An indoor mobile robot positioning system based on radio-frequency identification

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ABSTRACT. *Based on radio-frequency identification (RFID), this paper designs an upper and lower computer control system to solve the problems of existing indoor mobile robot positioning techniques. The Matlab graphical user interface was employed to build the software platform (i.e. upper computer) of the information database in the mobile robot positioning system, while the STM 32-based mobile robot control was adopted to design the hardware control system (i.e. lower computer). In addition, the data transmission between the computers and the robot was realized using the serial communication technology in Matlab Toolbox and CC2530 wireless communication, laying the basis for robot positioning. The proposed control system was proved effective in enhancing the robot's responsiveness and controllability and solving the problems of the lower computer (e.g. low computability and insufficient storage). This research marks the trend of mobile robot positioning technology..*

RÉSUMÉ. *Basé sur l'identification par radiofréquence (RFID en anglais), Cet article conçoit un système de contrôle de « upper and lower computer » afin de résoudre les problèmes posés par les techniques de positionnement de robots mobiles d'intérieur. L'interface utilisateur graphique de Matlab a été utilisée pour créer la plate-forme logicielle (upper computer) de la base de données dans le système de positionnement de robot mobile, tandis que la commande de robot mobile basée sur STM 32 a été adoptée pour concevoir le système de contrôle de hardware (lower computer) . En outre, la transmission de données entre les ordinateurs et le robot a été réalisée à l'aide de la technologie de transmission série de la communication sans fil de Matlab Toolbox et CC2530, jetant les bases du positionnement du robot. Le système de contrôle proposé s'est avéré efficace pour améliorer la réactivité et la contrôlabilité du robot et pour résoudre les problèmes de l'ordinateur inférieur (par exemple, une faible calculabilité et un stockage insuffisant). Cette recherche marque la tendance de la technologie de positionnement de robot mobile.*

KEYWORDS: *MATLAB GUI, RFID, positioning, indoor mobile robots, control box.*

MOTS-CLÉS: interface graphique de MATLAB, identification par radiofréquence (RFID en anglais), positionnement, robots mobiles d'intérieur, boîtier de commande.

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1. Introduction

As one of the foremost fronts of mobile robot studies and technologies, robot positioning technology is faced with strict requirements. Robots are expected to be positioned in precise coordinates and in real time so as to perform tasks quickly and accurately. Positioning methods vary with operating environments and are usually divided into outdoor positioning and indoor positioning. The former one includes inertial positioning, GPS positioning, and landmark positioning; while the latter one is realized by means of infrared (Kirsch *et al*., 1997), ultrasonic (Foxlin *et al*., 1988), WLAN positioning (Bahl and Padmanabhan, 2000), RFID positioning (Guo *et al*., 2012), visual positioning etc. Our research object is indoor mobile robots. Among the above approaches, GPS positioning and communication is based on satellites, which limits its use to outdoor environments. GPS is commonly used in military and civilian fields, but the positioning accuracy is not high enough in civilian areas due to the influence of various factors such as shadows and obstacles (Fang and Wan, 1996). Infrared positioning is narrowly applied because it requires close contact and parallel arrangement. Ultrasound positioning is inapplicable in large areas or complex conditions, albeit with high precision. For WLAN positioning, the transmitted signal strength may attenuate in complex indoor environment. In this case, the positioning precision is reduced. Radio frequency identification (RFID) devices locate robots by reading the sole ID number of an electronic tag, the tag size determining location accuracy.

In the mobile robot research, the control system is a robot’s key component, just like a human’s brain. With the continuous development of robotic, it has been applied in all walks of life. As the tasks of robots become increasingly complex, common processors can no longer meet the requirements of computing power, data storage, etc. In this background, the MATLAB software is used to establish the positioning system’s PC in the PC-based platform. We take advantage of the MATLAB software’s database storage capabilities and strong computability to perfectly coordinate the two control systems of a mobile robot.

2. MATLAB serial communication

Low-level protocol is a serial communication between two or more devices. The serial communication of MATLAB Toolbox (instrument control toolbox) enables the computer to control external devices. Below are the features of the toolkit (Luo and Lu, 2002):

(1) Support serial interface (RS-232, RS-422, RS-485), GPIB (IEEE2488, HPIB standard), and VISA bus communications;

(2) Support binary transmission of data between binary and text (ASCII);

(3) Support asynchronous and synchronous communications;

(4) Support event-driven communications.

