Intelligent Automation And Soft Computing, 2019
Copyright © 2019, TSI® Press
Vol. 25, no. 3, 451–458
https://doi.org/10.31209/2019.100000126

Intelligent Service Robot Vision Control Using Embedded System

Li-Hong Juang[1], Shengxiang Zhang [2]

[1]School of Electrical Engineering and Automation, Xiamen University of Technology, No.600, Ligong Road, Jimei, Xiamen, 361024, P.R.China
[2]Engineering College, HuaQiao University, No.269, Chenghua North Road, Fengze District, Quanzhou, Fujian 362021, P.R.China

ABSTRACT

Intelligent robots are the combination of computer engineering, software engineering, control engineering, electronic engineering, mechanical engineering, and systems design engineering in order to design, and manufacture useful products. In this paper, the author derives some novel computing and algorithm applications on computer vision and image processing and intelligent control and navigation of mobile robots for the intelligent service robot system. In this paper, we proposed an idea of flexible design for a intelligent service robot, which refers to a single robot with a variety of flexure structure. We presented an integrated system for vision-guided finding the person and completing obstacle avoidance. The simple algorithm based on path planning of vision is proposed, and we combine this algorithm and the centripetal rule of path planning in maze robot. The experimental results show that it has a good control effect and is able to extend its popularization and application.

KEYWORDS: intelligent service robot, flexure structure, vision-guided, obstacle avoidance, path planning

1 INTRODUCTION

FOR a long time, the prosperity and development of industrial robot that determines the strength of the country. Industrial robot replaces traditional manpower production activities on a large scale. However, in recent years, intelligent service robot research as the "engine" occupies an important position in Asian countries like China and Japan. We consider that the unique features of mobile robots and the intelligent service environment robots will be working for this with many new researches on task planning spring up. An extensible, flexible and practical planning system needs to be designed (Chen, 2018), (Aldana-Murillo, 2018), (Becerra, 2018), (Chou, 2018), (Ma, et al., 2016).

Domestic research on the robot started much later than Europe and the United States. During a long time to research, some of the achievements have been made. At the beginning in China, researchers independently developed the first category of humanoid robot, which has the characteristics of human body structure, and can simulate the human walking, running and other actions. In the end of the 20th century, this robot first appeared at the Changsha National Defense University. The advent of this robot symbolizes that the field of intelligent service robot in China, which has greatly narrowed the distance with the developed countries in Europe and America. The robot has achieved a major breakthrough in a number of key challenges: the realization of the static walks to run and other action to switch; the robot can change itself no matter in a specific environment or the complex unknown environment. Robot research and development in the Beijing Institute of Technology is currently at the leading level in the domestic industry. From 2002 to 2005, the humanoid robot can play Tai Ji, climb stairs, bypass and do other complex human body movements. The development of intelligent service robot technology has a certain breakthrough. However, due to the lack of hardware, the humanoid robot is not stable enough and not convenient with their feet (Cai, et al., 2017)

France Aldebaran Robotics company's NAO is one of the most widely used humanoid robot in the world, that has 25 degrees of freedom, more than 100 sensors, airborne computers, and provides 23 languages to understand. It has supported remote

CONTACT Li-Hong Juang lipuu@qq.com

control, and can be fully programmed. But the robot is a high-cost, which constrain their applications just in the education and entertainment. The arm configuration of the NAO robot does not permit simultaneous movement of the shoulder and elbow joint during human guided training process because of the attribute of discrete foot holds with minimal ground interaction and elbow roll design. This design would make the training process difficult and the learnt motion less natural (Tan, et al., 2014).

With the widespread use of LEGO robot (collectively the programmable LEGO modules, drive motors, multiple types of sensors, mechanical transmission builds), the idea of flexible design is born, and it can be traditional children's toys. The idea is that the user can freely play the imagination, assemble into a variety of structural models. Lego robot is a very effective learning tool, which facilitates the development of logical thinking, creativity, and greatly increases children's interest in learning programming (Strand, 2017).

