

Mobile Robot Navigation Projects at BMF NIK

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Abstract:

In the recent years we have been investigating the possibilities of developing and applying mobile robots within the framework of several projects at the Institute of Applied Informatics of John Neumann Faculty of Informatics at Budapest Polytechnic. The research included the study of development options of movement possibilities of mobile constructions, and also the automatic use of such in unknown environment. In this framework we have built a high speed, wheeled robot, which works, however, only at good lie of terrain, and also walking robots that are slower but can move at worse terrain conditions. Special sensors and cameras mounted on the robots are used for detecting the environment. The image-processing phase ensures that the obstacle positions and the free areas are detected.

In the talk I wish to present not only our results of the state of our current research, but the applied educational system as well.

Keywords: mobile robots, navigation, image processing

1 Educational-research background

Our institute has an established talent developing educational method [1], followed by robotics lab exercises. During the course the students have to solve a comprehensive task with a significant amount of substantive work in team based projects including many aspects of robotics and artificial intelligence. After acquiring the necessary knowledge of the equipment (robot arms, cameras and digitalization cards) in the first semester of the specialization, the teams begin to

work out their topic in the grounds of the given and self-researched relevant literature. They work out a systemic plan and implement it within the frame of continuous work in the second and third semester. In these semesters, they present and demonstrate their achievements at so called “mini conferences” where regularly external experts are invited. The work is not only documented in the half year tasks. Besides the systematic plan, a conference article and a homepage presenting the project also have to be made. A part of the completed work phases as well as further developed, researched versions appeared at scientific forums [2-8] in the recent years. The possibilities of the development of mobile robots are emphasized in the selection of subjects of the projects. In this article, we try to give a taste of the actual work of this kind.

2 Realization of tracking task with a caterpillar robot

The aim of the “Tarkus” project is to build a camera mounted caterpillar robot (Figure 1) with its own controller, which is capable of separated operation. An object is selected in the robot function assisting PC based frame program’s camera picture and after the properties of the object are saved in a database for further executed tasks. After this, the task of the selected object is told to the controller of the robot, which executes it. The present version of the system is capable of tracking the selected objects.



Figure 1. The caterpillar robot

2.1. The CMUCam vision unit

The CMUCam vision unit [9] uses a low-cost and fast microcontroller for fast processing the data of the camera, besides it contains a built in software which can be used for image processing. The high level information given by the vision module (e.g. the coordinates of the weight point the selected colored object) ensures that a simple microcontroller is able to process these data. So, a robot with little processing capabilities is able to solve comprehensive tasks and it does not need the help of a remote computer.

2.2. The set up of the caterpillar unit

The parts of the robot are the following:

- Microcontroller (Atmel 90S8515)
- 3 pieces of voltage regulator IC (7805 fixed and LT1085 variable voltage, which provide the power supply for the controller and the motors)
- 8 MHz oscillator (gives the precise clock stimulus for the controller)
- L298 type motor driver IC
- Extension plug
- State led-s (connected to the controller's A port; these give information about the robot's work and ease further development)
- Serial level converter IC and a serial port plug. (the camera is connected with the help of these)
- Extension plug (part of the controller's D port, it is used to communicate with the PC, it uses a programmed asynchronous transfer)
- Power supply plug (9-12 V DC)

2.2.1. The program of the microcontroller

The software is placed in the memory of the controller [10]. It holds many time sensitive parts, which means that real time processing is important for those parts. For example the PWM (pulse width modulation) signal generation and built in serial port handling. The development was assisted by the 8 leds as a debug tool.

2.2.2. The motor driver IC (L298)

The driver IC includes two transistor bridges, these with the help of TTL level inputs can drive inductive load (relays, DC and step motors). The both bridges of the circuit have three inputs. Two control inputs per bridge decide which transistor opens on the two side of the bridge; the direction of the current drives the motor in one or the other direction. The enabling input enables the effect of the two previous inputs. We can realize two different kinds of snub. If EN=0, beside IN1 and IN2 optional level, it makes a passive break (the motor slows freely). If EN=1 and IN1=IN2, then it makes an active break. In this case, the two inputs of the motor are on the same potential, it makes an effective break. The system uses this solution. After making the control software the rev regulation is made by a PWM signal. This controls the motors through the previously mentioned IC so the caterpillars can be controlled separately and the robot goes at an optional speed to an optional direction.

