Navigation of Mobile Robot Using PAL Optic

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ABSTRACT

The objective of the current research is obstacle and environment recognition for the navigation of a mobile robot using image information, which is provided by a CCD camera with PAL optic. For the basis of tests served the EXPLORATORES II four-legged walking robot.

1. INTRODUCTION

The detection of its environment greatly determines the applicability of a mobile robot. Correct object recognition is a crucial condition both of the autonomous mode as well as remote control. In most cases not only the direction, but also the distance of the object must be determined. In order to examine the whole environment of the robot several groups of sensors are applied for each direction, or groups of sensors are rotated round.

This paper discusses the application and results a methods, which ensures real-time processing of the 2D image of the 3D environment, based on the tools at our disposal and can be tested using the robot developed by the authors, EXPLORATORES II. The typical recognition of the environment can be performed only in a smaller area due to the narrower view of the traditional camera objective. Thus, research rather focuses methods and tools that are capable to provide the full environment from one image. Such a tool is the omnidirectional vision sensor (1), or the panoramic annual lens (PAL) objective (2, 3, 4) mounted on the EXPLORATORES robot.

2. EXPLORATORES II. (5, 6)

The mobile robot has four legs, and is made of lightened aluminium. 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 were used.

Steady walking is achieved by employing various statical and dynamical walking strategies (4, 6). The robot can function either autonomously, or via a connection to a PC, using a serial port. It is possible to test the behaviour 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 (Generalised Voronoi Diagram) based path planning modules, as well as other versions of these modules, that have been modified and explicitly matched to the robot (5). 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 its target. The more obstacles the robot manages to avoid, the more "experience" it gains about solving each situation. The robot can function either autonomously, or via a connection to a PC, using a serial port. The robot extracts information from its environment by the means of 6 retro-reflective infra and 1 CCD sensors. It is also equipped with a camera that employs PAL (Panoramic Annual Lens) (7) optic (Figure 1.). The objective of the sensors is to determine the exact positions of the obstacles.

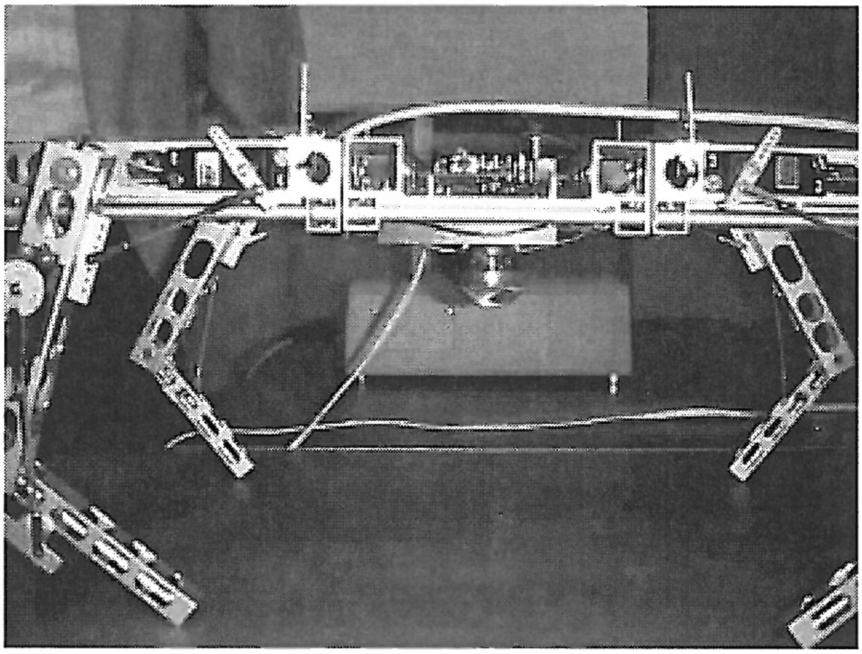

Figure 1. The PAL optic mounted on the belly of EXPLORATORES II. (Picture of Prof. Greguss, 1999)

3. FEATURES OF THE PAL OPTIC

PAL optic (3, 4) is a device that transforms the surrounding environment to an annulus. Huge advantage is that from the image provided by this optic the direction and angle of the object can be directly computed. The PAL-optic with its reflecting and refracting surfaces consists of one single glass block. An auxiliary optic, however, is needed to project the virtual panoramic annular image that is formed inside the optical block to the detector surface, preferably, a CCD chip. Using this lens as sensor may reduce the necessary number of sensors and thus energy use as well.

