UDC 621.65.052

CUSTOM MOBILE ROBOT CONTROLLED BY ANDRIOD SMARTPHONE

T. Vince, J. Hricko
Technical University in Košice, Slovakia
Park Komenského, 3, Košice, 042 00, Slovak Republic. E-mail: tibor.vince @tuke.sk

This article describes design and realization of mobile robot controlled by Android device. The hardware parts are described. Individual sections describe choice process over the suitable movement electric motors with wheels, power source – battery type, Bluetooth module, different type of sensors – IR and rotation sensor, LCD and microprocessor. Suitable PCB is designed, function model of the robot is built and in the end the control application for OS Android devices is described. Developed Android application allows the user to control the robot's movement using arrows or gyroscope of the smartphone. Presented example of design and creation a simple robot is very good experiment for a students to get experiences in PCB design, hardware construction but also software programming of microcontrollers and also Android devices.
Key words: mobile robot, Android, AVR microprocessor.

МОБІЛЬНИЙ РОБОТ ІНДИВІДУАЛЬНОГО ВИКОНАННЯ, КЕРОВАНИЙ ANDROID-СМАРТФОНОМ

Т. Вінсе, Я. Хрічко
Технічний університет Кошице, Словаччина
Парк Коменського, 3, Кошице, 042 00, Словаччина. E-mail: tibor.vince@tuke.sk

Описано проектування, розробку й апаратне забезпечення мобільного робота, керованого Android-пристроєм. Окремі частини роботи присвячені питанням вибору оптимального складу апаратного забезпечення, а саме: обертових електричних машин з колесами, джерела енергії типу «батарея», модуля Bluetooth, інфрачервоного датчика й датчика швидкості обертання, рідкокристалічної панелі та мікропроцесора. Розроблено відповідну печатну плату, побудовано функціональну модель робота й створено керуючий додаток для пристроїв, що працюють під керуванням операційної системи Android. Розроблене програмне забезпечення для операційної системи Android дозволяє користувачеві контролювати рухи робота із використанням піктограми зі стрілочками або гіроскоп пристрою. Наведений приклад проектування та розробки простого робота є хорошим експериментом для студентів, що дозволяє набути досвіду з розробки печатних плат, елементів апаратного забезпечення, програмування мікроконтролерів та Android-пристроїв.
Ключові слова: мобільний робот, Android, мікропроцесор AVR.

PROBLEM STATEMENT. Building own customized mobile robot consists of several aspects. It requires knowledge of electronics, mechanics, programming and possibly designing as well.

Anyone that is going to build such robot should already know what it should do. It can be hard to add something that we didn't think about in the beginning. Robots can have different interfaces used for interaction with their surroundings. Motors for movement, buttons and some sort of a display for human interaction are just basics and there is much more available. There are a lot of easy-to-use sensors available that enable robot to sense its surroundings. Mobile robot consists of many parts and for every part there is a number of alternatives. The sections bellows go over the over different types of motors that could be used, different type of batteries. Principles of used sensors for measuring the rotation of motors and infra-red sensors for measuring distance to objects are explained. PCB needed to be designed and created for completing the hardware part of the robot. Next robots microcontroller had to be programmed to control the motors and LCD, read data from IR sensors and optical encoders and manage the Bluetooth communication. Finally an application for Android devices needed to be created to enable user to control the robot wirelessly. Created application for Android devices is described at the end of the paper.

EXPERIMENTAL PART AND RESULTS OBTAINED. *Movement.* Robot that is supposed to move needs some sort of motors. Most commonly used motors for constructing a robots are DC, servo and stepper motors. Every type has its advantages, disadvantages and main use.

DC motors are very simple to use and they are mainly used as drive for robot movement. They do not offer any feedback so another sensor is needed for evaluating motor position or speed. They are powered by DC voltage and this is great since robots mostly use batteries. The difficult part is that motors require a lot of power. That means high current and robots use microcontrollers that are not able to supply that much current on their own. There is a simple solution and that is L293D. This IC is able to supply enough current for powering motors that will move the robot. It also contains diodes that will protect gates from voltage spikes created by motors. Speed of DC motors can be altered by changing the supply voltage. This can be done in different ways. One of them is PWM [1].

