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# PATH PLANNING ALGORITHM OF A LOT OF MOBIL AUTONOMOUS OBJECTS IN UNKNOWN CONSTRAINED ENVIRONMENT

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Abstract: A problem of path planning providing for mobile objects group (train), which consists of a large number of autonomous objects, is considered. Trains of this type may be used to operate in construction plant, which often is uncertain environment with a number of obstacles. Possibility of iterative recursive algorithm application, which has been developed for path planning of multi-links manipulator, for solving this problem for mobile objects group are discussed. Results received under modeling of mobile objects group path planning in unknown environment, are presented.

Keywords: path planning, mobile objects group, iterative recursive algorithm, unknown constrained environment.

## INTRODUCTION

There are many cases when a vehicle or a train consisted $n$ wagons has been used in the construction plant for carriage of constructional materials, delivery heavy constructional elements and etc. Usually constructional plants are characterized with a number of obstacles, which may be static (constructional materials) and dynamic (constructional equipment) ones. Therefore task of path planning for the train with avoidance obstacles and train motion control is arose in construction.

There are numerous tasks in construction when the train of mobile objects must to wide through tunnel-labyrinth or objects group to a goal point. Potential application fields, which are characterized with the obstacle cluttered environment, including also civil engineering, tunneling and mining. The train of autonomous mobile robots may be used in dangerous conditions for men.

Several approaches have been developed in order to solve the planning and control problem. Most of the approaches for path planning of complex mobile objects use a complete word model (see [7] and references therein), a potential field method [4] and different variant of approximating [5-6].

The behavior-based approach to complex mobile object control of Connell [3] allows only behavior schemes which are quite simple. The multi-agent approach is based on reactive planning and control for manipulators [1]. The sensor-based approach of manipulator control described in [2] deduces a simple geometric representation of the sensed obstacles, the approach is not suitable for the complicated environments.

In summary, the known approaches introduced above are not suitable for the mobile autonomous objects applications in unknown and complex environments. This is mainly due to the fact, that problems of path planning for mobile autonomous objects are rather complex.

In this paper, we describe how the developed iterative recursive algorithm for path planning of multi-links manipulator may be used for the train of mobile autonomous objects operated in unreseach environment. The main idea of suggested iterative recursive algorithm is connected with iterative improvement of a certain aim function while approaching the aim. The aim function depends on a object position and previous iterations results.

This paper is organized as follows: In section 1 we describe some features of the iterative recursive algorithm. In section 2 we present applications and results of modeling path planning for train of mobile autonomous objects. In section 3 we consider planning and control system based on multi-agents. In last section we summarize and give our conclusion.

## 1 PATH PLANNING ALGORITHM

The path planning task for uncertain environment has been solved for multi-links manipulator on base of the iterative recursive algorithm [9]. Formally the train of mobile autonomous objects may be considered as some model of the multi-links manipulator, which have next features:

- the train works in 2D;
- a number of objects may be about ten;
- the train has a head and may be moved to any direction;
- the turn angle of train objects is limited.

The environment is considered as a two-dimensional space with Cartesian coordinates. The following objects are specified in environment:

- a tunnel. Tunnel walls position is unknown in the initial moment;
- a train, consisted of $n$ wagons, which are connected with each other by the links. Length of link and maximum link turn angle are known. The base position is known, too;
- goal point with known coordinates;
- precision of attaining a goal point is given as the maximum interval from the first wagon to a goal.

To formalize the task, the basic objects are to be specified. Mathematical models of the task will be described through the corresponding objects:

- Space. This object is the main one, in it all rest objects are situated;
- Point. It is an elementary object. It is necessary to define the rest objects.
- Line. It is an object based on two point. All rangers of complex objects in space are defined by lines.
- Wagon. It is a projection of object to the work area.
- Train. This object consists of a group of wagons connected with each other:
- Tunnel. It is a set of Lines which are tunnel walls.

We define some global notation in the two-dimensional Space (the plane), which is a standard Cartesian notation with the beginning in the point with coordinates (0, 0). The simplest object Point has two coordinates in space (x, y). The object Line is an interval between two points P1 and P2.

The object Tunnel is an array of objects Line. A number of objects can't exceed the array dimensionality definition constant. Tunnel Lines can be situated arbitrarily in space even intersect.

