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Detection of Obstacles Motion in a Mobile Robot Environment

1. Robot navigation systems

Detection of obstacles' motion is another step in robot motion planning task. The obstacle detection in a robot environment can be accomplished in many ways [1, 6]. This is not a main subject of this paper, so various possibilities of obstacle detection in robot environment will not be presented in this article.

This paper is devoted to investigation of robot motion planning approach in changing environment. The signals can be used for verification of a current robot location calculated from odometry in a known environment and used to guide the robot in a free space between obstacles. The second case can be used only for "local" guidance; it can not be called as "motion planning" because lack of information about map of environment and target makes motion planning impossible.

Real-time Stereo Depth Analysis approaches for motion detection system can be applied to the different mobible robots. An example of this application for experimental XR4000 [5] and Sony Aibo [2] robots showed, that this approach may be effective and speed up robot motion planniing. Barnes and Liu [6] presented detailed discussion on different aspects of robot guidance controlled by vision systems. They introduced classification and categorization of vision-guided mobile robots. They stated, "a general computer vision is ill-suited to robot guidance". Classical approach performs many image processing operations leading to classification of all objects. Reconstruction of environment scene includes in it all classified objects without paying attention to the purpose of classification.

Let us assume, that environment map is known, stored in robot control system and is used for global robot motion planning from start (or current location) to the goal. The obstacles can be classified as static and dynamic changing their location with a certain speed. These obstacles can be either other robots, working machines or of course people. Robot is equipped with two sources of signal to detect obstacles: laser scanner and stereo video system. The system of obstacle motion detection can be presented in a following chart (Fig. 1).

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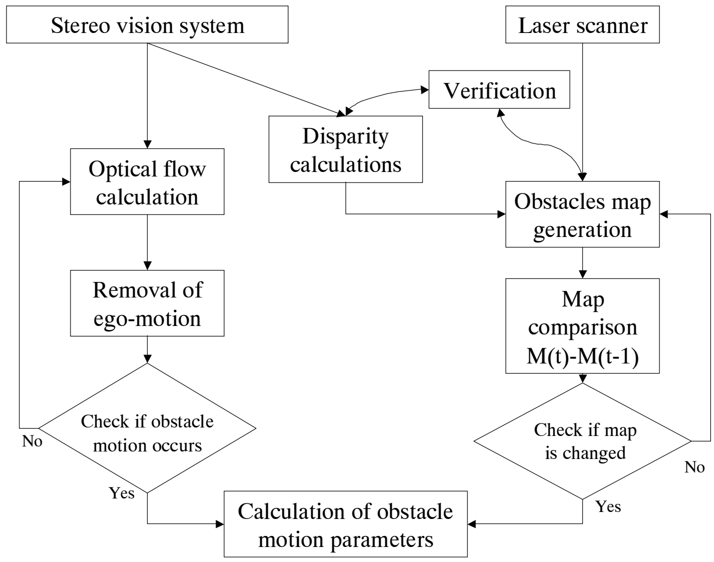

Fig. 1. Diagram of obstacle motion detection

2. Obstacle detection

The data about robot environment can be obtained from many sources. The most popular and commonly used in robotics are laser scanners and ultrasound sensors. The robot which is used in the Computer Engineering Department for investigations of motion planner is equipped with Sick laser scanner and odometry system, which enables to track the motion and find current position of a robot in a cluttered environment.

Another environment detection mechanism is application of stereo vision system. The robot is also equipped with two cameras mounted in a way creating canonical system. The aim of application a stereo vision system is to use it to obtain information about obstacles – to calculate their distance from the robot using computed disparity and then to conclude, weather obstacles are steady or are moving across the area in which robot is operating.

This obstacles motion detector module will pass the data to the robot planner to predict future obstacles location and apply this information in a global motion planner. Detection of moving obstacles is an important approach due to the more common situation of unattended robot operation and more robots interaction.

Calculated disparity computation can be used for obstacles motion detection. An application for obstacles map reconstruction from disparity calculation was developed. The following pictures show examples of disparity calculations performed on a pictures presenting rendered modelled scenes of robot environment with different simple-shaped obstacles. Each obstacle is placed at a different distance from the robot. Reconstructed obstacles map from the images shown in Figure 2 is presented on the left side of a Figure 3.