In this paper, we firstly discussed the flexible design in the field of intelligent service robot. The flexible design of intelligent service robots which refers to a single robot with a variety of mechanical structures. For example, a single AGV（Automated Guided Vehicle）can be used to complete different functions because of the multiform structures. Then, the robot can complete more functions through the multi-sensor fusion and integration technology. Furthermore, the effectiveness of the proposed approach in this idea is validated through comparing experiment results of what we got. We used the embedded system to reduce the production cost, and used the wheeled AGV to resolve the problem for walking of the humanoid robot which helps the robots extend their functions.

2 OVERVIEW OF THE SYSTEM

THE overall design block of the intelligent service robot control system is divided into flexible design system, embedded system and terminal control system, as Figure 1 shows.

Embedded system is a core link, and chains the flexible design system and terminal control system together. Through different levels of information fusion, the robot can perceive the external environment, and respond to what they are facing.

3 SPECIFIC SYSTEM IMPLEMENTATION PLAN

THE system uses a modular approach to complete the control system hardware circuit design (different hardware devices are embodied in the concept of flexible design), including: main control module, motion control module, video processing module, communication module and obstacle avoidance module as Figure 2 shows.

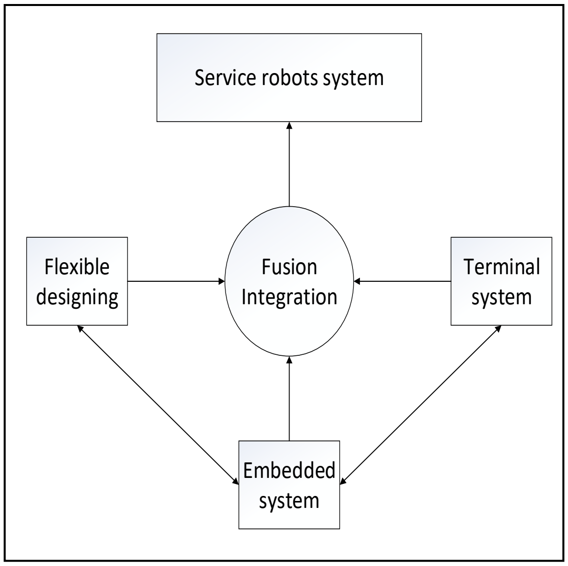


Figure 1. Intelligent service robot system.

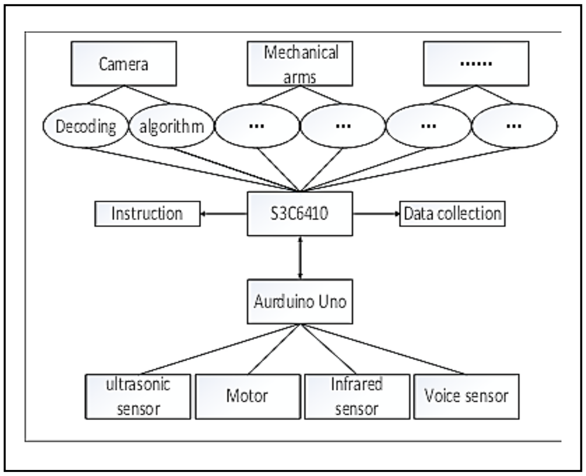


Figure 2. System description.

3.1 Main Control Module

In this paper, S3C6410 is chosen as the decision layer, launched by Samsung Corp, a low-power, high performance processor. The ARM11176JZF-S processor incorporates an integer core part. And instructions for the media processing of a single instruction flow expend Multi-stream. This special design improves video processing performance. In this experiment, the operating system used by the ARM board is Linux3.0.1, the main role is to collect data and handle the problems from the capture of the Camera. In order to achieve the purpose of intelligent service, the next step is sending command information to the other microcontroller.

3.2 Motion Control Module

The Basra is introduced in this paper, which is a development board designed by Arduino open source program. Because it is open source, the Basra was used for the main control board and Bigfish is the expansion board. Other devices are motor, motor drive and encoder. Choosing DC motor is simple way to control the speed, moreover the control method is easy to understand. So we choose the DC motor to drive robot movement. Motion control module is shown in Figure 3.

