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PATH PLANNING FOR A MOBILE ROBOT IN REAL TIME

This paper presents the research of a mobile robot (MR) actions planning in uncertain environment allows to determine dynamically time of approach of critical event on the basis of forecasting of possible consequences of the current situation with use of various environment processes laws knowledge.

During the last century, automation has become an extremely fast growing phenomenon impacting almost all facets of everyday life. Recently, robots have become a major part of this trend. Therefore, autonomously navigating robots have become increasingly important [1,3]. Motion planning [2] is one of the important tasks in intelligent control of an autonomous mobile robot.

An important feature of any autonomous mobile system is the ability to plan the movements to the specified target position. At the same time, intelligent mobile system features the ability to change or adjust the route in case of an unforeseen occurrence in the environment of foreign objects (or constraints). Thus, the challenge is that in general terms can be formulated as: find a path for the robot in its operating environment, from some initial position to some targets, taking into account the appearance and movement of obstacles. There are two possibilities:

a) information about the appearance and motion of obstacles in the environment of the robot is known;

b) information about the movements of the obstacles is not initially known.

The path-planning is again divided in two sections: global path planning and local path planning. Global path planning requires the environment to becompletely known and the terrain should be static. In this approach the algorithm generates a complete path from the start point to the destination point before the robot starts its motion. On the other hand, local path planning means that path planning is done while the robot is moving; in other words, the algorithm is capable of producing a new path in response to environmental changes. Assuming that there are no obstacles in the navigation area, the shortest path between the start point and the end point is a straight line. The robot will proceed along this path until an obstacle is detected. At this point, our path-planning algorithm is utilized to find a feasible path around the obstacle. After avoiding the obstacle, the robot continues to navigate toward the endpoint along a straight line (in our system the robot moves in a vertical or horizontal direction, not diagonally. Hence it will try to approximate a straight line.) until (1) the robot detects another obstacle or (2) the desired position is reached. An example of local path planning is shown in Figure 1.

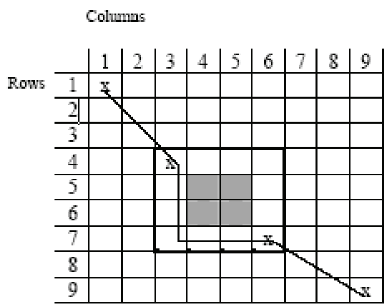

Figure 1. Path-planning example for local obstacle avoidance, applied on a subsection of the search space.

Planning of actions is the major function of the mobile robots independently working in dynamic and uncertain environments. For representation of robot actions plan we shall use hierarchical frame structure of the following kind. At the top-level plan FP_m is set by the frame of a kind:

$$FP_m = (PN_m, S_0 , Act_1, S_1, Act_2 , S_2 , . . . , S_{n-1} , Act_n, S_n),$$

where PN_m – is a name of m-th plan; S_0 - the current condition of environment; Act_i - is the frame of i-th action of the plan; S_i – is the frame of environment condition after performance of i-th action of a plan; S_n - the target condition of environment. Frames of environment conditions and actions of the robot contain slots «Type of the frame», «Name of the frame» and set of frames of the bottom level serving for representation of parameters of conditions and actions.

Parameters of environment conditions can be divided on the following groups:

- external world condition parameters, which value do not depend on robot actions;
- environment condition parameters and the robot in the environment, changeable as a result of robot actions;
- robot inwardness parameters, describing internal robot resources.

The process of decision-making by the intellectual robot in system of real time on the basis of actions planning includes the following steps:

1) preliminary estimation of a situation and definition of the general stock of time T_d for decision-making;

2) definition of actions variants set possible in the given situation;

3) distribution of the general budget of time for tasks of various actions variants estimation;

4) concretization and estimation of actions planning efficiency;

5) actions variants comparison and choice of the best of them.

Let's consider all listed steps of decision-making.

Time restrictions for decision-making by the robot are caused by possible approach of events undesirable to the robot if it in due time will not undertake corresponding actions. Time of approach of events is determined by dynamics of environment processes (in particular, actions of mobile obstacles) and a priori is not known.

Thus, the robot should possess ability to define dynamically the time of critical event approach on the basis of forecasting of possible consequences of the current situation with use of knowledge of laws of various environment processes.

Set of possible in the future critical events $\{CE_i\}$ can be put in conformity with every GPS. Function $f_d^i(P_j, ..., P_k)$ from predicates of the current situation, calculating stock of time T_d, caused by possible approach of the given critical event can be put in conformity to each critical event.

The kind of this function is known at a stage of MR control system construction, and its description is stored in corresponding slot of action plan. The valid value of a stock of time Td is calculated dynamically on the basis of the current values of situation parameters.

Every GPS at a stage of construction of base of MR knowledge puts in conformity set of tactical variants of actions submitted by plans of action $\{FP_1 , \dots ,FP_q\}$. Each such plan has slot "Precondition" in which predicate PC (precondition) is written down, determining additional conditions of the given plan applicability. The predicate is determined on parameters of the current situation (both external, and inwardnesses of the robot) and allows to exclude some plans from the further consideration.

Calculation of the given predicate is realized by function $g(P_j , ..., P_k)$. Computing complexity of this function should be low and the top estimation of its calculation time should be known. Calculation of predicate PC can demand gathering of the additional information for reception of facts, which are not contained at present in a database. As a result of definition of the validity of preconditions of all plans contained in $\{FP_1, \dots, FP_q\}$ the reduced set $\{FP_m\}$ of possible plans for the further analysis is formed.

As the estimation of efficiency of all tactical plans from set $\{FP_m\}$, should be executed in time T_d, it is necessary to allocate the general stock of time between corresponding tasks of a concretization.

Various plans of actions, generally, demand various time of a concretization and this time depends on parameters of the current situation and it is not known at a stage of knowledge base construction. Besides time of action plan concretization can vary over a wide range not only depending on an external situation, but also on internal resources of the robot. The time of this task decision depends on the area of the scanning, the current condition of touch and MR processing resources, and other parameters which values are a priori unpredictable. At the same time, set of such parameters can be allocated beforehand and for each concrete plan FP_m the bottom estimation of decision time of task of concrete definition T_m^* can be expressed as function from these parameters:

$$T_m^* = h_m(P_1, \dots, P_k).$$

These functions should have low computing complexity. Using the given functions, MR calculates the bottom estimation of total time of a concrete definition of all plans belonging to set {FPm}on the basis of the current situation:

$$T_\Sigma^* = \sum_m T_m^*$$

Conclusion

Use of suggested method of MR actions planning in uncertain environment allows to determine dynamically time of approach of critical event on the basis of forecasting of possible consequences of the current situation with use of various environment processes laws knowledge.

Tasks of search of optimum values of action plan parameters depend on the concrete mathematical models used for the description of corresponding steps of the plan, and can be the diversified. At the same time, MR control systems with recognition of situations and planning of actions are characterized by great volume of the processed information and high complexity of used algorithms of processing of the information and decision-making. High reliability demands are also made for them. The specified characteristics can be achieved due to use of multiprocessing computing systems, for example as an artificial neural network. In hardware realization neural network is a network from set of simple processors, each of which has small local memory and communication connections with other processors. Prototypes of such networks for MR control systems have been already in use now for forecasting of situations in financial sphere, images recognition, speech.

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