Braitenberg's Robots in Education and for Research

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***Abstract*— Braitenberg's concept on robotics, although 30 years old, still remains fresh and inspirational, not only in terms of education, but research, too. The paper presents the intent of development of robots based on Braitenberg's concept, under the course “Intelligent assembly systems”, of graduate study of mechanical engineering, module “Mechatronics and robotics”. Developed robot incorporates first few Braitenberg's robot configurations. The development included design of hardware and control, and covering: basic mechanical design (using Solidworks software), choice and modification of electromechanical components (sensors, RC servomotor), choice and programming of control unit (Arduino). At the moment, the robot is capable to perform simple motions actuated by light and physical obstacles. In a future work, additional sensors, hardware add-ons (arms and tooling) and wireless control will be added to facilitate even more complex robot's behaviour and ease of programming, including consideration of robots' teamwork. The latter emphasises the research motif and component of this work. Namely, availability of low-cost equipment allows development of various large-scale automatic – autonomous systems, where design-intent, systems' functioning or behaviour, surpasses traditional rationalities of aims and efficiency criteria and their measurement, establishing more volatile situation of indifference. Should construction or deconstruction occur somewhere in a second, it depends only on involved (pre-defined and instantly available) machinery?**

Keywords: mechatronics, robotics, design, behaviour, education

I. INTRODUCTION

The constant development of technology has led to an increasing degree of automation in material handling and transport systems, either as part of the production process (e.g. transport of semi-finished products between workstations) or the storage and distribution of finished products (e.g. warehouses, distribution centres, container terminals). One of the main components of the transport of materials are autonomous vehicles: AGVs − Automated Guided Vehicles, as shown in Fig. 1. Autonomous vehicles perform the transport of materials without human influence and thus contribute to cost reducing, increased efficiency and reducing of number of damaged items caused by negligence. However, they also require an effective management system for conflict resolution and jams.

Figure 1. Autonomous vehicles -- Automated Guided Vehicles [1].

One of the pioneers in the field of autonomous vehicles is recently late Valentino Braitenberg, who in his book "Vehicles: Experiments in Synthetic Psychology" [2] describes a series of experiments in which even the vehicle of simple structure may behave in unexpectedly complex ways, for an observer without sufficient information and prior knowledge. In his experiments he gradually designed more and more complex structures – vehicles, whose control mechanisms generated “behaviours” that might be connected with principles of aggression, foresight, optimism and even love and hate. Braitenberg gives this as evidence of the "law of uphill analysis and downhill invention", which means that it is much harder to try to guess internal structure just from observing the behaviour than it is to create a structure that gives the behaviour. This is very appealing motif for many nowadays researchers [3 to 7], to make and explore new Braitenberg's vehicles, especially taking into account current level of technology and equipment availability. Today’s automatic technical systems are rich of sensors, so there is no hard to imagine that such systems would become even “emotional” soon. This thrilling premise opens space for many questions about traditional rationalities and attitudes that stay ahead of all our activities, either in industry or education, and moreover, having in mind current global situation which reveals hidden automatism.

The realisation of vehicles, code name "BROT", has run in several stages: concept, development of electronic and mechanical assembly, programming and, for now, a production of the first prototype.

In the prototype a detailed analysis was done as well as all the necessary changes in construction, rework of mechanical parts, resolving of programming ambiguities and an upgrade of the driver. BROT is programmed to perform only the most basic operations of movement but with some additions (for example: a robotic arm) and improvement of programs, BROT could become a very autonomous robot.

Braitenberg depicts [2] the functional behaviour of 14 different vehicle models among which the attention is paid to the first four of them.

Vehicle I is the most simple of all the vehicles: it consists of a sensor, an actuator and a body (Fig. 2).

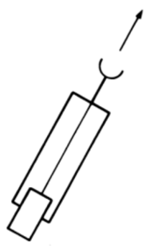

Figure 2. The vehicle I.

