Walking or Rolling: Mobile Robots at the Budapest Tech

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Abstract:
In the recent years we have been developing mobile robots at the Budapest Tech. The project researches included the study of development options of movement possibilities of mobile constructions, and also the automatic use of such robots in unknown environment. We have built a high speed, wheeled robots, which work, however, only at good lie of terrain, and also walking robots that are slower but can move at worse terrain conditions. In our experiments different sensors and cameras are used for detecting the environment.

In this paper I would like to summarize our results of the last decade in the field of mobile robotics.

Keywords: *mobile robots, walking robots, wheeled robots*

1 The background of the projects

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. 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. 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 [2-10] in the recent years. The possibilities of the development of mobile robots are emphasized in the selection of subjects of the projects.

1 EXPLORATORES II – quadruped walking robot

In the first and successful project the mobile robot named EXPLORATORES had four legs, and was made of lightened aluminum. The legs have three degrees of freedom, and are driven by servomotors. Thanks to the 12 servos on board the robot is capable of executing a wide range of different movements. To drive the robot five 89C 51 microcontrollers and four XC3020 logical gate circuits are used.

Steady walking is achieved by employing various statical and dynamical walking strategies [2, 4]. The robot can function either autonomously, or via a connection to a PC, using a serial port. It is possible to test the behavior of the robot using the software we developed. The set of programs for the PC contains neural network based, rule based, wave propagation based and GVD (Generalized Voronoi Diagram) based path planning modules, as well as other versions of these modules, that have been modified and explicitly matched to the robot [3]. The system makes testing and comparing the efficiency of various routing algorithms possible. The program contains modules to edit the rule base and the neural network's training patterns, and also, when using neural networks, allows training using pre-made or new training sets. A so-called "learn by experience" algorithm has been developed to aid the automatic creation of the rule base, and representative patterns for the neural network. This algorithm generates a table of size predefined, which contains the most often successfully applied rules. To achieve this, the user, with the help of the simulator, can introduce various obstacles that the robot needs to avoid in order to reach successfully it's target. The more obstacles the robot manages to avoid, the more "experience" it gains about solving each situation.

The robot extracts information from its environment by the means of retro-reflective infra and CCD sensors. It is also equipped with a camera that employs PAL (Panoramic Annual Lens) optics [5]. The objective of the sensors is to pinpoint the exact positions of the obstacles.

A DSP (Digital Signal Processor) card processes images taken by the CCD cameras. The DSP card can work automatically, parallel to the PC, or co-operating with the computer. The latter mode can yield a huge increase in speed, since the algorithms that would take up a lot of time are run by the DSP instead of the PC. Thus, only the results of the algorithms need to be sent.

8 bit grayscale image digitization was performed by a n integrated circuit that is capable of 20 million conversions a second. The raster size is 512*512. The 80 MHz RISC based HYPERSTONE DSP guarantees sufficient speed so that the A/D converter could be served real-time with the above parameters. Synchron signals are also processed by the above DSP. Digitization of an image takes 20 ms. The resulting image is stored and processed by the memory of the DSP card. Considering the fact that the digitized image is created directly in the operative memory, image processing may be regarded real-time.

The algorithms necessary for obstacle detection run on the DSP in order of the fast processing. For the sake of effective testing, the functions are called by the PC. To make this possible all DSP routines can be parameterized. These parameters can be set by the interface running on the PC. Thus, it is possible to directly investigate the effect of the various image processing algorithms, as well as program optimization.