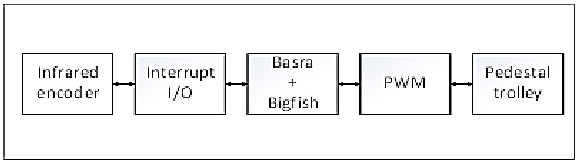


Figure 3. Motion control module.

Infrared encoder with slot-type photoelectric can trigger to output 5V TTL level, as long as the non-transparent objects go through the slot. Inside Schmitt trigger can wipe off the pulse jitter. As for the car speed measuring and controlling, we programmed the PID control algorithm to adjust the measured velocity. PID with PWM control principle diagram is shown in Figure 4. The system is composed of PID with PWM controller and the controlled object. From Figure 1, r(t) means an input value, y(t) means the actual output value of the system, e(t) means the deviation from the actual output value and input value.

$$y(t) = Kp[e(t) + \frac{1}{Ti}\int_0^t e(t)dt + Td\,\frac{de(t)}{dt}] \quad (1)$$

In the formula, Kp represents the scale factor of the controller; Ti represents the integral time of the controller, also called the integration factor; Td represents the differential time of a controller, also known as the differential coefficient.

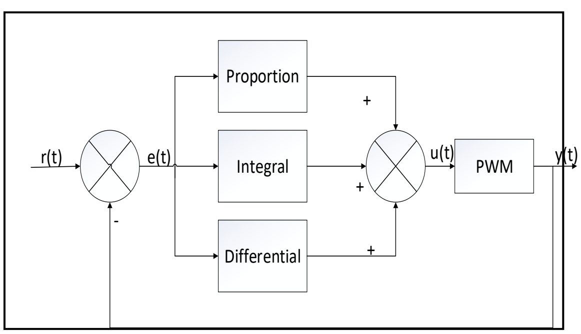


Figure 4. The PID with PWM control loop.

These Figure 5 - 7 are indicated the magnitude of the speed detected by the infrared encoder of the revolver when the proportional integral is 0.2, 0.4 and 0.8. The proportion of the role is to respond to the moment. When the deviation controller immediately is changed, then the proportion is working on. The control quantity is shown in reducing the change of deviation. The control effect depends on the proportional coefficient. When the proportional coefficient is bigger, the transition process is faster and the static error control process is smaller. Therefore, the proportion coefficient of choice must be appropriate to the transition, less time, small static error and stable effect.

