

Microcontrollers, Actuators and Sensors in Mobile Robots

István Matijevics

Polytechnical Engineering College, Subotica, Serbia
mistvan@vts.su.ac.yu

Abstract: A mobile robot consists of three main parts: mechanics (motion), hardware (image acquisition, processing and control units) and software (image processing, motion control and decision making). Every robot needs microcontroller(s), sensors and actuators of some type to interact with the world around it. This article presents a general overview of mobile robot hardware architecture.

Keywords: mobile robot architecture

1 Introduction

Mobile robots change their positions in space while carrying out their tasks. The most common is a two-dimensional (2D) change of position, though theoretically a (3D) solution is also possible (Figure 1).

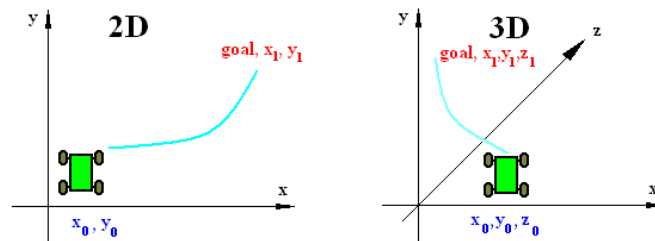


Figure 1
A 2D and 3D change of position

The mobile robot consists of many units:

- mechanics (chassis, housing, wheels, feet) (Figure 2),
- electromechanical parts (electrical engine (Figure 3), signal receiver),

- sensors (motion, distance, sound (Figure 4), image) and
- computer (Figure 5).



Figure 2
Mechanics of robot



Figure 3
Electrical engine



Figure 4
Sonar



Figure 5
Computer

Robots carry out many various tasks. During these tasks the robot moves and orients. While navigating, it uses signals from the environment and the contents of its own memory to make the correct decisions. This form of navigation may be manifold depending on the given task and problem. Often the goal can be sensed, there is no obstacle between the goal and the robot, but there are numerous times when this is not the case, then the marking points must be sensed and the route known. In order for the robot to be able to do this, it must contain two main components:

- Drive, motion and
- control, direction.

Our environment in reality is complex, not structured. In such an environment does the robot have to move, navigate and overcome the posing difficulties. The designer has limited and uncertain data of the surroundings, and during the robot's motion he has to deal with many unexpected occurrences and problems.

A possible way to create navigation is to apply artificial intelligence technique in which the connection with the environment may be put into several sub-categories (Figure 6).

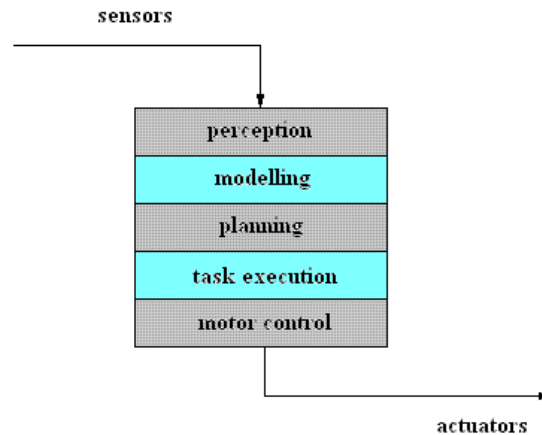


Figure 6
Robot navigation based on artificial intelligence

These units require complex hardware and software support, though their coordination also needs advanced software technology. The procedure includes the 'vertical' division, which requires the exact definition of tasks and at the same time, each unit is responsible for the execution of its own task.

The complicated artificial intelligence technique would be an alternative to the 'horizontal' organization, in which the specific units carry out the tasks in 'layers'. Every layer is capable of navigating the robot, though in the simplest possible way. Each layer also contains partial units present in the 'vertical' technique, however, in a much-simplified form.

According to Brooks [3] robot navigation may be multi-layered, where each unit is only responsible for the execution of its own task:

- 0 layer: the robot avoids touch with motionless as well as objects in motion,
- 1 layer: the robot moves aimless between objects without touching them,
- 2 layer: the robot 'sees' object further away if it moves towards them,
- 3-7 layers: significantly more complex tasks than those described in layers 0 to 2.

2 Architecture of Mobile Robots

Navigation of mobile robots is solved with microcontrollers and microprocessors. These micro devices have different capacities, they handle more or less in and outgoing signals, have various memory capacities and operating speeds.

The tasks of the robots may vary significantly from one to another, they range from fairly simple tasks to the execution of quite complicated tasks. This fact determines the architecture and complexity used for the robot's navigation. Within a mobile robot the architecture applied may be divided in the following way:

- a microcomputer for the execution of all tasks (Figure 7),
- one-level architecture with several microcomputers, using industrial bus (Figure 8) and
- two-level system using industrial and LAN, WAN busses (Figure 9).

