Results on static localization for the V.A.H.M.

A. COURCELLE, O. HORN
Laboratoire d'Automatique des Systèmes Coopératifs (L.A.S.C)
Université de METZ
Ile du Saulcy, BP 80794, 57012 METZ Cedex 01
FRANCE

Abstract - The static localization we developed lies on the matching of two occupancy grids. The first one is a registration of all the information about the environment. The second one enables to store the information around the robot obtained from ultrasonic sensors. The two grids are compared to determine their relative translation and rotation and to give the position and the orientation of the robot. In this paper we present how to avoid problems linked to the local grid rotation in order to keep it coherent whatever its orientation. Moreover, we show how to modify the global grid to improve the localization results. Tests have been carried out in three different rooms in simulation as well as in real conditions on our prototype.

Key-Words: - static localization-mobile robots-ultrasonic sensors-occupancy grids. IMACS/IEEE CSCC'99 pp.4601-4606

1. Introduction

This article presents the tests and improvement on the V.A.H.M. static localization. The V.A.H.M. (French acronym for Autonomous Vehicle for People with Disabilities) is a project which consists in assisting a person with disabilities in his daily movements [1]. In this respect, we equip a powered wheelchair with driving assistance modules which allow some movements to be carried out automatically. The problems we encounter are very similar to those of the autonomous mobile robots, and it is essential that the wheelchair will be able to automatically determine its position in its environment.

A dynamic localization technique using a method of matching segments has been developed for our application [2]. This localization is used to correct the dead reckoning position of the robot during its displacements. However, it is not suitable when the dead reckoning error becomes too great. Moreover, at the beginning of a trajectory, no information on the position are available. Indeed, the person using the wheelchair can decide at any time to switch from a manual navigation mode to an autonomous navigation mode. So, for all these reasons it is necessary to keep a static localization that could intervene at the beginning or during navigation when the dead reckoning error becomes too great. Likewise, as a person is on the vehicle, it is necessary that the robot can localize itself at any place of the room, this without moving. Thereby, we can not use a reference position or a fixed position for the beginning as it is the case of some applications of mobile robotics [3], [4]. In some works [5], the static localization is solved by using beacons. We rejected this kind of method to privilege the usability of the wheelchair in every type of environments.

This paper present the mean to have the more accuracy grid to represent the ultrasonic sensors data and the environment.

After the description in the part 2 of the localization algorithm we detail in part 3 how to obtain a coherent local map. Then we display our first real tests in part 4 followed by the modification of the global map in part 5. Finally, before to conclude in part 7, we present in part 6 how this modification allows to have better results in a second series of tests.

2. The localization algorithm

The employed technique is based on the principle of matching two grids introduced by Elfes [6] and still used in several projects [7]. The first one is the global grid which is a two-dimensional representation of the work space of the robot. The second one is the local grid containing information about the environment of the robot which is directly perceivable. In both grids, occupied cells are set with positive values and free cells by negative values whereas unknown cells are set to nil. The method consists in finding the best position by trying all possible translations and rotations inside an area of research [8]. This area is tunable by the application. For our application, this area correspond to a square of ± 80cm around the estimated position and a cone of ± 45° around the estimated orientation. The estimated position and orientation are provided by the navigation module when the dead reckoning error on the position becomes too great, or by the user at start. In this case, the user express the indication by simple formulation like "leaving room entry".

From these information we define the position $C(X_C, Y_C)$ of the global grid on which the local grid will be superimposed (Fig.1). We also define the orientation θ_r that will be applied on the local grid to obtained the oriented local grid (see part 3.). The cell C will iteratively correspond to all cells included in the area of research, that is 289 cells tested for a resolution of 10cm per cell. Similarly the orientation θ_r will correspond to all orientations situated in a cone of ± 45°, that is 19 orientations tested by cells with a 5° step.