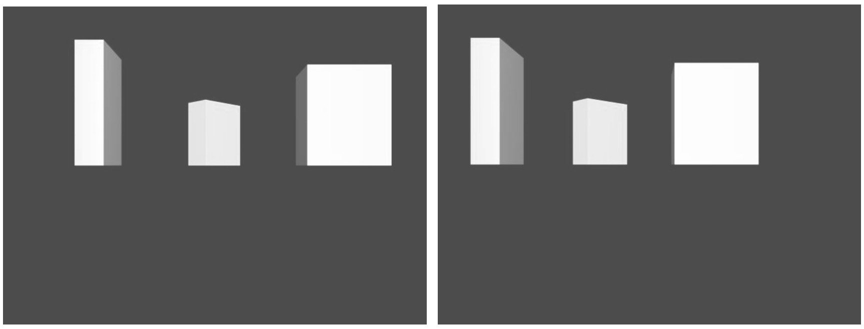

Fig. 2. Picture from left and right camera grabbed by stereo vision system

Fig. 3. Reconstruction of obstacles location calculated from disparity distribution. Left picture: from original images, right picture calculated from images with different obstacles location (stereo pictures not included)

It has not been pointed out, that disparity approach enables to calculate only distance from the front of the obstacle, due to invisibility of a backside of the obstacle. Therefore, “depth” of the obstacles is unknown and the reconstructed scene contains “obstacles shadow”. Although this is a limitation of the disparity calculation, obtained results are still applicable in a robot motion planning. It enables do guide robot in a way that avoid hitting obstacles.

3. Obstacles motion detection

Map of obstacles presented in Figure 3 is valid at a certain time instant. Due to the robot motion and possible obstacles, motion map computed after certain elapsed time shows the same obstacles in a different configuration relative to the robot. Correlation of these maps allows to detect a motion of an obstacle if it occurred. Computed obstacles map presented on the right picture of Figure 3 shows, that location of the obstacle placed between other was changed. The current version of the program does not allow to automatically compute obstacle displacement.

Disparity computation times (on P4 2,4GHz PC) varying from tenths of seconds to few seconds show, that this way of obstacle motion detection has same limitations, especially in on-line robot navigation. Disparity computations algorithms need improvement or different approach has to be developed.

4. Optical flow

Optic flow was introduced to describe visual effects of a motion, which reflects the difference between two successive images taken by moving object (camera). Optic flow is described by a vector field, which describes motion of each pixel from the first image to the corresponding pixel in the successive one. Optic flow computation can be based on intensity gradients. It can be expressed by the following equation

$$I_{t+dt}(x+u(x,y), y+v(x,y)) = I_t(x,y),$$

where:

$I_t(x,y)$ – image intensity of each pixel at instant time *t*,

$I_{t+dt}(x,y)$ – image intensity of each pixel at instant time *t+dt*,

$u(x,y), v(x,y)$ – horizontal and vertical flow of each pixel respectively.

The formula of optic flow is in general difficult to solve. Occlusion effects, if they take place, and signal noise introduce distributions in an image. Thus, the common solution is to minimize error of the equation by summing over all pixels of image.

Motion of robot with non-holonomic constraints can be calculated from odometry or from the drive control unit. It allows using this value as a starting parameter in the iteration procedure. Knowledge of robot motion constraints tracks the optic flow and allows to find its disturbances. Setting a certain threshold of an optic flow error allows to conclude that images do not match due to the changes caused by an obstacle and not by ego-motion of a robot. This gives the signal to the robot planner about the motion of an obstacle.

5. Conclusions

Robot motion planning in many applications requires detection of obstacles motion and consideration of this situation. Application of stereo vision system for detecting obstacles distance and motion in robot environment requires many image processing computations which slows down performance of the robot control system. Tests showed that disparity approach might not be sufficiently effective for on-line robot control. In the case of a robot with certain non-holonomic constraints optical flow approach may speed-up the generation of environment map using stereo vision system. Disparity map method can be used when robot moves with the speed lower than certain threshold value, below which optical flow method is not applicable.

References

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