World Journal of Advanced Engineering Technology and Sciences

eISSN: 2582-8266

Cross Ref DOI: 10.30574/wjaets

Journal homepage: https://wjaets.com/

WJAETS

(Research Article)

Check for updates

RESEARCH STATUS OF PATH PLANNING BASED ON MACHINE VISION

Zhang qing *

School of Mechanical Engineering, Tianjin University of Technology and Education, Tianjin 300222, China.

* Corresponding Author

World Journal of Advanced Engineering Technology and Sciences, 2026, 20(03), 018–024

Publication history: Received on 31 July 2026; revised on 09 September 2026; accepted on 11 September 2026

Article DOI: https://doi.org/10.30574/wjaets.2026.20.3.0434

ABSTRACT

This paper meticulously collates the applications of machine vision-based path planning in various fields, such as industrial manufacturing, logistics warehousing, agricultural production, and intelligent equipment, and analyzes the core technical systems and innovative research achievements in each domain. Representative cases in each field are selected to conduct a detailed technical analysis of the breakthroughs in this method from multiple aspects, including algorithm optimization, visual environmental perception, and trajectory control. On this basis, the current technical challenges are deeply analyzed, and the future development trends are discussed

Keywords: Machine Vision; Path Planning; Algorithm Improvement; Multi-Sensor Fusion; Dynamic Environment Adaptation

1 INTRODUCTION

Path planning is one of the key technologies in the development and improvement of robots, and it is also a core technology that reflects the strength of robots' autonomous operation performance. Its technical application level and actual performance directly determine parameters such as the safety and efficiency of robots in completing tasks. At this stage, the biggest problem with traditional path planning is that it requires certain environmental perception capabilities, making it difficult to design a feasible path in complex environments or environments with moving obstacles. However, machine vision has strong environmental information collection and processing capabilities, which can provide more complete perception and recognition information for path planning. It also enables robots to autonomously identify the surrounding environment and perform tasks such as path planning and target detection, which means that path planning based on machine vision is more flexible. At present, path planning based on machine vision has made significant progress in many different fields.

2 APPLICATION STATUS OF PATH PLANNING METHODS BASED ON MACHINE VISION

2.1 In-depth Application in Industrial Manufacturing

In the path planning of substation inspection robots, Zhu et al [1]. addressed the defect of improper obstacle handling by constructing an inspection environment model based on machine vision and evolutionary algorithms. They strengthened the management of the internal sensing system, analyzed the machine vision transmission status under different conditions, detected and processed obstacle image data, improved the accuracy of initial data processing and the efficiency of path planning, and thus enhanced the robustness of planning. The robustness comparison in complex environments is shown in Figure 1, which demonstrates improved planning accuracy. The robot's motion trajectory is collision-free, and the fitness value remains above 21 overall, effectively realizing the operation path planning of substation inspection robots.

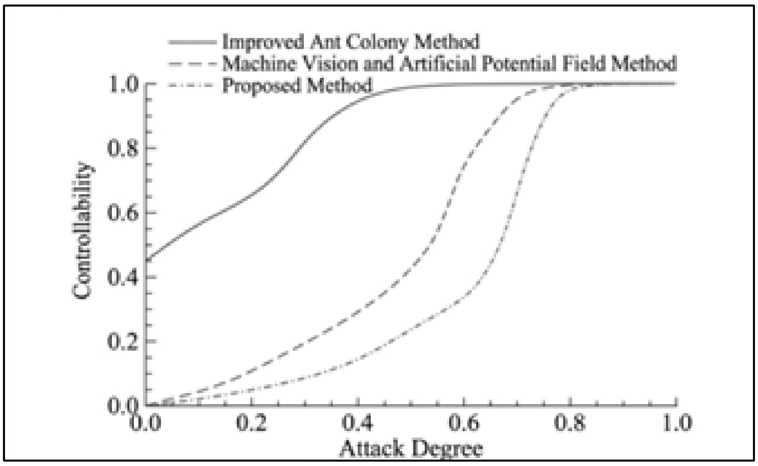

Figure 1: Robustness comparison in complex environments

In the design of robot path planning systems, Wang [2] aimed at the problem that insufficient obstacle avoidance ability of intelligent robots affects their work efficiency. He proposed constructing a single-chip microcomputer control unit, a drive circuit module, a machine vision module, and an information interaction module to complete the hardware design of the system, providing energy for the robot's mechanical movement and collecting video and images of the robot's environment.

