15th Triennial World Congress, Barcelona, Spain

CORRIDOR EXPLORATION IN THE EDN NAVIGATION SYSTEM

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Abstract: An example of autonomous generation of a topological map for the EDN Navigation System is described on this paper. This algorithm has been tested in a real robot. The EDN Navigation System consists of a sensorimotor and sensorial skills succession, which will guide the robot to its final destination. This succession of actions and events is stored as a topological map called Navigation chart. In this example the Navigation Chart of an environment made up by a corridor and some rooms is generated.

Keywords: mobile robots, robots navigation, environment, modelling, intelligent autonomous vehicles.

1. INTRODUCTION

Nature has given human being skills which are unknown and which could give the mobile robots field a new point of view for solving old problems. Among these problems the mobile robot autonomous navigation is found. Related to that type of navigation will be the spatial knowledge of the environment. With it, could be performed all type of tasks.

The theory developed by Piaget (Piaget 1960). and afterwards demonstrated with investigation results shows that the human being spatial knowledge has a jerarquical structure and it is obtained by means of state processes. Authors such as Nehmzow (Nehmzow 1995) and Truiller (Truiller 1997) which study the way to represent the environment and the way to move along it performed by animals and human beings, concluded that the natural way of navigation and environment representation is by topological structures and relationships.

All these theories and the ones developed by Kuipers and Byun (Kuipers 1987), Wallner, Kaiser, Friedrich and Dillmann (Wallner 1994) ,Aycard, Laroche and Charpillet (Aycard 1998) and by Tièche and Hügli (Tièche 1998) support the idea of the topological map as an environment representation also having in mind the geometrical information. The geometrical information in most cases is added to the map as additional information.

The topological map as an element, which represents the spatial knowledge the robot has of the environment, is related to the topological navigation used as a mean and as purpose of itself. It is used as a "mean" because it is necessary to navigate, to explore the environment. And is known it will be used to navigate on it.

2. EDN NAVIGATION SYSTEM

On this paper The EDN (Event Driven Navigation) system (Barber 2001b) is used. The EDN system consists of sensimotor actions and sensorial events which guide the robot to its final destination. The actions and sensorial events succession is also used to explore the environment. By using a succession of similar actions to those a human being will perform, the robot tries to explore an unknown environment acquiring a spatial knowledge of itself. For example, if a person wants to begin a new exploration from a room, the actions he will perform will be the following:

- Search for a door and exit the room.
- Travel a corridor locating the doors on it.
- Move to a door and cross it.

This map, which is not formed by a succession of places of the environment but by a succession of elementary skills is named (Barber 2001b) Navigation Chart. The Navigation Chart is a succession of nodes and edges. Edges represent sensorimotor skills which indicate the robot what to do (move towards a door) and nodes will be events (be in front of a door) which will lead to a new sensorimotor action.

The following work will describe how a robot can explore the environment which surrounds it and at the same time how Navigation Chart information will be stored using the EDN system.

To obtain the Navigation Chart we find out that the easiest way of representing it is by graphs. The graph considered on this article is a group of nodes joint by edges. Figure 1 shows and example of this graph.

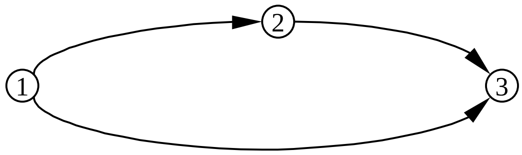

Fig. 1. Topological graph.

The chart has been represented as a parameterised and oriented graph. Nodes represent sensorial perceptions. Edges or transitions represent the robots sensorimotor actions. To follow this criterium it has to be beared in mind the fact that nodes represent specific situations for the robot, while transitions represent the change between nodes. A new specific situation of the Navigation Chart is defined using sensorial skills when detecting an event. The robot finds itself on the place or on the situation where a sensorial event is sensed. Using a specific motor skill it moves along nodes or sensorial perceptions Edges represent how the transition from one node to another is done.

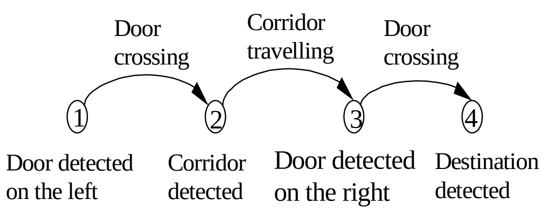

Fig. 2. Topological graph considered on the Navigation Chart.

