# Construction and Operating System of Robosoccer Agents

[1]Michal KOPČÍK, [2]Radoslav BIELEK (1st year)
Supervisor: [3]Ján JADLOVSKÝ

[1,2,3]Dept. of Cybernetics and Artificial Intelligence, FEI TU of Košice, Slovak Republic

[1]michal.kopcik@student.tuke.sk, [2]radoslav.bielek@tuke.sk, [3]jan.jadlovsky@tuke.sk

***Abstract*—This paper presents the results of the continuous work on the robot constructed mainly for the robotic football purposes. Most of the article focuses on the robot's hardware as it is the most developed part so far, but we also bring the draw of the control software and signal processing with the formulas for the computation of motor's speed and torque and the robot's position. The communication and software parts are also briefly presented.**

***Keywords*—Mobile robot, robotic football, MiroSot, microcontroller, signal processing, position calculation**

## I. Introduction

The main purpose and motivation to start the work on this robot was mainly to use it in the field of Robotic Football and to challenge other robotic football teams.

### A. *Robotic football*

The field of robotic football includes several fields for example robotics, motion control and artificial intelligence with focus on planning, strategy and optimization. Whole field of "robosoccer" is organized by the FIRA – Federation of International Robot-soccer Association.

There are several leagues and modification of this scientific sport according to the robot's shape and weight, one category even without the robots, using only competing strategies in the simulated environment.

We decided to contribute in the modification called MiroSot (Micro Robot World Cup Soccer Tournament) in which all matches are played by two teams, each consisting of three robots (one of them can be goalkeeper, but can contribute also as a regular player). Robots have to be fully automated, but there are three people allowed to be on the stage: manager, coach and trainer. Computational power for the match is focused in one host computer mainly dedicated to the vision processing. Robot's dimensions are limited by 7.5 x 7.5 x 7.5 cm excluding robot's antenna. Game is played with and orange golf ball on the 400 x 280 cm or 220 x 180 cm large pitch according to the league modification (Large or Middle) [1].

Markedly achievements in MiroSot were obtained by the group called TUKE Robotics from Department of Production System and Robotics, Faculty of Mechanical Engineering, Technical University of Košice. They are multiple euro champions (2006 - 2009) and also world champions for the year of 2010 [2].

### B. *Other usage of robot*

Even though the robot is constructed mainly for the purposes of the robotic football it can be used also in the MicroMouse competition which consists of solving the 16x16 maze. Events are held worldwide and demands usage of fully autonomous robots [3].

Last, but not least is the usage of the complete robot in the class, especially in the subjects of motion control and artificial intelligence.

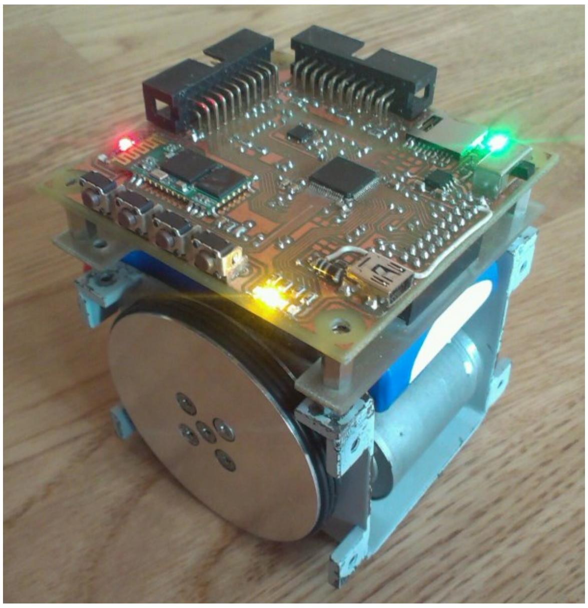

Fig. 1. Prototype of the robot.

## II. Mechanics

Mechanics of the robot consists of chassis, wheels and motors. Since the robot is constructed with the use of differential drive, there are used two same motors.

### A. *Chassis*

Chassis are made of 1.5mm steel plate. Wheel bearings are placed in the housings welded to the frame. For the material used, the frame is very durable, but also quite heavy.

### B. *Wheels and gears*

Wheels are made of aluminum, they are 10mm thick and the wheel diameter with tire is 62mm. Tire of the wheel consists of three 2mm O-rings placed in the groove on the wheel. Gear that connects wheel with the motor is located inside wheel and they are connected together using screws. Ratio of used gears is about k = 0.1.