4. USE OF PAL OPTIC FOR NAVIGATION IN LAB ENVIRONMENT

As the PAL optic transforms the environment into an annulus, it seemed reasonable to set the origin to the centre point of the rectangle determined by the four legs of the robot. The optic was mounted on the "belly" of the robot. An advantage of this arrangement was that the four legs of the robot appeared on the image. This information can also be used for leg movement (Figure 2.). On the other hand, as robot legs move in a predetermined region, these areas can be excluded from obstacle search. These areas occlude various objects of the environment due the movement of the robot, so they do not cause a problem from the point of view of obstacle recognition.

In order to use PAL optic for robot navigation the following questions had to be answered by the authors:

- What kind of image *processing algorithms* should be used?
- What computing efficiency is needed to find obstacle positions *fast*?

In order to minimise outside effects the tests were performed on flat area under homogeneous lighting. The robot had to walk on this area and was not allowed to enter a white paper (i.e. hit the wall). Recognition of obstacles was based on the digitised image taken by PAL optic. As the effectiveness of image processing algorithms was not known beforehand, a library of basic routines was developed.

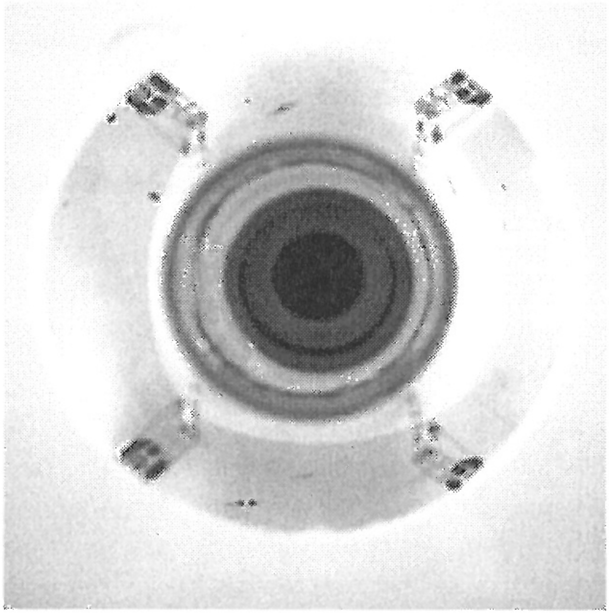

Figure 2. The legs of EXPLORATORES II. on the picture taken by the PAL optic

As noise of digitisation may result in erroneous conclusions in many cases, the first step was filtering. The main point was to find a fast and effective algorithm. Experimenting with several methods (Figure 3.) (namely morphological operators: averaging, median filtering, erosion, dilation, contour filtering, extrenum filtering; contour searching using Sobel, Laplace, Kirsh, Prewitt, Robinson convolution transformations, adaptive binarisation, histogram equalisation, etc.) the following two algorithms were selected. After digitisation a linear filtering was performed. Then came binarisation with a threshold depending on the actual illumination. On the binarised image white areas reflected obstacles and black areas meant free way.

On the image provided by PAL optic, 8 sectors were created in radial direction excluded the region of the legs. The operator determines each sector with an adjustable angle. Search for obstacles was performed in these sectors in a narrow annulus whose origin was the same as the image and the outer and inner radii could be set as parameters. This way the inspection of any region of the PAL image was possible. The width of the annulus influenced the depth of investigation of the environment. Narrowing the annulus areas near the robot could be checked, while widening of the annulus focussed the investigations on areas further away from the robot.

5. CONCLUSIONS

The experiences with the PAL-optic fixed on EXPLORATORES showed lot of advantages and some disadvantages of the omnidirectional vision technique. The robots equipped with traditional retro-reflective sensors or CCD camera capable to detect only a small region of the environment. A great advantage of the PAL-optic is the 360-degree transformation of the environment. Finding the directions of objects is rather simple as it does not need special computations, and there is no need for moving devices for inspection of the full environment.

