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BUILDING SIMILARITY MAPS OF THE ENVIRONMENT USING SONAR INFORMATION FOR THE NAVIGATION OF THE MOBILE ROBOTS

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Abstract: The objective of the work is to present a representation called similarity map based on some results in the evaluation of the SONAR system of a mobile robot. As environment a corner of our lab it is considered. Based on some reference positions, where the robot is making a complete rotation, some test positions are considered with the task of recognition of the environment, in order to be able to recognize the position. Using similarity measures based on Euclidian distance, similarities maps are defined and estimated. The results are useful in defining complex strategies of navigation using SONAR systems.

Keywords: Similarity measures, Pattern Recognition, Signal Processing, SONAR, Mobile Robots.

1. INTRODUCTION

The experiment is developed by using a mobile robot, ATRV-Jr mobile robot, (iROBOT 2002). The work is sustained by the built-in SONAR system of the mobile robot and it is a small part of the EU project called CIRCE - *Chiroptera Inspired Robotic Cephaloid: a Novel Tool for Experiments in Synthetic Biology*, (CIRCE 2002).

The objective of the work is to obtain a representation of the environment by building a map of similarity, as real bats are supposed to do and use in the navigation and into exploration of the environment. Such set of maps could be called auditory maps (even the frequencies are into ultrasound domain of humans) and it is expected to facilitate understanding of performance moving of the bats in the exploring of the environment. The set of similarity maps could be used in the design of navigations strategies of mobile robots, also.

In this work, the similarity map is based on Euclidian distance of ranges provided by SONAR. For practical reasons, the data processing is made on off-line basis.

The context and the main steps in the processing of the SONAR data are presented in section 2. In section 3 a short description of the experiment is presented. Later, in section 4, the signal processing by filtering of the outliers and segmentation of the environment is presented. In section 5 the method of building of similarity maps is presented and discussed. Section 6 is for conclusions and next steps to follow.

2. DESCRIPTION OF THE CONTEXT

The analysis and the path work are under the structure presented in Fig. 1. First, the mobile robot is inspecting the workspace and information about environment is collected using echolocation principle. The range measurements from environment are pre-processed by filtering (removing of the outliers) and segmentation (environment codification by ranges and angles).

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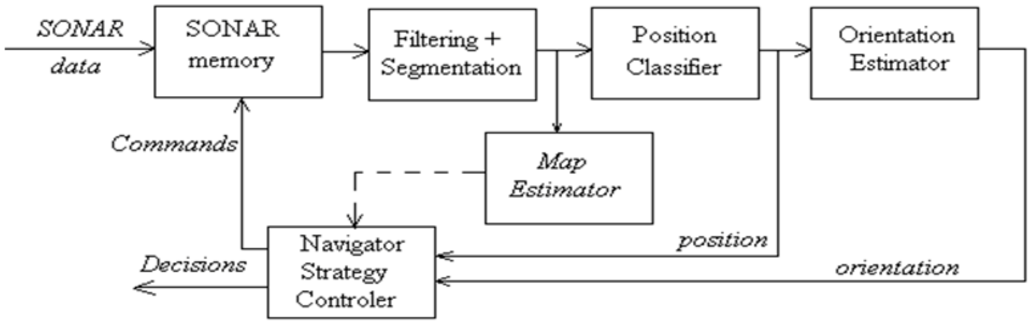

Fig.1 The structure for the estimation of the position, using SONAR data

In the context of the navigation, it is important to estimate the position and the orientation of the robot in the environment, and to decide on the best path to follow in moving into environment, from a start to a final position.

As the robot's SONAR sensors fire off pings and receive echoes, they continuously update a data structure. Each SONAR sensor detects obstacles in a cone-shaped region that starts out, close to the robot, with a half-angle of about 15 degrees, and spreads outwards. An obstacle's surface characteristics, as well as the angle at which an obstacle is placed relative to the robot, significantly affect how and even whether that obstacle will be detected. Rather than assuming that SONAR sensor data is infallible, there are multiple readings and appropriate cross-checking.

