# INFRARED BALL CHASING ROBOT

**Nayden Chivarov**

*Institute of Systems Engineering and Robotics*

*of the Bulgarian Academy of Sciences,*

*Bloc II Acad. Bonchev str., Sofia 1113, Bulgaria*

*e-mail: nshivarov@code.bg*

**Abstract:** The Infrared Ball Chasing Robot is a small robot with two active wheels that follows a ball emitting modulated infrared light. The robot has several infrared sensors ("eyes") that give the information needed for the robot to determine not only the presence but also the direction of the ball. The concept is based on the light-follower robot design. It relies on difference between the levels of light signals received by at least two sensors to determine the direction (angle) of the target in relation to the robot orientation and generate different wheel speeds accordingly, so that the robot moves towards the light source.

*Keywords:* Mobile robot, Infrared ball, Active wheels, Infrared sensors, Atmel's AVR ATMega8 microcontroller.

## 1. INTRODUCTION

The Infrared Ball Chasing Robot (see Figure 1) is a small robot with two active wheels, which follows emitting modulated infrared light ball. The robot has several infrared sensors ("eyes"), which gives the information needed for the robot to determine not only the presence but also the direction of the ball. The embedded controller then enacts the two wheels of the robot accordingly. This process repeats constantly making possible for the robot to track and follow even a moving ball.

For successful tracking of a moving target, several conditions are met. The total time of reaction is short enough for the robot to be able to compensate its direction and speed in real time. Otherwise the trajectory of the robot might miss the ball and circle around it. The time of reaction includes mechanical as well as electronic and firmware components and they are carefully balanced in order to achieve optimal results. Another important factor in this regard is the speed control resolution. Due to the digital nature of the Robot's Controller, the speed of the rotation of each wheel is controlled in small discrete steps. The size of one step is designed small enough for the robot to be able to adjust to the slightest changes in ball's position related to the position and velocity vector of the Robot.

Several key considerations are taken in the Ball's design. As the basic IR light transmitting element is a discrete infrared light-emitting diode, the number and mutual position of the diodes are carefully chosen so that the ball is "visible" to the Robot from any angle and orientation. Also precautions are taken for eliminating daylight disturbance as well as common IR noises (from devices like lamps, PC monitors, etc.) as most home devices emit some form of infrared light. Those precautions include selecting optimal IR range (near IR range of 940 nm is chosen for the design) as well as proper modulation of the light by manipulating current through LEDs.

The Robot meets all these requirements, making it ideal not only for toys but for a number of practical tasks for a home and industry robot applications**.**

Fig. 1. Infrared Ball Chasing Robot

*1.1 Chasing Robot Mechanical Design.*

Developed Two Active Wheels Chasing Mobile Robot consist of two bearings wheels used for keeping Robot in balance by providing a point of contact with the ground, two active wheels used to move the robot forwards or backwards driven by DC gear-motors, Robot body produced from plate iron and plastic mandrel, microprocessor controller, Infrared transceiver and receiver sensors, 9 V battery and battery holder (Figure 1).

Technical specifications of the developed Two Active Wheels Chasing Mobile Robot are presented in Table 1.

**Table.1 Technical specifications of our Chasing Robot**

| Parameters | *Two Active Wheels Chasing Mobile Robot* |
|---|---|
| Size | 7.5x7.5x7.5 [cm] |
| Motor type | 6V, DC Gear motor |
| Gear ration | 10:1 |
| Rotation Speed | Up to 215 rpm |
| Current at max torque | 85mA |
| Maximum torque | 1.5 Ncm |
| Robot Weight | App. 325 g |

Moving of our Chasing Robot is achieve by the two bearing wheels used for keeping Robot in balance by providing a point of contact with the ground and two active wheels used for controlling and moving the robot (Figure 2).