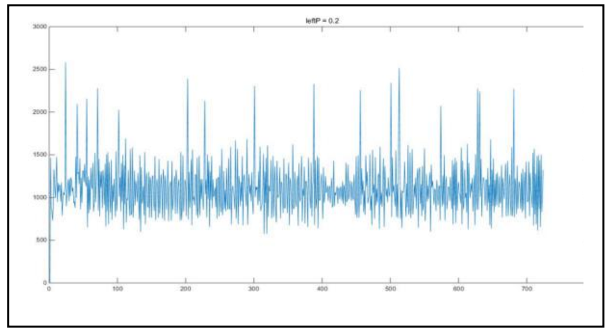


Figure 5. Proportion = 0.2

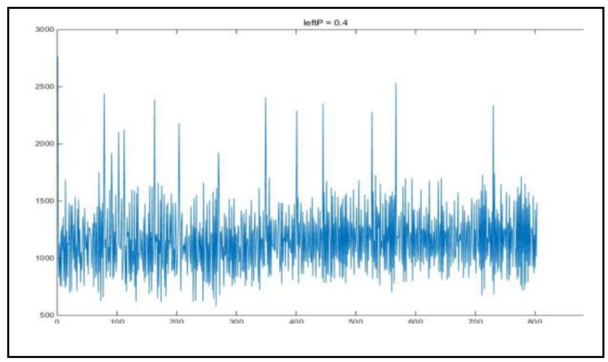


Figure 6. Proportion = 0.4

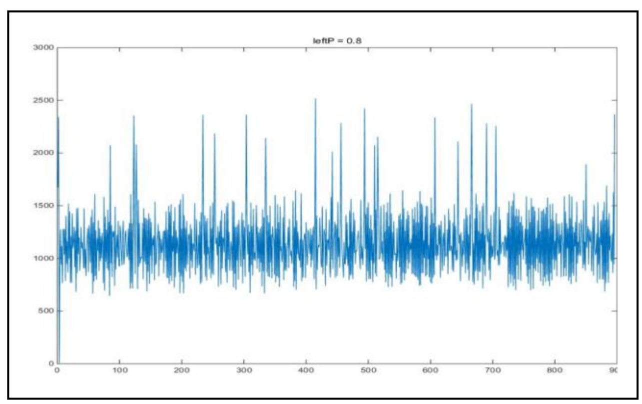


Figure 7.Proportion = 0.8

The results of simulation have proved that the output can track the input accurately.

3.3 Video Processor Module

In this paper, the camera chosen is Logitech Inc's C310, dynamic resolution 1280*720, the camera is 5 million pixels, driver free installation, and interface type is USB2.0. In Figure 8, there is the reality of human face detection.

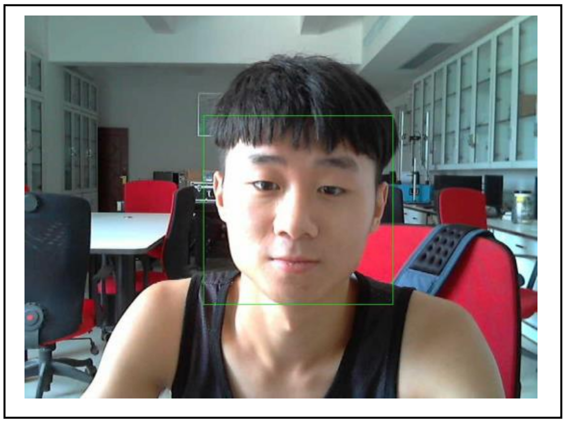


Figure 8. The reality of human face detection.

(1) The Face Detection

In the aspect of image processing, the face detection technique in Opencv (Open Source Computer Vision Library) is used in embedded system (Minichino & Howse, 2016). The face detection classifier we used is based on Haar features and trained by Adaboost learning algorithm. There is the general flow that the face detection technique going, as shown in Figure 9.

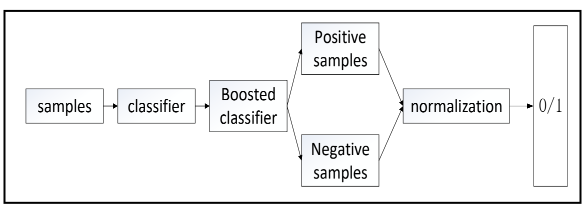


Figure 9. Haar training data process.

The next step is to implement the face detection algorithm on the ARM board, in other words, to make the Opencv interface available in the embedded system. The method used in this paper is to capture the video stream from the camera by using V4L2 (Video for Linux Two) and then call the functions directly through the Opencv interface. V4L2 is the unified interface provided by the kernel to the application access tone and video driver. As is shown in Figure 10.

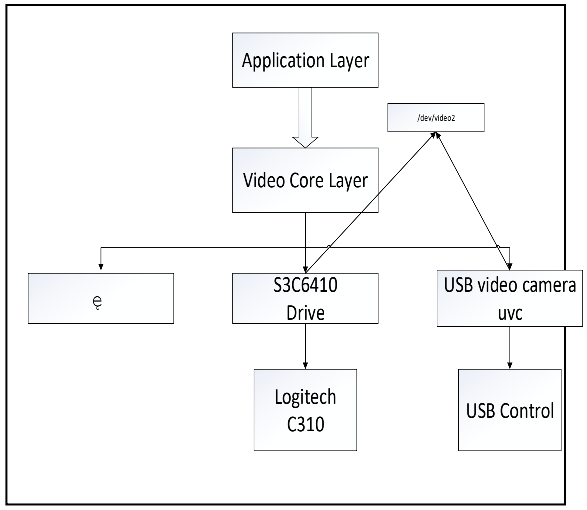
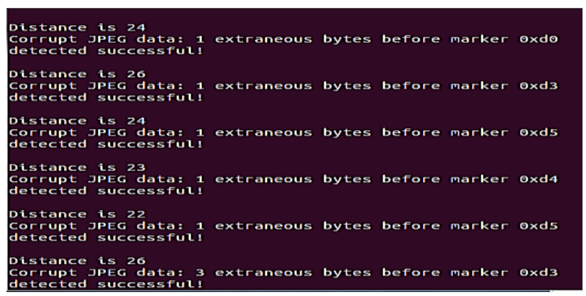


Figure 10. The demonstration for capturing from ARM system.