In the target grasping of steel processing robots, Xu [3] found that traditional target grasping path methods lack constraints on grasping path factors, resulting in low path smoothness. He proposed a machine vision-based target grasping path planning method for steel processing robots, which improved the automation and accuracy of steel processing.

In steel bar binding, Deng [4] developed a steel bar binding robot to solve the problems of cumbersome manual binding operations, low efficiency, and high costs. He combined the MobileNet V3-SSD and feature projection curve methods to realize intelligent identification and positioning of steel bar binding nodes (the network structure of SSD is shown in Figure 2). He also proposed an improved priority reciprocating full-coverage path planning method and an improved A-star dead zone escape algorithm to ensure efficient binding operations of the robot in the steel mesh area. The accuracy and feasibility of the algorithm were verified by physical prototype experiments.

In the welding and grasping operations of manipulators, Liu et al [5]. pointed out that factors such as strong arc light and spatter during welding interfere with and reduce the accuracy of weld feature extraction. Peng [6] took a 6-degree-of-freedom (6-DOF) manipulator as the research object and proposed an improved RRT-connect algorithm to address the shortcomings of the original algorithm. Du [7] took the DOBOT 4-DOF lightweight desktop manipulator as the research object, applied machine vision and path planning algorithms to the robot control system, and improved the RRT algorithm by introducing spline interpolation and a target point gravitational field. This ensures efficient path planning after the vision system obtains the target point position.

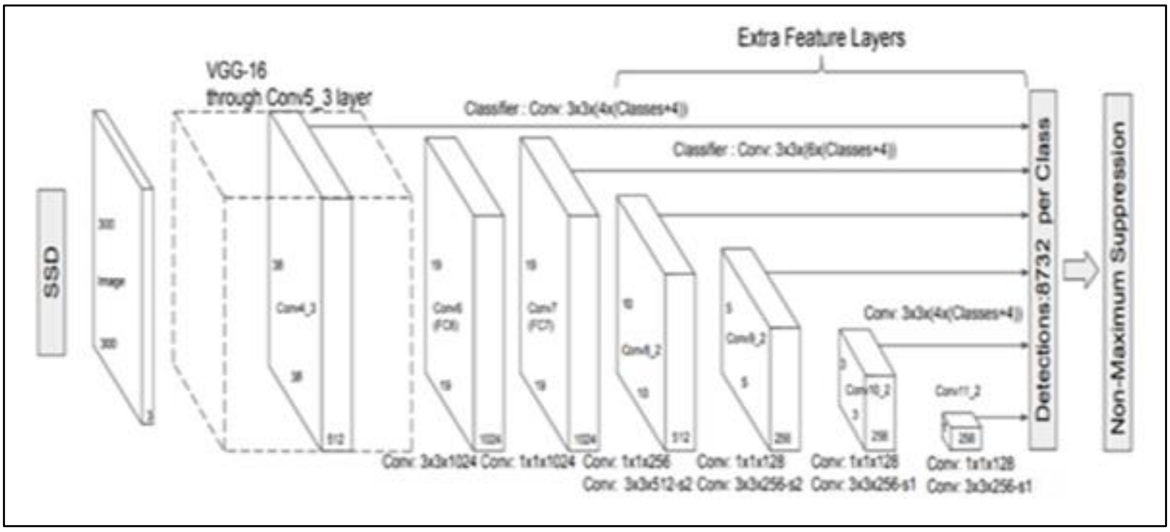

Figure 2: Schematic diagram of the SSD model architecture

2.2 Intelligent Upgrading in Logistics and Warehousing

In the field of logistics and warehousing, Zhang [8] addressed the difficulties in the control of logistics warehousing sorting systems. He adopted 2D/3D video technology, manipulator grasping technology, and AGV automatic handling technology, and successfully developed a logistics warehousing sorting system based on machine vision and AGV dynamic path planning. This system effectively reduces the number of package turnovers and improves package processing efficiency.