The vehicle is provided with one direction of movement only, shown by an arrow in Fig. 2, while the speed of motion is proportional to the amount of excitation of control sensor (the sensor directly controls the drive). Due to its simplicity and lack of control ability, the vehicle I. seems not very interesting and challenging so it is not discussed in this paper.

The vehicle II, shown in Fig. 3, consists of two engines, two sensors and a single frame. Engines and sensors can be arranged in three different ways and, consequently, may have three control logics.

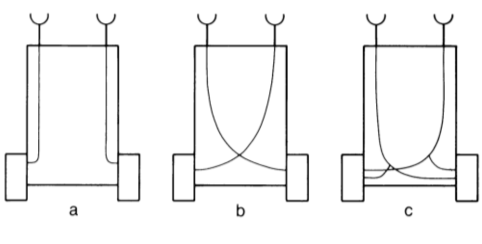

Figure 3. The variants of the vehicle II.

In Fig. 3, the vehicle “a” has laterally connected sensors and motors, so the vehicle principally "escapes from light”; the vehicle “b” has sensors and motors connected crosswise to drive the vehicle towards the source of light. The vehicle “c” has both sensors connected to both motors and it is, in fact, a version of the vehicle “b”. The vehicles II were chosen to be developed and will be described and discussed here in the paper.

II. Construction of the BROT

The whole BROT is constructed using 3D modelling engineering software package Solidworks 2009 [8].

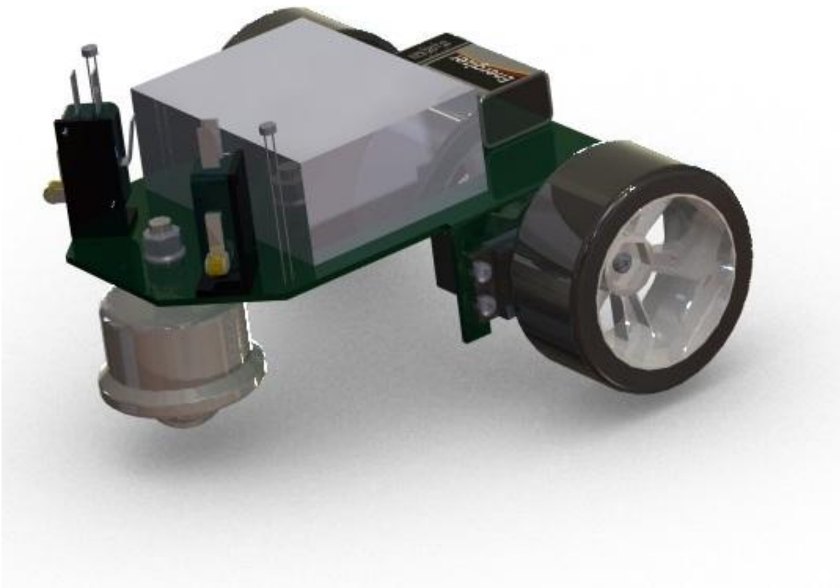

Figure 4. 3D model of the BROT vehicle.

The mechanical structure consists of a chassis, wheels and ball.

In order to create the chassis, a steel sheet (thickness about 1 mm) has been used. By cutting the metal a basic shape is obtained and then the loops were folded to allow connection of the motors together with the chassis.

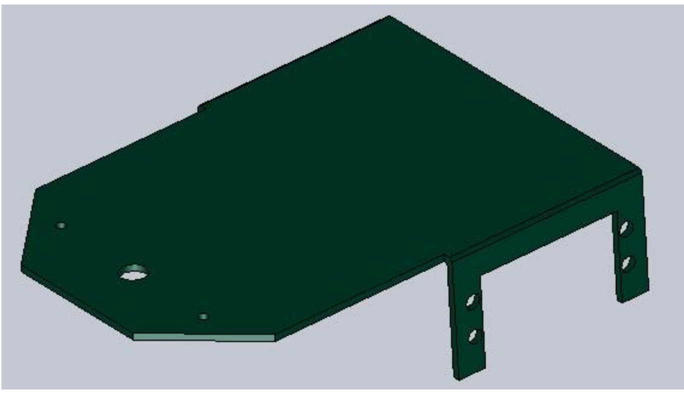

Figure 5. The chassis of the BROT.

