Towards a symbolic representation of an indoor environment

Philippe Hoppenot*, Gilbert Pradel*, Catalin Caleanu**, Nicolas Perrin*, Vincent Sommeilly*
* LSC, 40 rue du Pelvoux, F-91020 Evry Cedex
http://lsc.cemif.univ-evry.fr:8080/
hoppenot | gpradel@cemif.univ-evry.fr
** Applied Electronics Department,
Polytehnica University of Timisoara
Bv. V. Parvan, nr.2, RO-1900 Timisoara
catalin@ee.utt.ro

Abstract:

This paper describes a frescoes based method aiming at the representation of an indoor environment for mobile robot navigation. In particular, it shows fresco's landmarks construction and two selection criteria: barycentre and resemblance. The experimental results yield optimal threshold values for the above mentioned criteria, leading to the development of a language for indoor environment representation.

Keywords: qualitative environment representation, indoor navigation, mobile robotics, disabled people assistance

I. Introduction

The works presented here are interested in a qualitative description of an indoor environment. This description could be used by a mobile robot sent in an apartment to pick up objects in order to bring them back, for example, to a physically handicapped person. The robot needs the ability to navigate in environments, which are a priori unknown and cannot therefore be modelled in advance. Ideally, the mission, if based on the knowledge of room situation in the flat, could be given to the robot using orders very close to the natural language such as "Go to the kitchen, pick up the fork and bring it me back" through an ad hoc interface. But it is more realistic to think to a lower-levelled language based on a succession of topological markers as, e.g.: "move through the corridor, take the third opening on the left, enter the room" followed by a more precise description of the goal situation the robot has to find. In that case, the route and/or the place to go can be described both in global terms and by using landmarks giving to the robot must have the ability to build a model restricted to very global and syntactical information. We choose to describe the surrounding environment by means of clues such as "Opening, Closure, End_of_Closure, Angle_of_Closures,..." organised into ordered series called frescoes according to the data delivered by the sensor.

In the field of Image Based Navigation systems, several great classes of systems can be identified from the literature. The first one uses conventional telemeters and vision to find and identify objects in the environment [WIC 96]. The second one is the class of the systems coupling more or less directly sensor data to motor control thanks to a supervised learning process. Among them neural networks systems used as classifiers are noticeable. These systems classify the environment into global classes (corridor, corner, room, crossing ...) [ALA 96]. In addition to the restrictions related to the supervised learning, These classes give only a global description reducing their interest in complex environments. The third class includes the systems which compare current sensor data and predefined models both at a low level (edges, planes ...) [KIM 94] and at a high level (door, room, object ...). These systems use mainly vision sensors (cameras) that provide a huge amount of data that must be reduced to be processed in real time. The fourth class evoked here includes the systems trying to geometrically build environment models before deciding an optimised path plan [CRO 99].

In the field of shape understanding using sensor data, environment interpretation stresses the use of natural landmarks to ease the navigation and the pose estimation of a mobile robot. Among other works, [SIM 98a] is interested in defining islands of reliability for exploration and proposing strategies to couple navigation and sensing algorithms through hybrid topological metric maps. [OOR 97] considers the problem of locating a robot in an initially unfamiliar environment from visual input. Other works involves a methodology to bind raw noisy sensor data to a map of object models and an abstract map made of discrete places of interest.

In the field of vision based homing, several implementations are presented in [FRA 97]. In these works, a homing system extracts landmarks from the view and allows a robot to move to home location using sequence target locations situated en route between its current location and home. Other works are biologically inspired. [JUD 98] showed that ants store series of snapshots at different distances from their goal to use them for navigating during subsequent journeys. Judd and Collett have experimented their theory with a mobile robot navigating through a corridor. [WEB 99] proposes an approach using the bearings of the features extracted of the panoramic view leading to a robust homing algorithm.

The proposed work goes on the way proposed by [SiIM98b] and [GUI 02]. Our contribution applies mainly on a method to extract clues of interest among raw distance data delivered by a 2D panoramic laser range finder installed on the robot. Its originality stays in the digitisation process, the validation and the selection of the fresco for memorisation. The following points will be successively highlighted: i) how the robot recognises and sets up a description of the surroundings, ii) how these descriptions, the frescoes, thanks to two simple criteria can be used to describe the route followed by the robot.

