# Cost-effective WiFi controlled mobile robot

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***Abstract* — In this article, a simple-designed mobile robot built up from cost-effective parts is introduced. The mobile robot can be controlled via WiFi wireless network with the help of a simple application. Due to the cheap and simple design of the robot, it may be a useful developing tool for those, who can not afford themselves a much more expensive robot. Its ESP8266 chip based (manufactured by Espressif Systems) modules are cost-effective tools of performing WiFi wireless control functions, so the control of this robot has been achieved by applying this chip. That such designed device may be a quite useful example in education as well, regarding the fields of informatics and meachatronics, where the programming and applying of the embedded systems can be introduced through practical examples.**

## I. INTRODUCTION

Mobile robots are getting more and more important in our everyday life. By the development of electronics, embedded systems and informatics, the price of mobile robots significantly decreased, while their field of use increased.

One of the domestic uses of mobile robots is the field of hoovers or lawn mowers [1]. Hardware design of such a robot is not too complicated, so the simplified version of such a robot containing its control system and sensors required for moving can be assembled using cheap parts.

By the development of telecommunication technologies and ICs, there are several opportunities to perform wireless control, taking into consideration, that through this communication channel, transfer of complex information might be necessary, like continuous transfer of signals of some specific sensors beyond control signals, or even video signals. This means, that during communication, the proper speed of wireless transfer may reveal other opportunities in performing control of the mobile robot.

For controlling mobile robots, low-cost Bluetooth communication was applied in most cases [2], but the bandwidth of Bluetooth wireless transfer is not good enough and its range is only some meters either. There have been such ICs capable of WiFi communication available for some years, which support WiFi 802.11n transfer standard with appropriate encryption contrary to their relatively low prices, and their ranges are higher as well.

In this article, a simple-designed mobile robot assembled from cost-effective parts is introduced, which can be controlled via WiFi wireless network by a simple application.

## II. HARDWARE OF THE MOBILE ROBOT

During the development of the mobile robot, simple design, upgradeability, and wireless control were the main goals. In case of educational use, the application of modern ICT based technology and knowledge transfers are very offer new possibilities [4]-[6]. The developed device can be used well in education, because simple and clearly arranged layout, control features have to be achieved. Motor control of the mobile robot and the WiFi wireless communication are usually performed by two separate units; one unit, which performs motor control, is generally a microcontroller, while WiFi communication is ensured by a separate communication unit [3]. In case of a cheap, easy construction mobile robot, such a solution is preferable, where the microcontroller and WiFi communication units are achieved in one IC. For example such a cost-effective IC is the ESP8266 chip based modules (manufactured by Espressif Systems), available since 2014. When creating the mobile robot, this module was chosen. The main features of ESP8266 IC are summarized in Table 1.

The device is available in differently designed modules, for development purposes the ESP-12E was chosen, which contains integrated antenna, and important outputs of the IC are available. For the module, a 2nd generation LoLin development board was chosen, which contains the 3.3V voltage controller required for USB power supply, and USB-UART serial converter based on CH340G IC for programming via USB port. (Figure 1). Connection of other external modules to LoLin developer chip is made easier by a separate I/O adapter module (Figure 2).

TABLE I.
MAIN FEATURES OF ESP8266 WIFI CHIP

| Unit | Param | Other |
|---|---|---|
| Microcontroller | 32 bit RISC CPU | Tensilica Xtensa LX106 running at 80 MHz |
| Internal memory | 64 kB program, 96 kB data | RAM |
| External memory | 512 kB – 4 MB | Flash |
| WiFi communication | IEEE 802.11 b/g/n | WEP vagy WPA/WPA2 authentication |
| I/O | 16 GPIO, 1 analog | |
| Interfaces | SPI, I2C, I2S, UART | |

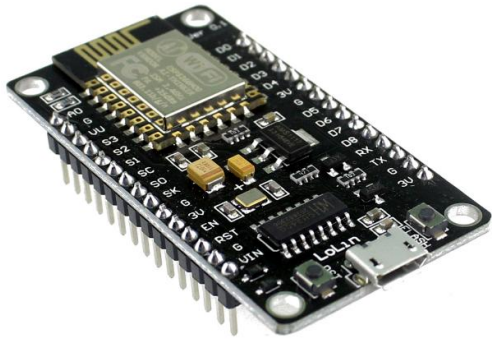

Figure 1. LoLin ESP8266 development module

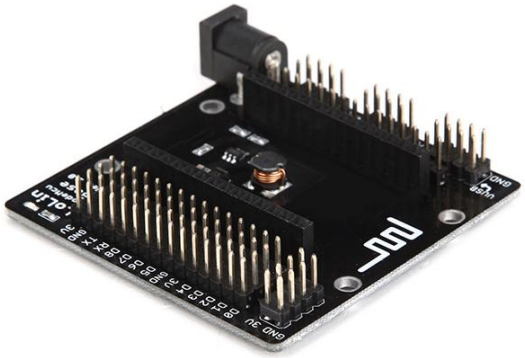

Figure 2. I/O adapter module

Programming of the device can be accomplished via UART connection, so for programming, no special (and usually expensive) programmer tool is necessary.