In the field of robot sorting system path planning, Huang [9] aimed at the problems existing in robot teaching operations. He proposed improved RRT and RRT-Connect algorithms, and then used cubic spline interpolation and an improved particle swarm optimization algorithm to optimize the trajectory, which can more effectively reduce path planning time. Zhu [10] addressed the obstacle detection and path planning problems faced by AGVs during operation. He proposed an obstacle detection algorithm combining DeepLabV3+ and improved FAST corner detection to ensure smooth logistics transportation.

2.3 Innovative Practices in Agriculture and Special Operations

Agricultural operation environments are complex and changeable, which puts forward higher requirements for the adaptability of robot path planning. Huang [11] improved the autonomous navigation system to solve the problems of apple tree canopy occlusion and low positioning signal accuracy in apple orchards. He used the U-Net semantic segmentation network and RTK technology to control the robot's motion trajectory. Simulation and field experiments verified that the navigation accuracy and operation efficiency were significantly improved.

Wang [12] studied the operation path planning method of combine harvesters. She used binocular vision and the Canny algorithm to detect targets and obstacles, and effectively avoided field obstacles based on the principle of the artificial potential field method.

2.4 Technological Breakthroughs in Mobile Robots and Intelligent Equipment

In terms of obstacle avoidance for mobile robots, Liu [13] proposed an algorithm combining vision and the dynamic window approach, which effectively improved the local dynamic obstacle avoidance capability of mobile robots.

In the field of unmanned road sweepers and engineering vehicles, Tong et al [14]. proposed using cameras and computers instead of human eyes to realize lane line recognition, enabling autonomous driving of road sweepers. Guan [15] detected feasible areas based on the ZED binocular camera and improved the dynamic window approach, which achieved good obstacle avoidance effects for both static and dynamic obstacles.

In the research on lateral obstacle avoidance of autonomous vehicles, Huang [16] proposed an obstacle detection algorithm based on YOLOv4-Tiny, combined with a multi-object tracking algorithm to realize continuous tracking of obstacle targets. He also proposed a lateral obstacle avoidance algorithm based on the improved artificial potential field method, which effectively solved the problems of local optimum and unreachable targets in traditional methods and improved the safety of vehicles in complex traffic environments.

3 CORE TECHNOLOGICAL PROGRESS AND INNOVATIONS

3.1 Continuous Optimization of Path Planning Algorithms

3.1.1 Optimization of RRT

Sun [17] improved the RRT algorithm by combining it with the artificial potential field method. She introduced probability values and gravitational forces to establish a repulsive force field, accelerating the convergence speed of path search and reducing the randomness of path search. Huang [9] improved the RRT and RRT-Connect algorithms by introducing an adaptive target bias threshold and a double-tree structure optimization strategy (the flow chart of the improved RRT algorithm is shown in Figure 3), which shortened the planning time and reduced the path length.