The object Wagon consists of four skeleton Lines L1-L4 and two auxiliary ones L5, L6. The skeleton Lines denote a geometric position of a wagon in the Space. Line L5 is the central line of the

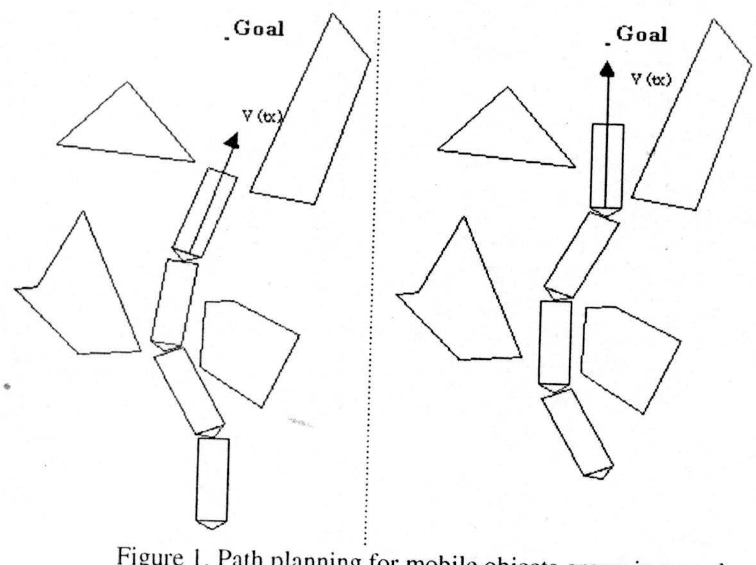


Figure 1. Path planning for mobile objects group in complex environment

*It is necessary to find the path planning algorithm for given mobile object allowing to get motion vectors of the first wagon v(t) so, that the first wagon would approached to goal on a distance, less or equal to the given precision.*

Wagon. The angle between two near-by wagons is a proper angle of the Wagon. The angle defines as the angle between their central lines. The angle is positive when it is measured clockwise. It is negative when it is measured anti-clockwise. Line L6 is the goal line of the Wagon. The motion vector v(t) of the first wagon is situated at this line. It is defined as a Line, which initial Point coincides with the end Point of central Line L5. The end point coincides with the goal Point. The object Train is the array of Wagons. A number of wagons doesn't exceed the array dimension. A current number of Train Wagons may be varied. Change of the first wagon motion vector changes the direction of the Train motion.

In view of the definitions above the task is formalized as follows: suppose, the objects Space and Tunnel, Train, goal Point and the goal approaching precision are given. It is need to design an algorithm to find a motion vectors array of the first Wagon of the Train, so that the length of the goal line L6 for the last calculated Wagon would be less or equal to the given precision. Lines L1-L4 for all calculated Train Wagons shouldn't cross Tunnel Lines.

The suggested algorithm has a recursive procedure of exhaustive search of objects positions variant from first to the final object with sift inadmissible variants. The main idea of the suggested algorithm is connected with iterative improvement of a certain goal function, while approaching the goal. The goal function depends on a link position, goal interval and previous iterations results. Information of tactile sensors , which are in front of the first wagon or distance sensors information, will be used for obstacle avoidance with objects in the work environment.. The algorithm provides a good adaptivity in conditions:

- near objects location;
- the goal point in high complex environment;
- low flexibility of train.

The path planning strategy supposes to use either recursivity for each wagon position store, with all recursive link motion, or a time-iterative cycle with motion direction choosing in each moment corresponding to rules.

The designing of this algorithm isn't a simple problem because of:

- a large number of interacting objects;
- particularities of the control object ;
- movement control is realized by the first wagon movement direction change, e.g. the rest of the wagons can't choose own path;
- complexity of building the goal function.

A fuzzily-determined goal function has been used for this algorithm to minimize the mathematical calculations in the main cycle. The goal function is defined through a penalty value, which is changed for each wagon and transmitted from previous wagon to next ones. Rules of changing the penalty value are the intellectual part of the algorithm.

The suggested algorithm may be use at local levels of the multi-agent control system for the group of mobile objects. This algorithm allows to solve a problem of path planning for a dynamic system, a train above-mentioned, which consists of $n$ wagons, in highly constrained environment.