The SONAR sensors can be fooled for a number of reasons, (iROBOT 2002):

- The SONAR sensor has no way of knowing exactly where, in its fifteen-degree and wider cone of attention, an obstacle actually is.
- The SONAR sensor has no way of knowing the relative angle of an obstacle.
- Obstacles at steep angles might bounce their echoes off in a completely different direction, leaving the SONAR sensor ignorant of their existence, as it never receives an echo.
- The SONAR sensor can be fooled if its ping bounces off an obliquely angled object onto another object in the environment, which then, in turn, returns an echo to the SONAR sensor. This effect, called specular reflection, can cause errors; the SONAR sensors overestimate the distance between the robot and the nearest obstacle.
- Extremely smooth walls presented at steep angles, and glass walls, can seriously mislead the SONAR sensors.

All these facts generate hard constraints in the generation of a navigation strategy and in the correct recognition of the environment. A way to avoid some of the presented problems is to build SONAR systems with multiple SONAR sensors, as the ATRV-Jr robot does, providing redundancy and enabling cross checking. More details on SONAR errors and solutions to correct them are described, e.g. in (Akbarally and Kleeman 1995; Budesnske and Gini, 1994; Peremans *et al* 1993).

3. DESCRIPTION OF EXPERIMENT

The built–in SONAR system of the mobile robot has 17 transducers of POLAROID type, (Polaroid, 2003), with a relatively large angle beam (15 degrees) using a carrier frequency of 50 KHz.

The considered environment is a corner of research laboratory from Antwerp University, with 35 marked positions. From those, the positions from 1 to 21 are reference positions. The remaining ones, from 22 to 35 positions are considered test positions. The size of the environment is of 5 by 5 meters. The distribution of the considered positions is presented in Fig. 2. In every position, from 1 to 35, the robot is rotating around its axis in steps of 30 degrees. For one position this result in 12 orientations. For every orientation of the robot, 11 measurements are performed with each of the 17 range sensors. From every set only one is considered using a median filtering, i.e. sorting the set of 11 measurements and keeping the 6^{th} one.

The initial orientation of the robot is neglected in this experiment. To be able to compare the set of obtained measurements with the real environment all the measurements are reported at the horizontal axis of the environment. This is obtained by adding the initial angles to all the theta angles that correspond the all orientations of one position (site). All range measurements are limited to a maximum value of 5 meters, in order to increase the readability of the map. This is equivalent of saying that it is not interesting on what is more then 5 meters away, from the center of the robot. The measurements are from all 12 orientations, and this is the explanation of the 'star' configuration.

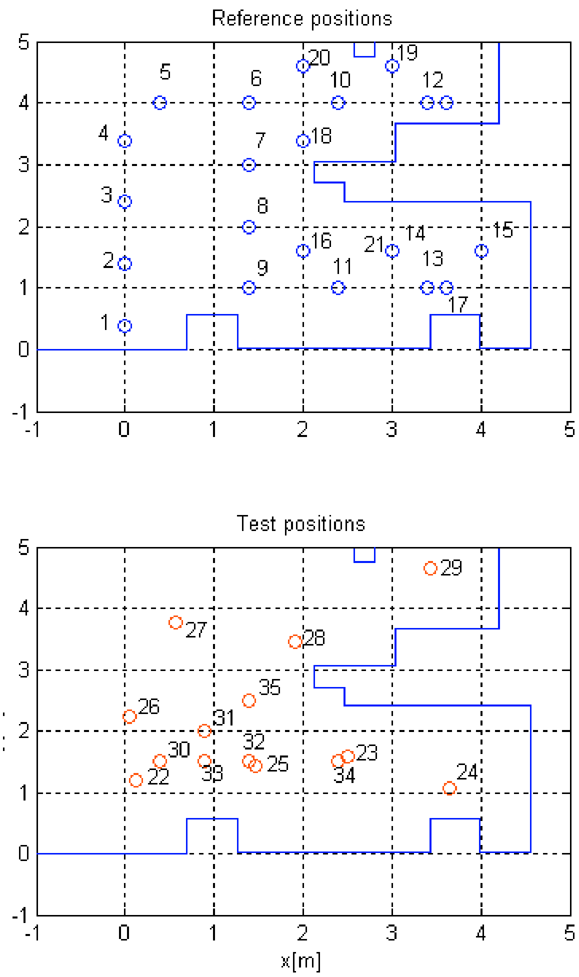

Fig. 2. The environment and the distribution of the reference positions (1:21) and test positions (22:35)

In Fig. 3 the measurements collected from position 2 are presented. It is interesting to see that the targets are correctly located in the field, at the small range. There are also some outliers, obtained from multiple reflections of echoes on the walls of the environment. Looking at all the positions a first conclusion can be drawn: the SONAR system reports fairly accurate measurements for close by objects but produces quite a lot of outliers. The next section will be oriented on how delete such outliers.