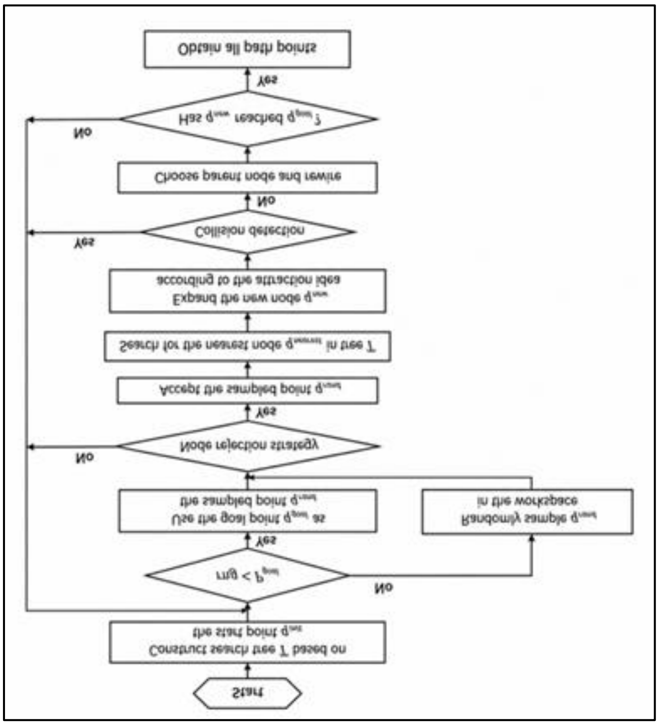

Figure 3: RRT Algorithm Flowchart

3.1.2 Optimization of A* Algorithm

Liu [18] addressed the problem that the traditional A* algorithm uses a constant heuristic function weight, leading to too many extended points and low search efficiency. He introduced an exponential decay function as the weight of the heuristic function to dynamically adjust the weight. Deng [4] aimed at the full-coverage binding requirement of steel bar binding robots and proposed an improved priority reciprocating full-coverage path planning method and an improved A* dead zone escape algorithm. For the problem of the algorithm falling into a dead zone, the improved A* algorithm is used for point-to-point path planning to escape the dead zone.

3.1.3 Optimization of Swarm Intelligence Algorithms

Swarm intelligence algorithms, such as evolutionary algorithms and genetic algorithms, are also widely used in path planning. Zhu et al [1]. used evolutionary algorithms to optimize the inspection paths of substations. Chang [19] proposed a genetic algorithm with a fitness function based on the number of turns and path length, and conducted full-coverage path planning simulation experiments.

3.2 Technological Innovation in Machine Vision and Environmental Perception

3.2.1 Deep Learning Plays a Core Role in Target Detection and Semantic Segmentation

YOLOv5 is used for license plate recognition [20], U-Net for orchard environment segmentation [11], and DeepLabV3+ for warehouse obstacle detection [10], all of which demonstrate powerful feature extraction capabilities. Wang [2] preprocessed environmental images in the intelligent robot path planning system, and used deep learning-based obstacle detection and TLD real-time target tracking to provide accurate environmental information for path planning. Huang [16] studied the obstacle target detection algorithm based on the YOLOv4-Tiny network, redesigned the size of

Anchor Boxes combined with the K-means++ clustering algorithm, and realized efficient and accurate obstacle detection on embedded devices.

3.2.2 Traditional Vision Technologies

The Canny algorithm [12] and optical flow method [21] still have great application value in specific scenarios. Deng [4] used image processing technology to process the predicted box area of steel bar binding nodes, and combined with feature projection curves to achieve precise node positioning. Multi-sensor fusion has become the key to improving environmental perception capabilities. Apple orchard plant protection robots fuse vision and RTK [11], warehouse AGVs combine vision and ultrasonic sensors [10], and engineering vehicles are based on binocular cameras and other sensors [15]. All these effectively compensate for the limitations of single sensors and improve the accuracy and reliability of environmental perception.

3.3 Improvement of Trajectory Smoothing and Dynamic Control Technologies

Trajectory smoothing methods such as Bezier curves [18] and B-spline curves [22] are used for path optimization. Curve fitting reduces inflection points on the path and improves the accuracy of robot motion. In dynamic control, Sun proposed a method for dynamic target tracking control of manipulators based on visual feedback, which realized dynamic target tracking on the ROS platform and provided technical support for the robot's dynamic operation in dynamic environments. Zhou [22] proposed the AGS-RRT algorithm for dynamic obstacle avoidance of 6-DOF manipulators. He first established models of the manipulator and obstacles, and then transformed the collision detection problem into the problem of detecting the intersection of lines and spheres. This algorithm realizes obstacle avoidance of robots through path planning and path tracking (as shown in Figure 4). Simulation experiments showed that it has better spatiotemporal performance compared with traditional algorithms.