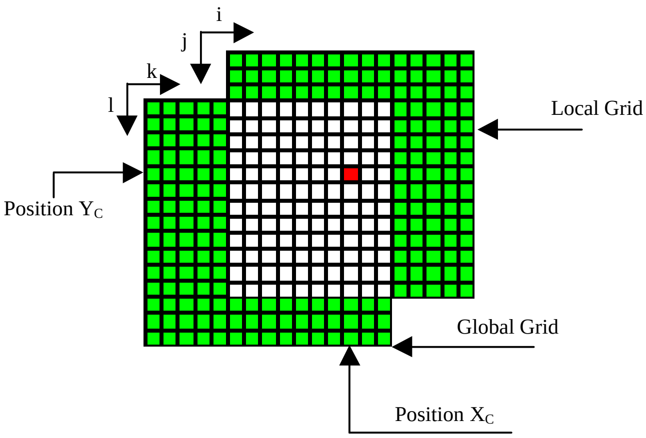


Fig.1 : Local Grid superimposed on the Global Grid at position $C(X_C,Y_C)$.

To obtain the best matching, the sum S of products of cells of the local grid by cells of the global grid, is calculated as follow :

$$S = \sum C^L_{i,j} * C^G_{k,l} \qquad (1)$$

where $C^L_{i,j}$ is the $C_{i,j}$ cell's value of the local grid, $C^G_{k,l}$ is the $C_{k,l}$ cell's value of the global grid and i,j,k,l correspond to all index included in the area of superposition as shown by light cells in Fig.1.

This sum is incremented when two cells have the same sign and is decremented when they have opposite sign and is remained constant if one of the two cells is nil. So this sum is maximal when most of the same cells are superimposed what indicates therefore the position and the orientation of the robot.

A grids reduction is used to speed up calculations. The principle of the reduction is to reduce four neighbouring cells into one [9]. However, this method does not preserve the model as it sometimes detects free cells behind occupied ones. In order to solve this problem we decided to create directly the reduced grid instead of reducing the grid after its creation. Reduced grids are used to calculate the localization and the result is given to the lower grids which make the calculation.

3. Improvement of the local grid

The local occupancy grid contains information about the environment of the robot which is directly perceivable. Therefore the grid is centred on the robot and integrates the sensory data into the local map. Our prototype is a Robosoft base used to evaluate the static localization. This base is equipped with a belt of 14 ultrasonic sensors.

Each ultrasonic sensor is defined from the center (x_0, y_0) of the robot by its position (β_c, r_c) and its orientation (θ_c) (Fig.2). The emission cone is defined by its angular resolution (α_c = 12° for our application) and the measured distance d_c (Fig.3).

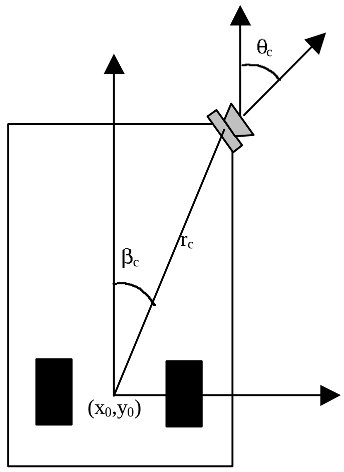


Fig.2 : Sensor's configuration

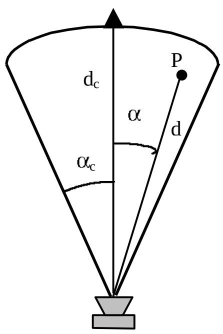
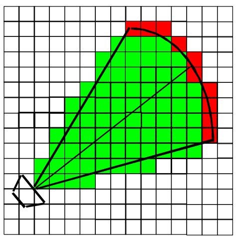