Although the image created with the PAL optic is unusual for the observer, but its processing can be easily performed. (In security applications it may be reasonable to convert the image, or at least some of its parts to traditional form so that it could be easier interpreted.) A disadvantage of this optic is that the annulus shape does not match the square-shaped sensor elements. Consequently, only 40 % of the image contains useful information. The optic is very sensitive to the inhomogeneous lighting conditions. In indoor environment the lighting sources, outside the sunlight produces very bright parts on the picture taken by the camera. The differences between the dark and light parts of the picture are so big, that the auto iris function of the simple CCD cameras has to switch off and special image processing algorithms have to use. Instead of this a solution if the optic is fixed on the belly of the robot, so the camera takes pictures downwards. In this case with additive threshold based algorithm the disadvantage of the inhomogeneous lighting can be reduced, or eliminated. Illumination from above resulted in shade under the robot. This shade was not disturbing. The distance of obstacle detection had to be set in such a way that one more step towards the obstacle should be possible without hitting it. With the correctly set parameters the robot was able to walk for several hours without stepping on the white papers (the obstacles).

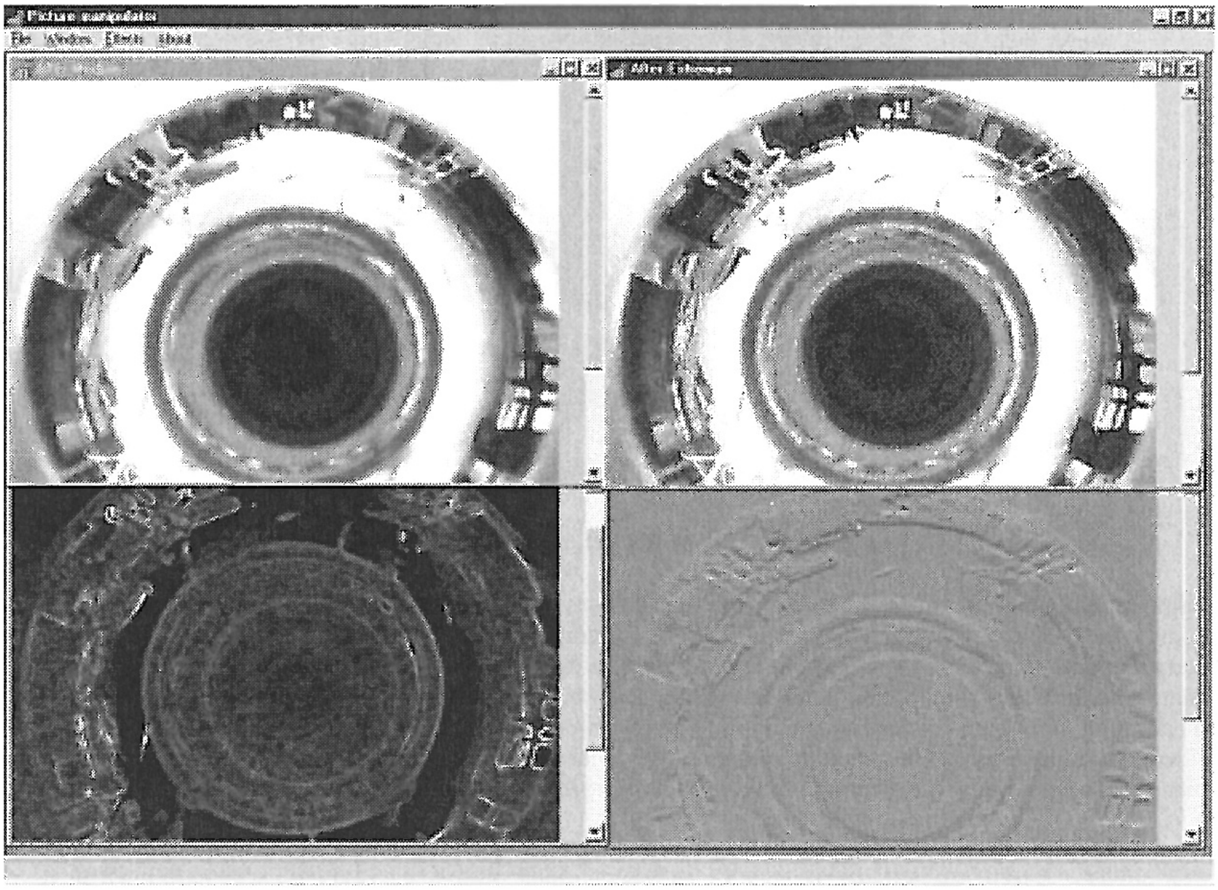

Figure 3. Testing the image processing algorithm for PAL optic based image

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