Figure 2 shows an example with a topological graph as the one considered in the Navigation Chart.

Nodes are defined by sensorial perceptions, meaning that nodes are what the robot is sensing in that moment. For example, a node can be: being place underneath a door, door detected on the right, or a corridor crossroad detected.

Edges or transitions are defined by motor actions. Transitions between nodes are performed by robot actions or robot movements. Each action is performed by a predominant skill which can either be simple or complex. A transition can then be actions such as turn right, follow a corridor, move until door detected or cross a door.

Edges are related to motor skills, being this the one that defines the edge.

The robot will navigate using the information which the Navigation Chart contains. One of the problems to deal with is the construction of the Navigation Chart. The chart can be a priori defined or it can be autonomously generated by the robot. In the present work a full example of how the Navigation Chart can be generated is shown.

3. ALGORITHM OF MAP GENERATION

In (Barber 2001a) a generation algorithm of a Navigation Chart is described. When building the map the steps to follow have to be structured clearly. The actions to carry out are performed in function of the different sensorial perceptions which the robot receives. Also in function of the situation in which the robot is at each instant.

During the development of the generation of the topological map two types of locations have bared in mind: rooms and corridors. With these types of locations an important range of environments is covered as can be buildings. On the following section the way to obtain the map algorithm will be discussed in detail.

3.1 Exploration beginning.

The robot can begin to explore any type of location, such as a room, a corridor or a corridor crossroad.

Suppose that the exploration begins in a room. The map generation will first place the robot waiting for a beginning signal (event) which will be called node 0. With this the robot can be located each instant in the map the robot has to carry out. When the robot receives this signal it will start identifying the room in which it is located, making difference whether it is located in a corridor or in a room. Once the robot has identified the room as its initial location, it will move towards the reference location and it will be orientated north. When the robot has done all the movements described above, it will search for crossing zones, that is, doors. To identify each crossing zone the robot will register the orientation and goal for each zone. The steps followed are shown in (Barber 2001b).

3.2 Generic Algorithm

Once the robot has detected the crossing zones, it will register and it will generate a topological subgraph for each new crossing zone as the one shown in figure 3. In this subgraph all the events that should be detected (nodes) and all the actions to be carried out (edges) to enter a new room are considered. The group of nodes and edges registered written down include not only the information needed to enter the new room but also the information needed to return to the actual room.

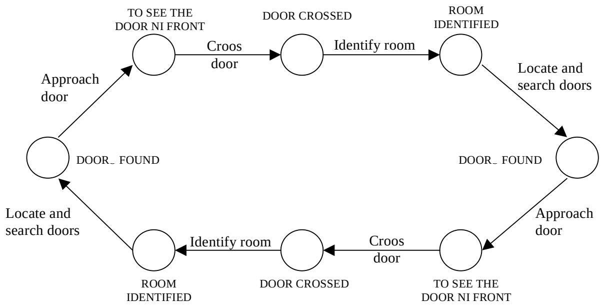

Fig. 3. Topological map for two adjacent nodes

3.3 . Corridor exploration.

So far it is considered what happens when the robot goes through a crossing zone and what happens when a room behind that crossing zone is found. There is also the possibility of finding a corridor once the robot goes through a crossing zone.

The way of proceeding changes. There are some differences between a corridor and a room. A corridor has a much longer dimension than a room. In a corridor all the crossing zones can not be seen from only one reference location, as it can be done with a room.

Once the new localization has been identified as a corridor, the corridor module is run, as shown in [9]

The robot will move along the corridor by a left turn, when the new location has been identified as a corridor. The turning direction is not important but a criterium needs to be established. The robot orientation is checked, once the robot is oriented on the corridors direction. If that orientation is less than 180º, the robot turns around the opposite direction. In this way, the robot discriminate both corridor ends. Naming corridor start to the end towards the robot is oriented while the corridor end corresponds to the opposite end. The corridor start and end will always be the same, being independent the way of accessing the corridor.

Once the robot has approach the corridor start it will start moving along the corridor counting up the number of doors the robot sees until the robot reaches the other corridor end. With this way of acting, when the complete corridor exploration is done, the map generator will know where to fit the corridor map with the one the robot previously has, this means, with the room the robot had entered.