(2) Location

In order to determine the distance from our camera to the face we detected, we are going to utilize triangle similarity. I learn some principles from the research (Linderoth, 2010). We show the result of monocular ranging and face detection data in Figure 11.



```
Distance is 24
Corrupt JPEG data: 1 extraneous bytes before marker 0xd0
detected successful!
Distance is 26
Corrupt JPEG data: 1 extraneous bytes before marker 0xd3
detected successful!
Distance is 24
Corrupt JPEG data: 1 extraneous bytes before marker 0xd5
detected successful!
Distance is 23
Corrupt JPEG data: 1 extraneous bytes before marker 0xd4
detected successful!
Distance is 22
Corrupt JPEG data: 1 extraneous bytes before marker 0xd5
detected successful!
Distance is 26
Corrupt JPEG data: 3 extraneous bytes before marker 0xd3
detected successful!
```

Figure 11. The location displays of face detection.

The triangle similarity goes something like this: There is a man's shoulder with a known width W. This marker is placed some distance D from our camera (De, et al., 2016). Take a picture of the object then measure the apparent width in pixels P. This allows us to derive the perceived focal length F of the camera:

$$F = (P * D) / W \qquad (2)$$

Then we can apply the triangle similarity to determine the distance of the person to the camera. D_N means the real distance from the person to camera; W_N means the width of the person's shoulder; P_N means the new pixels in the photo: As is shown in Figure 12, a simple chart that we can explain the principle of triangle similarity. In addition, the comparison of actual test and measured distance is given in Table 1.

$$D\_N = (W\_N * F)/P\_N \quad (3)$$

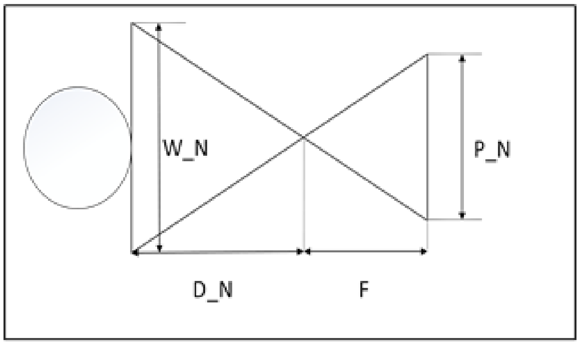


Figure 12. **The triangle similarity explanation.**

Table 1. **The actual test distance results**

Distance/cm	Measured distance/ cm	Actual distance/ cm	error /%
1	24.2	22.5	+1.07
2	25.9	22.5	+1.15
3	24.4	22.5	+1.08
4	21.5	22.5	-0.95
5	26.6	22.5	+1.17
6	24.5	22.5	+1.08

3.4 Communication Module

The mode of communication used in this paper is serial communication, including communication between computer and ARM, computer and Arduino, ARM and Arduino (Feng, et al., 2012). UART (Universal Asynchronous Receiver and Transmitter) in the S3C6410 provides four separate asynchronous serial I / O (SIO) ports. Each asynchronous serial I/O (SIO) port is operated by interrupt or direct memory access (DMA) mode. It is worth mentioning that, in the communication between ARM and Arduino, we use a soft serial port, which is the ordinary I/O port that is converted to serial port. As shown in Figure 13, there is the communication with each other.