### C. *Motors*

Motors determine robot's performance such as maximum acceleration, maximum speed, current consumption, etc. Motors used on the robot are Mabuchi RS-380SH with nominal voltage of 7.2V. Maximum speed and acceleration of the robot can be simply calculated from equation (1) and (2). Description of symbols used is presented in table 2.

$$v_{nom} = \frac{\omega_{nom} \times \pi \times d \times k}{60} \qquad (1)$$

$$a_{nom} = \frac{2 \times \tau_{nom}}{d \times m \times k} \qquad (2)$$

Acceleration and maximum speed depends on the mass of the robot (m = 0.55kg) and gear ratio (k = 0.1). Motor driver can provide continuous current about 6A to motors. At current 6A motors provide torque about $\tau_{nom} = 0.04 N.m^{-1}$ per motor so derived from the equation (2) theoretical maximum acceleration is about $a_{nom} = 26 m.s^{-2}$. Maximum speed of the robot calculated from equation (1) for speed of the motor driven at 6A is about $v_{nom} = 3.75 m.s^{-1}$. These values are only theoretical and doesn´t count externalities such as friction in gearbox and friction between tire and surface. Real speed of the robot is about 1/3 lower than calculated nominal speed and acceleration highly depends on material of the tire and surface. In real conditions maximum acceleration is about 5 $m.s^{-2}$.

## III. ELECTRONICS

Whole electronics of the robot consists of control board, power board and two sensor boards. Boards are populated mostly by SMD components and PCB's (Printed Circuits Board) are homemade and hand soldered to reduce cost of the prototype.

### A. *Control board*

Essential parts of the control board consist of 32-bit microcontroller and communication Bluetooth module. This board also contains MicoSD card socket, USB connector, gyroscope and accelerometer sensors, some buttons and LEDs for easier program debugging and 20-pin connector to connect extra sensors, actuators or digital camera.

Microcontroller used on this board is from a family of 32-bit Flash microcontrollers based on the ARM core Cortex-M3.

Control board is connected to the power board via 20-pin connector which is used to transfer power from the battery to the control board, to control speed and direction of motors and to transfer signals from rotary encoders. Block diagram of control board is shown in Fig.2.

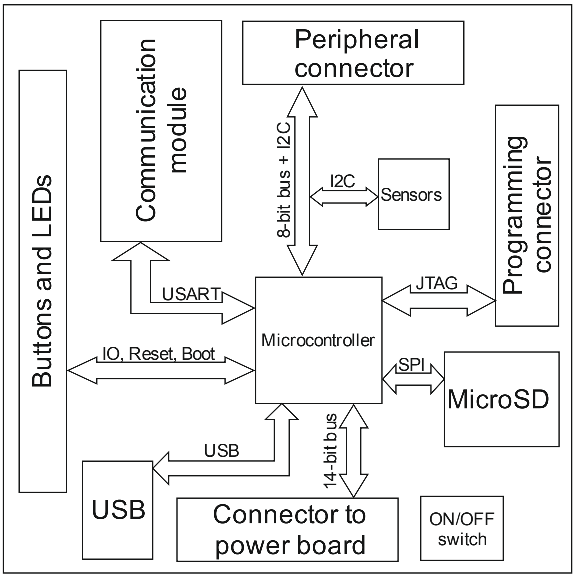


Fig. 2. Block diagram of control board.

### B. *Power board*

This board is used to drive two motors, connects rotary encoders to control board and provide power from battery to control board. There are two H-bridges made up of power bipolar transistors and auxiliary logic circuits which together form a complete motor driver with direction/enable inputs. Schematic diagram of H-bridge is shown in Fig. 3.

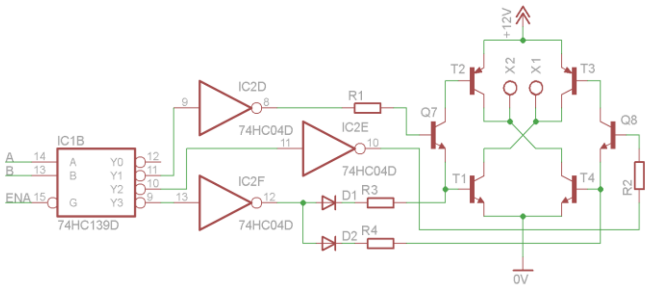


Fig. 3. Schematic diagram of H-bridge with auxiliary logic circuits.

Demultiplexer IC1 according to the input determines if the motor will turn, break or there will be no action. Inputs A and B determine action and input ENA will enable the action. Because outputs from demultiplexer are inverted, on each output is connected inverter IC2 to achieve positive logic. Demultiplexer guarantees that there won't be any prohibited states such as short caused by opening all power transistors. Table 1 shows logic states of the H-bridge depending on A, B and ENA inputs.

