Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 32 (2019) 572–577

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

The 12th International Conference Interdisciplinarity in Engineering

Mobile Robot Platform with Arduino Uno and Raspberry Pi for Autonomous Navigation

Stelian-Emilian Oltean[a,]*

[a] "Department of Electrical Engineering and Computers, University of Medicine, Pharmacy, Sciences and Technology of Targu Mures, Nicolae Iorga st., No.1, 540088 Targu Mures, Romania

Abstract

Mobile robots represent a very attractive and multidisciplinary field with a lot of applications and scientific research possibilities. The development of microcomputers, single board computers and embedded systems has helped to deploy low-cost solutions for this domain. In this paper is proposed such a low cost mobile robot platform with fixed four wheel chassis, commended by Raspberry Pi and Arduino Uno interfaces. The mobile robot has the ability to move into 2D environments as line follower robot with mapping, navigation, and obstacle avoidance features. The platform contains also one degree of freedom (DOF) robotic arm for lifting and transport of the obstacles.

Selection and peer-review under responsibility of the 12th International Conference Interdisciplinarity in Engineering.

Keywords: mobile robot platform; line follower robot; Raspberry Pi; Arduino; autonomous navigation; map-based navigation.

1. Introduction

Although the mobile robots have been used in industry for some time, they have become increasingly present in everyday life. The fast development in microelectronics, communication, automation, navigation and robotics has rapidly changed the working environment and now mobile robots are a part of modern life (see the autonomous vehicle, self-driving car, drones, security services, etc).

* Corresponding author. Tel.: +4-0265-233-212; fax: +4-0265-233-212.
E-mail address: stelian.oltean@ing.upm.ro

Selection and peer-review under responsibility of the 12th International Conference Interdisciplinarity in Engineering.
10.1016/j.promfg.2019.02.254

Mobile robots are generally those robots which can move from place to place to perform desired and complex tasks, simple but time intensive, repetitive or dangerous. Nowadays, robots replace humans doing indoor or outdoor activities in many fields including: office, military, hospital operations, sports, agriculture, and other [1,2].

There are different constructive variants of mobile robots, but lately with the mass development of microcomputers and embedded systems, it is possible to develop low-cost solutions. Depending on their destination, mobile robots may have different configurations, multiple sensors (infrared, ultrasonic, webcams, GPS, magnetic, etc) or different command and control algorithms, being locally or remotely supervised.

In [3,4,5] the wheeled mobile robots are real time controlled via the internet using a protected webpage or Internet of Things (IoT) technology. All the platforms are based on single board computer Raspberry Pi and allow online viewing of the working environment through the webcam. Some works [6,7] have a strong teaching focus, the mobile robots being modularly designed and reused as a support material in the study of robotics. There are, of course, platforms built with a more precise purpose. Thus, in [8] is presented a low cost autonomous indoor tour guide robot running on Raspberry Pi 2; in [9] a GPS-guided mobile robot based on Silicon Labs C8051f020 controller and Navman Jupiter 30 GPS chip is used outdoor for agricultural industries; in [10] the authors developed a mobile robot for the exploration and mapping of air ventilation ducts; in [11] the project aims to build a monocular vision autonomous car prototype. Besides the mechanical and electronic design, another important part of this field is related to mapping, localization and autonomous navigation algorithms, path following, monitoring or risky situation detection, obstacle detection and avoidance [7,10, 12-16].

In this paper we proposed a mobile robot platform which has a fixed four wheel chassis. The platform was designed around the Raspberry Pi single board computer and use Arduino Uno to control the movement of the chassis. The platform was equipped with multiple sensors and a Pi camera, but also has a robotic arm for lifting and transporting the obstacle. The communication protocol between the components and the features implemented on the platform are presented, and in the final part of the paper are proposed some applications that will be addressed in the future.

2. Aspects of hardware platform design

2.1. Mobile robot mechanical structure

The robot mechanical platform it is based on a fixed four-wheel configuration chassis driven independently by four DC motors. So, for a forward/reverse movement of the chassis, all the four motors are driven in the same direction with the same desired speed. In order to perform a chassis rotation, the motors on the different side will be driven counterclockwise. In this fixed four-wheel configuration, also two engines can be used, if a common two-wheel drive system is implemented on each side of the mobile robot.

