MOBILE MINI ROBOT

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Figure 1: Modular mini mobile robot

ABSTRACT

Research and development of the last years not only resulted in small microcomputers with higher performance but also in highly integrated sensors and actuators. Designing very small intelligent devices such as miniaturized intelligent autonomous systems is thus becoming possible.

The Institute of Robotics of the Swiss Federal Institute of Technology at Zurich (ETH) recently started exploring the field of mobile mini robots with on board intelligence and power supply. The goal of several master student projects was to design a mobile mini robot with on board intelligence and power supply. The robot's intelligence is based on a PIC16C84 micro controller and powered by two small watch batteries. Its actuators are watch type stepping motors which are geared down by 1:60. The motor coils are directly connected to the output of the micro controller. At the moment two different robots have been realized. One can follow a black line on white ground. The second can follow a wall and can simultaneously be teleoperated by a joy-stick. The wireless unipolar communication from the joy-stick to the robot allows to feed the robot with a global path. The local infrared reflection sensors allow to keep the robot at a constant distance from the wall. The control software is written in Assembly and allows sampling times up to a couple kHz.

1. INTRODUCTION

Integrating sensors, actuators, intelligence and power supply into a small autonomous unit is a key issue for the development of sophisticated and innovative micro-systems [1], [2], [3], [4]. Such miniaturized modules could be used to inspect and repair small devices or micro-tubes, or perform non-invasive microsurgery in the human body. Even if these challenging applications seem to be far away, it is important to gain experience in this field to encourage the development of new technologies. The mini robot presented in this paper has also taken part in the International Micro Robot Maze Contest in Nagoya 1996 where it became second in the category of wireless autonomous mobile robots. Our design with an autonomy of around 6 to 10 hours was by fare the best solution concerning power consumption and intelligence.

2. BASIC HARDWARE DESIGN

The major issue in designing autonomous microsystems with on board power source is the power consumption of the components. In our case of a mobile robot the main power consumption comes from the motor drives and the micro controller. It is therefore very crucial to select appropriate motor drives and controllers.

2.1 Actuators

After investigating different approaches we chose watch type motors (LAVET motor [6]) for the differentially driven wheels. They are the only available solution with small size and very small power consumption..

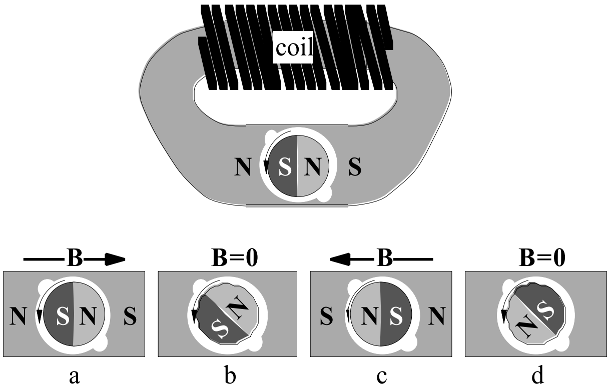

Fig. 2: Operation principle of the watch motor

Watch type motors are specially designed stepping motors using only one coil with many windings and relatively high inductance (850 mH). The magnetic flux path forms two poles on the stator. In contradiction to traditional applications, the two poles are not separated by an air gap, but by a reduction of the iron's cross-section, leading to a saturation, which is similar to an air gap. The rotor, sizing only around 2 mm, is equipped with a permanent magnet generating the north and south poles. Two opposite indentations cause that the rotor has got two preference states if no external field is applied.

A rotation is divided into four phases. In phase a and c, the rotor's direction follows the direction of the external magnet field, whereas in phase b and d, where no external field is applied, the rotor aligns with one of the two preference states. A disadvantage of this principle is, that it allows only rotations in one direction.

To increase the torque a gear is required. The axis of the watch's second hand, which usually makes 1/60 of a full rotation per second, is directly used as wheel. In our application, the motor is driven at a maximum frequency of around 50 Hz instead of 1 Hz, which gives a maximum velocity of about 20 mm/s at a wheel diameter of 8 mm.

Two motors are used to drive the robot, whereas a glass hemisphere is used for the third contact point to the ground. This kinematics configuration allows both, moving straight and following curved lines by choosing the appropriate velocity at the differentially driven wheels.

2.2 Sensors

The two major tasks of the mini robot are following a black line on the floor and driving along a wall which means also avoiding obstacles. In our approach we use miniature infrared (IR) diodes and photo transistors for both tasks.