4. REMOVING OF THE OUTLIERS

By outlier is understood a spike in the representation of the SONAR range. By removing of the outliers is understood the filtering of the outliers and the segmentation of the environment. Taking out the outliers is equivalent with a noise filtering operations. Such filters could be designed on a heuristic basis, taking into account the semantics of the elements (physical dimensions) or can be designed by using some classical structures, like

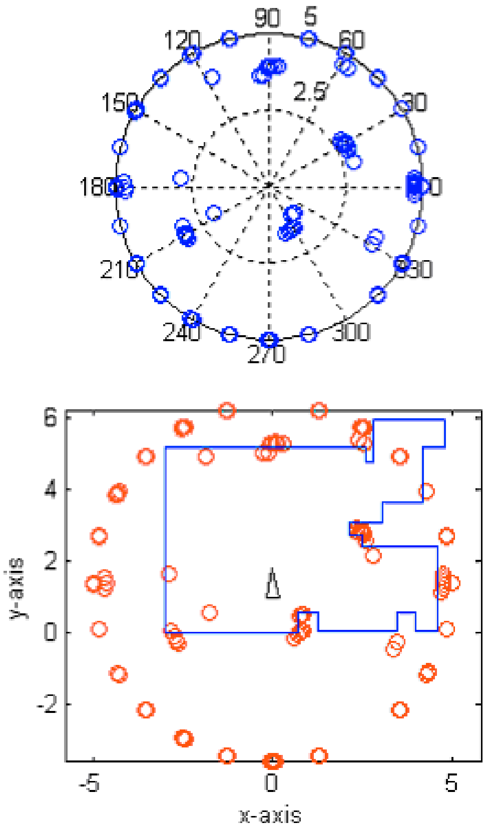

Fig. 3. Raw measurements of position 2

median filtering using a window of fixed or variable length. The filtering process should be tuned to the number of outliers, which are necessary to remove.

At the output of the filtering process a more accurate picture (or map) of the environment, it is obtained. In Fig.4, a median filter on a window of 5 elements filtered the outliers. The raw range measurements are sorted based on global angle, which is the sum of the orientation of the robot and of the angle of the direction of the transducers.

The optimum length of the filtering window is fixed by inspecting the results of the filtering. Values started from 3 to 11 were tested and it seems that good results are obtained by using a length of 5 of the filtering window.

In Fig. 5 is presented a SONAR image of the environment from position 2, in polar coordinates, with and without outliers. Information is presented now in polar coordinates. On the top, the un-filtered set of measurements is presented. The environment now is more clean and ready to be processed. The next step is for defining and evaluation of the similarity maps of the environment. Because such maps are used in navigation mainly and represent the environment, they could be called *perceptual maps* as well.

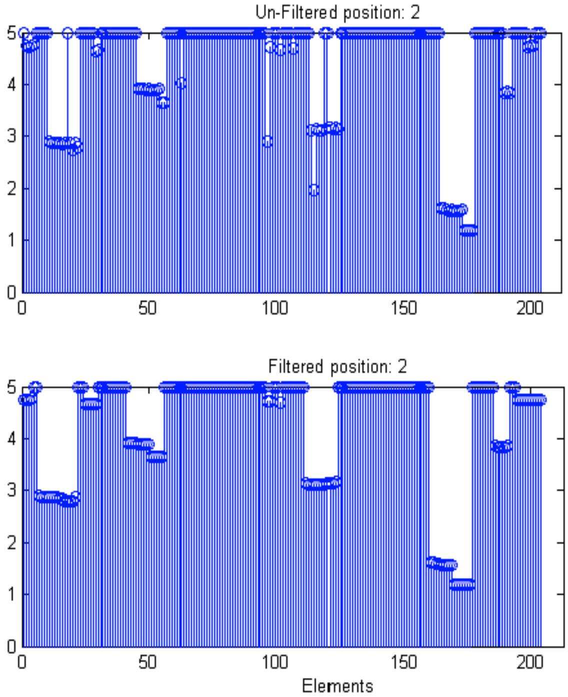

Fig.4. Removing of outliers by median filtering (Cartesian representation)