Servo motors are basically DC motors but they also contain sensor for position feedback. Most servo motors are not able to rotate continuously, they usually rotate about 90 to 180 degrees but some can rotate even 360 degrees or more. They are used for precise control of angular position, velocity and acceleration while still being relatively cheap. For these reasons they are used

for RC planes, helicopters, boats or robots as arms, legs etc. [2].

Stepper motors are DC motors containing multiple coils instead of one. Full rotation is divided into number of equal steps and coils need to be activated in certain order to generate motor rotation. Steps can be counted and that way position of motor can be evaluated. There are different stepper motor drivers, but it is possible to control stepper with main microcontroller and circuits like L293D. One L293D is needed for every two coils (e.g. if stepper contains four coils, two L293D circuits are needed). Coils need to be activated in certain order to generate motor rotation in certain direction. Rotation speed can be varied by changing frequency of coil activation [3]. Different motor types are shown in Fig. 1.

DC motor   Servo motor   Stepper motor

Figure 1 – Different motor types

Communication. Robot needs to have some interfaces, which can be used to control it. It is not about its own touchscreen or voice commands, simple buttons will do. Buttons can be directly hooked up to microcontroller and their function can be programmed. Since this paper is about building a mobile robot it will very likely need some kind of remote controller. We don't want to run after our robot to press button on him. The project will focused on using smartphone/computer as remote controller using Bluetooth or Wi-Fi. But generally there more options like RF, IR, ZigBee etc.

Bluetooth is wireless communication protocol with a master-slave structure and is commonly used for devices with limited power sources, such as batteries. Pretty much every smartphone and laptop available nowadays has Bluetooth or adapter can be bought separately and connected via USB.

Wi-Fi is wireless communication technology using Internet protocols used for high-speed data transfer. It is used in smartphones and computers for wireless Internet connection and as Bluetooth modules, Wi-Fi modules can be bought separately and connected via USB. Wi-Fi offers much higher speed compared to Bluetooth. It has also longer range but requires more power.

Power. Robot needs power source for powering its logical circuits, motors, sensors, communication modules etc. Mobile robots usually use battery to power up all components. There are different kinds of batteries available that differ in price, power output, capacity and other attributes.

Lead acid is still popular due to easy and inexpensive manufacturing process. Problem is that they are very large and heavy. In order to prevent battery failure lead acid batteries need to be kept charged. Even when battery is not used it discharges and it needs to be charged fairly often [5].

NiMH (Nickel-metal hydride) batteries are commonly used for building robots. They have good power output rate and the highest capacity. These batteries take a long time to recharge and also suffer from high self-discharge rate, i.e. even when battery is not used it will discharge on its own [6].

NiCad (nickel–cadmium) batteries have high power output rates and are more affordable than NiMH's. They can be recharged very quickly but they suffer significantly from memory effect. It means that every recharge lowers the capacity of the battery. In order to prevent this from happening, the battery needs to be fully discharged before recharging [7].

Li-ion (lithium-ion) batteries combine the capacity of NiMH's and power output rates of NiCad's. They also weight less and do not suffer from memory effect, thus they can be recharged whenever. Price of Li-ion batteries has been dropping but they are still fairly expensive.

Lead acid   NiMH   NiCad   Li-ion

Figure 2 – Different battery types

Електромеханічні і енергозберігаючі системи. Випуск 2/2015 (30)

40

Choosen mobile parts. Optimal types of motor, battery, communication interface etc. depend on requirements for the mobile robot. The main requirement were to build simple mobile robot with ability to control it using Android smartphone. The robot should have own interface with LCD and buttons for setup and change mode. The robot should be equipped with sensor to avoid a collision with other object.

The most important part of the robot is a microcontroller. Microcontroller determines everything that the robot is capable of. What peripheral components can be used and how does it use them. ATMega128 board was selected, shown in Fig. 3. Board also contains external 8 MHz crystal for clock, reset and power button. Ports of the microcontroller are routed to connectors and are

more accessible [4].