For the main purpose of the mobile robot, primarily the simple-design, upgradeable chassis and the control of mechanic movement was preferred. Thus, for performing control mechanism, driven front wheels and a free rear wheel was chosen. For chassis of the mobile robot, such design is expedient, which makes placing other accessories required for further developments, and sensors possible. On the international market, several kits containing the chassis of the mobile robot are available, and such solution was chosen, where the battery holder responsible for power supply can be placed on the lower part of the chassis, leaving more free space for other units on the upper part of the chassis (Figure 3 and 5).

Figure 3. 2 Wheel Drive Mobile Robot Kit

Figure 4. L9110S motor control module

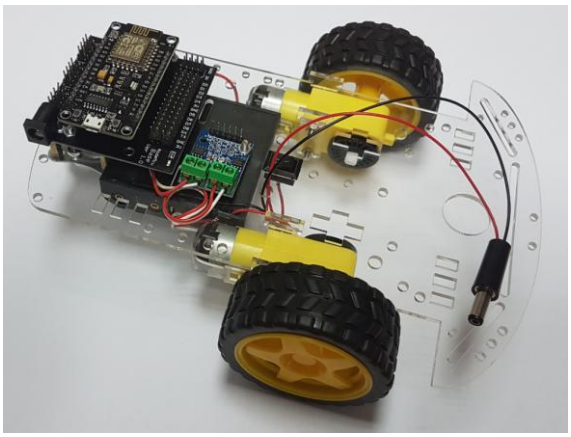

Figure 5. Assembled mobile robot

The mobile robot kit contains a removable coated transparent plexi chassis, two driven wheels, two direct current motors with 1:48 transmission ratio, one free wheel, battery holder and other accessories required for assembly. In the battery holder, 4 pcs AA type 1.5 V battery can be inserted, so the supply current is appr. 6 V. The current of the direct current motors measured during operation are below 500 mA, so for their supply, a module built on L9110S motor controller's IC was chosen, whose operating voltage range is between 2.5 and 12 V, while its continuous output current is 800 mA (Figure 4). The assembled mobile robot containing modules placed on the chassis, and also the motor and power supply input is shown on Figure 5.

## III. SOFTWARE OF THE MOBILE ROBOT

For programming ESP8266 IC, there are several developer environments available. For the development of embedded systems' software, generally C or C++ programming languages are used, which are also supported by the freeware Arduino development environment, so this one was chosen. (Figure 6).

In the development environment, the ESP-12E module is not among the supported developer tabs, but with the help of 'Boards Manager', it can be easily added. For programming the developer tab, driver of CH340G IC performing USB-UART conversion needs to be installed, which creates a virtual serial port on the computer. For programming, the proper serial port has to be selected in the development environment, as well as the 115.2 kbit/s bandwidth.

Programming is supported by the ESP8266WIFI function library. By the function library, connection to WiFi network, creation of server making the connection of external clients possible, and the client-server data connection can be handled easier.

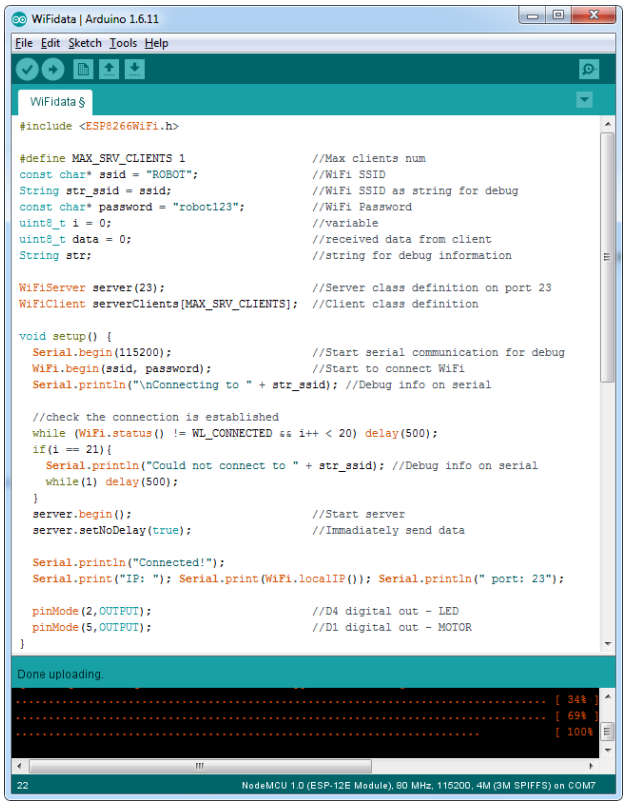


Figure 6. Arduino IDE

The PC control software, sends the speed parameters of the robot motors (in the range of 0...100), connecting to the control unit of the mobile robot (as server) as a client, via TCP/IP connection. The speed of the mobile robot is defined by the speed of the controller-motor unit supplying each wheels, which in case of permanent magnet direct current motor. In case of permanent load the supply voltage of the motor is proportional to the speed. The effective, low-loss control of the motor's speed is performed by switching operation, the speed control was performed by pulse width modulation (PWM). Digital outputs of ESP8266 IC are capable of creating direct pulse width modulated signal, whose default base frequency is 1 kHz. So in the program code, speed control was performed by the value defining the duty cycle of PWM output sent by the PC control software. The flow chart of the program ensuring speed control of the mobile robot is shown on Figure 7.

