Scholar Publishing Group
Kinetic Mechanical Engineering
https://doi.org/10.38007/KME.2020.010202
ISSN 2790-2676 Vol. 1, Issue 2: 9-16

# *Implementation of Intelligent Robot Following System Considering Finite Difference Method*

**McMaster Tacgin***

*Warsaw Univ Technol, Inst Elect Syst, Nowowiejska 15-19, PL-00665 Warsaw, Poland*

**corresponding author*

***Keywords:*** Finite Difference, Intelligent Robots, Tracking Systems, Laser Radar

***Abstract:*** In recent years, with the improvement of computer vision technology, intelligent following robots have also been rapidly developed, greatly improving people's lives. This paper mainly studies the design and implementation of intelligent robot following system considering finite difference method. In this paper, the liDAR sensor, servo motor and control board of the tracking robot system are debugged under the ROS system, and the software and hardware platform of the tracking robot system are built and tested with the modular engineering thinking. The object detection of the following robot system is studied with finite difference method. Through field experiments in complex indoor environment and outdoor corridor, the real-time performance and effectiveness of the robot target following system are verified.

## 1. Introduction

With the development and promotion of artificial intelligence, the rapid development of robot technology has greatly influenced the field of production and manufacturing and warehousing logistics in our country. With the advancement of science and technology, the introduction of financial capital and the support of state policy, logistics robots have achieved rapid development in China. For mobile robots, motion control is the most basic problem. To complete any task, it is necessary to control the motion of the mobile robot, otherwise the task will fail, and the serious will lead to financial damage and personnel injury [1-2]. The existing mobile robots generally set their running path and trajectory according to the starting point planning in the actual application scene, and then their navigation device guides the mobile robot to travel along the trajectory curve [3]. However, for some non-repetitive tasks of man-machine integration and man-machine cooperation, such as the need for mobile robots to assist people in carrying and sorting goods, the operator's position can be tracked and followed in real time, reducing human labor intensity and improving labor efficiency [4]. Smooth realization of mobile robot on the safety of the people follow, in addition to want to consider the power output and torque of the motor itself, the processor's operation ability, the operating system's inherent factors such as message transmission mechanism, still need to add the constraints, to solve the delay may lead to deviation and collision issued instructions, pedestrian accident broke into danger, Improper parameter Settings of the robot lead to problems such as vibration and jitter [5-6]. Therefore, the design of a mobile robot following control system, so that it can be safe and friendly interaction with people, achieve stable following effect, can improve work efficiency, reduce production costs.

At present, the global development of artificial intelligence related technologies is very rapid, which has had a profound impact on transportation, aerospace, medical treatment and other aspects [7]. The daily lives of ordinary people have been transformed. Intelligent service robots, riding on the boom of artificial intelligence technology, have also been greatly developed. Various service robots, such as cleaning robots and intelligent wheelchairs, are constantly improving the quality and level of people's life [8]. Intelligent following robot is the main component and function module of service robot [9]. The technologies for following robots are also complex and varied. It mainly includes infrared tracking, ultrasonic tracking and visual tracking [10]. In the infrared tracking system, it has strong adaptability to the complex and changeable environment, but the measurement accuracy is low. The ultrasonic tracking system can process data quickly and simply, and has strong dirt resistance. However, its research cost is high and its accuracy is low [11]. The realization of intelligent following robot in this paper depends on good visual object detection technology.

This paper designs a mobile robot following control system, so that it can interact with people safely and friendly, achieve stable following effect, can improve the work efficiency, reduce production costs.

## 2. Robot Following System Considering Finite Difference Method

### 2.1. Robot Platform Construction

(1) Overall design

The following robot system is mainly composed of liDAR sensor, motor control system and robot control system [12]. As shown in Figure 1, under the ROS operating system, when the liDAR sensor detects the following target, the distance information of the liDAR is transmitted to the host computer, and the host computer calculates the position and posture of the next robot through the algorithm of target recognition and motion control. At the same time, the upper computer sends instructions to the lower computer, and the lower computer controls the linear and angular velocity of the robot by controlling the rotational speed of the left and right motors [13-14].