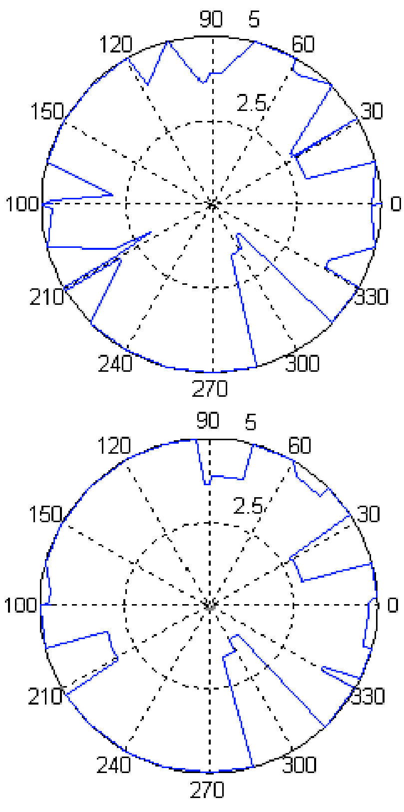

Fig. 5. Position 2 processed by removing of the outliers, by median filtering on a window of 11 elements

5. BUILDING THE MAPS

From the 21 reference positions a database is obtained with vectors of (17*12) x 21 sizes, with elements ordered on theta angle. Every position has a pattern vector of (17*12) x 1 size. The problem is to decide, for an arbitrary (test) position in the field, e.g. from 22 to 35, which reference positions are closest, i.e. to recognize its location within the environment. For this task a classifier based on minimum distance is used.

For every test position, a distance is computed. After comparison with all the reference positions a vector of 21 distances is obtained. Sorting in ascending order of distance values and taking the first *k*-distances we can obtain an estimation of the position inside of the considered environment.

In fact, this is a multi-winner problem in the sense that for each test position it is possible to have more than one solution, i.e. it is possible to have more then one reference position at equal distance from the considered test position.

For simplicity reasons the first considered distance function was the Euclidian distance. The result is a matrix of size 14 x 21, which corresponds to the 14 test cases and 21 reference positions.

Using quantitative results could be difficult in some cases. Another way to represent the results of classification is to draw a map of similarity, using equal-distance curves. Details of the importance of having right similarities can be found in, e.g., (Veltkamp and Hagedoorn, 2000).

The representation is obtained by using the contour of the similarity function defined by

$$S(x,y)=\sum_i w_i \cdot exp\left(-\frac{(x-x_C)^2(y-y_C)^2}{\sigma^2}\right) \quad (1)$$

with

$$w_i \approx \frac{1}{dist(pos\_ref,pos(x,y))} \quad (2)$$

being the weights coefficients. They are defined to be in inverse ratio with the distance from actual position of coordinates (*x*,*y*) till the reference position *pos_ref* of coordinates (x_C, y_C). The resolution of the map is controlled by the parameter σ called variance. As examples, in Fig. 6 and Fig. 7, the similarities maps of the environment for all test positions are presented.