2.2.3. The PWM signal generation

The PWM signal was needed because of the rev regulations of the motor. The generated fill out coefficient of the signal grows proportionally with the rev of the motor. During the trials it turned out that if the coefficient increases, the motors first do not respond, only after 33% they start to move and accelerate more and more.

The PWM signal production is helped by the TIMER1 counter of the microcontroller. For the usage of the two separate motors two separate signals have to be generated. Because we get the clock of TIMER1 from the oscillator, the PWM signal has a frequency of 122Hz ($= 8\text{Mhz}/65536$). The PWM generator has 16 bits resolution, but we simplified it and just the higher eight bits are used, so the speed level can be given between 0 and 255.

2.2.4. The built-in serial port handling (camera–robot link)

The 90S8515 microcontroller includes one built-in UART (Universal Asynchronous Receiver/Transmitter) circuit, so the communication with the camera is easy (CMUCam). The serial port is handled through interrupts.

2.2.5. The programmed serial port handling (PC–robot link)

Because the 90S8515 microcontroller has only one UART circuit, we had to write software for programmed serial asynchronous transfer also for the connection between the robot and the PC. The printed circuit board of the robot locates the plugs of port D, which allows for simple connection.

The main program executes the commands similar to the data coming from the camera: it is doing the job on the ground of the command code and returns a “receipt”. In case of a bad command code, it returns an error receipt. The command codes can be seen on the Figure 2.

| COMMAND CODE | DESCRIPTION |
|----------------------------|--------------------------------------|
| ROBOT_PRESENT | Robot’s availability can be checked |
| SET_RIGHT_MOTOR_SPEED | The speed of the right motor |
| SET_LEFT_MOTOR_SPEED | The speed of the left motor |
| SET_RIGHT_MOTOR_DIR | The direction of the right motor |
| SET_LEFT_MOTOR_DIR | The direction of the left |
| CMU_RESET | Camera (CMUCam) initialization |
| CMU_SET_TRACKCOLOR | The color of the tracked object |
| CMU_SET_TRACKCOLOR_OPTIONS | Properties |
| CMU_TASK_STOP | Clearing the present task (stand by) |
| CMU_TASK_TRACKCOLOR | Begin color tracking |

Figure 2. Command codes and their meanings

2.3. Introduction to the PC frame program

2.3.1. Object identification, testing of tracking

First step is to mark a nearly homogeneous colored object which has to be followed (in other words, the color spectrum which is relevant to that object):

- We acquire a picture from the camera (in case of blurred or too dark picture the focus and brightness can be changed)
- A point of the object is selected (throughout the process, the area under the mouse pointer shown in a smaller picture)
- After clicking the “selection” button, the selected points, which are in the given threshold, are highlighted on the picture. The program in this step creates the properties to be sent to the “Track Color”, so we can check the tracking by moving the object in front of the camera. After sending out the “Track Color” command, the program draws a square which covers the tracked points.
- If the test verifies the data, then we can save it to the database.

After all of these, the data of the object can be sent to the microcontroller (or one can be chosen from the database) and the robot is ready to track it. The robot remembers the properties of the last object, so it can operate without the PC.

2.3.2. Object tracking and the test of control

If the data of the object arrived to the microcontroller, it forwards it to the camera, which sends back the coordinates of the central point. This allows the robot to control the motors. Throughout the tracking process the speed of the motors and the direction are graphically visualized. The robot can also be controlled manually.

3. CCEXplorer – The wheeled mobile robot

3.1. Aim of the project

The aim of the CCEXplorer project is to design and build a radio controlled wheeled mobile robot, based on a model car controlled and navigated by an external computer. The car should carry only the sensors, the power plants (accumulators) and the sender and receiver units needed for the communication.

Navigation in the macro environment is based on the Global Positioning System (GPS), while obstacles in the micro environment are recognized by a monochrome camera and distances measured with a sonar. It is a significant aspect during the development to design a computer based robot navigation system, which is easy and cheap to implement or upgrade and available for educational applications.