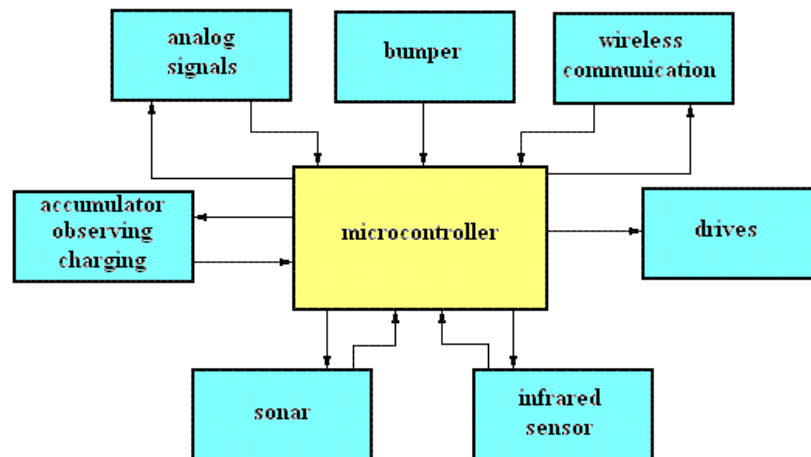


Figure 7

Simple architecture – one microcontroller

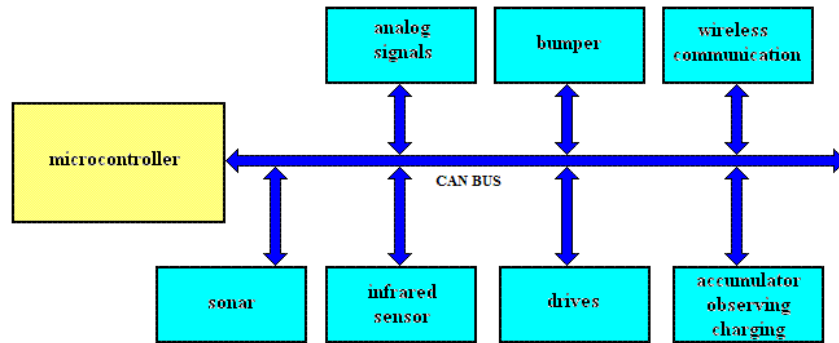


Figure 8
Industrial bus architecture – more microcontrollers

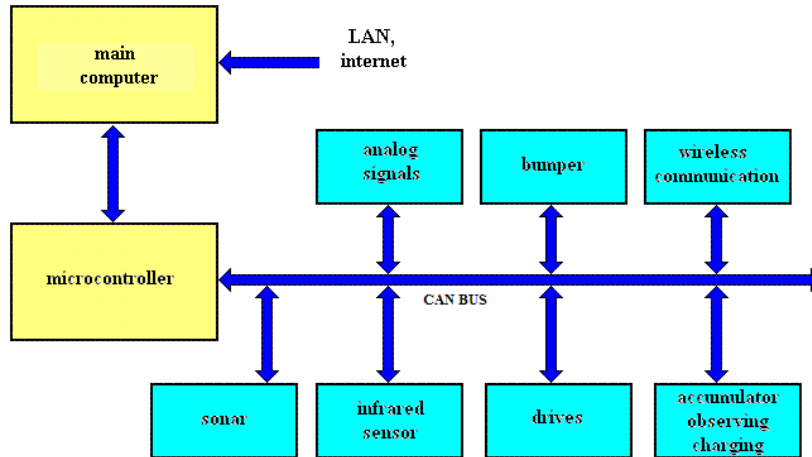


Figure 9
Industrial bus architecture, LAN, – more microcontrollers

3 Measuring of Distance Using Ultra-Sound (Sonar)

The mobile robot during its motion is sometimes nearer, sometimes farther from given objects which may inhibit it in its movement, though it may also use them to determine its own position. The distance of objects can be determined with a very

simple method, namely using ultrasound. As it is well-known, sound moves in air at the speed of $v = 330m/s$, at a temperature of $20C^{\circ}$. The theory of measuring is shown in Figure 10. A piezo crystal with a resonance frequency of $f_r > 28kHz$ emits a sinus signal for a short time. The reflected signal from the object is then measured by another (or the same) crystal, amplified and filtered by adequate technology and transformed into a logical signal. In this way it is easy to determine the distance of the object by measuring the time. Since the emitted signal can be kept within a limited range, the measuring is controlled. The ultrasound measuring device may be in a fixed position, but there is also an option to have servo engine attached to the robot which drives the sensor in a given direction.