The wheels are made of polyamide rods (35 mm in diameter), cut in rolls (width 10 mm); the flanges are attached to the wheels to connect the wheels to the motor (Fig. 6). In the front of the chassis a hole is made (diameter 8 mm) into which the pellet is inserted to support the third point in the plane (Fig. 6).

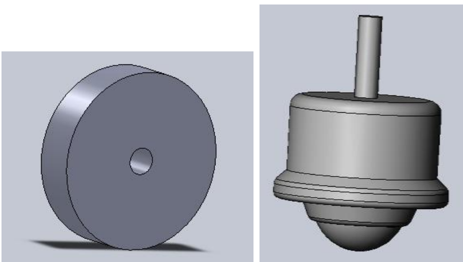

Figure 6. Vehicle wheel and pellet.

III. ELECTRICAL SYSTEM

A. *Sensors*

The BROT vehicle contains two photo resistors (Fig. 7) and two microswitches with a roller (Fig. 8).

On the basis of a voltage divider, the control unit reads the voltage drop of the photo-resistor on the analog port so that it could calculate from which side more light comes from, in the room where the BROT vehicle is located.

Figure 7. Photo-resistor.

Microswitches are connected to the interrupt pin of the control unit and it is activated if BROT vehicle touches the obstacle. In that case, the control unit calls interrupt routine which executes the pre-programmed routine for obstacle avoidance. That routine controls the motors regardless of the sensors and the vehicle will be moving back a few seconds while it is not moved away from the obstacle.

Figure 8. Microswitch with a roller.

B. *Control Unit – Arduino*

Arduino [9] − Fig. 9, is an *open-source* platform based on a simple printed circuit board (PCB) with digital/analogue inputs and outputs. It includes a free development software interface. Thanks to the simplicity and the large number of inputs and outputs it enables easy and rapid development as well as creating effective and impressive projects.

The PCB contains an Atmel ATmega328 microcontroller, which has: 14 digital channels of which six can be used as PWM channels (Pulse Width Modulation), six analog inputs, 16 MHz crystal oscillator, a USB connector (programmable and capable for bi-directional serial communication), etc. More details on the characteristics of this microcontroller are given in [10].

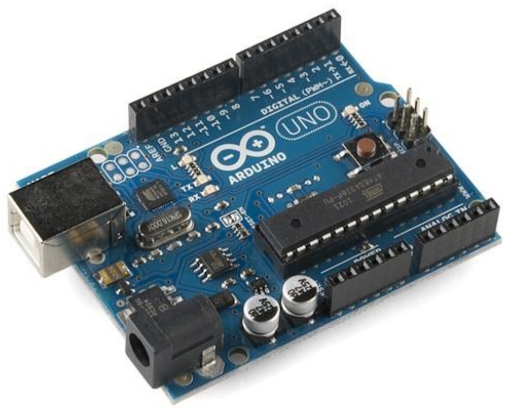

Figure 9. Control unit Arduino UNO.

Arduino UNO is a new version of the PCB which includes an ATmega8U2 chip that replaces the old FTDI. This enables faster communication and eliminates the need for special drivers. It also allows the presentation of the Arduino as a USB keyboard, mouse or joystick.

C. RC Servomotor

Operational charge of the motor (Fig. 10) is produced by TowerPro, whose characteristics are: angular velocity of 0,9 ˚/s and the rated voltage of 5 V DC. Considering that the concerned servomotors do not have the option of a full rotation, but have a 90˚ rotation in either direction, it was necessary to make certain modifications of the RC servomotor.

Figure 10. RC servomotor TowerPro MG995.