Development is in progress on multiple, parallel threads. The tasks and the subsystem developments are sorted as listed below:

- Sender and receiver side electronic; sensor connections; control; using the sonar
- Computer Vision; obstacle recognition; following target objects; support the navigation subsystem by the recognized features of the environment factors
- Navigation; path calculation and correction; processing GPS data.

According to the intention of the project, the development of the navigation subsystem is performed as an independent project. This subsystem communicates with the CCEXplorer system through a standard interface.

3.2. Parts of the system

3.2.1.. Utilized appliances

- Tomya model car
- Graupner MC-10, 8 channel radio sender and receiver (to control the car)
- PC (to run the developed computer vision based control system)
- Camera with radio transmission placed on the robot
- TV Tuner card to digitalize video signals
- GPS receiver
- Ultrasonic sonar

3.2.2. Controlling the robot car

The basic condition of computer based controlling was making the radio sender able to transmit the signals received from the computer instead of that sensed on the manual switches. However it was reasonable to retain the original manual controlling ability for the case of emergency. The best solution to do so was the teacher module option of the Graupner MC-10 controller unit. This allows for connecting an external PPM signal to the sender. The best possibility was the use

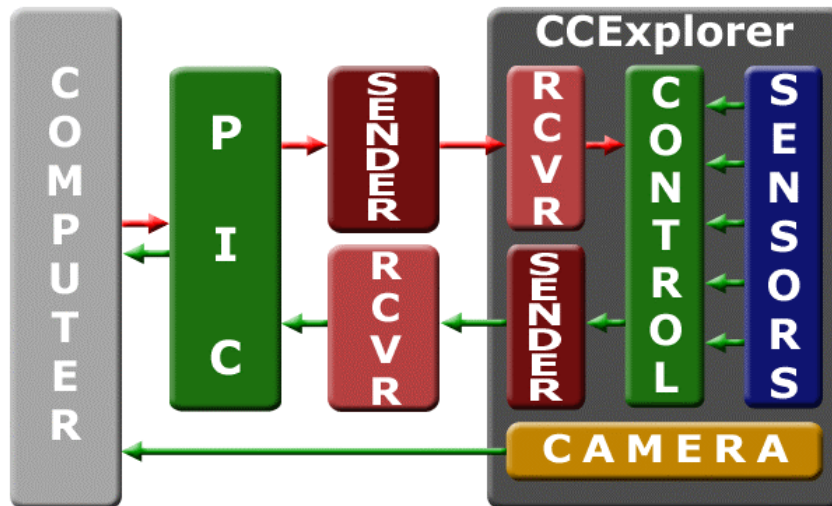


Figure 3. Block scheme of the system

of a microcontroller which is able to receive, convert and transmit the navigation commands of the PC. Microchip's PIC family microcontrollers [10] includes everything needed to a simple method of signal transforming, from clock generator, registers, to serial communication support.

3.2.3. Collision avoidance based on computer vision

One of the main objectives of computer vision is to find the necessary information from the two dimensional image data received from the camera. According to the intention of the CCEXplorer project the use of a single camera was preferred to reduce costs and to increase processing speed. The transmitted video signal is connected through a TV tuner to the PC. The processing algorithm written in Borland Delphi reaches the video stream through a Video for Windows component which works with API calls.

For avoiding obstacles, the program observes the field before the robot using the Optical Flow [11] method. Two frames following each other are compared. The displacement of each pixel is straight to the distance of the object containing the pixel. Controlling commands can be determined by the displacements recognized on the left and right side of the seen image.

3.2.4. Following objects

The easier way of following is trying to identify target objects by searching for its color. For the sake of simplicity we settle for recognizing object contrasting with their environment. The algorithm employs simple histogram rating method. The

disadvantage of this method is that two lapping objects can not be separated. At the same time the developed software is adaptive, it can sense the shade fluctuation of the target object. Nevertheless, to do so, a color camera is needed.