On the chassis are mounted two 15cmX20cm boards as shown in Fig. 1 which contains all the electronic interfaces connected to the sensors and motors.

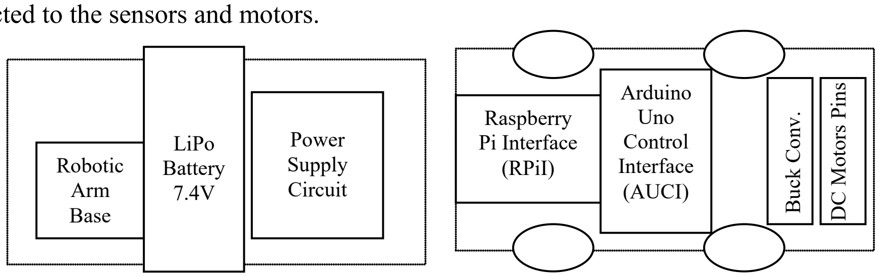

Fig. 1. Mobile robot platform (a) Top floor board; (b) Lower floor board.

On the top floor of the robot chassis the board contains the power supply circuit, the LiPo battery (with 4000 mAh capacity, 7.4V) connected to it and the base of a robotic arm. The lower floor houses the main control components such as Raspberry Pi and Arduino Uno, but also the Buck converter. For powering the four DC motors positioned under the robot chassis there are eight pins available. The front of the robot contains the three infrared sensors which can be used for line follower robot applications, a central ultrasonic sensor needed to detect the obstacles and a Raspberry Pi camera to identify the color or shape of the obstacles. On each side of the robot there is an ultrasonic sensor that can be used to detect the walls. The platform includes a 1DOF robotic arm with a gripper who has 13 cm maximum opening length that allows the lifting and eventually transporting the obstacles. The arm and the gripper are actuated by two servomotors.

2.2. Electronic interfaces

The block diagram of the electronic part of the mobile robot is shown in the Fig. 2 and has two main components, Raspberry Pi Interface (RPiI) and Arduino Uno Control Interface (AUCI). These two components communicate through I2C (Inter-integrated Circuit) bus and the functionality of the mobile robot is dependent on the continuous exchange of information. As can be seen from Fig. 2, RPiI has direct access to the camera and controls the robotic arm servomotors, while AUCI has the role of reading and interpreting infrared sensors, reading the ultrasonic sensors and controlling the DC motors which drive the platform.

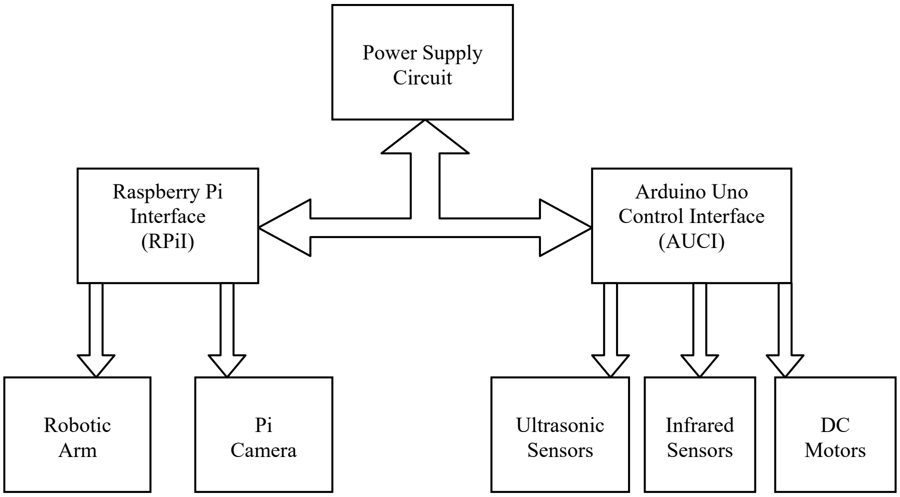

Fig. 2. Block diagram of the electronic part of the mobile robot platform.

