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Navigation on Topologic Feature-Maps

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Based on the idea of using topologic feature-maps instead of geometric environment maps in practical mobile robot tasks, we show an applicable way to navigate on such topologic maps. The main features regarding this kind of navigation are: handling of very inaccurate position (and orientation) information as well as implicit modelling of complex kinematics during an adaptation phase.
Due to the lack of proper a-priori knowledge, a reinforcement based model is used for the translation of navigator commands to motor actions. Instead of employing a backpropagation network for the central associative memory module (attaching action-probabilities to sensor situations resp. navigator commands) a much faster dynamic cell structure system based on dynamic feature maps is shown. Standard graph-search heuristics like A are applied in the planning phase.*

1. Introduction & Motivation

The central aspect in our robotic project “ALICE” is the ability of a mobile robot to efficiently explore unknown environments in order to generate robust qualitative models of the actual surrounding. This kind of world modelling is particularly important for driving (collision avoidance) and navigation tasks instead of applications like docking or grasping, where more detailed (accurate) modelling is required. In this sense ALICE should improve the “lower” levels of mobile robots (qualitative modelling, reflexes, navigation, exploration) and should offer a solid basis for more specific tasks.

The classical geometric environment models (2d or 3d) generally need a huge amount of (exact) range data in order to build up a sophisticated – but not easy to adapt – map. The second group of techniques often used are the rigid (mostly grid-based) models with high position jitter and high memory requirements. In most practical mobile robot tasks a more qualitative but easy to adapt and stable environment model would be desirable. The resolution of the model (resp. the memory requirements) should be determined through the “complexity” of the environment. As being shown in [5], the topologic map-building applied in the ALICE-project fulfils these requirements.

In order to make obvious that the topologic environment maps are sufficient for navigation, we discuss a “qualitative” kind of navigation in this paper.

2. ALICE Structure

ALICE consists of only a few main components, which might be classified in an explicit abstraction part (topologic map) and a control hierarchie (figure 1). The control modules can immediately interact with the environment (actuators) or communicate with lower components (here: Navigation might use a behaviour-based module (Reflexes) or steer the robot immediately). The explicit world model is reduced to a topologic map and a permanently correlated actual position (according to the actual and previously seen sensor situations).

ALICE is a round (40 cm in diameter, 20 cm high), fully autonomous platform with an omnidirectional kinematic. 24 whisker-light-sensor pairs are distributed symmetrically at the border of the vehicle and three light-sensors are directed towards the ceiling. A rough internal position is being determined by dead-reckoning.

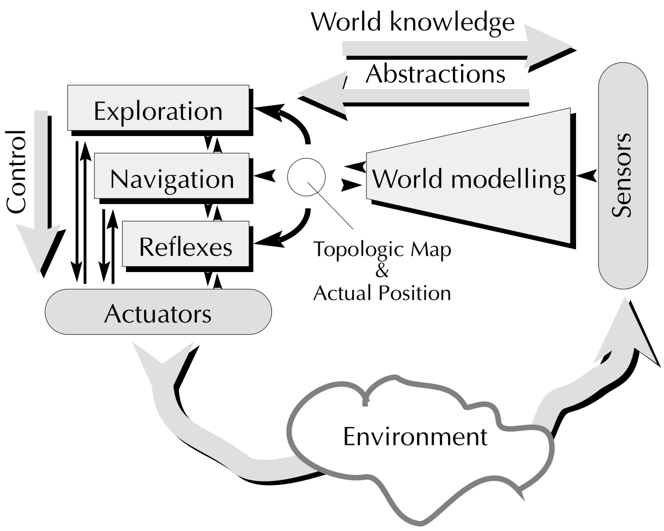

figure 1 : ALICE main-structure

3. Topologic mapping

As being shown in [5], applying a dynamic feature map system like [3] resp. refinements from [4] leads to topologic environment maps, which are stable regarding drift and sensor noise. A related but symbol-oriented approach called “Qualitative Topologic Maps” is presented by Kuipers and Byun in [1]. The map from figure 2 represents a typical result of an exploration phase (in this case manual exploration). The nodes nearest to the obstacles represent the border (which has been detected by whiskers) whereas the nodes in between represent different light situations (three light sources were attached here).

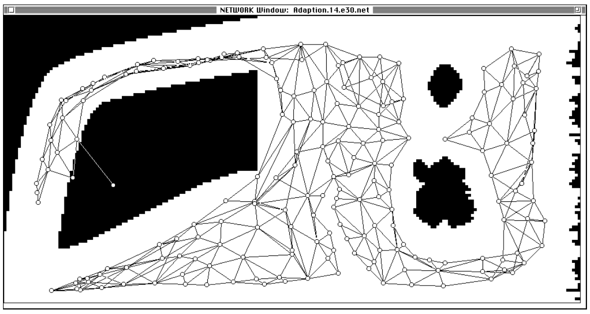

figure 2 : Topologic map

Due to the fact that we are not using any distance-measuring sensors, we can only detect nodes to be neighbours in the topologic graph by driving along their connections, and not simply by “seeing” them.

4. Navigation

The navigation module is being split into two layers, which refer to the path-planning task and the problem of translating the planned path into adequate motor actions.

4-1. Path planning

The path planning is being done on the topologic map (graph) by steepest gradient methods and a modified A* algorithm. Depending on the complexity of the environment both methods produce adequate results. The important criterion is the evaluation speed rather than finding the best way, because

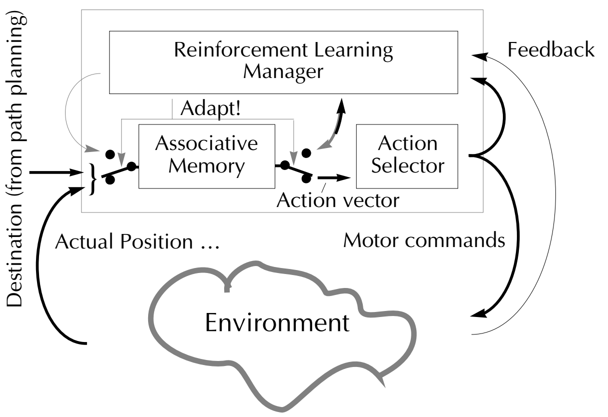

figure 3 : Reinforced learning

small changes in the environment may lead to a failure when trying to drive along a planned path. Therefore the path planning component is employed each time when a plan fails and because we are using inaccurate sensors and dynamic environments this may happen quite often. On the other hand this replanning might be done quickly, because the topologic map is – in the perspective of the path-planner – overspecified and offers a lot of alternative routes.

4-2. Adapting motor actions

In order to navigate a planned path, we have to find a mapping from a pair of nodes in the topologic map (temporary start and destination points) to adequate motor commands constrained to a certain accuracy. The kinematics of ALICE are quite simple, because we have an omnidirectional platform and furthermore high accelerations. So we are able to learn this mapping including drift effects, depending on the actual environment as well as on tolerances in the driving / dead-reckoning part of ALICE.

The adaptation is being done (in parallel to the topologic-map-building) with an reinforcement learning scheme (figure 3), where supervised dynamic feature maps (introduced in [3]) are applied in the associative memory module. Later on, the learned translation is applied to areas of the map, which were not available during the learning phase (generalisation).

5. Conclusions

Due to lack of space only principal structures could have been discussed in this paper. The simulation results, which could not been shown here in detail, may be found in [2]. Despite the fact that we are using simple passive light sensors, whiskers and only a rough position and orientation measurement, the maps and navigation results are encouraging, regarding stability and performance.

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