Modelling Control Systems by Autonomous Mini Robot

József Tick

Institute for Software Engineering, John von Neumann Faculty of Informatics, Budapest Tech
Bécsi út 96/B, H-1034 Budapest, Hungary
tick@bmf.hu

Abstract: The modelling of control systems provides several useful information on the expected behaviour of a final system. A great advantage of modelling, which might be considered as a supplement to the simulation of controlling is demonstration, and the examination of the impact of parameters that can be simulated only with difficulty on the system to be developed. This paper deals with the selection and application of a mini autonomous robot that can be used for demonstration and experimental development in higher education. The paper also considers the special requirements determined by the given environment, the selection criteria, the questions of implementation into systems and a case study.

Keywords: control systems, robotics

1 Introduction

Nowadays at the development of control systems, during experiments and in education the simulation of simple and complex systems, and their modification or further development based on the simulation is an established practice. Beyond simulation, the physical realisation and testing of modells provide further important information on the given system. In education the demonstration and the experimental opportunity with a physically built and operational modell is of especially high importance. Apart from that, with the help of modelling such complex parameters can be considered that are quite difficult to determine during the simulation.

Due to the above reasons the demand for building and implementing a mini autonomous robot to be used in experimental development in higher education with success has emerged. Own design and developments are always professionally challenging, however, the manufactoring of the product is not economical due to the small volume needed. The expected tennish number does not cover the development and PCB production costs. The own development of the software system enables high level of creativity and flexibility, however, development time hinders the implementation of the robot into the system. The software provided with the robot can be changed with an own developed software any time.

As a result, the examination of products available on the market and the purchase of a selected product seems satisfactory. Loads of robots with similar features but with different structure and attributes can be purchased and/or built from different kits.

In the following chapters requirements set by the environment described above, the selection criteria and the experimental application of the assembled robot will be discussed.

2 Requirements and Selection Criteria Facing Mini Robots

The parameters described in the introduction will play a determining role at the determination of requirements and selection criteria facing mini robots. The requirements split into three main groups are as follows:

2.1 Application Requirements

Considering that, in the field of controlling, autonomous operation and intelligent problem solving, a mini robot will be applied in order to give modells, demonstrate and educate, that is why the following features are primarily important:

- Wide field of applications, general purpose sensores
- Flexibility, large freedom in programming
- Autonomous operation (for relatively long time)
- Simple realisation, easy reproduction
- Easy programming, comfortable developing environment

2.2 Hardware Requirements

There are several opportunities to realise the hardware of the robot ranging from very simple to quite integrated and compact ones. For our purposes a middle sized, not too complicated, not too integrated, bargain price levelled hardware has met the hardware requirements to the largest extent:

- Clear physical architecture, standardised application methods, easily understandable, easy-to-demonstrate functions,
- Application of such a microcontroller, which is used in education, the professional culture is available,
- Hardware solution for communication to PC (IRDA, WiFi, Bluetooght, etc),
- Small power consumption, while long term operation,
- Reliable circuit solutions with simple components, robust, stable structure,
- Flash memory programme storage capabilities, with programme downloading function.

2.3 Software Requirements

In case of sotware requirements the embedded operating system in the robot, which takes care of the real time operation and the necessary system routines must be considered, while, on the other hand, the development environment, the possible programming languages, and the sofware support of the development must be taken into account. Considering all these, the following requirements can be stated:

- Simple, compact real time operating system, with high level system routine support,
- The usage of widespread programming language for the development of applications (C, C++, C#, JAVA),
- Comfortable, PC based integrated development environment, which includes the necessary tools ranging from editor via assembler to simulation,
- Useful programme library to support development,
- Reliable, comfortable simple programme downloading facility.