Sensor: A detection device that follows a robotic system. It can detect the information data of the measured objects around the robot and convert these data into electrical signals or other signals. The sensor device in this paper mainly refers to the liDAR sensor [15].

Operating system: The algorithms and programs by which machines control hardware platforms and mobilize software resources. The operating system needs to deal with tasks such as monitoring and configuring memory, determining the priority of multilevel algorithms, and controlling sensor and motor input and output [16].

Motor control system: The left and right motor control devices that follow the robot system. According to the type of motor and different use scenarios of the robot, the motor's start, acceleration, operation, deceleration and stop are controlled. The encoder records the rotation distance of the motor, so as to calculate the moving distance and rotation Angle of the robot in the response time, and feedback the relevant information to the lower computer [17].

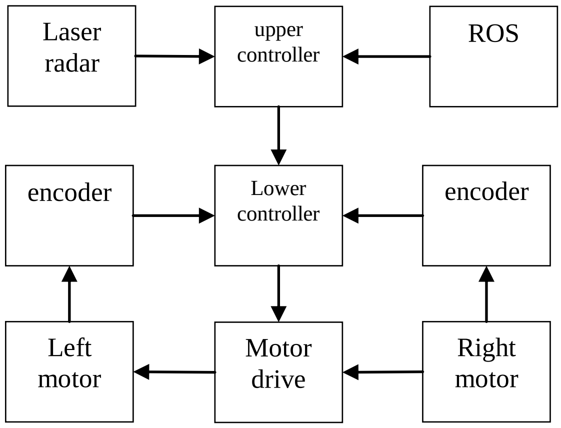


*Figure 1. Follow the robot system block diagram*

Robot control system: A motion control device that follows a robot system. It is mainly divided into upper computer and lower computer. Among them, the upper computer is a computing unit that can directly issue control instructions and execute algorithms for robot target recognition and motion control. The lower computer is a computing unit that directly controls the device to obtain the condition of the device, and can directly read the motor rotation distance, motor rotation number and other information of the encoder [18].

(2) Robot hardware

In this scheme, the liDAR scanning in the range of 360 degrees is placed in the center of the robot, and the robot can scan and detect the surrounding environment. At the same time, a planetary motor reducer is added in front of the servo motor, which can control the rotation speed of the motor with large torque and low noise, and prevent the motor gear from being damaged when the robot stops braking suddenly.

The lidar used in this project is OMD10M R2000-B23-V1V1D LIdar produced by PEPPERL+FUCHS. As shown in Table 1, it is a two-dimensional lidar which can scan 360 °. Pulse Detection Technology shoots out LiDAR spots with high frequency and low density. The safety level is level I, which ensures that the laser beam will not cause damage to human eyes and can be safely used for man-machine collaboration. The measurement distance is 0.2-10 meters and the measurement speed is up to 250,000 times per second.

*Table 1. Hardware parameters of LiDAR*

| Laser radar index | Technical specifications |
|---|---|
| Measuring range | 0.2m-1m |
| Repetition frequency | 250kHz |
| Measurement noise | -9mm - +9mm |
| Resolution of angle | 0.014 ° |
| Scanning repetition accuracy | 12mm |

The control board selected in this paper is the United States NVIDIA (NVIDIA) company production of Jetson TX2 development board, referred to as TX2.

(3) Software system

The software system used by the follower robot is the ROS operating system. ROS (Robot Operating System) grew out of a collaboration between Stanford University's Artificial Intelligence Lab and robotics company Willow Garage. This article's follower bot system used the ROS system on Ubuntu20.04.

ROS systems have the following characteristics:

Nodal design. When a ROS system executes a large number of processes, which can be run on different hosts in different regions or in separate segments, you only need to call each node on the process for task scheduling.

Toolkit is abundant. The ROS system integrates a number of open source tools to help researchers develop robots. For example, Gazebo, an open source software that can simulate 3D mechanical structure and motion state of robots, PCL library that can process 3D point cloud and depth image data, OpenCV library that can process camera image and computer vision, and MoveIt library that can plan robot motion.