D. Modifications of the RC servomotor

The first thing needed is to open the motor. The next step would be to carefully dismantle the servomotor gears (Fig. 11) and separate the parts of the entire motor (Fig. 12). In Fig. 12 there are visible electronic components of the servomotor (DC servomotor PCB, potentiometer and other various elements). The potentiometer is then removed and replaced with an equivalent resistor pair, in this case of 2,2 kOhm (Fig. 13).

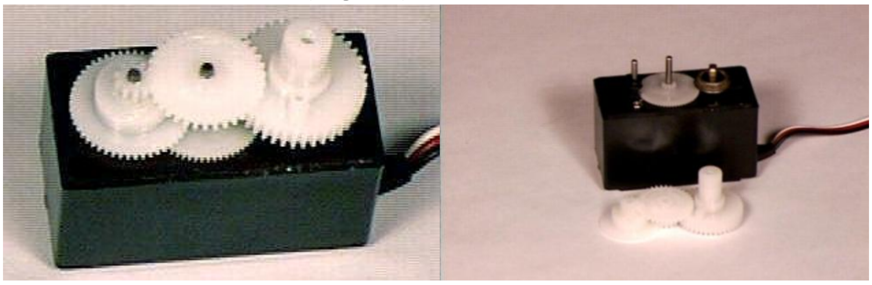

Figure 11. Removing the main gear.

Figure 12. Disassembled servomotor.

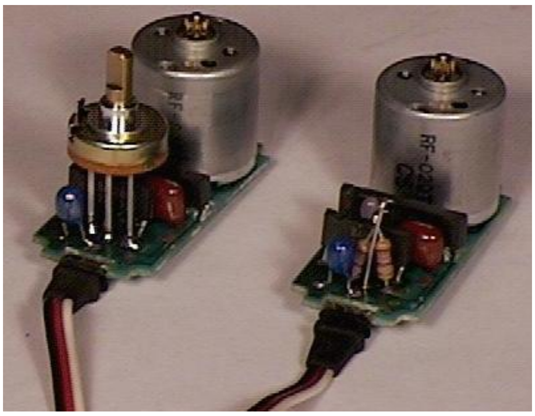

Figure 13. Replacement of the potentiometer with a pair of resistors.

Now, the electronic part of the modification is done and the next step would be to abolish the mechanical blockage of the main shaft shown in Fig. 14.

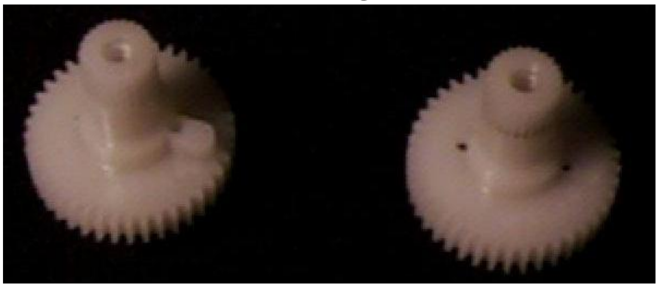

Figure 14. Modification of the main shaft of the servomotor.

Modification of the shaft is done with hand tools such as a wood file, the latter was used for removal of the limiter.

After all these operations, both motors are carefully re-assembled and ready to function as servomotors with a circular motion.

E. The Operation Logic

The task of the Braitenberg autonomous vehicles is to drive to the light or away from it. The control unit reads the voltage drop on the left and right photo resistor via the analog input and stores that value from 0 to 1024. Using the command "map" (Fig. 15) the read value of the photo-resistor becomes the new variable in the range suitable for RC servomotor PWM.

```
map(value, fromLow, fromHigh, toLow, toHigh)
a = map (analogRead(A0), 0, 1024, 0, 94);
```

Figure 15. An example of the „map“ command.