3 Potential Robots Meeting the Requirements

After a careful evaluation of offers, specifications from the producers and material available on the internet it can be stated, that considering the availability and the price factors four robots out of several dozens of similar ones meet the requirements stated above. These are the following in descending order:

ASURO developed by the Institute of Robotics and Mechatronics of the German Aerospace Center meets the requirements to the largest extent. It is based on ATMEGA8 processor, has two photodiode-sensored linefollower, 6 bump sensors, two ODO meters, and it is driven by two DC motors with gears. Communication is realised by infra LED and phototransitor. Applications are developed in C programming language, and these developments are supported by UNIX and WINDOWS based integrated developing environment. This robot can be easily purchased in kits in Hungary. It is widely used in educational institutes in Germany.

Mark III developed by Portland Area Robotics Society is based on the 16 bit microcontroller PIC 16F877. It uses the Fairchild photoreflector for line following, and a Sharp infrared ranging sensor for Ranging. Two servo motors ensure driving. Two different batteries provide electricity to the control panel and the servo motors. Communication with PC is realised via serial cables. A programming language can be selected from CH BASIC, C, JAL and OOPIC. The developing environment is mid-ranged. The product can be purchased in kits from overseas and it is one and a half times more expensive than the previous one.

SoccerBot S4 made by Joker Robotics is the next robot. The SoccerBot S4 is a small, compact mobile robot built around the EyeBot controller and EyeCam camera. The robot consists 2 DC motors with encapsulated gears and encoders, 3 infra-red PSDs and an EyeCam digital camera. The controller software is an RoBIOS. The programming languages could be C, C++ and ASSEMBLER. A serial cable is to be used for communication between the robot and the PC. This robot is much more expensive than the previous ones.

Rug Warrior Pro robot has been developed by MIT Artificial Intelligence Laboratory. The hardware based on MC68HC11 microprocessor contains 32 Kbyte memory, bump sensors, dual light sensors, which measure the light intensity in the robot's environment, two infrared emitters and one infrared sensor, and a microphone. The robot is driven by two DC motors with gears and ODO meter. The system can be programmed in interactive C and the developed application can be loaded to the robot via a serial cable. The full documentation for assembling the robot is available, but the product itself can be purchased neither in kits nor in assembled form.

Considering the requirements determined earlier, the availability, the popularity and the price factors the **ASURO** robot made by the German Areospace Center was chosen for our purpose.

4 ASURO – German Aerospace Center –Institute of Robotics and Mechatronics

The ASURO robot made by the Institute of Robotics and Mechanotrics operating in the German Aerospace Center was especially developed for educational purposes. Developers strived to make a simple and flexible robot with clear physical structure.

The software support of the robot is excellent. The robot can be programmed in C and a complete developing environment is available with several types of services. The development is confortable and the realisation of applications is supported by a large programme library. The developed and compiled programme can be downloaded by IR transmitter and receiver operating on R232 or USB. Only the physical barriers of IR communication might hinder communication during the operation of the robot.

The robot can be purchased in kits, assembling, implementing and testing of the robot last around 5-6 hours. The assembled robot with sensors motors and gears are shown on Figure 1.