Multi-language support. Different developers rely on different language habits. In order to meet the needs of multiple languages, ROS systems support the compatibility of C++ and the popular Python language.

Integrated and streamlined. Robot software engineering contains the code base that follows the robot system. Unfortunately, the middle part of these algorithms is often disorganized due to the maintenance of many people, and it is difficult to extract part of the code for porting to the robot.

## 2.2. Finite Difference Method

When using finite difference method to solve differential equation, the first thing to do is to discretize the continuous equation. Therefore, the region to be solved needs to be meshed. This paper takes parabolic partial differential equations as an example to explain mesh generation and introduces some common terms.

For the initial boundary value problem of parabolic equation:

$$\begin{cases} \dfrac{\partial u}{\partial t} = a\dfrac{\partial^2 u}{\partial x^2} + f(x), \quad 0 < x \le 1, \quad 0 < t \le T \\ u(x,0) = g(x), \quad u(0,t) = u(l,t) = 0 \end{cases} \tag{1}$$

Take space step h=I/J and time step t=T/N, where J and N are natural numbers. Then, two families of parallel straight lines x=xj=jh (j=0, 1,..., J) and t=tn=n7t (n=0, 1,..., N) are used to divide the solution region G={0<x ≤ l; 0<t ≤ T) into rectangles. The divided grid nodes are represented as (Xj, tn). Ujn is used to represent the function defined on the dot (xj, tn). 0 ≤ j ≤ J,, 0 ≤ n ≤ N, and then a reasonable difference quotient is used to replace the partial derivative in the equation to obtain the finite difference scheme of the equation.

When using finite difference lattice method to solve differential equations numerically, the calculation process is calculated layer by layer according to the time layer. Consider 2 finite difference scheme: to calculate, calculate the numerical solution on the n + 1 layer need to use the first n level has been calculated value, and when calculating the value of rounding error (including n = 0, at this time is due to initial value condition calculation error or caused by the error of the initial data) will inevitably affect the value of the numerical solution. Therefore, it is necessary to analyze the situation of the error propagation, analyze the influence of the error propagation, and get the control difference scheme to solve the error, which is the significance of studying the so-called stability problem.

Taking the difference scheme for solving parabolic equation (1) as an example, the forward difference scheme is as follows:

$$\begin{cases} u_j^{n+1} = ru_j^{n+1} + (1-2r)u_j^n + ru_{j-1}^n \\ u_j^0 = g(x_j) \end{cases} \tag{2}$$

The numerical solution u and the initial value g(xj) are defined only at each grid point. If Fourier method is to transform the above scheme, the domain of both u and g(xj) must be extended to make them meaningful for any $z \in R$.

## 3. Intelligent Robot Follows the Experiment

In this paper, the robot target following platform will be tested in two environments, namely the laboratory and the outdoor corridor. The indoor test is mainly because the indoor environment is chaotic and complex, which is a huge challenge to the semantic segmentation of the robot tracking target and scene. The outdoor corridor is long and narrow, and the robot has a far field of view, which can test its ability to follow the target and plan the path at a long distance. In this section, we will first show the accuracy of the distance between the robot and the target measured by a single camera, and then show the actual following effect in indoor environment and corridor environment respectively. When the robot is tracking the target, in order to prevent the robot from being damaged because the target is too close to the robot, a safe distance range (90cm-100cm) is set in this paper. If the range is larger than this, the robot will approach the target. Less than this, the robot moves away from the target.

In this paper, the real-time performance and detection accuracy of intelligent following system implemented by YOLO and finite difference models on Raspberry PI are compared and tested.

## 4. Analysis of Experimental Results

### 4.1. Research on Algorithm Performance

*Table 2. Real-time robot performance results*

| | 50 | 100 | 150 | 200 |
|---|---|---|---|---|
| YOLO | 274 | 263 | 259 | 286 |
| Finite difference | 32 | 47 | 41 | 49 |

As shown in Table 2 and Figure 2, the real-time performance and detection accuracy of the intelligent following robot based on Raspberry PI platform are compared between the two algorithms. It can be seen from the figure that although finite difference is slightly inferior to YOLO in detection accuracy, it is superior to YOLO in real-time performance on the premise of ensuring the required detection accuracy of the system.