Fig.3 : Emission cone

We choose not to work with constant cell's values because they generate some problems. Indeed for short range values, the arc is contained into a single cell, meaning that it contains surely the point that produced the echo and therefore it is assigned with a probability of 100%. For larger range values the arc spans over several cells and this certainty must be shared by all of them. So each cell is updated by the value ***1/n***, where ***n*** is the number of cells that contain the arc. This principle is also used for the free space of the cone. As a consequence we give to the ***n1*** cells of the arc a value equal to ***1/n1***, and to the ***n2*** cells of the free sector before the arc a value equal to ***-1/n2***, while the unexplored cells are kept to ***0*** (Fig.4). Moreover, the cells corresponding to the area covered by the robot's shape are affected by the value ***–14/n*** where ***n*** is the number of cells included in this area and ***14*** is the number of ultrasonic sensors.



n1 occupied cells affected by the value $1/n_1$

n2 empty cells affected by the value $-1/n_2$

Fig.4 : Ultrasonic data modelisation.

The employed discretisation which corrects the arc of an ultrasonic data with an "8-connexe" model and which corrects the overlapping cones with an appropriate algorithm allows to get a more coherent local grid and permits to improve the results. However the grid rotation applied on the local grid induces errors in the model. Some cells are affected twice, while others are suppressed. The solution we propose is to orientate the model that will be discretized to create the grid.

To orientate the model it is necessary to use a geometrical representation. This representation has to contain a region designating the robot and 14 other regions representing the emission cone of each ultrasonic sensor.

The equation giving the position (x, y) of a point P situated in the cone of emission (with an angle α and at a distance d) is therefore :

$$\begin{cases} x = -r_c * \sin(\beta_c) - d * \sin(\theta_c + \alpha) \\ y = r_c * \cos(\beta_c) + d * \cos(\theta_c + \alpha) \end{cases} \tag{2}$$

In order to get regions directly oriented according to the angle of the robot (θ_r) we have to introduce it in (2) as shown in (3).

$$\begin{cases} x = -r_c * \sin(\beta_c + \theta_r) - d * \sin(\theta_c + \alpha + \theta_r) \\ y = r_c * \cos(\beta_c + \theta_r) + d * \cos(\theta_c + \alpha + \theta_r) \end{cases} \tag{3}$$

Then we discretize this model to obtain the oriented grille. As a consequence it is necessary to construct as many models and grids as there are different orientations to compare. Nevertheless thanks to this method, we obtain an approximately constant local grid whatever the orientation of calculation. The example of the next figure illustrates well this principle by comparing a grid which has been turned round 135° after its creation and the same grid directly oriented with the same orientation (Fig.5). This figure shows that in the turned grid (left side) some cells are set to free and other occupied cells appear behind obstacle (in the left of the grid), whereas in the oriented grid (right side) free spaces behind obstacles as well as incoherence have disappeared.

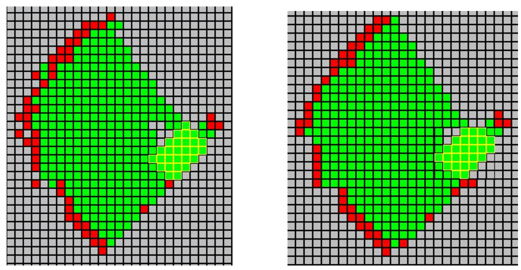


Fig.5 : Difference between turned grid and oriented grid.

4. First real tests

Real tests have been realized in three different environments. These environments have medium size and are not much cluttered. These choice have been defined to evaluate the robustness of the algorithm in difficult situations. Indeed greater rooms are going to induce great measures and therefore greater uncertainties. The three environments are presented in the figure 6.

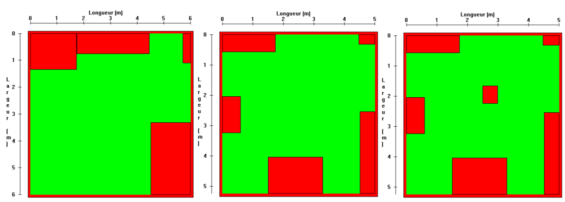


Fig.6 : The three tested environments

Conditions for a good localization are a maximal error in position of one cell (10cm) and a maximal mismatch in orientation of 7°.