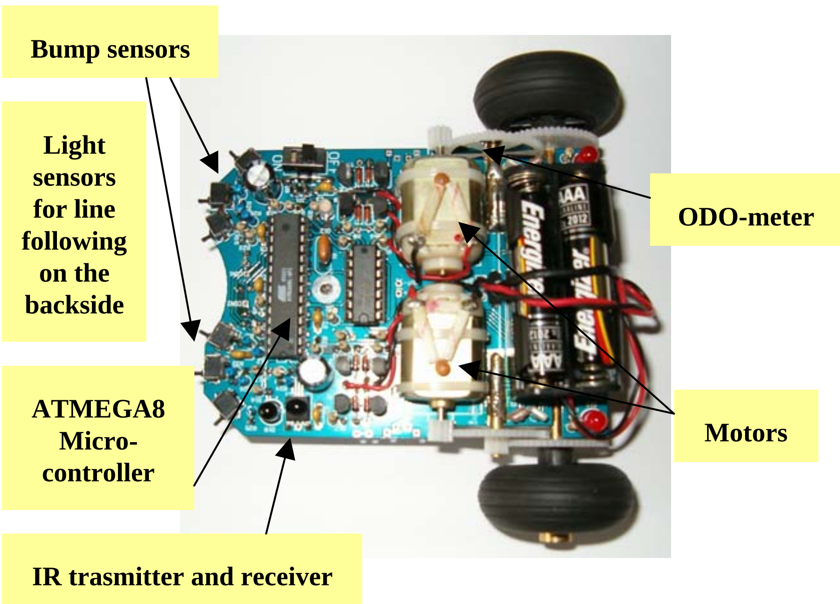

Figure 1
An assembled ASURO robot

The robot's embedded software enables flexible application and the available system routine services are good. As it can be seen on the block diagram of the system (Figure 2) the sensors and other peripherial equipments are connected to the microcontroller directly and thus they can be handled quite flexibly from the software.

5 Modelling of Control System Ensuring the Tracking of a Fixed Track

The tracking of fixed tracks in case of control systems is a regular task. The form of tracks might range from the optical tracks to ones operating with electronic signal source. Autonomous industrial robots operating in storage houses and in the industrial production are doing this job. The modelling of control systems is excellently apllicable for tracking an optical track. Modelling of track shadowing with a built physical system illustrates all the uncertainties of control technics quite well thus can be used for educational purposes with success. During the modelling process I used a proportionate type (P type) control intentionally due to the explicit behaviour of the system in this case. The shadowing of the track is a simple task, however due to the faults of the sensors and the time constant of the system, imprecision was experienced.

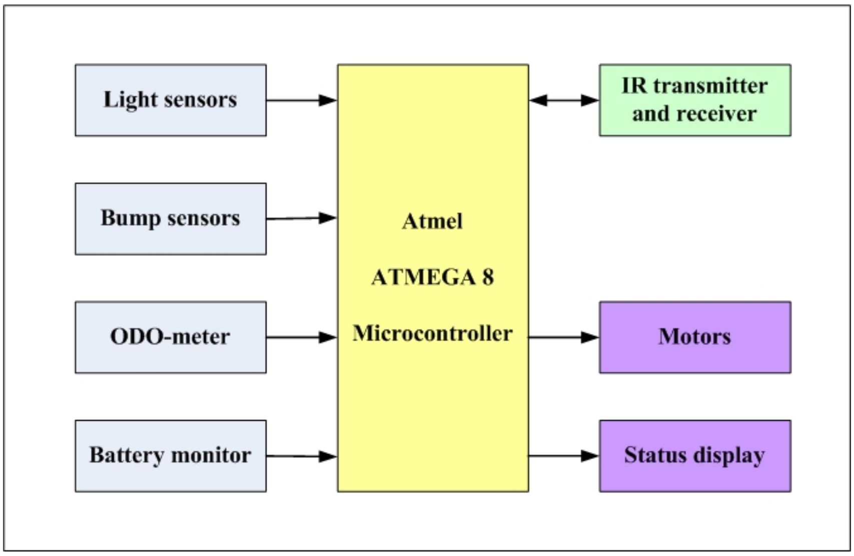

Figure 2
The blockdiagram of ASURO robot

The assembling of the model is demonstrated on Figure 3. The C programme made for the experiment realises the P type controlling. The speed of the robot was adjusted to 35 cm/sec. At a lower speed the robot is cabaple of following the track more precisely, while at a high speed, simple controlling does not work and the robot goes sideways. The chosen speed secures that the robot follows the track with slight mistakes. The presentation of the mistake is a significant part of this modelling of control.