The toolbox creates objects through serial port. Serial objects are called according to properties and set to support functions. Users can configure serial communication, use the serial port control pin and callbacks, read and write data, and record information onto disks (Luo and Lu, 2002). Therefore, MATLAB Serial Instrument Control Toolbox supports the communication between PC and lower computer. The toolbox's schematic diagram is shown in Figure 1.

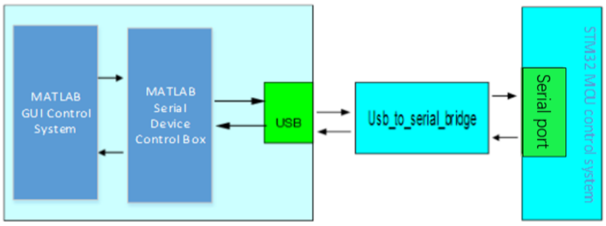


Figure 1. MATLAB environment under real-time control serial communication system diagram

3. MATLAB GUI introduction and application

MATLAB GUI design is an object-oriented programming language (Wang *et al.*, 2012) without much complicated work on programming. GUI is a human-machine interface that can be easily established.

MATLAB GUI provides various operational controls, including a convenient GUIDE user interface that is controlled by callbacks in M-files. Only by modifying programs in the M-file can a user complete the corresponding control. Also, by programming procedures, users can control GUI behaviors (Wang *et al.*, 2012). The GUIDE interface is shown in Figure 2.

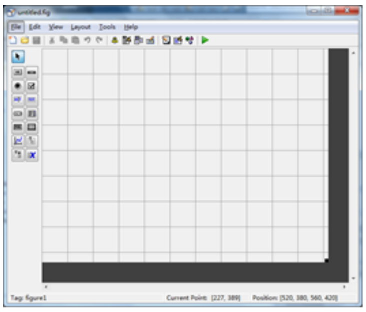


Figure 2. MATLAB GUI design interfaces

In this paper, the user interface control objects are created by using Push Button, Check Box, Edit Text, Static Tex, Toggle Button, axes, etc. With fig files, we set up the whole control interface of M-files and modify programs. Serial communication parameters are set, and the reception and transmission of positioning data are displayed in charts. In addition, the user interface has video monitoring serials and robot control buttons. It can acquire the coordinates of indoor robots and store all the information in the M-file.

4. Indoor mobile robot PC interface design

PC-based real-time serial communication is realized in the microcontroller of the MATLAB Serial Device Control Toolbox. The implementation of mobile robot localization and image monitoring system greatly simplifies system development and shortens its time. The host computer of the mobile robot positioning system is designed with functions of data reception, data transmission, robot positioning coordinates display, robot positioning simulation graphics, video surveillance robots, robot control, robot camera, etc. These functions are performed on the premise of serial communication of data transceivers. Therefore, serial communication control is the first priority of PC interface design, followed by the setting of serial communication parameters of serial number, serial port opening and baud rate. The PC interface of the indoor mobile robot control system is shown in Figure 3.

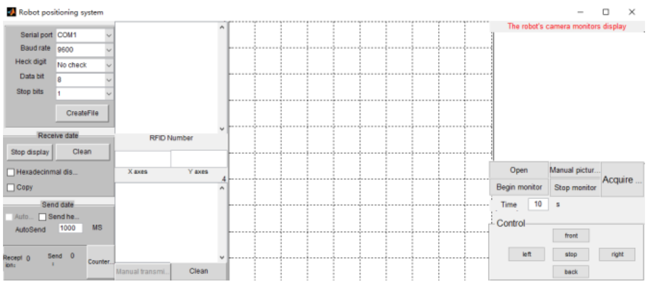


Figure 3. Indoor mobile robot control system PC interface

The entire layout can be seen from the interface of Figure 3. PC serial interface parameter setting is required to realize PC serial communication. The interface can display the simulated or real-time location coordinates and location model patterns; It also supports the extra functions of robot image monitoring and robotic camera control. For example, the camera can move left, right, forward, or back under manual control.

5. RFID technology

In recent years, radio frequency identification (RFID) technology has become a well-received automatic identification technology. This non-contact identification system identifies RFID tags via radio frequency signals and processes related information in chips (Hanel *et al*., 2004). A simple RFID system is composed of radio frequency tags, readers, software and other add-ons (Finkenzeller, 2003). Robotic is one of the many application fields that RFID serves for (Yamano *et al*., 2004; Ohno *et al*., 2003). The operating principle is that every RFID tag has a card number with unique features which corresponds to the one and only coordinate of the mobile robot in the operating environment. The accuracy of RFID positioning is about 8cm, which can address conventional positioning issues.