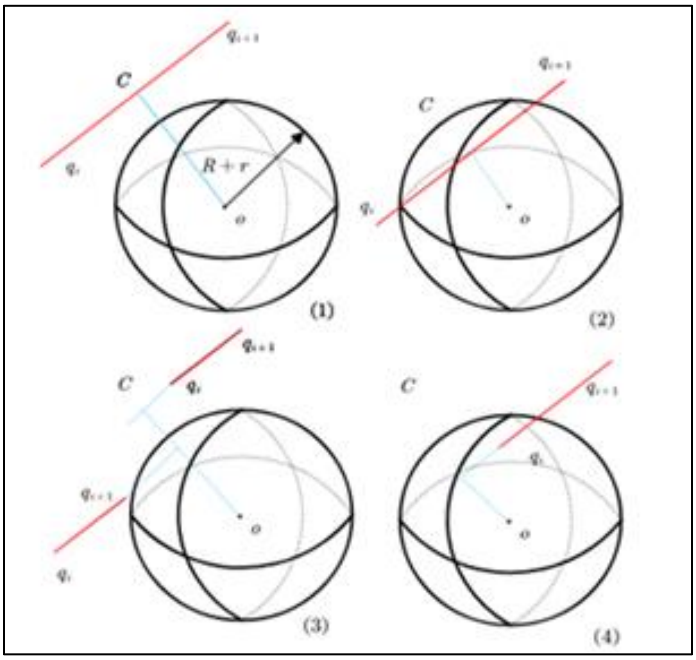

Figure 4: Collision Detection between the Manipulator and Obstacles

4 EXISTING CHALLENGES AND FUTURE DEVELOPMENT TRENDS

4.1 Existing Technical Bottlenecks

There are many problems in complex environment adaptability. For example, strong arc light in industrial welding, illumination changes and occlusion in agricultural operations, and complex road conditions in traffic scenarios all affect the accuracy of machine vision detection, leading to path planning failure. The efficiency of high-dimensional space planning still needs to be greatly improved. Due to the large computational load of path planning for complex systems such as 6-DOF manipulators, current algorithms can hardly meet real-time requirements. Research on multi-robot cooperative control is insufficient. While single-robot path planning technology is mature, obstacle avoidance and task allocation strategies for multi-robot collaboration are still imperfect. In addition, the generality and portability of algorithms need to be improved. Algorithm optimization in different scenarios requires a lot of targeted research, which increases the cost of technology application.

4.2 Future Development Directions

In terms of future prospects, integrated innovation will be a development trend. Deep learning will be further integrated with traditional optimization algorithms, and their respective advantages will be complemented to improve the overall performance of the entire path planning link. For example, part of the robot's work thinking can be handed over to the robot itself, which can obtain more accurate dynamic optimal paths through its own practice and learning experience. The application of deep learning and reinforcement learning methods will optimize path planning to the best effect. Multi-sensor information fusion will further develop towards intelligence and depth. By fusing multi-source information such as vision, LiDAR, ultrasound, and RTK, and applying intelligent algorithms for information complementation and efficient processing, new sensor fusion architectures will be developed to improve the stability and reliability of sensor systems.

5 CONCLUSION

Many research achievements have been made in the field of machine vision-based path planning, and the efficiency of robot operations has been improved through algorithm innovation, visual technology upgrading, and multi-sensor fusion. This paper introduces the applications and innovations of machine vision in fields such as industrial manufacturing, logistics warehousing, agricultural production, and intelligent equipment from different perspectives, including key technologies such as path planning algorithm optimization, machine vision and environmental perception, and trajectory smoothing and dynamic control. However, facing problems such as complex environment adaptability, high-dimensional space planning efficiency, and multi-robot collaboration, future solutions need to be continuously explored in aspects such as strengthening technological integration, optimizing algorithms, and developing more new application scenarios.