Then the variable "a" is sent to the function "servo.write" (Fig. 16) that generates PWM output. The function "servo.write" is already included in the library “Servo.h” which is exclusively made for servomotors such as those used in BROT vehicle.

```
#include "Servo.h"
Servo rightServo;
void setup() {
rightServo.attach(9);
 }
void loop() {
......
rightServo.write(a);
}
```

Figure 16. An example of the „servo.write“ command.

The command "servo.attach" is used during initialisation, to discover whether the motor is connected to the PWM channel (In this specific case the channels 9 and 11 were used.). The Arduino programme code is given by Fig. 17.

```
 #include "Servo.h"

 Servo leftServo;
 Servo rightServo;
 int leftValue = 0;
 int rightValue = 0;
 int a;
 int b;
 int c;


 void setup() {
  leftServo.attach(11);
  rightServo.attach(9);
  Serial.begin(9600);

}

 void loop() {
  // sensor values between 50..900
  a = map(analogRead(0), 0, 1000, 114, 0);
  b = map(analogRead(5), 0, 1000, 95, 170);

  c = analogRead(0) - analogRead(5);

  if (c < -60) {
  leftServo.write(95);  // pin10 from 0 to 95 moves backward, if greater moves forward
  rightServo.write(a);  // pin9 from 0 to 114 moves forward, if greater moves backward
Serial.print ("less");
}
  if (c > 50) {
   leftServo.write(b);  // pin10 from 0 to 95 moves backward, if greater moves forward
  rightServo.write(114);  // pin9 from 0 to 114 moves forward, if greater moves backward
  }

  if ( c > - 49 && c < 49) {
   leftServo.write(b);
   rightServo.write(a);
  }

 delay(10);
 Serial.print(a);
 Serial.print(" , ");
 Serial.print(b);
 Serial.print(" , ");
 Serial.println(c);
   }
```

Figure 17. Arduino programme code.

CONCLUSION

This paper describes, in detail, the design and manufacture of the prototype of autonomous vehicles, "BROT", inspired by Braitenberg's work (the vehicle II). The vehicle is manufactured with components that can be bought in the most of specialised shops, thus making it easy to multiply vehicle already developed in this work or to develop similar vehicles.

The vehicle is tested regarding its, at the moment, rather limited capabilities: finding sources of light and obstacle avoidance. There is no possibility of absolute orientation for BROT in a space because of the lack of input variables or sensors, which requires mechanical re-design an upgrade of programme code.

In a future the prototype can be extended in several ways: addition of new sensors, wireless communication and many enhancements in control software which includes intelligent and autonomous interaction with other similar vehicles.

The vehicle is equipped with a microcontroller system based on the Atmel ATmega328 microprocessor that allows a fast execution of instructions (16 MIPS). Due to the extremely strong microcontroller, there is a possibility of implementation of remote management for the vehicle based on Bluetooth communication. Bluetooth communication is possible via a Bluetooth module for Arduino (Fig. 18). Arduino's concept of stackable modules − shields allows many possibilities of installation of additional equipment. With the implementation of wireless communication, there is a possibility of working on more vehicles together and implementing artificial intelligence into their work.

Figure 18. Bluetooth module for Arduino UNO.

It would be necessary, also, to implement additional sensors on the vehicle, such as sonar, which would allow mapping of the space for better orientation (Fig. 19).

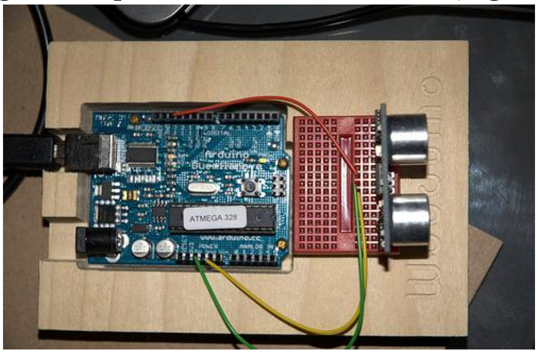

Figure 19. Sonar.

So, in the future work, several differently equipped robots will be made, in order to conduct experiments of task assignment in processes of construction and deconstruction.

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