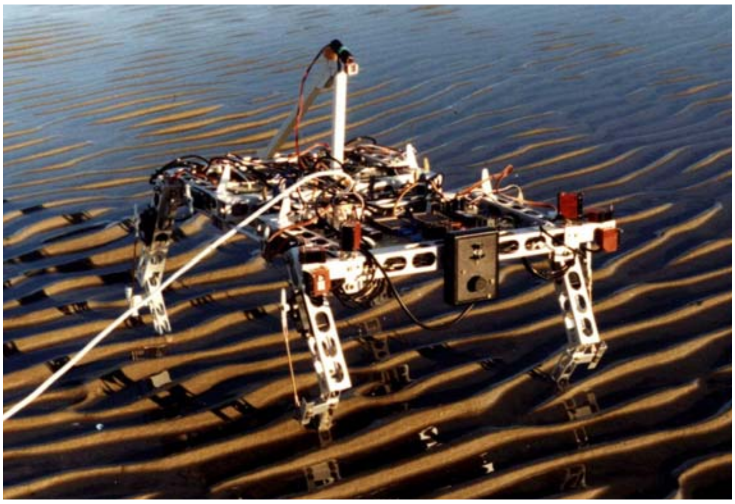

Figure 1. EXPLORATORES II.

2 Experimental biped robot using SMA actuators

The aim of this project is the examination of shape memory alloy (SMA) based actuators in walking robots [8]. Since the power-mass ratio of SMA's is extremely high compared to typically used actuators (hydraulic, pneumatic and electric motors), it is reasonable to try SMA's in robot applications as well. The experiments resulted in a biped walking robot (SILENT1) that is moved via shape memory alloy based actuators.

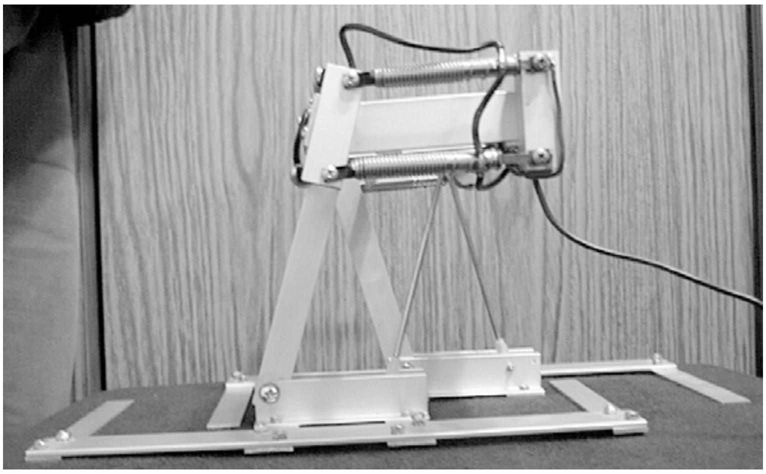

Figure 2. Experimental biped with SMA actuators

3 FOBOT, the Hexapod Walking Robot

The idea behind the creation of the six-legged mobile robot called FOBOT [9] was to design a robot that is -when placed in a specific geographic location – able to explore its unknown environment and send visual information from the area to the remote PC. To do this, it is necessary for the robot to be able to adapt itself to its environment, to have a high mobility and it has to be able to transmit information at a high rate. The cockroach-like movement of the robot is achieved by rotating legs, so it can use different walking-strategies for rough terrain. The DC motors on the feet are controlled by separate PIC microcontrollers.

The navigation is based on the analysis of the pictures of the environment and the data from the global positioning system (GPS) receiver. The camera on the front of the robot is monitoring the area in front of the robot to detect and avoid obstacles. The camera on top of the robot has a vertical-axis, mounted with PAL-optics and produces a 360 degree omnidirectional image of the outer world. With this system, the position of the robot can be calculated more accurately in a known environment. For getting the geographical position of the robot, the data from the built-in GPS receiver is used. The controlling-, the image- and the GPS data – right now – is transmitted over a cable connection, but the system is expandable to communicate over radio transmitted commands. The position and the movement of the robot; the GPS- and the image data are monitorable on the computer.