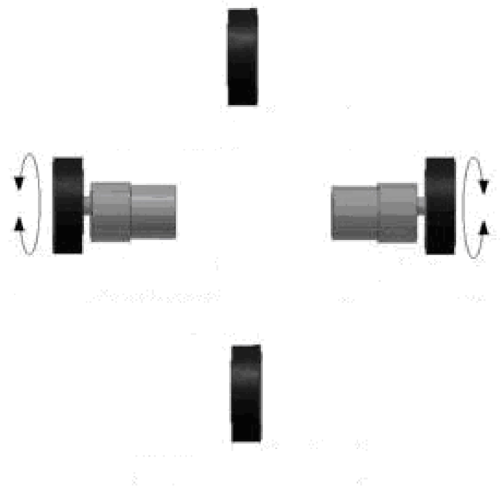

Fig. 2. Achievement moving of our Chasing Mobile Robot

Moving the two Active wheels forward – achieve robot moves forward.

Moving the two Active wheels backwards - achieve robot moves backwards.

Moving one active wheel forward and the other backwards - achieve robot turns around within a small circle which center lies in between the 2 powered wheels.

Moving one active wheel slower than the other - achieve robot turns in the direction of the slower wheel. How fast it turns depends on how large the difference between the 2 speeds is.

## 2. CONCEPT

The concept is based on the light-follower robot design. It relies on difference between the levels of light signals received by at least two sensors to determine the direction (angle) of the target in relation to the robot orientation and generate different wheel speeds accordingly, so that the robot moves towards the light source. Basic design concept is shown on Figure 3.

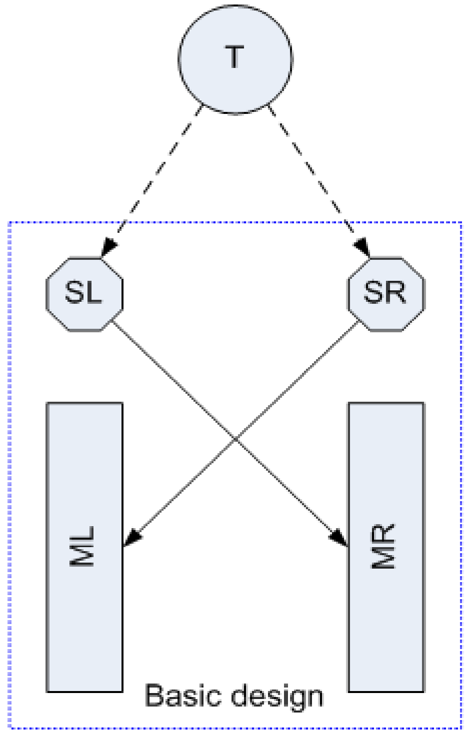


Fig. 3. Basic Design Concept

The robot has two active wheels that make it both simple and flexible enough to achieve the great number of possible tasks and application requirements. Those wheels allow not only for making sharp turns when necessary, but also to spin the Robot around its own axis, making possible of easy tracking and quick approach to the ball from any direction.

The idea behind target tracking and following is implementing a negative feedback in the robot system. That means enacting the left and right wheels in a way that compensates for the deviation from the target. Figure 3 shows a simplified implementation of the negative feedback: the left sensor SL enacts the right movement module MR and the right sensor SR enacts the left movement module ML. If the light-emitting target T is exactly in front of the robot the two wheels rotate with equal speeds thus moving the robot forward in a straight line towards the target. If the target is closer to the left sensor SL, it receives signal with a higher level than the level of the signal received by SR, thus enacting faster rotation of the right wheel, making the robot to turn to the left, and vice versa. This concept is behind many motor functions of living organisms. It is well known that the right part of the human's brain controls the left limbs i.e. the left hand, and vice versa.

This concept is behind many motor functions of living organisms. It is well known that the right part of the human's brain controls the left limbs i.e. the left hand, and vice versa. It is applied when a butterfly approaches a source of light. It also applies to the control of our arm i.e. when we want to reach for a glass of water. The principle is that the error (deviation away from the target) is converted to proper signals to the actuators in the opposite direction in order to compensate for the error.

The minimal number of sensors needed to achieve this is two – the least possible number to perform a comparison and make a decision. But in the case of a light-following robot, there have to be more sensors on each side in order to cover all possible ball positions and angles, including those from behind. So the number of sensors is selected to be 4, two for front side and two for rear side of the robot, making possible to cover 360$^{o}$ around the Robot. Below the two left sensors are referred as SL and the two right sensors – SR combined.

## 3. IMPLEMENTATION

A more thorough block diagram of the Robot is shown on Figure 4.