Since the speed of sound is temperature-dependent, the AD channels of microcontroller to measure the temperature, then correct the measured distance with the data of temperature.

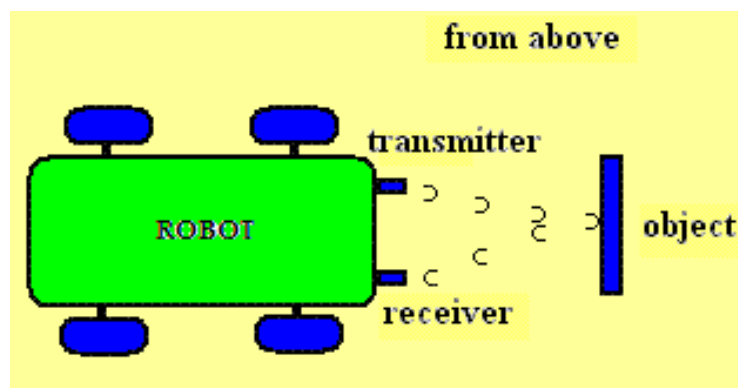


Figure 10
Determining the distance using ultrasound

The University of Ilmenau developed the HOROS mobile robot [5] equipped with 16 ultrasound sensors (sonar). A robot (Figure 11) is the advanced version of the ActiveMedia Pioneer model.

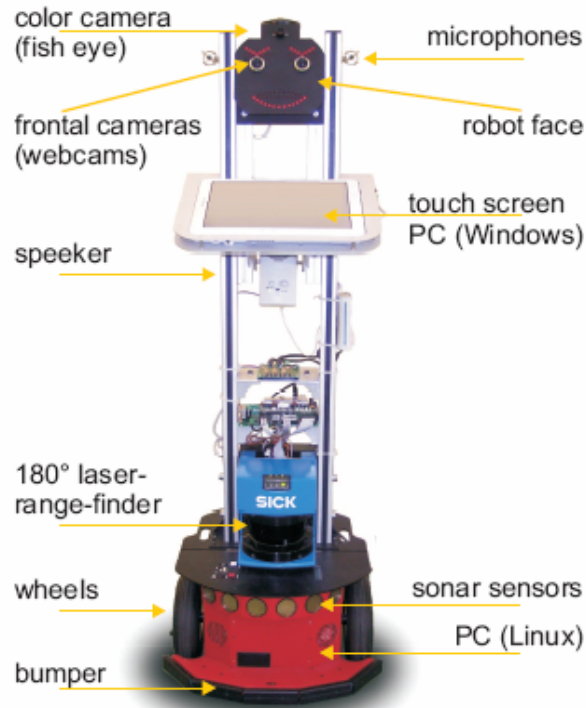


Figure 11
The mobile robot HOROS

The sensors are situated approximately 20 centimeters above ground. The sound travels in a 15° form of a cone at each sensor. A huge disadvantage is the impreciseness, as the result of the measuring does not solely depend on the distance but also on the angle between the object and the direction of measuring. The measurements are further distorted by crosstalk. Taking the previously mentioned facts into consideration the sensed area may be determined in which the robot ought to sense the person (Figure 12). Experience shows that this is possible within a circle of a 2m radius.

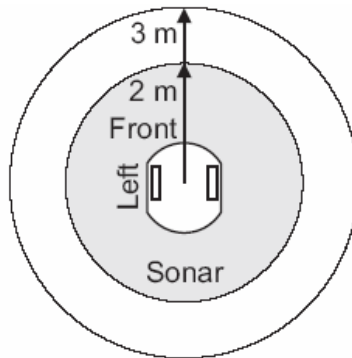


Figure 12
Field of vision of HOROS, top view

4 Crash Sensing (Bumper)

Although the mobile robot obtains information on the location of the various objects, and their directions, neither the ultrasound, nor infra measuring can sense each and every obstacle. Besides these other objects, for example another moving robot may also bump into the robot. Such objects may be sensed with crash switches which can be set up point by point or in a line. Figure 13 presents an in-line solution along with the sensor electronics.