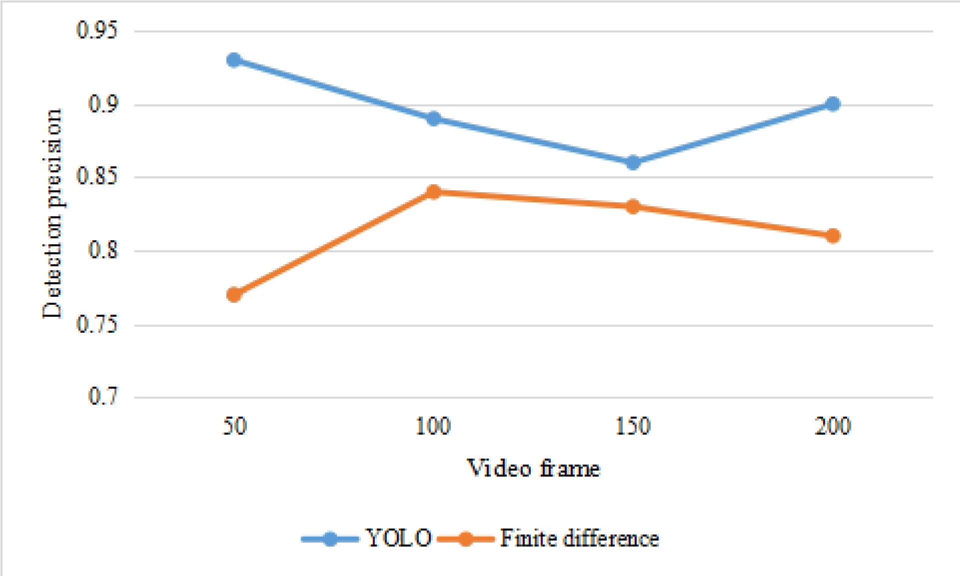


*Figure 2. Robot detection accuracy comparison diagram*

## 4.2. Follow the Path


*Figure 3. Follow the motion*

As shown in figure 3 for the robot and the target trajectory figure, following experiment indoors, horizontal, vertical, experimental site of length and width, respectively, through the motion trajectory of robot and the target, can be more intuitive to see robot target tracking process, further reflects the robot to track movement of good accuracy and real-time performance.

## 5. Conclusion

In this paper, the following method of mobile robot equipped with liDAR is studied. By studying the target detection link (pedestrian recognition) and target following link (motion control) of the following robot, the shortcomings of the following robot in the field of pedestrian recognition and motion control are improved. The system can not only be used as an independent intelligent robot in the actual scene, but also become a functional module of a complex multifunctional integrated commercial robot, and its application prospect is very broad. The next research direction of this paper is to further improve the functions of intelligent following robot system by adding modules such as path planning and obstacle avoidance by using semantic map and other methods.

## Funding

This article is not supported by any foundation.

## Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

## Conflict of Interest

The author states that this article has no conflict of interest.

## References

*[1] Yan Q, Huang J, Yang Z, et al. Human-following control of cane-type walking-aid robot within fixed relative posture. IEEE/ASME Transactions on Mechatronics, 2020, 27(1): 537-548. https://doi.org/10.1109/TMECH.2020.3068138*

*[2] Sapietová A, Saga M, Kuric I, et al. Application of optimization algorithms for robot systems designing. International journal of advanced robotic systems, 2018, 15(1): 1729881417754152. https://doi.org/10.1177/1729881417754152*

*[3] Kubo R, Fujii Y, Nakamura H. Control Lyapunov function design for trajectory tracking problems of wheeled mobile robot. IFAC-PapersOnLine, 2020, 53(2): 6177-6182. https://doi.org/10.1016/j.ifacol.2020.12.1704*