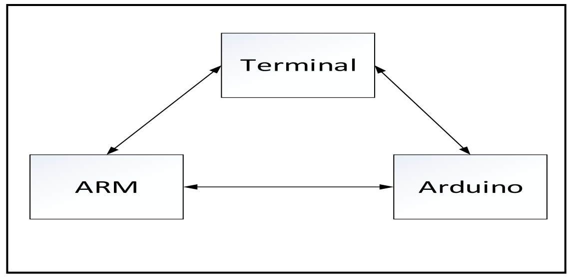


Figure 13. **The serial communication diagram.**

3.5 Security Obstacle Avoidance Module

In this paper, a simple algorithm based on vision for path planning is proposed, and we combine the algorithm and the centripetal rule of path planning in maze robot. The algorithm, in a nutshell, based that gray image is converted to binary one by suitable threshold (Sonka, et al., 2016). When the sum of the pixels of the object in the image is greater than the threshold, the trolley deflects in the direction of where are the pixels less in the picture. This simple algorithm has a certain miscarriage of justice. So we combine the centripetal rule in the algorithm of maze robot, and control the car to avoid obstacles, through the sensor data (Kragic & Christensen, 2017). HC-SR04 ultrasonic integrated module and the near infrared sensor are used in this paper. But the ultrasonic sensor plays the leading role, near infrared sensor equals to the second guarantee (Zhu, 2017). In this paper, the moving average filtering method is used to make the ultrasonic sensors more stable.

3.6 Multi-sensor Fusion and Integration (MFI)

Luo and Kay (1990, 1989, 1995) defined the functional roles of multi-sensor integration and multi-sensor fusion, then proposed a three-level fusion category with adequate fusion algorithms according to the processed data formats proposed the multi-sensor fusion and integration (MFI), which is formed to treat the information merging requirements. These researchers (Luo, et al., 2011) used them to explain the theories, applications and its perspectives. The MFI aims to provide the system a more accurate perception enabling an optimal decision to be made. The wide application spectrum of MFI in mechatronic systems includes industrial automation and development of intelligent robots. The experimental results show that the flexible design system has a good control effect and be able to extend its popularization and application. The robot is used by a carrier and varied mechanical design (such as manipulator, vision, etc.) to realize the intelligent service for human that Figure 14 shows its reality. Figure 15 is the algorithmic processing results for filtering, segmentation and gray, with lighting, without lighting and morphological process. Table 2 is the algorithmic statistics pixel number comparison for lighting and no lighting. Figure 16 shows the intelligent service robot under for two normal conditions, left hand rule and right hand rule. These tests used the proposed method database as Table 3 shown which is for various turning control rules (Luo & Kay, 1995).

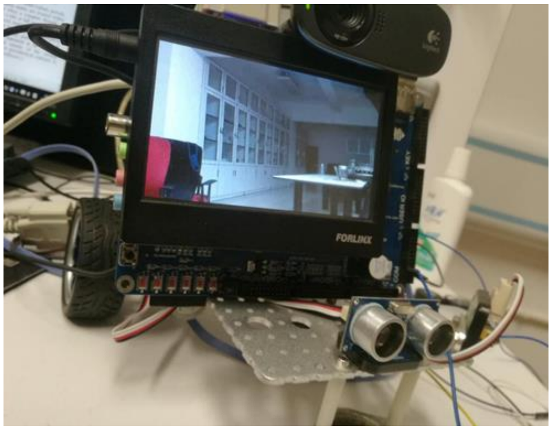


Figure 14. **The realization for the flexible design of intelligent service robot.**