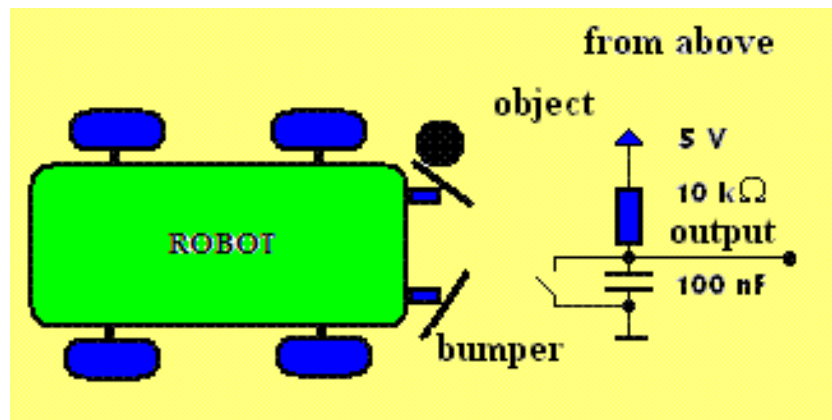


Figure 13
Bumper

5 Infrared Sensing

The crash-free sensing of nearby objects can be solved using LED diodes functioning in the infrared spectrum (see Figure 14) at 35-40 kHz square signal. The modulation is needed because other sources of light, e.g. the sun or lamps could disturb its operation. With the use of a modulated signal the unwanted signals can be filtered.

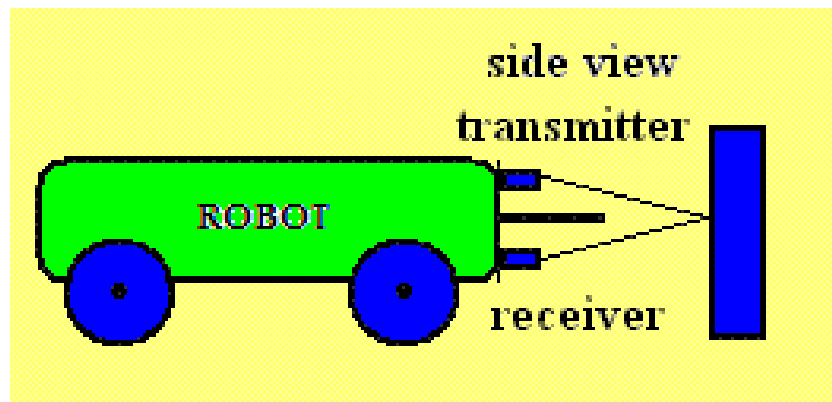


Figure 14
Sensing objects using infrared sensor

8 Drive

For the changing of location of mobile robots the most often used techniques are:

- wheels and
- feet.

For the driving of wheels three types of engines are used:

- DC motor,
- step motor and
- servo motor

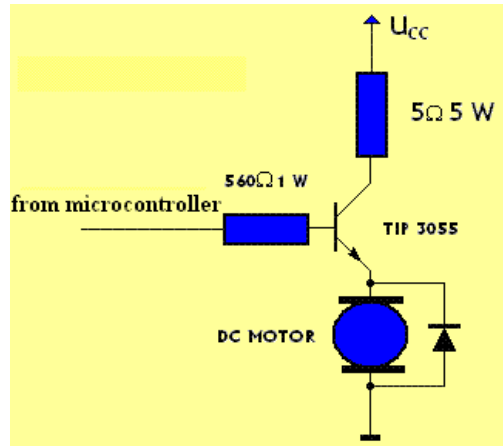


Figure 15
Switching on and off of the DC motor

Rotating a DC motor in both direction is done with the help of a transistor bridge, as it is presented in Figure 16.

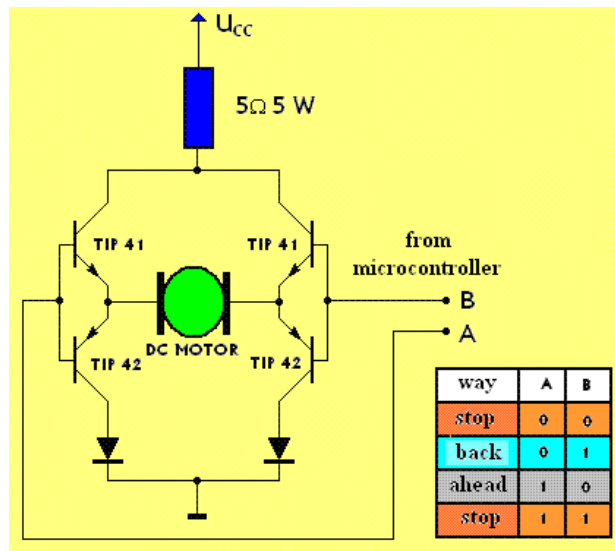


Figure 16
Transistor bridge for driving the direct-current engine

Conclusion

From the above-described it can be seen that the architectures and technical solutions used with mobile robots may greatly vary. The architecture must be carefully chosen in accordance with the tasks to be executed by the robot. Following that the sensors and executive parts must be carefully chosen. These steps will ensure the robot's reliable and safe operation. In instances when reliability and safety is especially sought after, even greater attention must be paid to architecture reliability analysis.

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