A modeling system based on the suggested planning algorithm is realized. It may be used for object modeling, visualizing, demonstrating and work testing.

## 2 APPLICATION AND MODELING RESULTS

Suggested algorithm was realized with using object-orient programming principals with post-graduated students Nikiforov D.V., Shakhmametova G.R participation. The algorithm is intended for motion simulation for the wagons group.

The path is calculated without using precise mathematical methods. The main advantages of the algorithm are:

- adaptability. Data about the train and tunnel are easily changed by objects parameters.
- flexibility and simplicity. The algorithm finds the path without using complex equations systems.
- working "blindly". The algorithm structure supposes working in information deficiency conditions, when the location of tunnel walls is unknown.

The area of subject is defined as a set of data about the train, the tunnel under investigation and the goal point in the environment. The tunnel configuration is unknown beforehand. All data about it are a result of sensors analyzing . Data about the goal are Cartesian coordinates of the point, defined in global notation of environment. Data about the train include geometric sizes, a number of wagons, the maximum deviation angle.

The computer program has been developed in the language Pascal with using object programming principles for IBM PC. The computer program, based on the suggested planning algorithm also realizes functions of object modeling, visualizing, demonstrating and work testing (see Figure 2). Mathematical models are described by Pascal objects, which visualizing methods are added in accordance with the interface requirements.

The path planning algorithm for connected group of the mobile objects has been tested by the special method. The method includes the next features:

- the set of the work environment variants were created for testing. The variants are characterized with the different location of the obstacles;
- the set of goal points derivated by grid points are selected for each variant of the work environment. The distance between lines of the grid is equal to required precision of goal point attaining;
- for each goal point it is tried to find the path for mobile objects group with given parameters by using of the researched algorithm;