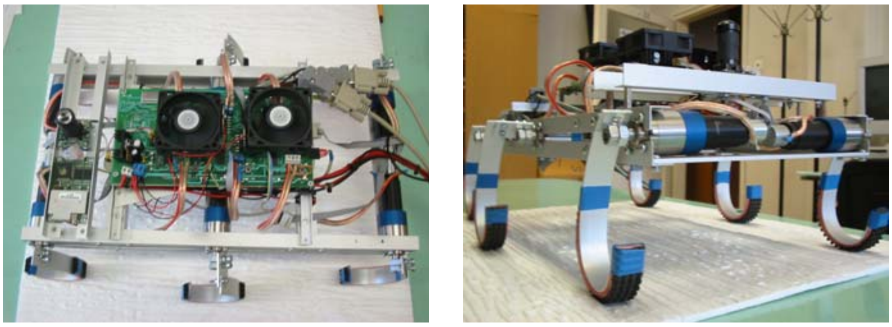

Figure 3. FOBOT, hexapod mobile robot with cockroach like gaiting

4 I. Henrik Wheeled Mobile Robot

The developed six wheeled mobile robot connected to an IBM PC [6]. The rover controllable with high level commands generated via visual information. The system contains a CCD camera hung above the working environment. During the image processing phase status information is extracted like robot location and orientation. The accessible and forbidden regions of the working area can be observed and mapped. If the selected target location is available, minimal cost path is sought. The generated control command sequence is converted into stepper driving signals and dispatched to the driver unit placed on the rover. The occurring errors and slips are balanced by continuous solving of the current visual input and by dispatching new command sequences.

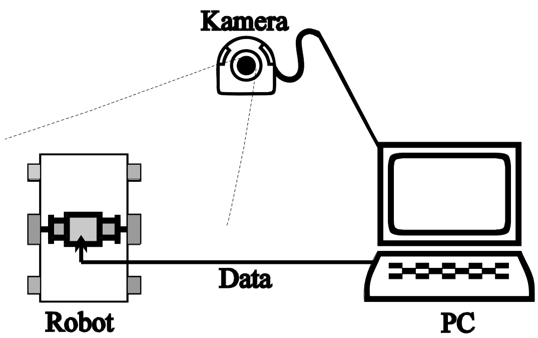

Figure 4. The main parts of the robot system Henrik I.

5 Caterpillar robot for object tracing

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 [10]. 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 5. The caterpillar robot

6 CCExplorer – The wheeled mobile robot

The aim of the CCExplorer project [10] 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 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;
- Computer vision; obstacle recognition; support the navigation subsystem by the recognized features of the environment
- Navigation; path planning 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.

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 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.

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. The prepared the electronics to control the robot form the PC by adjusting the speed and steering in about 30 steps.

The strength of the project is that the robot is able to navigate and avoid collision with obstacles.

Figure 6. The robot car on its way

7 Further mobile robots

Beside of the above projects a robotized sailing ship [7] and some others wheeled mobile robots were developed (Figure 7 and 8). Using the signals of the compass and PIC based control circuits the ship is able to go in a priori determined direction. The mobile platforms with the mounted camera avoid the obstacles that appear in front of the robots.

Figure 7. Robotized sailing ship

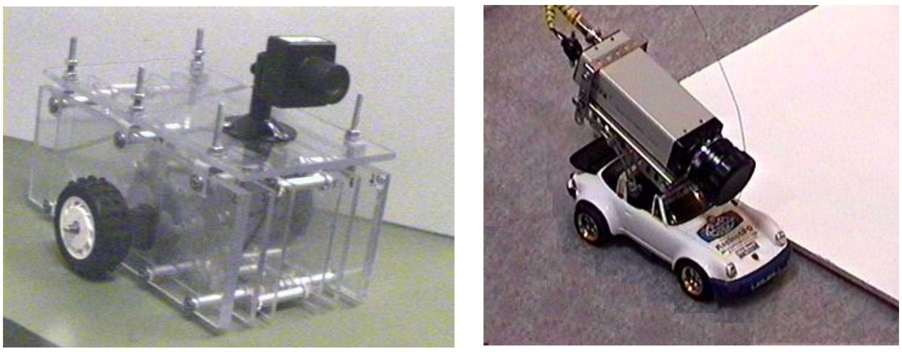

Figure 8. Robotized models

Conclusions

Notable researches have been underway in the area of development and appliance in the last decade. We examined the prospects of the motion possibilities of mobile robots, developed and implemented obstacle avoidance, motion planning and navigation algorithms at the Budapest Tech. The research results were published at international publications and exhibitions. Besides, our students achieved remarkable successes at national science contests.