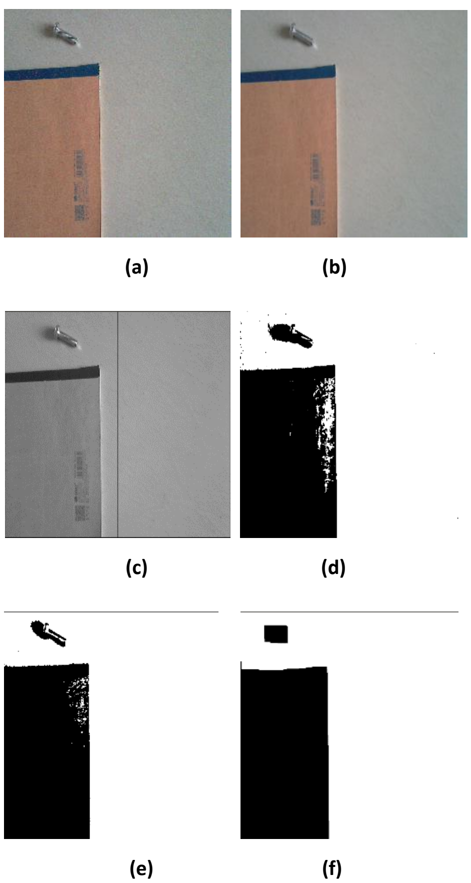


Figure 15. **The algorithmic processing results (a） the original image（b） After filtering (c) segmentation and gray (d) with lighting (e) without lighting (f) morphological process**

Table 2. **The algorithmic statistics pixel number comparison.**

	algorithm	Left pixel number	Right pixel number	%	value
lighting	Adaptive threshold	373940	35	0.0093%	136
	Proposed method	392389	0	0	136
No lighting	Adaptive threshold	417744	4	0.0095%	66
	Proposed method	427469	0	0	66

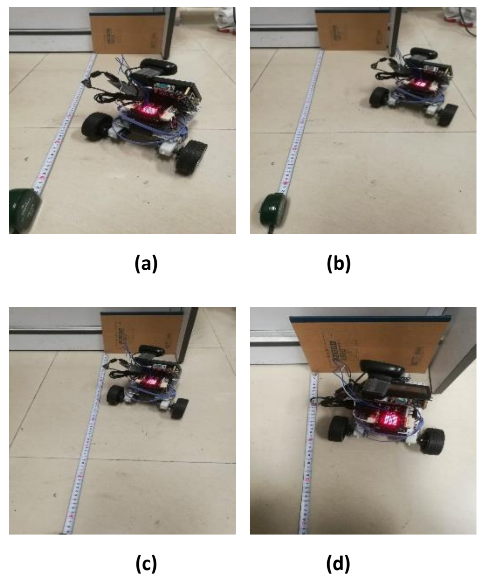


Figure 16. **The intelligent service robot under various conditions (a) normal condition 1 (b) normal condition 2 (c) left hand rule (d) right hand rule.**

Table 3. **The control rule database.**

No.	Pixel comparisons	Measured distance	output
1	left>right	>20cm	Turn right
2	left>right	10-20cm	Turn right
3	left>right	<10cm	stop
4	left<right	>20cm	Turn left
5	left<right	10-20cm	Turn left
6	left<right	<10cm	stop
7	misjudge	>20cm	Turn left
8	misjudge	10-20cm	Turn left
9	misjudge	<10cm	stop

4 CONCLUSION

IN this paper, the design and implementation of a intelligent service robot control system with ARM11176JZF-S as the core module. The design is the modular idea in the control system, and each module cooperates with each other based on multi-sensor data fusion and integration theory with a simple vision algorithm and a control method. A flexible design concept of intelligent service robot is proposed and tested. The experimental tests show that the intelligent service robot can precisely detect obstacles and judge the turning direction.

5 REFERENCES

Aldana-Murillo, N. G., Hayet, J. B. & Becerra, H. (2018) Comparison of Local Descriptors for Humanoid Robots Localization Using a Visual Bag of Words Approach. Intelligent Automation and Soft Computing, vol. 24, no. 3, pp. 471-481.

Becerra, H. (2014), Fuzzy Visual Control for Memory-Based Navigation Using the Trifocal Tensor. Intelligent Automation and Soft Computing, vol. 20, no. 2, pp. 245-262.

Cai, J., Wu, Y. & Xu, H. (2017), & Zhang, W., Design and Implementation of Control System for a Restaurant Service Robot. Computer Measurement & Control, vol.25, February. pp. 77-80.

Chen, M. Y. (2018). The SLAM Algorithm for Multiple Robots based on Parameter Estimation. Intelligent Automation and Soft Computing, vol. 24, no. 3, pp. 593-607.

Chou, Y. C. & Nakajima, M. (2016), Particle filter planar target tracking with a monocular camera for mobile robots. Intelligent Automation and Soft Computing, vol. 23, no. 1, pp. 117-125.

