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PLANNING OF INTELLECTUAL ROBOT ACTIONS IN REAL TIME

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Summary: *In article the mathematical model of the mobile robot actions planning at recognition of situations in extreme conditions of functioning is offered. The purpose of work is reduced to formation of a concrete plan of the robot actions by extrapolation of a situation and its concrete definition with the account a priori unpredictable features of current conditions.*

Key words: *the mobile robot, recognition of a situation.*

Introduction

Creation of the intellectual mobile robots, capable to adapt and plan the actions in conditions of aprioristic uncertainty of dynamically changing habitat, is one of the important strategic problems of modern techniques. Absence of preliminary environment formalization, and also presence of any way moving obstacles and purposes in it complicates the use of automatic control traditional methods. The given circumstance stimulates development of new control systems with presence on mobile robots (MR) board of situation recognition system on the basis of the multiprocessing computer with elements of artificial intelligence that provides adaptability of MR behavior in an environment.

Recognition of situations is the new area of cybernetics. The closest area is images recognition. But there is a basic distinction of these concepts: the image is "static", and the situation is dynamical, recognition of situations is always connected to a prediction (extrapolation) that usually does not happen in the theory of images recognition. At situation recognition there is no aprioristic classification as the number of possible situations is unlimited, but results are classified and have the final alphabet.

For MR control system we shall understand that the situation is a set of events, developing in time and space limited in radius of its action, and having the important consequences from the point of view of the chosen criterion function. The situation includes three basic components:

- the ground conditions fixed during the certain moment of time (presence of obstacles in a way);
- processes which can occur both with its condition, and with MR condition (dynamism of obstacles and the robot);
- result or possible consequences (planning of actions and forecasting).

To distinguish a situation by control system - means to develop decision about result of further MR movement on the basis of environment and proceeding process information.

Traditional mathematical models of MR management in extreme conditions of functioning becomes insufficiently as MR proper response to change of situations is not described, especially at occurrence of obstacles. The given problem was examined by many researchers, and there exist various ways of its decision [1-3].

Planning of actions is the major function of the mobile robots independently working in dynamic and uncertain environments. Scripts [4] are effective model of knowledge representation in such systems. Scripts represent the generalized description of sequence of MR actions in some stereotyped situation, allowing to achieve a required target condition. Formation of a concrete plan of action is carried out by a choice of one of possible situations and its concrete definition with the account a priori unpredictable features of current conditions. At functioning in the uncertain environment, time restrictions on decision-making are a priori unknown; therefore the robot should possess ability to adapt time of decisions to dynamics of processes occurring in the environment. Known models of representation and recognition of situations do not support such opportunity.

Formal representation of actions plan

For representation of robot actions plan we shall use hierarchical frame structure of the following kind. At the top-level plan FPm 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 - a name of *m* plan; S_0 - the current condition of environment; Act_i - the frame of i action of the plan; S_i – the frame of environment condition after performance *of i* 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.

Let MR, moving in a priori unknown to it environment, to find out on the way an obstacle and as one of possible variants of actions to consider a detour of an obstacle on the right. In this case it is possible to allocate two stages of obstacle overcoming: turn to the right and alignment of movement. Accordingly plan of MR action «Obstacle overcoming» contains two frames of action with names "To the right" and "Directly" and three frames of condition: «Before an obstacle», "Alignment" and «Behind an obstacle». It is obvious, that success of realization of the given plan is defined by ability of the robot to make a detour of an obstacle and entrance on a target trajectory. The successful detour depends on MR maneuverability and speed. In its turn speed depends on capacity of engines and density of a ground in a detour place, i.e. is defined as internal robot opportunities (ability to provide required speed at turn), and external conditions (character of a ground on a trajectory).

Statement of decision-making task in real time on the basis of actions planning

Under generalized problem situation (GPS) we shall understand the generalized description of environment condition in which the robot is required to make some decision. GPS is identified by the name; for example, GPS «Obstacle overcoming» corresponds to an above-mentioned example.

Generally in some problem situation the robot has not unique variant of possible actions and, accordingly, a plan of action subject to the analysis. So for an above-mentioned example the robot can, along with the script «Detour on the right», to consider also the script «Detour on the left». Decision-making with use of actions planning in real time assumes definition of the most effective in the given situation way of actions for limited time. Thus the stock of time T_d for decision-making should be defined dynamically, proceeding from the analysis of the current situation.

Proceeding from the aforesaid, 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.

1. Definition of the general stock of time.

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. For example, in a situation with obstacle overcoming (the detour on the right), critical event for MR moving is presence of a wall or a hole to the right as an obstacle. The robot stops before the obstacle if movement is impossible owing to the appeared dynamic obstacle. 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 T_d is calculated dynamically on the basis of the current values of situation parameters.

2. Definition of a set of possible variants of actions.

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 $\{FP1, ..., FPq\}$. 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. For example, the detour of an obstacle at the left can be impossible because of a reservoir, taking place there, movement can be stopped owing to a steep slope of a line, etc.

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 $\{FP_1,...,FP_q\}$ the reduced set $\{FP_m\}$ of possible plans for the further analysis is formed.

3. Distribution of the general stock of time between tasks of action variants estimation.

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. For example, the concretization of the script «Detour of an obstacle» assumes scanning a surface of road for definition of roughnesses and density of a ground with the purpose of definition of an optimum trajectory of movement. It is obvious, that 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:

$$T_m^* = h_m(P_l ,..., P_k)$$

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 $\{FP_m\}$ on the basis of the current situation:

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

Then time allocated for concretization of *i* plan of action, will be determined as follows:

$$T_d^{(i)} = T_d * (T_i^* / T_\Sigma^*)$$

4. Concretization and estimation of actions planning efficiency.

Concretization of action plan Fp_i is reduced to a concretization of all of its steps - frames - actions. This task should be solved for limited time $T_d^{(i)}$ 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. However, not narrowing the generality of consideration it is possible to count, that these tasks are under construction as a task of undefined time [5].

Thus the set $\{v_i^k\} = \{(T_i^k, Q_i^k)\}$ variants of its decision distinguished by time T_i and quality Q_i of received result should be put in conformity to each single task of step concretization. Use of a variant of undefined time creates a basis for formation of task decision for allocated time due to reduction in quality of the decision.

For MR working in the uncertain environment, variants of individual concretization tasks decision distinguished by time and quality of the decision should be formed dynamically in view of the current parameters of external conditions and internal resources of the robot. With this purpose in everyone frame - action of the plan slot is added, containing function $u_S(P_l ,..., P_k)$, forming set $\{v_i^k\} = \{(T_i^k, Q_i^k)\}$ for a concrete situation (index k - number of variant of tasks decision). Function $u_S(P_l ,..., P_k)$ should have low computing complexity.

The received sets $\{v_i^k\}$ serve as the initial data for distribution of time $T_d^{(i)}$ allocated for concretization of the given plan of actions, between individual tasks of separate steps concretization.

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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