology is flourishing and, at the same time, it is also imperceptibly changing the operations of many industries, offering more convenience to residents in more areas, and driving the high-quality development of social economy. The development of robot technology is generally a step-by-step process, in which the autonomy of technological advancement has become the focus of researchers. At present, robot technology is still in its infancy, and there are many difficult problems that need to be resolved particularly in regard to path-planning strategies for autonomous mobile robots that need to be addressed by researchers in related fields. Autonomous mobile robots generally need to collect and analyze data about their surroundings when devising path planning strategies. Most of the existing path planning strategies are precise data analysis and processing models. The path planning strategies under this model have certain advantages, but cannot perform well in complex and dynamic environments. Therefore, this study proposed a path planning strategy that includes the fuzzy control algorithm, which can enable robots to move autonomously and appropriately in a complex and variable environment.

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