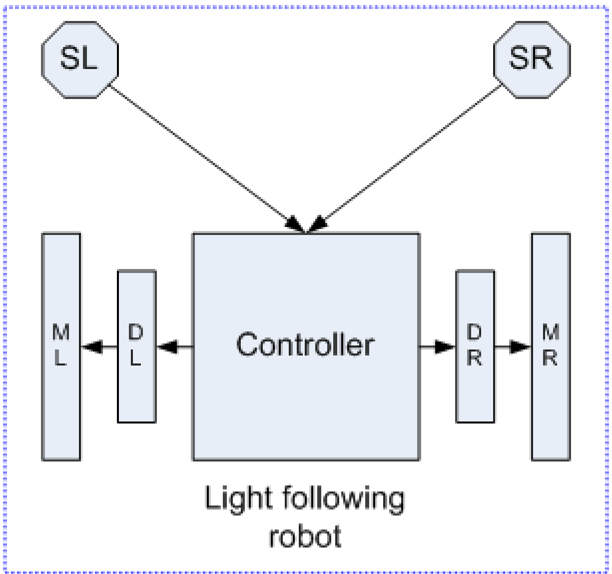


Fig. 4. Infrared Ball Chasing Robot Block Diagram

### *3.1 General Description*

The infrared signal from the Target (Ball) is modulated with a specific frequency in order to avoid disturbance from daylight and most background noises. The block diagram of the Ball is shown on Figure 5. The Battery feeds the Modulator which controls the Light Emitting Diodes $E_1$… $E_N$. They emit infrared light in the infrared range of 940 nm of wavelength.

The Light Emitting Diodes (LEDs) are situated in a way that covers all space around the ball, not leaving any gaps uncovered by IR light signal. The number of diodes is calculated in dependence on the space angle covered by one single LED.

Sensors SL and SR are infrared phototransistor for 940 nm infrared light and are electrically and spectrally matched to the light emitting diodes of the Ball. They generate signals to two Controllers' analog inputs. The Controller module is basically an Atmel's AVR microcontroller ATMega8. It runs on 16 MHz frequency that allows some very useful functions to be performed in real time, as described below. The Controller processes the input signals from the sensors and generates proper control signals for the drivers DL and DR, controlling left motor ML and right motor MR correspondingly. The speeds of the motors (and Robots' wheels) are controlled by PWM (Pulse Width Modulation) signals fed to DL and DR. It allows for 128 steps of the velocity from full stop to the maximum.

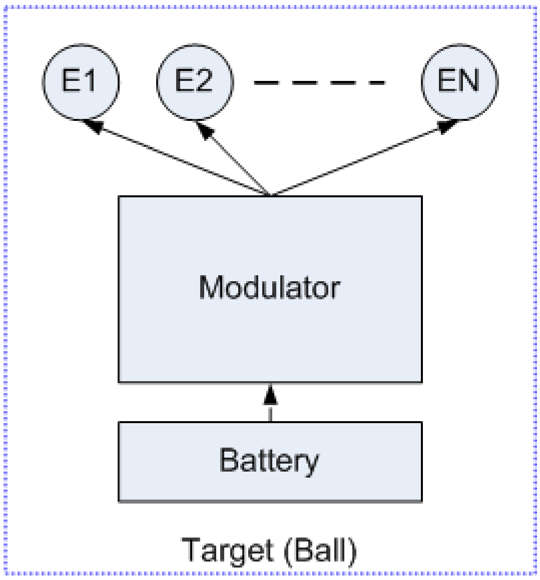


Fig. 5. Infrared Ball Block Diagram

### *3.2 Signal Processing*

For design simplicity the signals from the sensors are not processed by sophisticated hardware filters but are passed directly to the analog inputs of the microcontroller instead. The filtering function is implemented in firmware instead. This is accomplished by a 64-points FFT (Fast Fourier Transform) algorithm and taking the amplitude of several spectral lines that characterizes the presence of the Target.