Once the robot has reached the corridor start it turns around to begin the exploration. Then the visible crossing zones are found and counted from the actual location, registering the position.

If after the exploration of a group previously seen the robot finds itself at the end of the corridor, it will conclude the corridor travelling, leading the exploration map recently created with its specific crossing zones. The topological structure created when travelling along the corridor, when the robot finds itself on a crossing zone, is shown in figure 4.

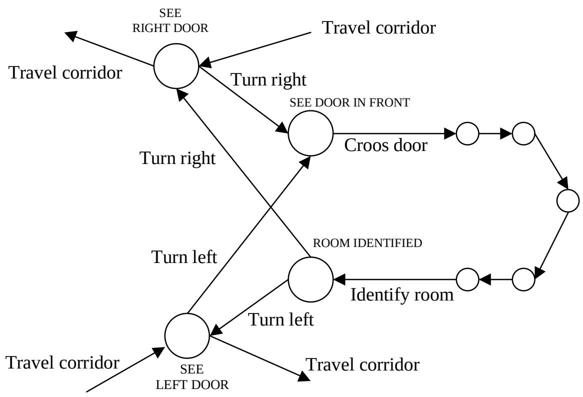

Fig. 4. Corridor-room joint

After the first corridor exploration, the exploration of the registered crossings zones begin. Once the robot behaviour is as it was described in the general algorithm. It is necessary, to continue the exploration in an orderly way, to know where exactly the robot is placed in the corridor. The way the crossing zone from which the robot has entered the corridor would be recognized by the number of crossing zones done from the corridor start.

The corridor exploration will end when all the registered crossing zones are explored.

4. THE CORRIDOR NAVIGATION CHART

The experiments have been focused in a part of the entire algorithm. Exactly, it has been considered the autonomous generation of the navigation chart of a corridor. The robot begins exploring the corridor an makes the navigation chart as it finds the different opened doors.

There is one important thing that must be taken into account; the sequence needed for the generation of the navigation chart is very different from the sequence generated by the navigation chart itself.

Here the first one is going to be explained, the sequence of skills needed to generate the navigation chart of the corridor. However, as it will be described later on, the skills used for the generation will be reused on the navigation chart. The same skills are used for different objectives.

Two skills are considered in our experiment the "Corridor travelling" and the "Door detection". As the robot navigates down the corridor avoiding any obstacle on its way, it registers the doors detected at both sides. With this information the robot will generate autonomously the navigation chart of the environment. The flux diagram is shown in figure 5.

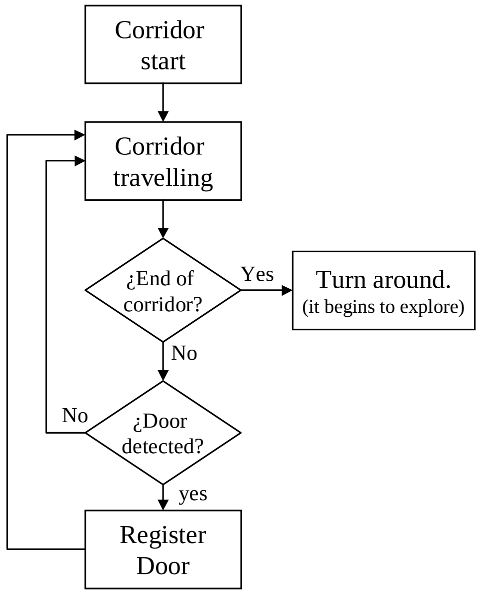

Fig. 5. Flux diagram.

The navigation chart obtained with the sequence shown in figure 5 will have the structure represented in figure 4. The sequence of the navigation chart contains both the "Corridor travelling" skill and the "Door detection" skill. These skills are needed to explore the different rooms.

The final result will be the corridor Navigation Chart, which contains the instructions needed to go from one point in the environment to another following the sequence of skills generated by a scheduler.

5. EXPERIMENTAL RESULTS

The experiments described in this section have been tested in a B21 robot by RWI, figure 6, equipped with a SICK PLS laser scanner. The maximum number of measurements values transferred by this laser is 361 with an angular resolution of 0.5º.

Fig. 6. B21 robot with a laser telemeter.

The previously mentioned skills and sequencers have been implemented in C++ language, using the system specified by CORBA which provides interoperability between objects in a heterogeneous, distributed environment.