Bluetooth was chose as an communication interface with mobile. Bluetooth offers reasonable communication speed and low power consumption. HC-06 Bluetooth module already soldered to a board was selected. This module enables Bluetooth communication with remote controller and communicates with the microcontroller via serial interface [5]. Bluetooth module is shown in Fig. 4.

As a power supply was selected the NiMH battery with capacity 3000 mA/h and output voltage 7.2 V. Since logical circuits of the robot will need a constant voltage supply the stabilizer 7805 that will reduce the voltage from battery to constant 5 V was added [6]. Battery is shown in Fig. 5.
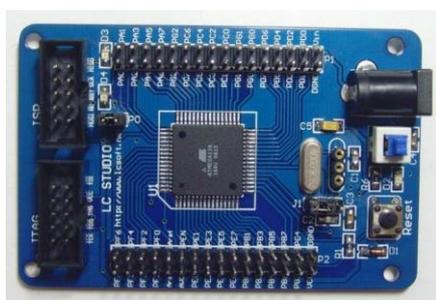

Figure 3 – Board with ATMega128

Figure 4 – HC-06 Bluetooth module

Figure 5 – NiMH 7.2 V 3000 mA/h battery

For a movement was chosen solution with two wheels on both side and third stand on back for stabile position. As an motor was selected DC motor with mounted wheel. Used DC motors that operate at 5–10 V with reduction ratio 48:1 is shown on Fig. 6. The motors cannot be powered directly by the microcontroller, so an integrated circuit LM293D is used [8]. Speed will be controlled by PWM. For a rotation measurement a IR sensor is used.

Display should show information about the robot to the user even the robot is not connected to the remote

controller – mobile device. For this purpose a LCD Module 1602A-1 was selected. This LCD is monochromatic and can display 16 characters in 2 rows. Besides preprogramed characters it can display up to 7 custom made characters [9]. Display module is shown in Fig. 7.

To measure a objects distance in front of the robot a IR sensor is used specifically type GP2Y0A02YK. Sensor measures the angle of the light beam and determines the distance to the object. Sensor outputs a voltage that is proportional to the distance of the object [11]. IR sensor is shown in Fig. 8.

Figure 6 – DC motor with wheel

Figure 7 – 5 LCD Module 1602A-1

Figure 8 – IR sensor

Schematic and PCB. Schematic PCB needs to be designed and created for completing the hardware part of the robot. Next robots microcontroller had to be programmed to control the motors and LCD, read data from IR sensors

and optical encoders and manage the Bluetooth communication. Schematic and the PCB was created in Eagle. The schematic contains also contains voltage dividers for battery charge detection, adjusting the voltage for Bluetooth

Електромеханічні і енергозберігаючі системи. Випуск 2/2015 (30)

41

module and adjusting the contrast of the LCD. Included are also ICs – 7805 for changing the voltage from battery to 5 V and L293D and for driving the motors [8–12]. The PCB also contains switches for power and LCD backlight. The PCB design is shown in Fig. 9. The created before drilling the holes is depicted in Fig. 10.

Construction of robot. Connection between the microcontrollers board and the designed PCB is done using 34-pin IDE cables. These connectors are placed on the sides of both PBCs. Connectors for sensors are located in the back of the PCB.