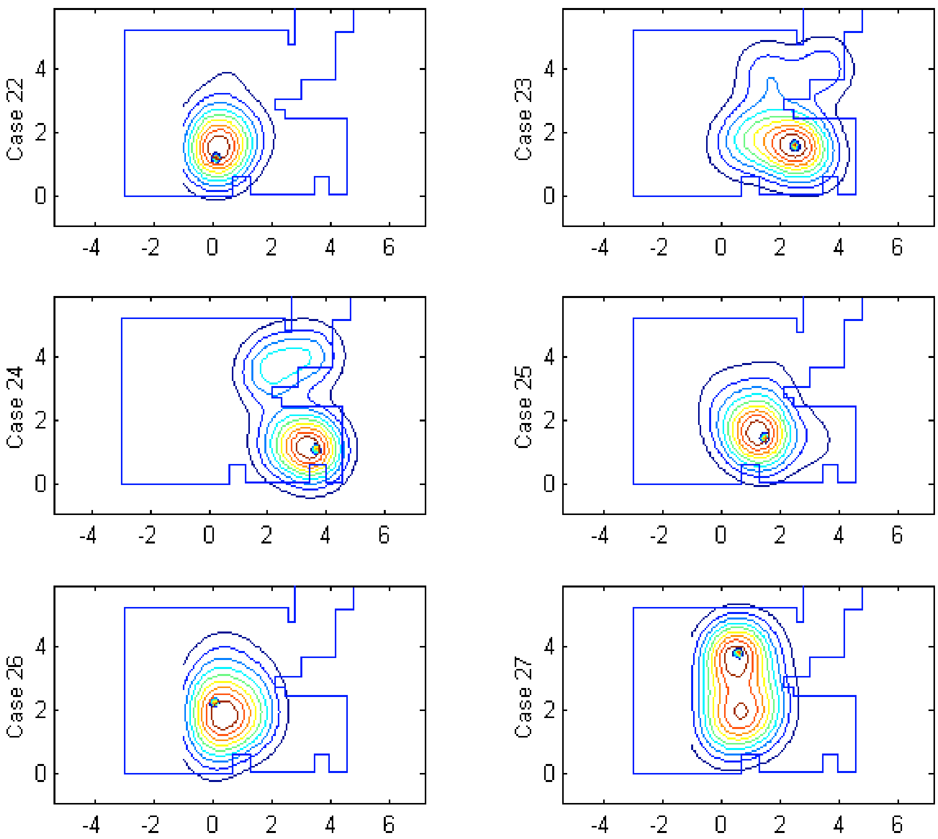

Fig. 6 – Similarity maps for the test positions from 22-27

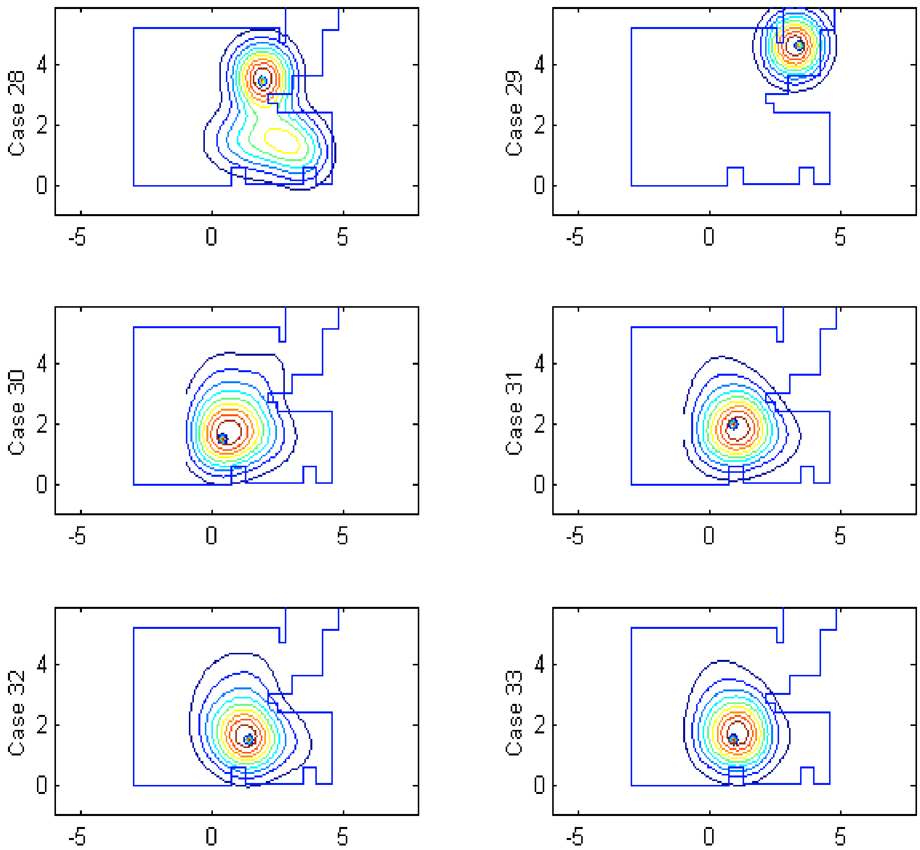

Fig. 7. Similarity maps for the test positions 28 to 33

These kinds of maps are good qualitative instruments for evaluating of the results of the classification based on Euclidean distance and to recognize globally the environment. For the test case 24, the similarities in the environment are very strong. This is correctly reflected by the evolution of the distance in the corner of the environment on the right side. This is true also for the test case 27, where the similarity map reflects the similarity of the environment.

6. CONCLUSIONS

Roughly speaking, two kinds of representations could be used for the purpose of the navigation: a quantitative, based on the discrete results of the classifier, and a qualitative one based on a similarity map. The objective of the paper was to present a method to built a similarity map of the environment, using information coming from SONAR systems, with multiple transducers. The next research step is to design a strategy of navigation based on obtained similarity map.

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