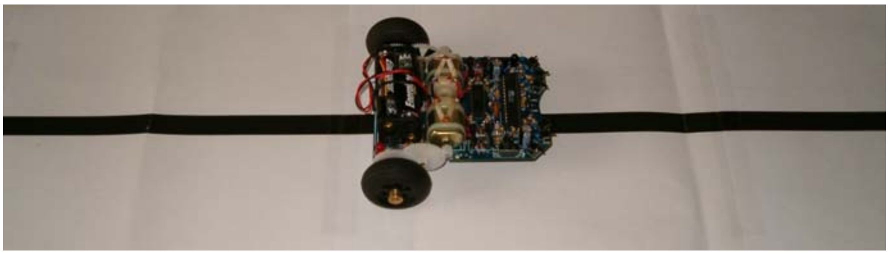

Figure 3

ASURO follows the track

The track of the robot by stabilised oscillation is presented in Figure 4. The fixed track is drawn by broken line. The failure and the time constants are presented in a normalised diagram, transformed to time on Figure 5.

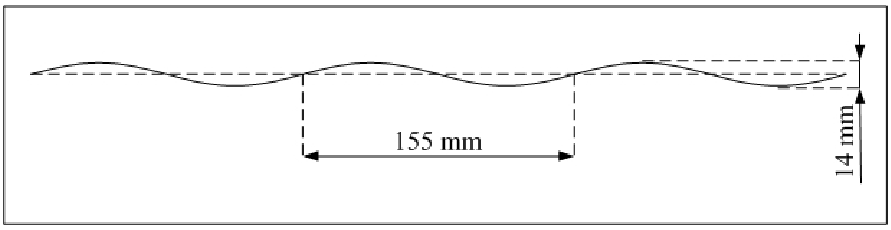

Figure 4

A movement of the robot in steady swinging state

The approximately 450 m/sec oscillation time well presents that the fast C software cannot compensate the mechanical bias due to the simple controlling algorythm. In absolute value, the failure is not large compared to the size of the robot, however the waving movement can be well seen at the given speed.

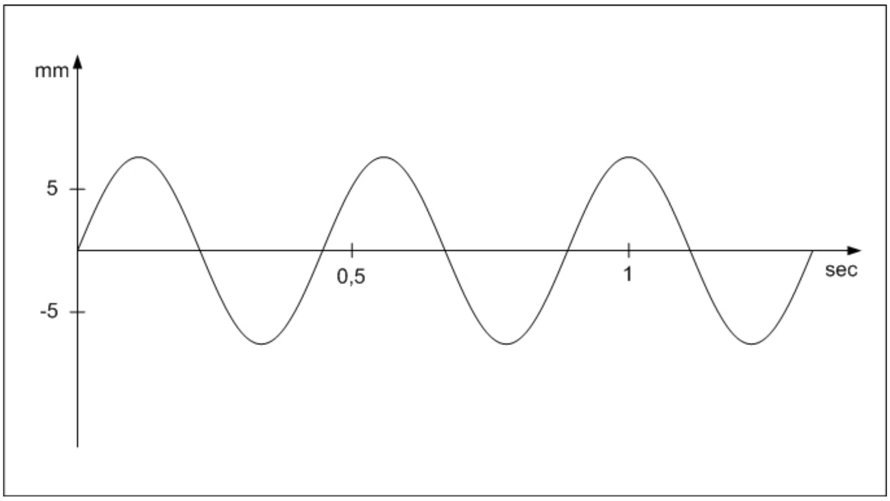

Figure 5

The form of mistake at constant swinging state in time

Conclusions

The assembled robot functions excellently, modelling demonstrates the specifications of the control system explicitely, spectacularly and in accordance with physical laws. The next step will be to develop controlling algorythm. The examination of a fuzzy controlling opportunity is also emerged in paralell with PID controlling.

References

[1] Arcot Sowmya, David Tsz-Wang So, Wan Hung Tang: Design of a Mobile Robot Controller using Esterel Tools, Electronic Notes in Theoritical Computer Science 65, No. 5 (2002), pp. 1-8

[2] Alessandro Saffiotti. The Uses of Fuzzy Logic in Autonomous Robot Navigation. Soft Computing **1**(4):180-197, 1997

[3] S. Skaff, G. A. Kantor, D. Maiwand, and A. Rizzi, "Inertial navigation and visual line following for a dynamical hexapod robot," 2003 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Vol. 2, October, 2003, pp. 1808-1813