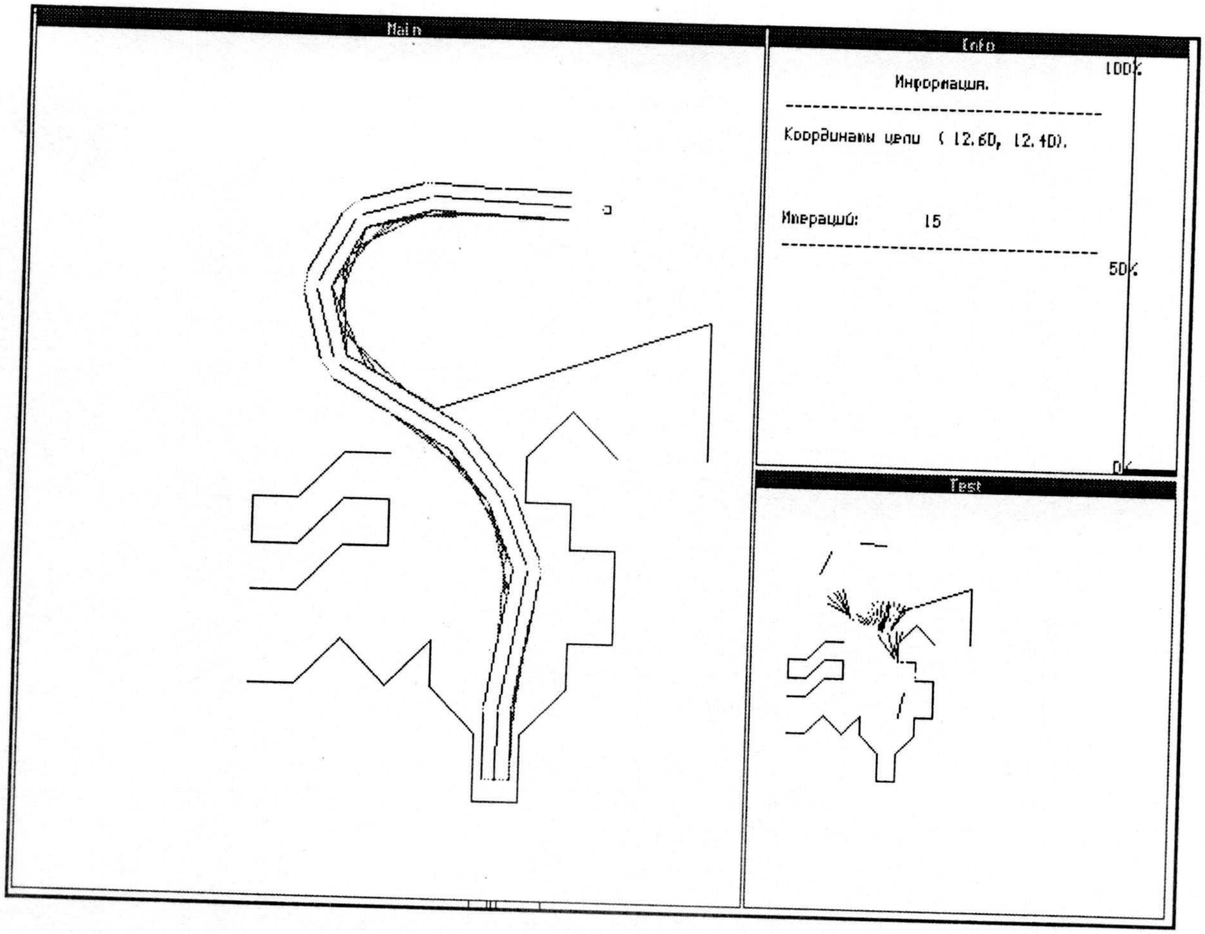


Figure 2. Program interface

- the results of path planning are fixed for the each goal point;
- the obtained results are used for calculation of different quantitative characteristics.

Six variants of work environments for testing with various features of structure were designed. On this base the efficiency characteristics estimation was executed.

Testing of the algorithm for different variants of work environment showed achievement from 80 to 100 % of points. The average time of result obtaining is from 0.01 to 11 sec. The objects average quantity if from 10 to 23. The maximum number of objects is 39.

The research results confirm possibility of suggested algorithm using for quick path planning for a lot of mobil autonomous objects in unknown constrained environment.

## 3 PLANNING AND CONTROL SYSTEM BASED ON MULTI-AGENTS

Solution of the planning and control problem consists a multi-agent approach. The planning and control architecture are organized hierarchically, consisting of a local level where the reactions are calculated and complex planning level to optimize the overall behavior of the system. The agents are located at the local level (see figure 3).

The superior optimization level communicates with the agents and gives them directives. The agents provide their actual state at this level. As the optimization algorithms are much slower than the reactive ones, the agent corrects their goals whenever information from this level is available. In the meantime, the agents continue autonomously with their calculations.

## CONCLUSION

As a result of our analyzing of the problem of path planning for the train with a large number of wagons:

- the main objects of the task have been defined, and their mathematical models have been described;
- an algorithm for quick path planning for a two-dimensional redundant manipulator in obstacle cluttered has been developed and realized in the modeling system for IBM PC;
- the results of modeling show that the algorithm may be used for control of this type objects in real time;

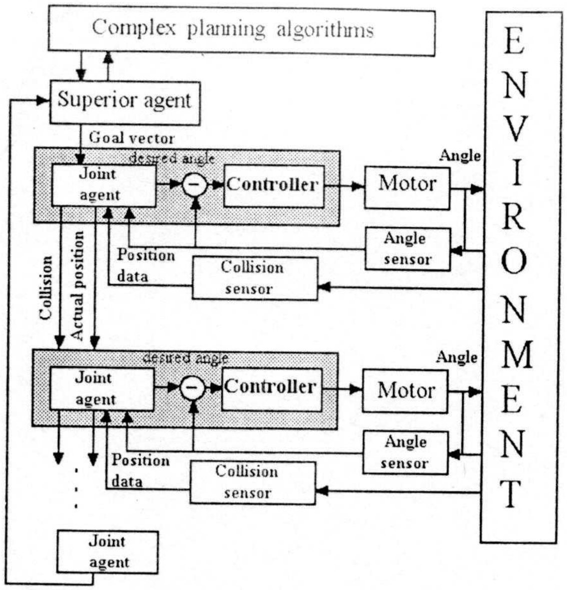


Figure 3. Architecture of the planning and control system

- suggested planning local algorithm for dynamic systems may be used on local levels of multi-agent control system.

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