The method of seeking geometrical features is the more complicated way to find target objects. Simplifying the tests in this case, the target object was a ball, so we just needed to find circles or arcs on the images. The seeking was performed on images filtered by a SUSAN [12] edge detector. The advantages of our modification of the method described at [13] are that target objects can be unequivocally identified, moreover, multiple targets can be followed. Edge detectors work with black and white images, so we do not need color cameras.

3.3. Results

During the development of the project we managed to find a computer based robot navigation system, which is easy and cheap to implement or upgrade and available for everyone so competent for educational applications. We prepared the electronics to control the robot from the PC by adjusting the speed and steering in about 30 steps.

A PC based controlling software is ready and working, applying computer vision technology to navigate and control the car. Furthermore it supports the later integration of the object following module and other subsystems (GPS, obstacle detection with the sonar etc.).

The strength of the project is that the robot, already in its current condition, is able to navigate and avoid collision with obstacles. Although the object following software is reliable only upon special conditions, the collision avoidance algorithm works in real and not only in a test environment including laboratories, streets, even surfaces.

3.4. Current tasks

The development is continuous. Currently the capability expansion on-the board electronics and the integration of additional sensors (sonar, GPS) are in progress. In parallel to that, a complex navigation software is under construction for receiving and processing GPS data. With the capability of path calculation and correction it will be responsible for the navigation in macro environment. The abilities of the computer vision subsystem are enhanced continuously.



Figure 4. The robot car on its way

Conclusions

Notable researches have been underway in the area of development and appliance in the recent period. We examined the prospects of the motion possibilities of mobile robots, developed and implemented obstacle avoidance, motion planning and navigation algorithms at the Budapest Polytechnic. The research results were published at international publications and exhibitions. Besides, our students achieved remarkable successes at national science contests. The systems presented in the article and still under development have serious chances to follow the good traditions.

In summing up the pros and cons, application-oriented lab courses have been found to be an overwhelmingly positive experience. One of the lessons learned is that many students are willing to invest far more time and energy than usual so that their results can be distributed to a wider audience at various professional gatherings. The competition among the students for this honor and the possibility of the publicity involved are highly motivating to the students. Many even invest their own money in order to produce a more effective, higher quality end product.

Another advantage is that they introduce the students to real-world challenges and constraints. The complexity of the projects requires the students to apply not only the AI techniques being studied, but also what they have learned in other subjects such as electronics and digital technology. The process of designing, procuring and actually assembling the various mechanical and electronic components illustrates the complexity of engineering tasks encountered in the real world. The students also learn the importance of being able to present their results effectively – in this case to their fellow students. Finally, the desire to provide meaningful guidance to the students motivates professors and outside advisors to continue their own research and improve their teaching.

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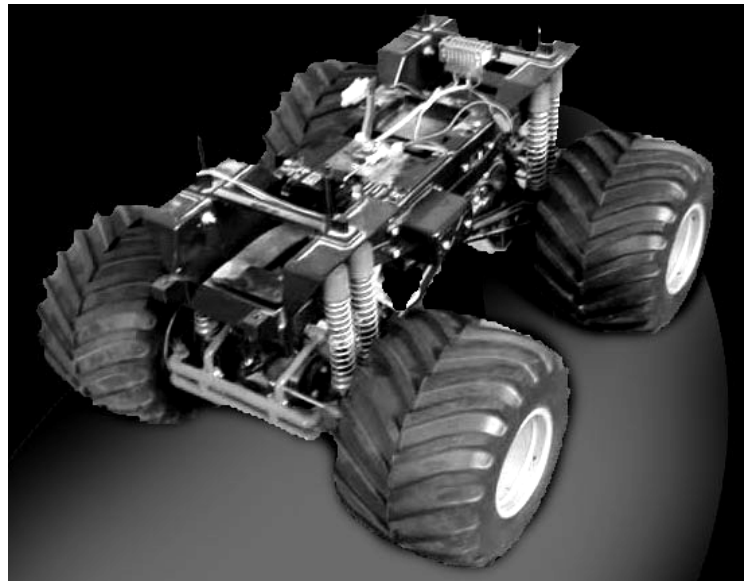


Figure 5. CCEXplorer mobile robot