De, X., Ming, T. & Yuan, L. (2016), Visual Measurement and Control for Robots. National Defense Industry Press, 2016, pp.124-127.

Feng, X., Chu, X. & Yan, W. (2012), ARM11 Embedded Linux System Practice and Application, China Machine Press, Sep.2012, pp.132-153.

Kragic, D. & Christensen, H. I. (2017), Cue Integration for Visual Servoing. IEEE Transactions on robotics and automation, Vol.17, No.1, pp.460-463.

Linderoth, M., Robertsson, A., Åström, K. & Johansson, R. (2010), Object Tracking with Measurements from Single or Multiple Cameras. IEEE International Conference on Robotics and Automation Anchorage Convention, USA, 2010, 4525-4530.

Luo, R. C., Chang C. C. & Lai, C. C. (2011), Multisensor Fusion and Integration: Theories, Applications, and its Perspectives. IEEE Sensors Journal, Vol.11, No.12, pp. 3122 - 3138.

Luo, R. C. & Kay, M. G. (1990), A tutorial on multisensor integration and fusion. in Proc. 16th Anuu. Conf. IEEE Ind. Electron., 1990, vol. 1, pp. 707–722.

Luo, R. C. & Kay, M. G. (1995), Multisensor Integration and Fusion for Intelligent Machines and Systems. Norwood, MA: Ablex Publishing, 1995.

Luo, R. C. & Kay, M. G. (1989). Multisensor fusion and integration in in-telligent systems," IEEE Trans. Syst., Man, Cybern, vol. 19, no. 5, pp.901–931.

Ma, C., Fang, F. & Ma, X. (2016), Task planning of mobile robots in distributed service framework. IECON 2016 - 42nd Annual Conference of the IEEE Industrial Electronics Society, Italy, 2016, 342-347.

Minichino, J. & Howse, J. (2010), Learning OpenCV3 Computer Vision with Python. China Machine Press, 2016, pp.70-82.

Sonka, M., Hlavac, V. & Boyle, R. (2016), Image processing, analysis, and machine vision, Tsinghua University Press, 2016, pp.130-139.

Strnad, B. (2017), Programming Lego Mindstorms for First Lego League Robot game and technical interview. 2017 40th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Croatia, 2017, pp.958-960.

Tan, B. H., Tang, H., Yan, R. & Tani, J. (2014), A Flexible and Robust Robotic Arm Design and Skill Learning by Using Recurrent Neural Networks. IEEE/RSJ International Conference on Intelligent Robots and Systems, USA, 2014, pp. 522-529.

Zhu, F. (2017), Artificial Intelligence, Tsinghua University Press, 2017, pp.312-322.

6 NOTES ON CONTRIBUTORS

Li-Hong Juang received the B.S. degree in civil engineering from the National Chiao Tung University, Taiwan, in 1990 and the M. S. degree in applied mechanics from the National Taiwan University, Taiwan, in 1993, and Ph.D. degree in control and embedded system group from Department of Engineering at Leicester University, UK, in 2006. After his master's degree, he worked for machinery, electrical and computer industries for over ten years, then he went to the Department of Engineering, Leicester University, and began his PhD study for electrical engineering about motor design and control for three years. Finally, he published six SCI papers including two IEEE transaction journal papers. After finishing his PhD, he worked at several universities as an assistant professor to the chair professor for over another ten years. During that period, his research interest was focused on power systems, medical systems, system control, and AI robots. Now, he joins the School of Electrical Engineering and Automation, Xiamen University of Technology, and serves as a distinguished professor. He continues to make his contribution to the smart system application for engineering and science, especially for the computer vision, intelligent robot, medical system, and cloud computer platforms for the Internet of things. He has gotten fourteen project grants and published fifty SCI papers, twenty-five EI papers, six book chapters, one whole book, and twenty-four patents. Currently, he services as the Editor in Chief for Journal of Mechanical and Automation Engineering and the Associate Editor for IEEE Access Journal.

Shengxiang Zhang is pursing the M. S. degree in Department of IOT, National HuaQiao University, P. R. China. His research interests are in robot control and pattern recognition.