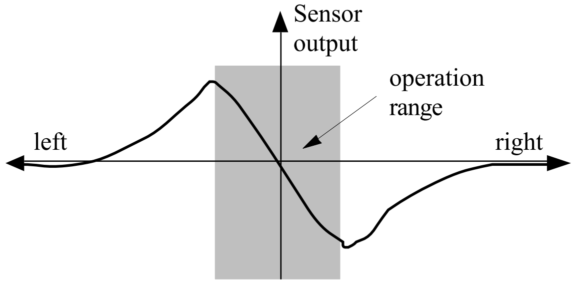

Fig 3: Characteristic of the line following sensor

In the first task, the infrared diode emits its light to the floor and two photo transistors placed on each side of the diode measure the reflected light. Figure 3 shows the resulting differential signal of the two photo transistors.

For wall following and obstacle avoidance one IR diode with photo transistor is placed on each side of the robot. They are looking towards front left and front right of the mini robot. Through the feedback controller the robots movement is changed as soon as one of the sensors detects a wall or an obstacle. This sensor system allows the robot to precisely follow a wall appearing on the left or right side.

2.3 System design, micro controller

In order to realize a mini robot system, that can fulfill various tasks, flexibility in hard- and software is needed. A modular approach has thus been adopted (figure 3).

The *base module* contains a microprocessor and a two-channel A/D-converter. Two small watch batteries are added for energy supply, as well as two small watch motors (from a SWATCH) [6] [7]. This module doesn't include any sensor. To extend the robot's abilities to solve specific tasks, extension modules are provided. They are connected to the base module by several connectors, giving access to the A/D input and digital I/O of the microprocessor and supplying the extension module with power (fig. 4).

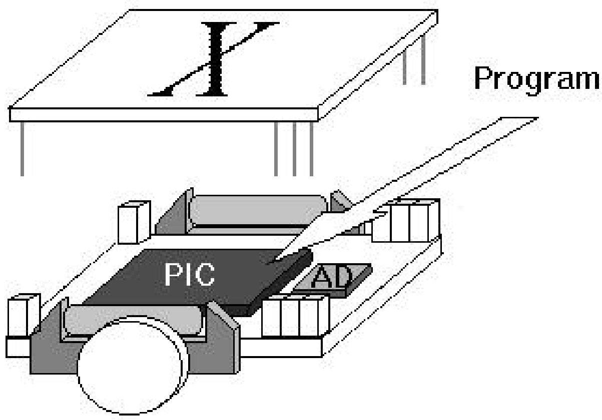

Fig. 4.: Robot consisting of a base and an extension module

To get a flexible system in software, the choice of an appropriate microprocessor is ve1y impo11ant. Small microprocessors in SMD are often 'one time programmable' (OTP). Using an OTP microprocessor in a robot system, software flexibility is poor, since the processor, once programmed, always runs the same software. In our design, a PIC 16C84 is used [8]. lt is in a SMD package and equipped with an EEPROM, which allows to download new software from a personal computer. Several digital 1/0's and a timer are the other features of this micro controller.

2.4 Extension Module

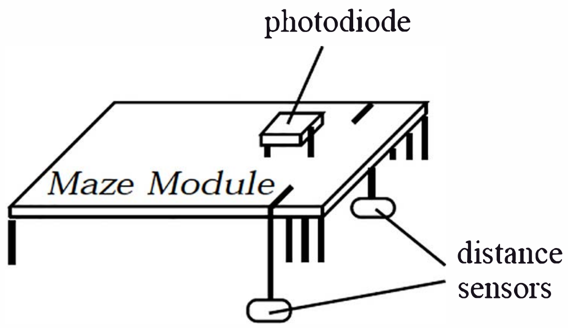

Fig. 5: I/O extension module for the maze contest

To adapt the robot to the micro robot maze contest, the 1/0 extension module (fig. 5) needs to be able to perfonn the two-stage control principle discussed in chapter 3. The global feedback is realized by an infra.red remote control. The human operator is able to send commands to the mobile mini robot using a sender box. On top of the maze extension module, a photo diode receives the signal from the sender. The signal is transfened through the connectors to the base module to control the robot's movements.

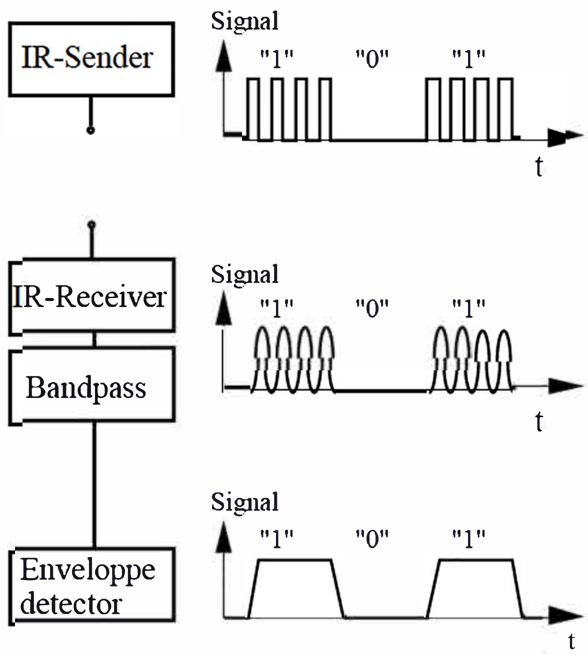

Fig. 6: Basic principle of the infrared remote control

The signal of the IR-sender is modulated by a canier wave of 5kHz. On the receiver side, the signal is füstly filtered using a band-pass filter. Disturbances such as light from bulbs, neon lamps or the stm are thus minimized. An envelope detector is then added to digitize the signal. Tue shape of the different signals are shown in figure 6.