II. Definition and use of Frescoes for mobile robot localisation

Frescoes are ordered series of semantic clues that can be recognised in the environment. Landmarks used in fresco construction are described before the mechanism of construction of fresco can be given. Then, the use of frescoes for mobile robot localisation is explained.

A. Landmarks used in frescoes

In indoor environments, very specific natural landmarks are present due to geometrical construction: wall, angles, openings… The basic idea is to list them and try to recognise them with the robot sensors. In our case, the sensor used is a laser range finder with 256 measures in 360°. Table 1 shows the list of landmarks used for the fresco construction. A complete description of landmark extraction is given in [PRA 98] and [PRA 01].

Symbol	Landmark	Position	Off-sight	Certainty
	Angle of closure			True
	End of closure	Lengthwise		True
	End of closure	Lengthwise	Off-sight	False
	End of closure	Crosswise		True
	End of closure	Crosswise	Off-sight	False
	End of closure	Diagonal1		False
	End of closure	Diagonal1	Off-sight	False
	End of closure	Diagonal2		False
	End of closure	Diagonal2	Off-sight	False
	45° angle	Lengthwise		False
	45° angle	Crosswise		False
	Opening	Lengthwise		True
	Opening	Crosswise		True
	Breakthrough	Lengthwise		True
	Breakthrough	Crosswise		True

Table 1: Landmark language used in fresco construction.

B. Fresco construction

Figure 1 shows the different steps followed for fresco construction. An ordered list of semantic cues is obtained. Then the fresco is validated using neighbourhood rules: each landmark can have only few other landmarks as neighbour. If a fresco is not valid, it is rejected for the following treatments: only consistent frescoes are kept for localisation mechanism. All results are presented in [PRA 00, PRA 01].

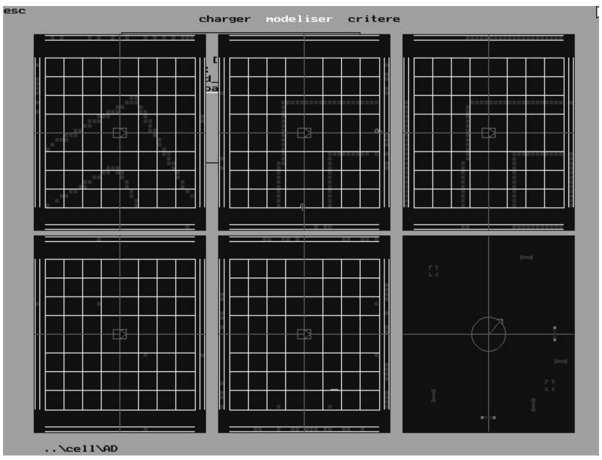


Figure 1: Example of fresco.

C. Use of frescoes for mobile robot localisation

A fresco represents the environment seen by the robot at one place. The frescoes are stacked to keep information about the trajectory followed by the robot. Is it useful to keep all the frescoes? If only few frescoes are useful, how is it possible to select them? Is a specific sequence of frescoes able to describe a part of the environment? Answering, at least partially, to these questions is the aim of this paper. Two criteria to select informative frescoes are presented in the next section. Experimental results and discussion are then proposed.

III. SELECTION CRITERIA

A. Mechanism of selection

Frescoes are saved in a LIFO. So, information about the nearest parts of the environment is easily available. The first remark is that parasite landmark appear in the frescoes due to erroneous interpretation of the measures. The solution to avoid them is to put the three latest constructed frescoes in a FIFO. If a landmark appear only in one fresco, this one is rejected. This first filter is only effective to eliminate parasites but does not take into account the informative level of the different frescoes.

The second question to solve is to know the informative level of each fresco. Indeed, it is not use to keep a fresco if it is very near the previous one. An example is the frescoes obtained in a long corridor: they are all very similar excepted at both extremity. So, it seems interesting to reject the major parts of the frescoes taken in the corridor and to put only informative one in the LIFO defined previously. Two criteria, called barycentre and resemblance, are proposed to evaluate a kind of distance between frescoes. A new fresco is kept only if its distance to the previous stacked one regarding one of the criteria is larger than a threshold. The two next paragraphs describe these criteria. In the next section, a systematic study of them gives an evaluation of the thresholds to use to make the criteria effective.