Switches for turning on/off the robot and backlight are in the front of the PCB along with trimmer for adjusting the contrast of the LCD. The designed PCB is placed above the microcontrollers PCB. LCD is placed on the top. Battery is located in the back so that robot is well balanced. First testing version of the robot was made by breadboard instead of PCB. Breadboard version of the robot is shown in Fig. 11. After checking that robot's hardware is fully operational, designed PCB was applied. Final version of the robot is shown in Fig. 12.
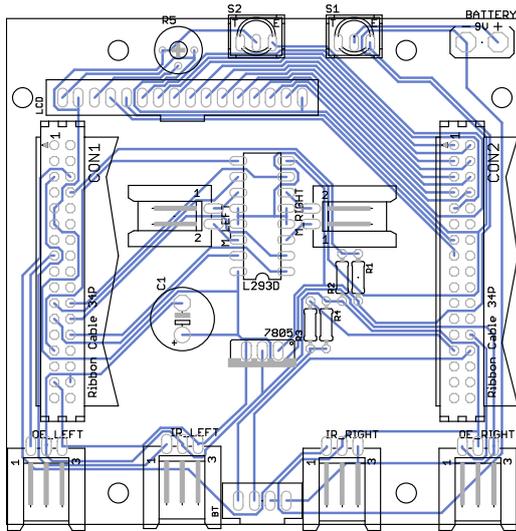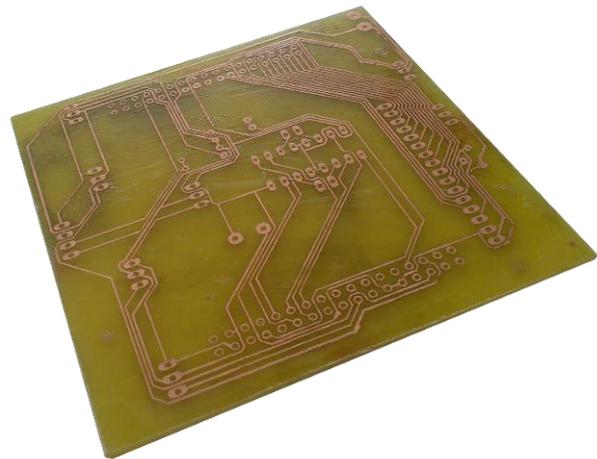

Figure 9 – PCB design
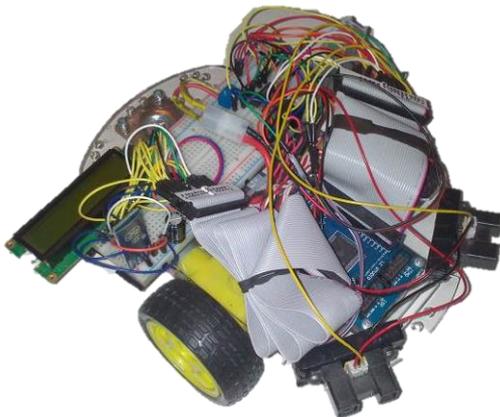

Figure 10 – Created PCB
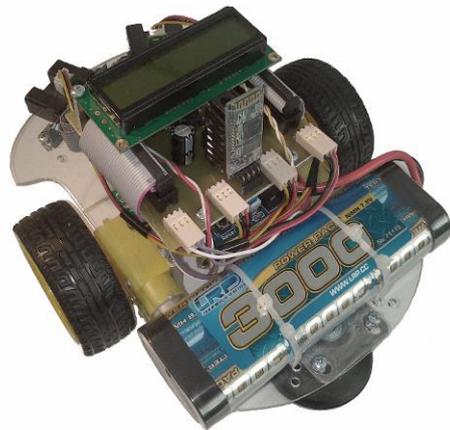

Figure 11 – Robot breadboard version

Figure 12 – Robot final version

Control application for OS android. The android application was created using Eclipse environment. Application is named BTRC (Bluetooth Robot Controller). When application starts, only one button is displayed - in the top left corner. This button is used to turn on the Bluetooth communication, connect to the robot or disconnect from it. After successful connection application launches arrow controls, depicted in Fig. 13.

Button 1 is used for turning on the Bluetooth and connecting or disconnecting from the robot. Button 2 switches between arrow and gyroscope controls. Button 3 is used to turn on or off the safe mode. Section 4 displays information from robots sensors. Slider 5 is used for controlling the speed of the robot. Section 6 contains arrows for controlling the robots movement. Switching to gyroscope controls is depicted in Fig. 14.