The FFT algorithm is a fast implementation of DFT (Discrete Fourier Transform) which is defined by the formula:

$$X_k = \sum_{n=0}^{N-1} x_n e^{-i2\pi k \frac{n}{N}} \qquad k = 0, \dots, N-1.$$

Here $x_0 ... x_{N-1}$ are complex numbers and $N$ is the number of samples (points), in this case $N = 64$.
In many cases the input data for the DFT are purely real, in which case the outputs satisfy the symmetry:

$$X_{N-k} = X_k^*,$$

This is true for the current application. The 64-point FFT gives 32 spectral lines (including “zero” frequency) and this is enough to perform basic filtration.

The algorithm is implemented in Assembler and consists of three basic subroutines: *fft_input, fft_execute* and *fft_output*:
*fft_input:*

*3.3 Robot’s Behaviour*

It is more complicated to create a useful implementation of the principles above. For example, the ball might be just behind the robot, lying on the line of symmetry thus making difficult for the robot to approach it properly (with its front side turned to the target). The basic idea does not provide proper response logic for this case. Also the robot might get stuck with an obstacle and require certain behavior that is more complex and sophisticated enough to achieve the target. This requires programming of a more complex logic in the Robot’s Controller and that is where the use of a common programmable microcontroller as implementation of the Controller proves its advantages. The signals from the robot’s sensors are analyzed in order to determine the quadrant in which the target is present and take appropriate actions. For instance, if the ball lies in the quadrant in front of the Robot, both wheels must have the direction needed for a forward movement. However if the target is discovered behind the robot, a spin around the axis is preferred as achieving the proper orientation using less amount of time and power.
If the target ball lies to the left or right of the robot so that left/right pair (back and forward) sensors receive approximately the same signal levels, a spinning response is again appropriate.

4. FUTURE DEVELOPMENT AND APPLICATIONS

The future perspectives of development of this project include automatic search of the optimal frequency for optimal signal detection in various environments and automatic signal level adjustment in order to achieve the most adequate robot behavior in a vast range of background noises, working distances and other changing conditions. Also the Robot’s behavior has to be further refined to achieve the target faster and/or with less energy consumption. The applications of the Robot include industrial and home navigation, automated

5. CONCLUSIONS

In the beginning of robotics development, most of the Robot applications were related to industries and manufacturing and these Robots were called Industrial Robots**.** With development of the new technologies, sensors and microprocessors, today Robots are working in many fields of Service. Starting from Service Robots for professional use to Service Robot for personal use including also educational, entertainment and leisure Robots.

We can expect that the number of service robot applications will grow much faster than that of the industrial robots. All this is expected because of the penetration of service robots in all spheres of human life and activities.

People perceive robots in a different way than other machines because they are performing tasks like humans who are programming them. Robots are entering more and more human homes today and are realizing often a real interaction with them

Based of those features educational robots are the best tool for learning about robotics and interaction between robots and humans.

Educational Robotics is multidisciplinary scientific field which includes mechanics, electronic hardware, software, artificial intelligences, sensor and sensory systems etc. and is very good test bed for education of students, young specialist and researchers and is necessary for all technical schools, colleagues, laboratories and Universities.

Having our Robot as a good example tool for learning about robotics and interaction between robots and humans we will develop a family of Educational Robots for a variety of applications.

REFERENCES


Chivarov, N,. Shivarov, N., Kopacek, P., A Tool Kit for Intelligent Mobile Robots, Syroco”00, September 21-23, Vienna, Austria; p.313- p.318;

Kopacek, P., Chivarov, N., “Modular Approach in Projecting of Intelligent Mobile Robot”, Second Austrian-Bulgarian Automation Day, Problems of Engineering Cybernetics and Robotics, Volume 53, p 36, Sofia, Bulgaria, 2002.

Chivarov, N., Shivarov, N., Development of a Soccer Robot; Practro’2007, June 12-15, Varna, Bulgaria, p.281 – p.286.

Chivarov, N., Shivarov. N., Mobile Robot for Inspection; Robotics and Mechatronics 2007, October 10-12, Drjanovo, Bulgaria; p.54-p.57.

http://read.pudn.com/downloads97/sourcecode/embed/394130/AVR-FFT%E8%BD%AC%E6%8D%A2%E7%A8%8B%E5%BA%8F/ffft.S__.htm

http://en.wikipedia.org/wiki/Fast_Fourier_transform