For the local feedback, two distance sensors based on an infrared emitter diode and a receiver photo transistor, are placed at each side of the maze extension module. The signals from the receiver are converted by the two *A!D*-converters of the base module and allow the robot to follow the walls of the maze.

3. CONTROL STRATEGY

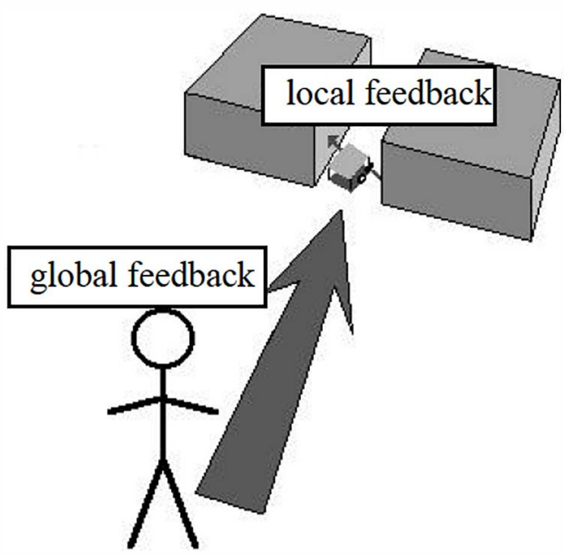

Fig. 7: Two-stage control strategy

As we are talking about primitive mini robots, some patt of the intelligent behavior is usually supplied by an extemal computer or a human operator. Thus, a two-stage control strategy, with a global and local controller, has been implemented for our system (fig. 7).

The global control commands or a prinutive task, as for example go straight, turn left or follow line, are remotely defined by an external robot controller or by the human operator. lt defmes the actual robot task.

The local controller then dlives the robot autonomously according to the local sensors and the given task. For exarnple, if the given task from the global controller is 'follow the wall rmtil you are able to turn left', the robot uses the optical distance sensors on both sides to drive along the wall and find the appropriate spot to turn left. The robot can also store a whole sequence of tasks and execute them later.

In order to drive the robot safely from a starting point to the goal position through an rmknown environment, several modes of motion have been implemented:

1. Remotely supported movement:

   In this mode, the robot moves straight if no obstacle is in its way. If an obstacle is detected it changes its direction to avoid a collision. If an obstacle is present, the robots movement can be controlled through the external control unit or the human operator using the infrared remote control. This allows to navigate the robot safely through an unknown environment.
2. Preprogrammed mode for structured environments:

   Within this mode the robot follows the walls in little corridors using the on board distance sensors. The human operator preprograms the robot path by choosing a sequence of actions to be executed at each intersection in the corridor. After preprogramming, the robot executes the given task autonomously. An intersection is detected if the local sensors measure a significant change.
3. Debugging mode:

   In the debugging mode, the strategy is the same as in 1 or 2, but the robot stops after each part of the sequence and waits for a new command.

4. CONCLUSION

In this paper, a mini mobile robot, developed in master students projects has been presented. The autonomous robot system has on board intelligence and power supply. It has the following main features:

- Global feedback and task specification are downloaded through a infrared remote unit to the robot. The robot then autonomously fulfills the given tasks using local feedback from on board sensors.
- The robot consists of different modules; a base module, which contains a microprocessor, two batteries and two swatch motors and different extension modules which adapt the system to various tasks.
- The robot has an on board PIC 16C84 micro controller, with an EEPROM. It allows to change the software according to the task.

The technical data of the remote controlled mobile mini robot are specified in the following table .

dimensions	21mm×21mm×19mm
velocity	20 mm/s
power consumption	< 10 mW
Infrared communication	6 m
System autonomy	up to 10 hours

Table: Specifications of the remote controlled mobile mini robot

Even if the mobile mini robot is still not very intelligent, it can fulfill its task with high robustness. Due to the very small power consumption of the motors no power amplifier is required. This allowed us to realize a mobile mini robot with only 5 electrical components, the micro controller an oscillator, a capacity and two resistors.

The presented mini mobile robot is probably the smallest intelligent autonomous system ever built.

5. REFERENCES

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