B. Barycentre criterion

This criterion is inspired by the distance of Hausdorff ([AHU 95], [HUT 93]), which measures the distance between two sets. In our case, this notion was very simplified to take into account the real-time constraints according to those embarked on the robot. It takes into account only the number of certain landmark (Table 1). Four quadrants are defined. The number of certain landmarks in each of them is computed. They are positioned as indicated on Figure 2 and the barycentre is positioned. Any variation of the number of elements in a quadrant implies a movement of the barycentre. If this displacement is superior to a fixed threshold, the fresco is kept.

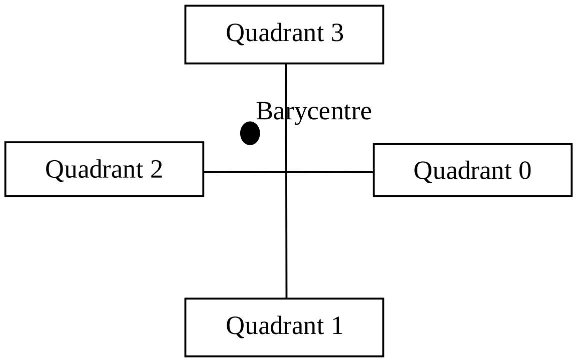


Figure 2: Barycentre computation.

C. Resemblance criterion

This criterion uses a nearby principle of that presented in ([HON 91]): a correlation function allows to calculate the resemblance between two frescoes. This criterion has been tested in the same environment than that used for the construction and the validation of the frescoes. The use of this criterion shows that the landmarks not defined as certain (Table 1) act like a noise making very difficult the evaluation of the resemblance. So only the certain elements were kept. The resemblance between two consecutive frescoes is calculated by taking into account the difference between the number of certain landmarks in the corresponding quadrants. The comparison of this difference with a threshold indicates if the current fresco should be kept or rejected because not bringing enough information

IV. EXPERIMENTAL RESULTS

The problem is to find the right threshold for each criterion. A representative panel of situations is first established and systematic tests are computed on each situation in which kept frescoes are listed for different thresholds of the two criteria. Then an interesting threshold for each criterion is fixed taking into account firstly the ratio of kept frescoes and secondly the position of kept frescoes with respect to the situation. Finally, defined thresholds are tested in a complex environment.

A. Choice of different types of environment

Indoor environments can be described using limited situations: opening, angle and crossing. All of them are detected by changes in sensors measures. Tested situations are:

- Angle on the Left (AL)
- Angle on the Right (AR)

- Opening on the Left (OL)
- Opening on the Right (OR)
- Crossing (CX)

Figure 3 shows the example of the opening left situation. Numbers on the left of the figure shows the different positions where frescoes have been constructed. For this example, 31 frescoes are taken, and only one of five is drawn to make the figure readable.

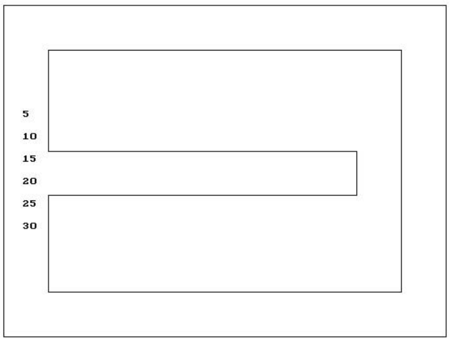


Figure 3: Situation example. Opening on the Left (OL).

In the different situations, the initial numbers of frescoes are different (Table 2).

Situation	Number of frescoes
AL	31
AR	31
OL	31
OR	31
CX	42

Table 2: Initial number of frescoes.

B. Number of frescoes stacked

It is firstly interested to observe the number of frescoes kept for different values of thresholds. For barycentre, values between 0 and 2 with a step of 0.05 are tested. For resemblance, values between 0 and 12 with a step of 0.5 are tested. Beyond these limits, only fresco number one is kept.

As the initial number of frescoes is different in all situations, the ratio between the number of frescoes kept and the initial number of frescoes is analysed. Figure 4 shows the results for resemblance criterion and Figure 5 shows the results for barycentre criterion. The first interesting result is that curves in each figure are all similar. That means that criteria have the same answer in all the environment situations. So it seems possible to find a common threshold.