These tests have also been realized in simulation. The simulation algorithm differs from the one used in real by the determination of the measured distances. In real conditions these distances are provided directly by ultrasonic sensors. In simulation distances from sensors to obstacles are determined by a graphic method. This method consists in searching the closest obstacle by detecting on the screen the first obstacle in the emission cone of a sensor. This technique supposes that all surfaces are rugged enough to be able to be detected whatever the orientation of the sensor.

The 100 tests performed have provided the results shown in the left of the figure 9.

It appears that a problem still subsists in the algorithm since we obtain only 74% of success in simulation. The analysis of results in simulation reveals that contrarily to the local grid, the global grid is not suitable. Indeed in some cases as shown in figure 7, some cones appear to have a good superposition “inside” objects although it is not possible to get an information from behind an obstacle as applied on the local grid. Therefore, it becomes necessary to apply the same principle also on the global grid.

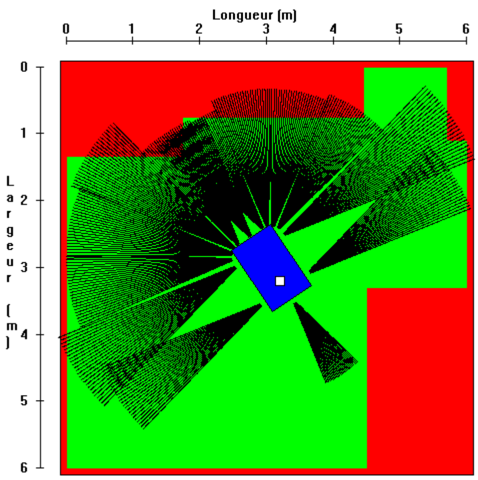


Fig.7 : Example of result where cones are inside objects.

5. Improvement on the global grid

The global grid is based on a plan of the environment in which are enclosed coded objects. The grid applied on this plan assigns free cells with the value -1 and occupied cells with the value 1. In this case, all cells corresponding to an object are set. Or, in the local grid, the arc of an ultrasonic sensor affects an arc with only one cell thickness because of the lack of knowledge of what is behind the detected obstacle. So, if we want to superimpose an arc of the local grid on an obstacle of the global grid, both grids must have the same model.

Thus, to avoid information behind an obstacle, a dedicated algorithm is applied on this grid to obtain the contour of obstacles with only one cell thickness. An example of the correction of the global grid is presented in the figure 8.

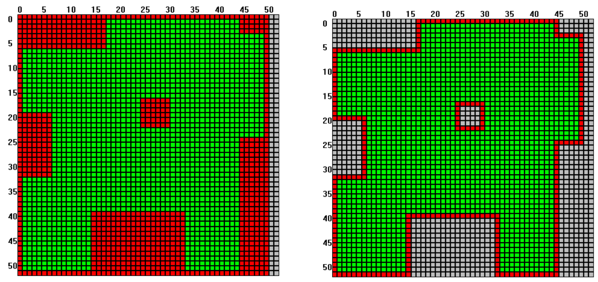


Fig.8 : Example of a global grid before and after correction.

6. Second real tests and discussion

To show the contribution of the new global grid, we have performed the same tests in the same positions. As shown in figure 9, results are clearly improved.

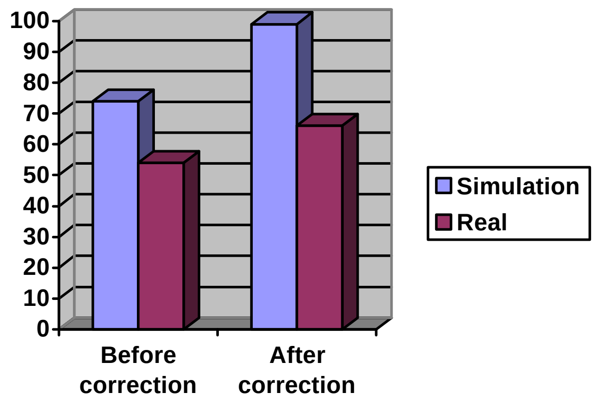


Fig.9: Results of the 100 tests before and after the correction of the global grid.