TABLE I
LOGIC STATES OF THE H-BRIDGE

| A | B | ENA | State |
|---|---|---|---|
| X | X | 1 | No action |
| 0 | 0 | 0 | No action |
| 0 | 1 | 0 | Clockwise rotation |
| 1 | 0 | 0 | Counter clockwise rotation |
| 1 | 1 | 0 | Active breaking |

## IV. Robot's Position Calculation

Robot can calculate its own position by using magnetic encoders mounted on the wheels. Calculated position is only approximate and deviation from real position increase by travelled distance. This deviation can be decreased by using onboard gyroscope and accelerometer. When using robot as soccer player, position is determined by computer using camera placed above soccer field.

### A. Encoder Sensors

Robot features two contactless magnetic rotary encoders for accurate angular measurement of each wheel. The absolute angle measurement provides instant indication of magnet's angular position with a resolution of 0.35° = 1024 positions per revolution [4]. Sensor need for its operation strong rare earth magnet with designated parameters. Magnet must be cylindrical with proper dimensions and diagonally polarized.

### B. Signal Processing

Sensor can work in various modes like quadrature A/B mode and Step/Direction mode. In this case the quadrature mode is used. Output A/B signals from the sensors are directly connected to the input pins of the microcontroller. These input pins are all capable of triggering external interrupt (EXTI) so on every edge of the signal a subroutine is executed that counts impulses. Every 10 ms is then executed another subroutine that is triggered by internal timer. This subroutine calculates position from counted impulses and the result is x, y axes and φ angle of the robot.

### C. Equations

From impulses received from encoders we can simply determine position and angle of the robot. These equations are discrete in time.

$$\varphi(i) = \varphi(i-1) + \frac{dr - dl}{i} \quad (3)$$

$$x(i) = x(i-1) + \frac{\cos(\varphi(i))(dr + dl)}{2b} \quad (4)$$

$$y(i) = y(i-1) + \frac{\sin(\varphi(i))(dr + dl)}{2b} \quad (5)$$

Constants i and b in equations (3), (4) and (5) depend on wheel diameter with tire (*d* = 62 mm), distance between the wheels (*l* = 67.5 mm) and number of impulses per revolution (*n* = 512 imp/rev). Constants can be calculated from equations (6) and (7). Description of symbols is in table 2.

$$b = \frac{n}{\pi \times d} = 26286 \quad (6)$$

$$i = l \times b = 177{,}4321 \quad (7)$$

TABLE 2
Description Of Symbols

| Symbol | Description | Units |
|---|---|---|
| dr | Right motor counted impulses per time | imp/dt |
| dl | Left motor counted impulses per time | imp/dt |
| x | x position of robot | m |
| *y* | y position of robot | m |
| *φ* | Angle of the robot in radians | rad |
| *i* | Number of impulses per radian | imp/rad |
| *b* | Number of impulses per meter | imp/m |
| *n* | Number of impulses per revolution of the wheel | imp/r |
| *d* | Diameter of the wheel | m |
| *l* | Distance between the wheels | m |
| *k* | Gear ratio | - |
| *τ* | Motor torque | N/m |
| *ω* | Speed of the motor | rev/s |
| *m* | Mass of the robot | kg |

imp = impulses, dt = time constant, mm = millimeter, rad = radian, rev = revolution of the wheel, s = second, kg = kilogram.

## V. Communication

Communication with computer provides HC-05 Bluetooth module located on the control board. Bluetooth module is connected to microcontroller via two data pins transmit (Tx) and receive (Rx). Communication module provides full duplex asynchronous serial communication with baud rate up to 1382400 bits per second and with range up to 10 m. When connected to PC, module acts like virtual COM port. HC-05 also features two digital outputs to connect LEDs which serves to display status of the device.

Microcontroller uses communication interrupt when transmitting or receiving data bytes. When byte is received, it triggers interrupt handler which put byte into queue FIFO buffer. When byte is recognized as new line character, interrupt handler set semaphore that enable string recognition subroutine to be executed.

## VI. Program and Operating System

Most of robot's basic functions such as calculating position of the robot, communication handling and speed control of motors are executed at the program's lowest level. These functions are executed using interrupts and provide the programmer's base tool he can work with. For higher functions such as string recognition, maze solving algorithm, and other function that consume more processing time there is real time operating system that distribute processing time for multiple programs. In this robot is used FreeRTOS (Real Time Operating System) operating system.

Most operating systems appear to allow multiple programs to execute at the same time. This is called multi-tasking. In reality, each processor core can only be running a single thread of execution at any given point in time. A part of the operating system called the scheduler is responsible for deciding which program to run when, and provides the illusion of simultaneous execution by rapidly switching between each program [5].

## VII. Conclusion

Since this robot is a prototype it has few bugs we found during tests and we made corrections in the design to refine robot.

The next step of the work will be improvement of the motion control together with its diagnostics from integrated sensors.

In the future we plan to mount the video camera on the robot in order to make it fully autonomous and participate in the MicroMouse competition.

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