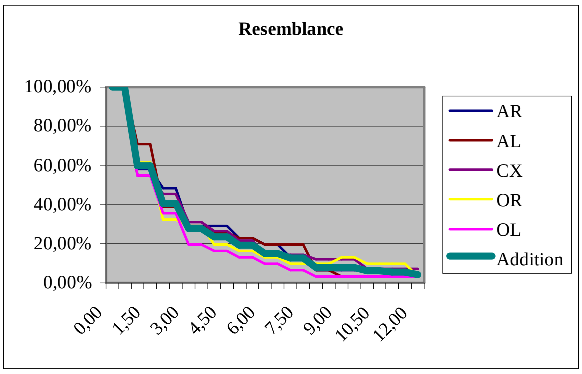


Figure 4: Percentage of frescoes kept by resemblance criterion with respect top threshold.

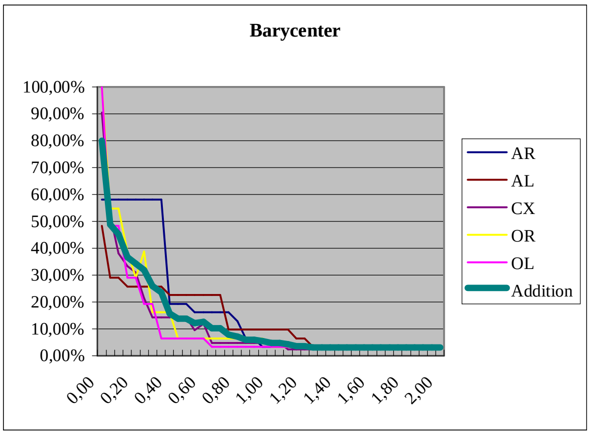
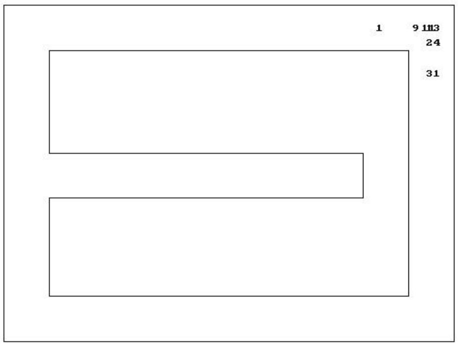


Figure 5: Percentage of frescoes kept by barycentre criterion with respect top threshold.

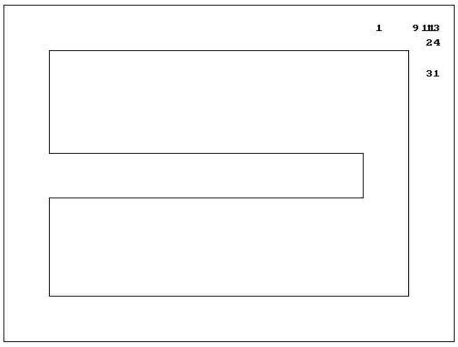
The second interesting point is that curves fall quickly for low values of thresholds and then are more flat. With a threshold equals zero almost all the frescoes are kept which is clearly unsatisfying. Indeed, taking the example of Figure 3, it appears that frescoes between 1 and 10 represent the same part of the environment with very little differences. The objective is to keep a reasonable part of frescoes between 10% and 20% in the first approximation. For resemblance criterion, that means thresholds between 5 and 7 and for barycentre, that means thresholds between 0.4 to 0.6.

C. Positions of stacked frescoes

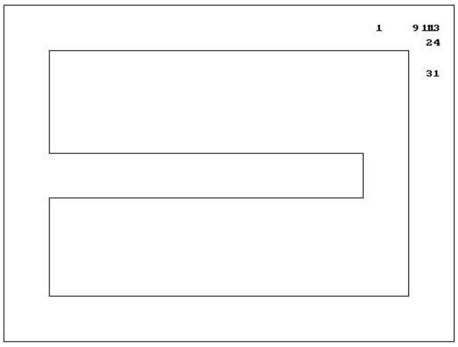
For both criteria, it is interesting to visualise which frescoes are kept. The example of barycentre criterion for the angle on the left situation is represented on Figure 6: numbers of frescoes are represented for the five thresholds called reasonable in the last paragraph.