The main advantage is that the complexity of the projects requires the students to apply not only the studied techniques, 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. Finally, the desire to provide meaningful guidance to the students motivates professors and outside advisors to continue their own research and improve their teaching.

References

[1] Vámossy, Z., Kutor, L., Csink, L.: Application Oriented Robotics and Artifical Intelligence Education at Kandó Polytechnic, In: Proc. of 7th International Workshop on Robotics in Alpe-Adria-Danube Region - RAAD'98 (Slovak Academy of Sciences), (K. Dobrovodskŷ (Ed.)), Bratislava, Slovakia, 1998, pp. 103 - 108.

[2] Brünner, R., Molnár, A., Varga, L., Vámossy, Z.: Exploratores, Quadruped Robot, In: Proc. of 7th International Workshop on Robotics in Alpe-Adria-Danube Region - RAAD'98 (Slovak Academy of Sciences), (K. Dobrovodskŷ (Ed.)), Bratislava, Slovakia, 1998, pp. 215 - 220.

[3] Vámossy, Z., Molnár, A., Brünner, R., Varga, L.: Path Planning Methods for a Quadruped Mobile Robot, In: Proc. DAAAM'98, Cluj-Napoca, Romania. (B. Katalinic (Ed.)), DAAAM International, Wien, Austria, 1998, pp. 483-484.

[4] Vámossy, Z., Molnár, A., Brünner, R., Varga, A.: EXPLORATORES II., the Four-Legged Mobile Robot, In: Proc.of International Symposium on Climbing and Walking Robots - CLAWAR'98, (Y. Baudoin (Ed.)) BSMEE, Brussel, Belgium, 1998, pp. 41-45.

[5] Vámossy, Z., Molnár, A.: Obstacle Avoidance for a CLAWAR Machine, In: Proc. of 2nd International Symposium on Climbing and Walking Robots - CLAWAR'99, Portsmouth, (Virk, Randall, Howard (Eds.)),) Professional Engineering Publishing Limited, London, 1999, pp.597-603.

[6] Vámossy, Z., Novák, A., Horváth, M.: I. Henrik Wheeled Mobile Robot - Optimal Path Planning and Tracking Based on Visual Information, In:8th International Workshop on Robotics - RAAD'99. (Ed. G. Schmidt), Munich, Germany, 1999, pp. 171-176.

[7] Szilágyi, A., Boskó, G., Kóré, L., Vámossy, Z.: Robotvitorlás, Banki Dónát Műszaki Főiskola Jubileumi Ülésszaka, In Proc. of the Jubilee International Conference, (Ed. Rudas). Budapest, 1999, pp. 401-406.

[8] Molnár, A. Vámossy, Z. (2001) Experimental biped robot using SMA actuators, Proc. of International Symposium on Climbing and Walking Robots - CLAWAR'2001 (Eds. Karsten Berns and Rüdiger Dillmann) Karstruhe, Germany pp. 811-818.

[9] Vámossy, Z., Molnár, A., Balázs, A., Pécskai, B., Supola, B., (2003) FOBOT, the Hexapod Walking Robot, 35th International Symposium on Robotics (IFR), Paris-Nord Villepinte, 23-26. March 2004., abstract: pp. 15-16, (CD issue)

[10] Vámossy, Z., Molnár, A., Hirschberg, P., Tóth, Á., Máthé, B. (2003) Mobile Robot Navigation Projects at BMF NIK, In: International Conference in Memoriam John von Neumann, December 12, 2003., Budapest, pp. 209–219.