The application managing TCP/IP-based connection and performing the control of the mobile robot is built up by two classes. In the first class, there is the description of TCP/IP connection , where the responsibility of the object of TcpClient class is to establish, maintain and close new connections on the IP address and port nr.: 23 (defined in the mobile robot program). In the second class, there is the description of performing control of the mobile robot by cursor keys. NetworkStream class is responsible to send the speed parameters for the mobile robot via the already created object. The application interface of the program is very simple. The user has to define the IP address of the robot and click on the connect button. When the connection is established the state of the connection is changing from Inactive to Active. When the connection is active the cursor keys can be used to control the robot. The application windows can be seen in the Figure 8.

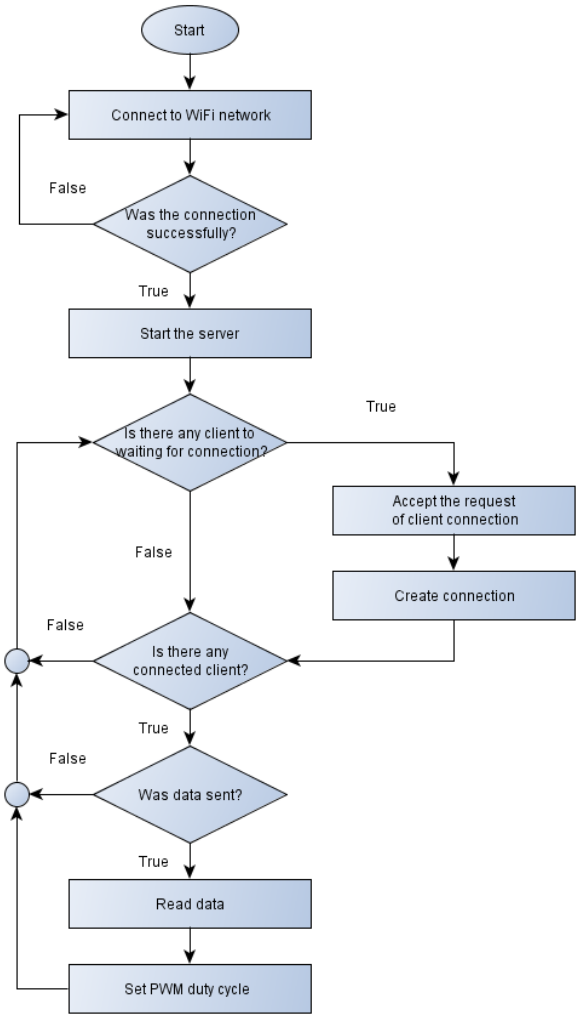


Figure 7. Flow chart of the mobil robot's control program

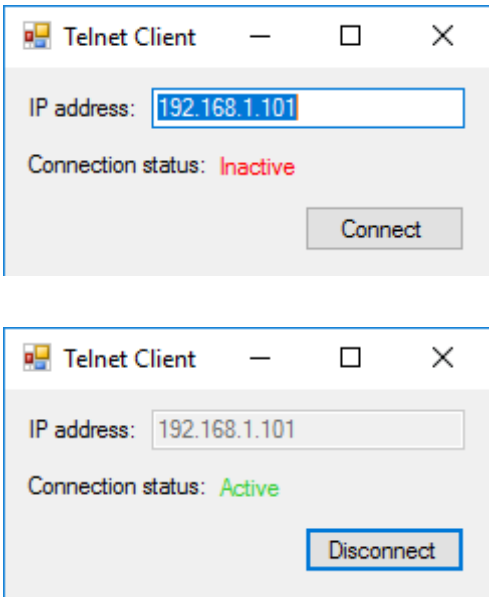


Figure 8. PC control software

## IV. SUMMARY

A simple-designed mobile robot assembled from cost-effective parts introduced in this article, can be well-used as a tool for those, who are interested in this field of mechatronics and informatics. This cheap, easy-to-build system even for students can be well-used for educational purposes too to support ICT based learning [4] and knowledge transfer [5], which helps to understand the design, and the application, programming and wireless communication use of embedded systems through practical examples.

For creating the mobile robot, modules based on ESP8266 chip are enable cost-effective design and WiFi wireless control features.

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