The RFID equipment used in this paper has 9 uniformly distributed label cards with the size of 25cm*25cm, and the operating frequency is 2.5GHz. Figure 4 shows the positions of RFID cards, with a cross mark in the center.

Figure 4. Set 9 RFID cards

The indoor test is conducted in a 2.5m × 2.5m space with 30 × 30 RFID cards covering the area, as shown in Figure 5. The host computer's database is stored in a 30 × 30 matrix, which means that each tag is stored in a row and column. In this way, the PC provides an absolute position coordinate or location information for the label card. The barrier gate of the RFID card in the operating environment is shown in Figure 5. The obstacle map is created to simulate robot positioning in PC graphics.

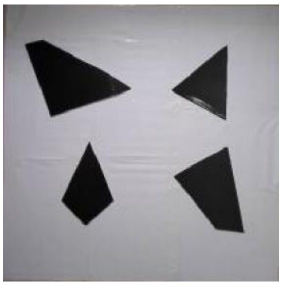


Figure 5. Robot operating environment

6. Building a wireless communications platform

The wireless communication method is commonly used in achieving mutual communication between the upper and lower computers. In this paper, the wireless communication module consists of Texas Instruments' CC2530. It has a high degree of integration and rich peripheral interfaces. TI's Z-Stack protocol stack supports and easily modifies multiple platforms. An operating system abstraction layer (OSAL) provides operating system calls to software and hardware (Peng, 2014).

According to ZigBee wireless networking, a terminal node and control center (CC2530 coordinator) constitute a wireless network. After data are collected by the slave computer, they are sent from the STM32 to the coordinator via the serial port. Then, the coordinator forwards the data to the PC. The PC processes and analyzes data and sends data commands to the terminal. The STM32 recognizes the instructions and acts under the command. The flow charts of the program coordinator and the terminal program are shown in Figure 6 and Figure 7, respectively.

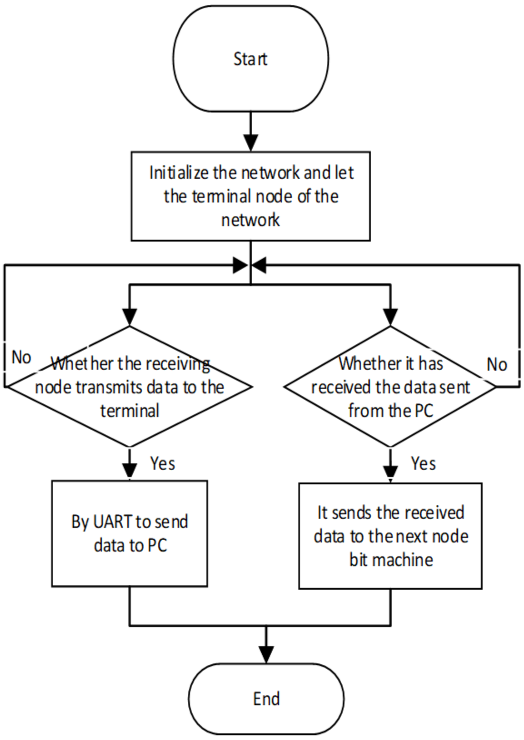


Figure 6. Control system programs flows diagram coordinator

As can be seen from Figure 6, the coordinator is responsible for the formation of the whole system network. When the terminal is attached to the network, the coordinator determines whether the information is sent to the terminal and PC via the serial port. When the PC sends a command to the coordinator, it immediately triggers an interrupt, and the command is sent to the lower computer through broadcast. When the coordinator receives the information sent from the terminal, it will transmit the message to the host computer.

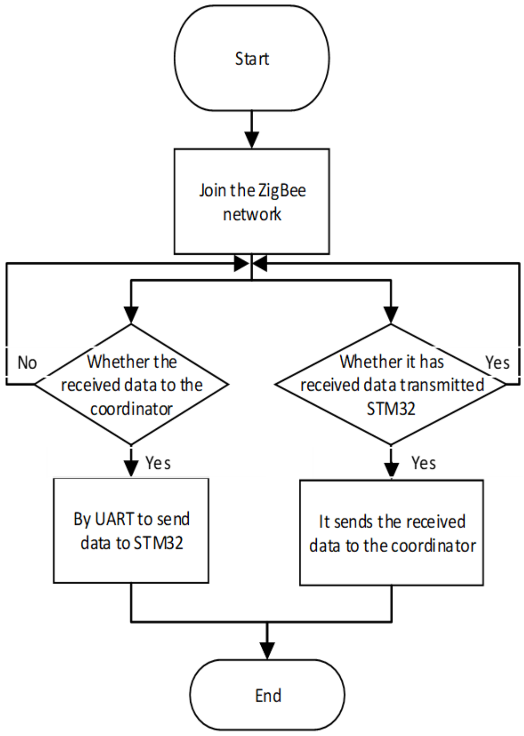
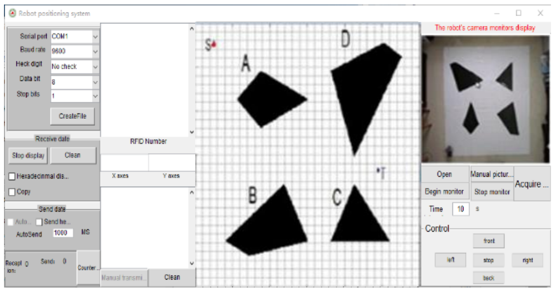