The simulation gives a result of 99% of success, while the 1% failure reveals a misorientation of only 10°. However real tests have not followed the progression as we expected. By analyzing this second series, we have been able to underline problems related to crosstalk and to multiple reflections that do not appear in simulation. Problems linked to the crosstalk can be reduced by applying the EERUF method developed by Borenstein [10].

Other tests will have to be performed in an environment closer to the future application, that is an environment similar to a citizen apartment. These tests will allow to evaluate the accuracy of our algorithm in a real application. In order to overcome cases of failure the robot can signal to the user the degree of confidence of a result. This criterion will allow to inform if the localization is accurate or not. That will be the subject of our future works.

7. Conclusion

In this paper we have presented the results on the static localization method based on occupancy grids. This method enables to locate the robot by using only fourteen ultrasonic sensors. More than a hundred real tests have been achieved in three different rooms. The accuracy of the method has been largely improved with the introduction of oriented local grids instead of turned local grids and thanks to the contour correction of the global grid. Other tests in an environment similar to a citizen apartment will be performed in our future works. These works will also focus on the elaboration of a factor of confidence enabling to warn the user in case of bad accuracy of the localization result.

References :

[1] BOURHIS G., MOUMEN K., PINO P., ROHMER S., PRUSKI A., « Assisted Navigation for a Powered Wheelchair », *Proceeding of the IEEE International Conference on Systems, Man, and Cybernetics*, 1993, pp 553-558.

[2] HORN O., RIEMER G., « Dynamic location for the V.A.H.M », *Proceeding of the IMACS International Symposium on Signal Processing, Robotics and Neural Networks*, 1994, pp 512-516.

[3] MALLET P., AUBRY P. : « A low-cost localisation system based on a map matching technique », *Intelligent Autonomous Systems*, 1995, pp 72-77.

[4] YAMAUCHI B. : « Mobile Robot Localization in Dynamic Environments Using Dead Reckoning and Evidence Grids », *Proceedings of the IEEE International Conference on Robotics and Automation*, Minneapolis, Minnesota, April 1996, pp 1401-1406.

[5] KO J.H., KIM S.D., CHUNG M.J. : « A method of indoor mobile robot navigation using acoustic landmarks », *Proceedings of the IEEE International Conference on Robotics and Automation*, Minneapolis, Minnesota, April 1996, pp 1726-1731.

[6] ELFES A., « Using occupancy grids for mobile robot perception and navigation », *IEEE Computer*, June 1989, pp 46-57.

[7] PAGAC D., NEBOT E.M., DURRANT-WHYTE H., « An Evidential Approach to Map-Building for Autonomous Vehicles », *IEEE Transactions on Robotics and Automation*, Vol 14, N°4, August 1998, pp 623-629.

[8] COURCELLE A., HORN O., « Ultrasonic data representation : application to mobile robots localisation », *Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems*, Victoria, B.C., Canada, October 1998, pp 1559-1564.

[9] COURCELLE A., HORN O., PRUSKI A., « Autonomous Mobile Robot Localisation Using Sonar », *IMACS Multiconference on Computational Engineering in Systems Applications*, Nabeul-Hammamet, Tunisia, April 1998, pp 360-364.

[10] BORENSTEIN J., KOREN Y., « Noise Rejection for Ultrasonic Sensors in Mobile Robot Applications », *Proceedings of the IEEE International Conference on Robotics and Automation*, 1992, pp 1727-1732.