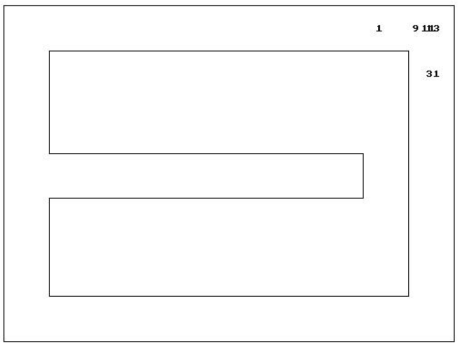
ad - Barycentre 0,40



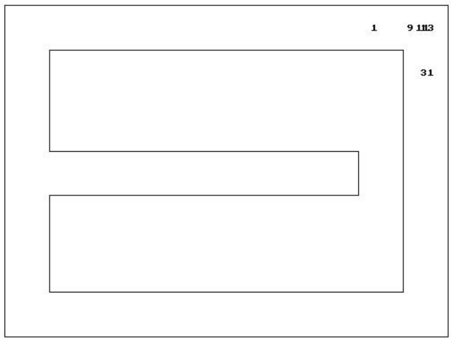
ad - Barycentre 0,45



ad - Barycentre 0,50



ad - Barycentre 0,55



ad - Barycentre 0,60

Figure 6: Barycentre criterion for angle on the left situation.

Frescos number 1 and 31 represent the beginning and the end of the trajectory: they are present for all the thresholds. Frescoes 9, 11, 13 and 24 represent the heart of the turning. They are very close considering Euclidean distance but they differ in term of orientation. Fresco number 24 disappear for threshold equals 0.55 or 0.60. 0.50 is really the central value for barycentre criterion.

The same analysis can be done for the other situations. The study of resemblance criterion leads to the same conclusion with 6.0 as central threshold.

D. Discussion

If only the number of retained frescoes is taken into account, one can see that:

- The response for each criterion is similar for all the situations.
- For each criterion, it is possible to evaluate an acceptable threshold for all the situations.

But the position of the retained frescoes must also be considered. The visualisation of the retained frescoes for all the combination of situations and criteria shows that retained frescoes are well situated in the environment to have a satisfying representation (Figure 7).

For this second level of analysis, the comparison of the criteria shows that they are sometimes complementary. Figure 8 gives the result of both criteria with the chosen threshold. Resemblance criterion gives a very interesting result: only three frescoes are kept, one before the opening, on the middle of the opening and one after the opening. That seems to be the best representation of this situation in terms of concision and precision. Barycentre criterion does not see the end of the opening. The question we are working on now is to know which criterion to use in which situation. For that, the situation must be recognised.

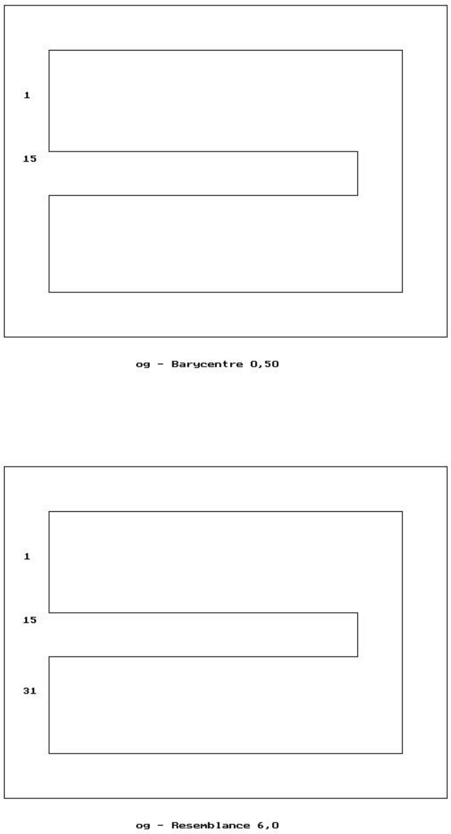


Figure 8: Comparison of criteria. Opening on the left.

The objective of our study is to find a way to represent indoor environment for mobile robot navigation. The first step with think about is to find the way back for a trajectory. The first question is to see if frescoes staked are sufficient to recognise the way back. The second question is to see if frescoes staked are sufficient to command the robot on the way back. Then, the following step is to give a language for indoor environment representation.

V. Conclusion

Within the framework of frescoes, an appropriate method for indoor environment mobile robot navigation has been described. Some contributions regarding clues of interest extraction among raw distance data delivered by a 2D panoramic laser range finder, are presented in this paper. The originality of the method stays in the digitisation process, the validation and the selection of the fresco for memorisation. This final issue, namely fresco selection, is tackled by two methods: barycentre and resemblance criteria; it has been shown the complementary nature of them together with optimal threshold values. Future work will analyse the opportunity of using one or another selection method, depending of environment type.

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