Figure 7. Control system is terminal node program flow charts

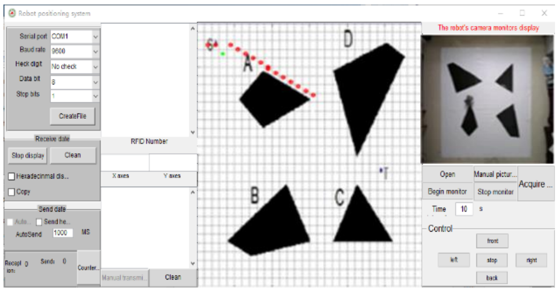
As can be seen in Figure 7, the configuration information of the terminal node initializes itself and automatically joins the ZigBee network. Then, the receiver sends a message back to the coordinator, which will be decided by the STM32 whether or not to be transmitted to the terminal device. When the terminal receives the information from the coordinator, the information is transmitted to the next instruction via the serial-bit machine.

7. Indoor mobile robot control system implementation

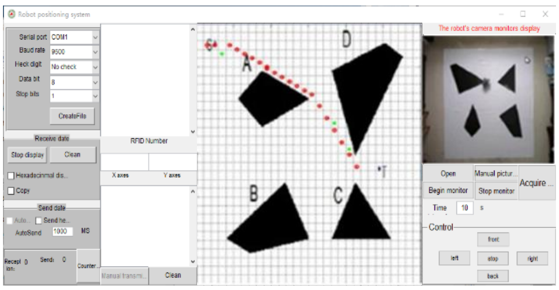
The indoor mobile robot control system can be divided into three parts: PC, the slave computer, and the wireless module. The PC of the robot positioning system is started in the operating environment. The serial communication parameters of the wireless module are set. Then, the slave computer is started to scan RFID tags. The tag numbers are sent to the host computer to search for robot coordinates by using the function of [x, y] = find (RFID = ID) [RFID to store the ID (i.e. tag numbers) of all RFID tags in a matrix]. In this function, x is the horizontal axis of the robot and y is the vertical axis of the robot. Robot positioning is simulated in PC graphics. The external camera properties are determined in MATLAB Toolbox. The test results of indoor mobile robot navigation and positioning are showed in Figure 8.



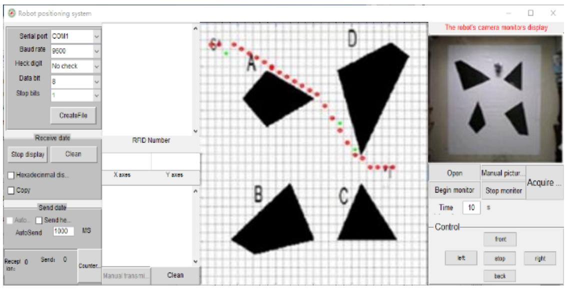
(a)



(b)



(c)



(d)

Figure 8. Indoor mobile robot navigation and positioning test renderings

8. Conclusion

In the field of indoor mobile robot research, robot positioning technology has become a major research direction. In this paper, the upper and lower computers of the indoor mobile robot control system are designed. The PC system software is established in MATLAB platform to take advantage of its computing power, data processing capabilities, and rapidly developed interactive control interface; for the lower computer, the control platform is established on the ARM STM 32 chip, so as to meet the data processing capability of the robot. The ZigBee wireless network enables the communication between PC and the lower computer. In this way, the indoor mobile robot positioning system is implemented. This design approach can save the storage resources of the lower computer, strengthen the computing power of the control system, and simplify the process of information database building. It can also enhance the sensitivity and controllability of robots. The experimental results show the feasibility and effectiveness of the indoor mobile robot positioning system.

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