The demo was performed in a 26m corridor (figure 7) with four opened doors. Its mission was to start from one end of the corridor, navigate down the corridor, and make the corridor navigation chart autonomously.

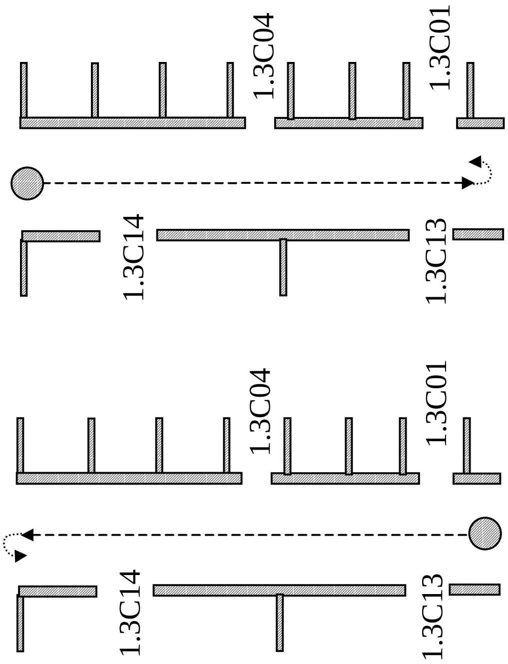

Fig. 7. Representation of the two paths followed by the robot.

The end in which the robot begins the corridor travel does not interfere with the corridor navigation chart. The instructions generated by the navigation chart will not be different if the robot goes from the left side of the corridor to the right side of it or vice versa. For this reason, when carrying out the experiment for the system robustness analysis, the map generation is considered in both ways. The correct navigation chart generated is shown in figure 8, T.R. means turn right and T.L. Turn left.

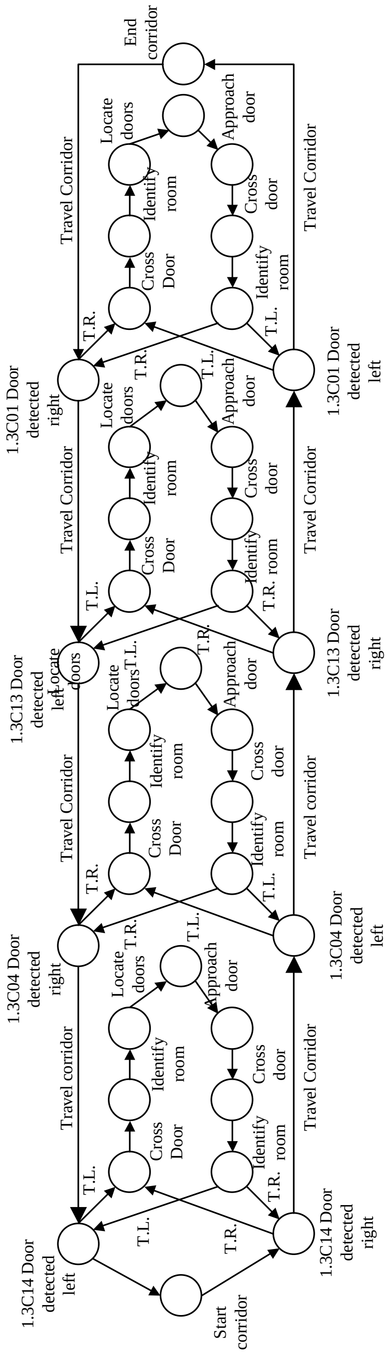

Fig. 8. The four rooms corridor navigation chart.

Ten missions were attempted. Of those missions nine were successful. The failed mission resulted from an unsuccessful attempt to find a door. A person blocked the door and the "Door Detection" skill failed.

Table 1 Experimental results

	1º	2º	3º	4º	5º
Time (s):	38 ☑	42 ☑	42 ☑	40 ☑	48 ☑
	1º	2º	3º	4º	5º
Time(s):	☒	46 ☑	40 ☑	44 ☑	40 ☑

The upper values, 48, 46, 44 correspond to instants were people were in the corridor. The "Corridor travelling" skill had to avoid obstacles increasing the time to accomplish the mission.

6. ACKNOWLEDGEMENTS

The authors gratefully acknowledge the funds provided by the Spanish Government through the CICYT project TAP 99-214.

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