REFERENCES

[1] Zhu D Z, Yan Q, Wang L N. Path Planning Method for Substation Inspection Robots Based on Machine Vision and Evolutionary Algorithm [J]. Microcomputer Applications, 2024, 40(12): 202-206.

[2] Wang S P. Design of Intelligent Robot Path Planning System Based on Machine Vision [J]. Techniques of Automation and Applications, 2025, 44(05): 19-23+42.

[3] Xu D B. Target Grasping Path Planning Method for Steel Processing Robots Based on Machine Vision [J]. Automation Application, 2024, 65(21): 36-39.

[4] Deng L. Research on Steel Bar Binding Node Recognition and Binding Path Planning Based on Machine Vision [D]. Xi'an: Xi'an University of Architecture and Technology, 2023.

[5] Liu X Y, Ma X Y, Wang R F, et al. Research Status of Application of Machine Vision-Based Path Planning for Multi-layer and Multi-pass Welding of Robots [J]. Welded Pipe and Tube, 2024, 47(08): 1-8+18.

[6] Peng L Y. Research on Path Planning and Grasping of 6-DOF Manipulator Based on Machine Vision [D]. Wuhan: Jianghan University, 2024.

[7] Du J X. Research on Manipulator Path Planning Method Based on Machine Vision [D]. Changchun: Changchun University of Technology, 2023.

[8] Zhang G H. Development of Warehouse Sorting System Based on Machine Vision and AGV Dynamic Path Planning [J]. Logistics Engineering and Management, 2024, 46(08): 40-42+15.

[9] Huang Z L. Research on Path Planning Based on Machine Vision for Robot Sorting System [D]. Fuzhou: Fuzhou University, 2022.

[10] Zhu Y H. Research on AGV Obstacle Detection and Path Planning Based on Vision [D]. Nanjing: Nanjing University of Science and Technology, 2022.

[11] Huang P F. Research on Autonomous Navigation of Apple Orchard Plant Protection Robot Based on Vision-RTK [D]. Beijing: Chinese Academy of Agricultural Sciences, 2024.

[12] Wang F. Operation Path Planning Method of Combine Harvester Based on Machine Vision [J]. Agricultural Engineering, 2023, 13(12): 44-48.

[13] Liu Y Z. Research and Implementation of Obstacle Avoidance Algorithm for Mobile Robots Based on Machine Vision [D]. Chongqing: Chongqing University of Posts and Telecommunications, 2021.

[14] Tong G, Li J, Xu F, et al. Design of Unmanned Road Sweeper Path Planning System Based on Machine Vision and Internet of Things Cloud Platform [J]. Chinese Journal of Construction Machinery, 2021, 19(06): 518-523.

[15] Guan W. Research on Feasible Area Detection and Path Planning of Engineering Vehicles Based on Machine Vision [D]. Changchun: Jilin University, 2021.

[16] Huang L X. Research on Lateral Obstacle Avoidance Algorithm of Autonomous Vehicles Based on Machine Vision [D]. Nanjing: Nanjing Forestry University, 2021.

[17] Sun Y. Research on Manipulator Path Planning and Tracking Control Based on Vision [D]. Kaifeng: Henan University, 2024.

[18] Liu J J. Research on Dynamic Path Planning and Obstacle Avoidance Technology of Robots Based on Machine Vision [D]. Lanzhou: Lanzhou University of Technology, 2024.

[19] Chang H J. Research on Image Segmentation and Processing Path Planning of Paint Removal Robot Based on Vision [D]. Zhenjiang: Jiangsu University of Science and Technology, 2022.

[20] Huang R Y, Cai Y L, Cai Z N, et al. Research on Parking Space Detection and Path Planning in Underground Parking Lots Based on Machine Vision [J]. Computer and Telecommunication, 2024(05): 10-13.

[21] Zhou J T. Research on Target Detection and Path Planning of Mobile Robots Based on Vision [D]. Jinan: Qilu University of Technology, 2021.

[22] Zhou D B. Research on Dynamic Obstacle Avoidance Path Planning of Manipulator Based on Vision [D]. Shenyang: Shenyang Ligong University, 2024.