The “brain” of the mobile robot platform is Raspberry Pi which is a small single-board computer that can be programmed to manage the robot operation (mapping, navigation, obstacle detection and avoidance/transport). The Raspberry Pi 3 Model B used in this project offers 4 USB ports, 1 ethernet port, wireless and bluetooth connectivity. This model delivers good performance thanks to its 1.2 GHZ quad-core ARM Cortex A53 and 1GB of RAM. In order to be used as a normal computer the Raspbian operating system must run.

In addition to this small computer, other components such as the Arduino Uno, ultrasonic and infrared sensors, servomotors and dc motors are required. The Arduino Uno Control Interface AUCI is a microcontroller board based on the ATmega328P (datasheet) and has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button.

The power supply circuit board has a 7.4V input from the LiPo battery, required to power the Arduino Uno Control Interface and the Buck converter (CC-CC type) and has 5V output required for the Raspberry Pi board, DC motors drivers and sensors.

The four DC motors, two on each side of the chassis, are controlled by Arduino Uno, with PWM signals via specialized drivers (with H-bridge circuits). The DC motors have a maximum torque of 0.8 kg-cm, at a supply voltage between 3 and 6 V. At 5 V, the DC motors consume about 100mA to reach a speed of 200 rpm.

The robotic arm is actuated by two servomotors. The first servomotor is located at the base of the robotic arm and assures 15cm movement of the arm link, being able to develop a maximum torque of 9.4 kg/cm at a supply voltage of 4.8V. The second servomotor is located at the top of the robotic arm for catching/lifting the objects. It is able to develop a maximum torque of 3.17 kg/cm at a supply voltage of 4.8V.

3. Software features implemented on the mobile robot platform

3.1. I2C communication protocol

The information exchange between RPiI and AUCI takes place through the I2C synchronous communication protocol. Raspberry Pi is the "Master" component that initiates the data transfer to the "Slave" component Arduino Uno, which provides the response messages.

Messages sent on I2C bus are divided in two frames: an address frame representing the address to which the message is to be sent and a data frame that may contain one or more 8-bit fragments.

The software protocol implemented on the robot platform includes two types of messages in the data frame: *Command message* and *Request message*. According to this protocol the first byte of the data frame is the identification code of the message. For a *Command message*, AUCI performs the command received through the protocol, while upon receipt of a *Request message*, AUCI provides the necessary information for the Raspberry Pi.

The Table 1 shows all the messages implemented in the transmission between Raspberry Pi and Arduino Uno and Fig. 3 shows as example the *Command message* sent by the RPiI. In this message the address where the message should be sent is 0x04, representing the address of the AUCI Interface and the identification code of the message is 22. The others 4 byte from the data frame set the duty cycles of the PWM command signals used by Arduino Uno to control the desired speeds of the DC motors. The maximum 8 bit value sets a 100% duty cycle of the PWM command signal given by the Arduino Uno.

Table 1.Messages implemented for I2C serial communication.

Messages	Identification codes
Command messages	22, 44, 55, 66, 77, 99, 110, 121
Request messages	11, 33

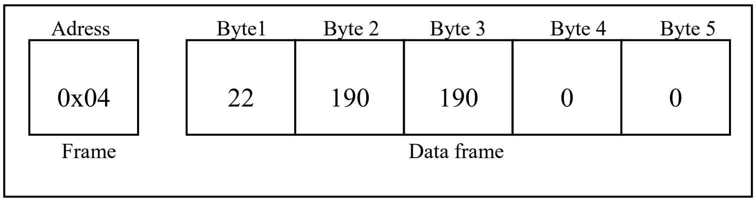

Fig. 3. I2C Message sent by RPiI (*Command message, code 22*).