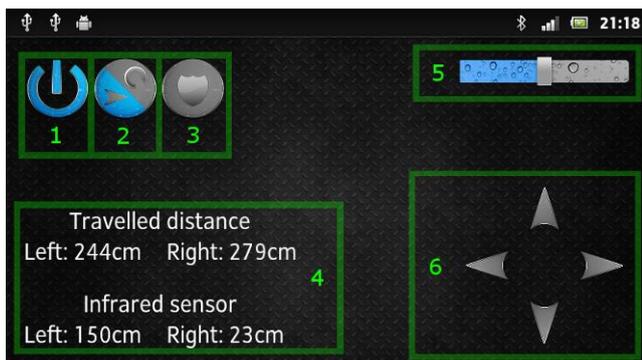Електромеханічні і енергозберігаючі системи. Випуск 2/2015 (30)
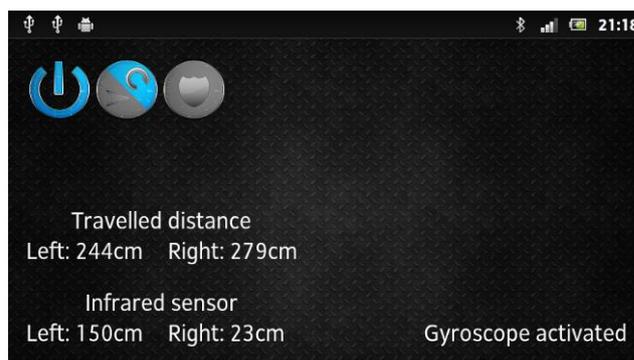
42

Figure 13 – Arrows control screen

Figure 14 – Gyroscope control screen

Gyroscope controls enable user to control robots movement by rotating the smartphone. Starting position for smartphone is horizontally with display pointing up. This is important because right after switching to this mode the robot would start moving.

CONCLUSIONS. The aim of the paper was to present a possibility to create custom simple mobile robot controlled by android application. Created robot is able to move using two motors with wheels. User is able to control the speed and direction of rotation of both motors. Both motors have optical encoders attached to them which are used to track the travelled distance. The travelled distance is tracked up to 50 m and after that is reset to 0. Robot uses two IR sensors to measure the distance to the objects in front of it. IR sensors are able to measure distance between 20 and 150 cm.

Robot contains LCD for displaying the travelled distance and distance measured by IR sensors. It also displays the charge of the battery. Robot contains Bluetooth module that enables it to be controlled wirelessly.

Created android application allows the user to control the robots movement using arrows or gyroscope of the smartphone. Application displays the distances measured by sensors of the robot. It allows user to turn on/off safe mode that stops the robot while moving forward if it gets closer than 30 cm to an object.

The task to design and create a simple robot is very good experiment for a students to get experiences in PCB design, hardware construction but also software programming of microcontrollers and also android devices.

REFERENCES

1. Society of Robots (online), Quoted 2015-01-05, available at: http://www.societyofrobots. com/ (accessed April 15, 2015).

2. GUPTA, Avinash, Controlling DC Motors: AVR Tutorial Series (online), (cit. 2015-05-1), available at: http://www.extremeelectronics.co.in/avrtutorials/pdf/avr _tutorial7---motor-control.pdf (accessed April 15, 2015).

3. SAWICZ, Darren, Hobby Servo: Fundamentals (online), quoted 2015-01-05. available at: http://www.princeton.edu/~mae412/TEXT/NTRAK200 2/292-302.pdf (accessed April 18, 2015).

4. Atmel, ATmega128 datasheet, (online), Atmel, 1.6.2011, (quoted 2015-01-05), available at: http://www.atmel.com/images/doc2467.pdf (accessed April 17, 2015).

5. Core electronics, JY-MCU Bluetooth to UART Wireless Serial Port Module for Arduino, (online), Core Electronics User Guide, (quoted 2015-01-05), available at: https://core-electronics.com.au/attachments/guides/ Product-User-Guide-JY-MCU-Bluetooth-UART-R1-0.pdf (accessed April 17, 2015).

6. RCS components, HC Serial Bluetooth Products, User Instructional Manual, (online), RCS components, (quoted 2015-01-05), available at: http://www.rcscomponents.kiev.ua/datasheets/hc_hc-05-user-instructions -bluetooth.pdf (accessed April 12, 2015).