*[4] Feingold-Polak R, Barzel O, Levy-Tzedek S. A robot goes to rehab: a novel gamified system for long-term stroke rehabilitation using a socially assistive robot-methodology and usability testing. Journal of NeuroEngineering and Rehabilitation, 2020, 18(1): 1-18. https://doi.org/10.1186/s12984-021-00915-2*

*[5] Abdulhamid M, Mutheke M. Design of Digital Control System for Line Following Robot. Technological Engineering,, 2018, 15(2): 48-52. https://doi.org/10.1515/teen-2018-0018*

*[6] Le T D, Ponnambalam V R, Gjevestad J G O, et al. A low‐cost and efficient autonomous row‐following robot for food production in polytunnels. Journal of Field Robotics, 2020, 37(2): 309-321. https://doi.org/10.1002/rob.21878*

*[7] Saravanan D, Perianayaki E R A, Pavithra R, et al. Barcode System for Hotel Food Order with Delivery Robot//Journal of Physics: Conference Series. IOP Publishing, 2020, 1717(1): 012054. https://doi.org/10.1088/1742-6596/1717/1/012054*

*[8] Jiang B, Karimi H R, Yang S, et al. Observer-based adaptive sliding mode control for nonlinear stochastic Markov jump systems via T-S fuzzy modeling: Applications to robot arm model. IEEE Transactions on Industrial Electronics, 2020, 68(1): 466-477. https://doi.org/10.1109/TIE.2020.2965501*

*[9] Sibilska-Mroziewicz A, Możaryn J, Hameed A, et al. Framework for simulation-based control design evaluation for a snake robot as an example of a multibody robotic system. Multibody System Dynamics, 2020, 55(4): 375-397. https://doi.org/10.1007/s11044-022-09830-3*

*[10] Neloy A A, Bindu R A, Alam S, et al. Alpha-N-V2: Shortest Path Finder Automated Delivery Robot with Obstacle Detection and Avoiding System. Vietnam Journal of Computer Science, 2020, 7(04): 373-389. https://doi.org/10.1142/S2196888820500219*

*[11] Čech M, Wicher P, Lenort R, et al. Autonomous mobile robot technology for supplying assembly lines in the automotive industry. Acta logistica, 2020, 7(2): 103-109. https://doi.org/10.22306/al.v7i2.164*

*[12] Al-Shabi M, Hatamleh K S, Gadsden S A, et al. Robustnonlinear control and estimation of a PRRR robot system. International Journal of Robotics and Automation, 2019, 34(6): 632-644. https://doi.org/10.2316/J.2019.206-0160*

*[13] Gradolewski D, Maslowski D, Dziak D, et al. A distributed computing real-time safety system of collaborative robot. Elektronika ir Elektrotechnika, 2020, 26(2): 4-14. https://doi.org/10.5755/j01.eie.26.2.25757*

*[14] Khoramshahi M, Billard A. A dynamical system approach for detection and reaction to human guidance in physical human-robot interaction. Autonomous Robots, 2020, 44(8): 1411-1429. https://doi.org/10.1007/s10514-020-09934-9*

*[15] Dudzik S. Application of the Motion Capture System to Estimate the Accuracy of a Wheeled Mobile Robot Localization. Energies, 2020, 13(23): 6437. https://doi.org/10.3390/en13236437*

*[16] Zhonglin Z, Bin F, Liquan L, et al. Design and function realization of nuclear power inspection robot system. Robotica, 2020, 39(1): 165-180. https://doi.org/10.1017/S0263574720000740*

*[17] Morales Bieze T, Kruszewski A, Carrez B, et al. Design, implementation, and control of a deformable manipulator robot based on a compliant spine. The International Journal of Robotics Research, 2020, 39(14): 1604-1619. https://doi.org/10.1177/0278364920910487*

*[18] Khoramshahi M, Billard A. A dynamical system approach to task-adaptation in physical human-robot interaction. Autonomous Robots, 2019, 43(4): 927-946. https://doi.org/10.1007/s10514-018-9764-z*