The *Command message 22* described in the previous paragraphs sets the PWM signals duty cycle. *Command messages* with codes 44, 55, 66 and 77 allow the Raspberry Pi to control the status of the robot without directly modifying the PWM settings of the DC motors. Depending on the identification code from the message sent, the robot can be stopped (STOP), it can continue (CONT) or it can rotate to the left/right (LEFT / RIGHT). The code 99 can be used to move the robot a little bit forward when it is not close enough to the object that should be picked up. Codes 110 and 121 are used to enable/disable the robot scan mode when the robot does not have any information about the route and needs to do a 2D mapping. Code 110 activates the mapping mode and all ultrasonic sensors, in front and on each side of the chassis needed for the obstacles and walls detection. Code 121 disables this mode of operation and activates the line follower mode when only the front ultrasonic sensor is needed to detect the obstacles for a known route.

In case of *Request messages*, the AUCI responds with the ultrasonic sensors values (for code 11) or the infrared sensor values (for code 22).

3.2. Functions

In the way the mobile robot platform was designed, the Arduino Uno Control Interface has direct connections to: infrared sensors, ultrasonic sensors and DC motors. Thus, the application implemented on the Arduino Uno ensures:

- moving the robot in the desired direction;
- reading the infrared sensors for line detection;
- operation as a line follower robot by reading the infrared sensors and controlling the four DC motors;
- reading the ultrasonic sensors to detect the route walls and the distance to the obstacle.

To program the AUCI, the Arduino IDE development environment and the C / C ++ type programming language were used. One of the most important features of the AUCI is to provide the line follower robot mode. In this function AUCI uses the information from the infrared sensors, indicating their relative position to the desired line (Fig. 4).

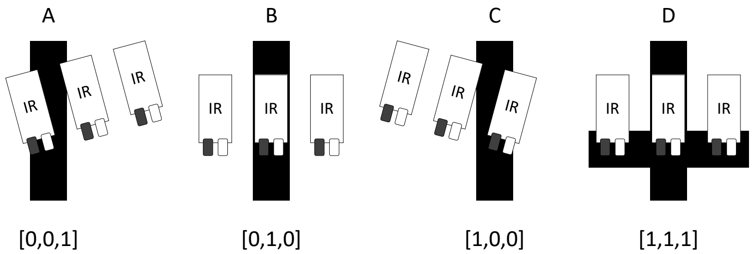

Fig. 4. Positions of the infrared sensors on the line.

The first three situations presented in Fig. 4 are treated locally by the AUCI for line follower mode. The latter case is encountered at the intersection of lines (rows and columns) and treated on the Raspberry Pi application for mapping the route.

The Raspberry Pi Interface has direct connections to: Pi camera and servomotors which moves the robotic arm. So, the following tasks could be activated on RPiI:

- 2D mapping, route planner and navigation;
- image capturing using the Pi camera and detection of the obstacle
- digital image processing to obtain the shape or color of the obstacle;
- catching and lifting the obstacles;
- transporting obstacles to the desired positions.

4. Environment

The platform was designed for autonomous navigation in 2D environments with the map shape presented in Fig. 5. These maps will have horizontal and vertical lines which must be recognized by infrared sensors, walls and obstacles recognized by ultrasonic sensors and camera. Depending on the desired specifications, several operating modes can be implemented on the mobile robot:

- navigation in a known 2D map (the number of intersections, length and width of the map are known);

- navigation in unknown environments (the walls and intersections of lines are used for 2D mapping).

Also, the navigation contains several features: point-to-point trajectory, route from a fixed starting point to different desired locations of the map; route with obstacle avoidance, route with recognition and identification of the obstacles, route with obstacle transportation to the specified location on the map.

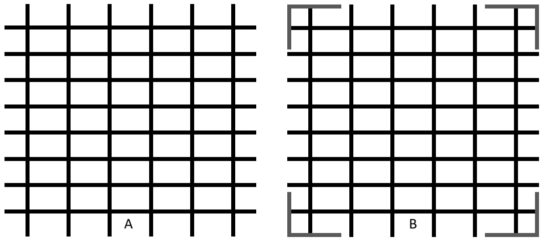

Fig. 5. Map shape proposed for the 2D environment: (a) known environment; (b) unknown environment with walls.