7. LRP, LRP Power Pack 300 – 7.2V – 6-cell NiMH Stickpack, (Online), LRP, (quoted 2015-01-05), available at: https://www.lrp.cc/en/products/vtec-batteries/stick-packs-6-cells/produkt/lrp-power-pack-3000 -72v-6-zellen-nimh-stickpack/details/ (accessed April 13, 2015).

8. Texas Instruments, L293, L293D Quadruple half-H drivers, (Online), Texas Instruments, 2002, (quoted 2015-01-05), available at: http://users.ece. utexas.edu/~valvano/Datasheets/L293d.pdf (accessed April 13, 2015).

9. Shenzhen Eone Electronics Co., LTD, Specification for LCD Module 1602A-1 (V1.2), (online), Shenzhen Eone Electronics Co., LTD, 16.6.2014, (quoted 10-1-2015), available at: http://www.openhacks.com/uploadsproductos /eone-1602a1.pdf (accessed April 11, 2015).

10. K. Craig, Optical Encoders, (Online). Multidisciplinary Mechatronic Innovations, (quoted 10-1-2015). available at: http://multimechatronics.com

Електромеханічні і енергозберігаючі системи. Випуск 2/2015 (30)

43

/images/uploads/mech_n/Optical_Encoders.pdf (accessed April 13, 2015).

11. Sharp, GP2Y0A02YK Long Distance Measuring Sensor, (Online), Sharp, (quoted 10-1-2015), available at: http://www.erasme.org/IMG/ gp2y0a02_e.pdf (accessed April 11, 2015).

12. Texas Instruments: µA7800 series positive-voltage regulators, (Online), 2003, (quoted 22-4-2015), available at: ttps://www.sparkfun. com/datasheets /Components/LM7805.pdf (accessed April 16, 2015).

13. Bereš, M., Perdulak, J. and Kováč, D. (2014), Autonomous mobile robot with obstacles prediction In: *SSIEE 2014*, *Proceeding of scientific and student's works in the field of Industrial Electrical Engineering,* Vol. 3, pp. 166–169, ISBN 978-80-553-1711-4.

14. Guzan, M., Špaldonová, D., Hodulíková, A. and others (2011), "Boundary Surface and Load Plane of the Ternary Memory", *Electromechanical and energy saving systems,* Vol. 15, no. 3, pp. 163–167, ISSN 2072–2052.

15. Czerniak, J., and Zarzycki, H. (2003), "Application of rough sets in the presumptive diagnosis of urinary system diseases", *Artificial intelligence and security in computing systems,* pp. 41–51.

16. Kováč, D., Kováčová, I. and Molnár, J. (2009), "Elektromagnetická kompatibilita – meranie", 1, vyd. Košice, pp. 71, ISBN 978-80-553-0151-8.

МОБИЛЬНЫЙ РОБОТ ИНДИВИДУАЛЬНОГО ИСПОЛНЕНИЯ, УПРАВЛЯЕМЫЙ ANDROID-СМАРТФОНОМ

Т. Винсе, Я. Хричко
Технический университет Кошице, Словакия
Парк Коменского, 3, Кошице, 042 00, Словакия. E-mail: tibor.vince@tuke.sk

Описаны проектирование и разработка мобильного робота под управлением Android-устройства. Описано аппаратное обеспечение. Отдельные части статьи посвящены вопросам выбора оптимального состава аппаратного обеспечения, а именно: вращательных электрических машин с колёсами, источника энергии типа «батарея», модуля Bluetooth, инфракрасного датчика и датчика скорости вращения, жидкокристаллической панели и микропроцессора. Разработана соответствующая печатная плата, построена функциональная модель робота и создано управляющее приложение для устройств, работающих под управлением операционной системы Android. Разработанное программное обеспечение для операционной системы Android позволяет пользователю контролировать движение робота, используя пиктограммы со стрелками на экране или гироскоп устройства. Приведённый пример проектирования и разработки простого робота является хорошим экспериментом для студентов, позволяющим приобрести опыт по разработке печатных плат, элементов аппаратного обеспечения, программирования микроконтроллеров и Android-устройств.

Ключевые слова: мобильный робот, Android, микропроцессор AVR.