5. Conclusions

In this paper it was proposed a mobile robot platform with a fixed four wheel configuration chassis and having an electronic system designed around the Raspberry Pi and Arduino Uno Interfaces. The mobile platform meet some basic design requirements for this stage of development, being a low-cost solution, highly reliable and extendable, used in teaching (as didactic stand for microcontrollers, electronics, automation, robotics), but also in research activities to study different algorithms of mapping, localization, navigation, obstacle detection and transport. The mobile robot platform could be a starting point for future research and some possible applications are: autonomous guide robot for indoor environment; medical use for assisting the patients; military applications; packaging and organizing pallets in warehouses; transport of waste material, laundry, food, pharmaceuticals or mails.

Acknowledgements

This paper is based upon work supported by the Energy and Electrotechnologies Management research centre. I would like to thank eng. Eduard Stănescu for his support in developing and testing the mobile robot platform.

References

[1] R. Siegwart, I.R. Nourbakhsh, Introduction to Autonomous mobile robots, A Bradford Book, The MIT Press, (2004).
[2] L. Jaulin, Mobile robotics, ISTE Press Elsevier, (2007).
[3] Nabeel Kadim Abid Al-Sahib, Mohammed Zuhair Azeez, Build and Interface Internet Mobile Robot using Raspberry Pi and Arduino, Innovative Systems Design and Engineering, 6:1 (2015) 106-114.
[4] M. Vanitha, M. Selvalakshmi, R. Selvarasu, Monitoring and controlling of mobile robot via internet through raspberry Pi board, 2016 Second International Conference on Science Technology Engineering and Management ICONSTEM, (2016).
[5] E. Küçükkülahl, R.Güler, Open Source Mobile Robot with Raspberry Pi, Balkan J. of Electrical & Computer Eng., 3:4 (2015) 242-247.
[6] B.Benson, A.Danowitz, J.Edmonds, Design of an Autonomous Robot with the Raspberry PI platform, Summer Workshop College of Engineering Cal Poly, (2016).
[7] Daniel Jimenez Mendoza, Computer Vision applied to autonomous robots using Raspberry Pi, Universitat Autonoma de Barcelona, (2014).
[8] Alpha Daye Diallo, Suresh Gobee, Vickneswari Durairajah, Autonomous Tour Guide Robot using embedded system control, Procedia Computer Science, 76 (2015) 126-133.
[9] Samuel J.O. Corpe, Liqiong Tang, Phillip Abplanalp, GPS-Guided Modular Design Mobile Robot Platform for Agricultural Applications, Seventh International Conference on Sensing Technology, (2013) 810-814.
[10] M. A. Koledoye, D. De Martini, M. Carvani, T. Facchinetti, Design of a Mobile Robot for Air Duct Exploration, Robotics, 6, 26 (2017) 1-17.
[11] Gurjashan Singh Pannu, M.D. Ansari, P. Gupta, Design and Implementation of Autonomous Car using Raspberry Pi, International Journal of Computer Applications, 113:9 (2015) 22-29.
[12] C.F. Ciurea, A.V. Duka, S.E. Oltean, Automatic mapping of an enclosure using a mobile robot, Procedia Technology 8 (2013) 50–56.
[13] S. E. Oltean, M. Dulău, R. Puskas, Position Control of Robotino Mobile Robot Using Fuzzy Logic, IEEE International Conference on Automation, Quality and Testing, Robotics AQTR, (2010).
[14] David Filliat, Jean-Arcady Meyer, Map-based navigation in mobile robots: I. A review of localization strategies, Cognitive Systems Research, 4:4 (2003) 243-282.
[15] F. Bonin-Font, A. Ortiz, G. Oliver, Visual Navigation for Mobile Robots: a Survey, J. of Intelligent & Robotic Systems, 53:263 (2008), 1-26.
[16] Jean-Arcady Meyer a David Filliat, Map-based navigation in mobile robots. II. A review of map-learning and path-planning strategies, Cognitive Systems Research, 4:4 (2003) 283-317.