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THE POTENTIAL FIELDS APPLICATION FOR MOBILE ROBOTS PATH PLANNING

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ABSTRACT
This paper presents some of methods of mobile robots' navigation in an indoor environment (laboratories, corridors of buildings) and it explains in more detail solution of global navigation through the potential fields. This method is suitable for solving many of the problems, in the first place from technical praxis, but also from another fields (physics, mathematics, geology etc.). In the past, it was just the application of potential fields that was shown as the appropriate method to find potential solutions for mobile robots' navigation. These potential fields navigate the mobile robot safely along the trajectory between obstacles to goal position.
Keywords: mobile robot, potential fields, mobile robots' navigation, simulation software

1. INTRODUCTION

Nowadays there is a massive progress in mobile robotics. Specialists at many of universities and research institutes deal with research and development in this field [8]. One of these places is also The Department of Machining and Automation at Faculty of Mechanical Engineering at University of Žilina. In last few years there was designed some construction concepts of flywheels mobile robots, concretely on three, and four-wheel base [6, 7]. There was also designed the first version of simulation program, which is using for verification of possibilities to mobile robots navigation and control [5]. Choice of navigation method in mobile robots environment is one of the fundamental problems, which is solving by the design process of all autonomous mobile robots (AMR). This method also will be described in this paper.

2. NAVIGATION OF MOBILE ROBOTS`

How it was written, the planning and the realization of movement within the operation (action) space is the most important task of AMR. Approach of movement is dependent on required level of mobile robots autonomy, on kind of fulfilled tasks and on character and level of environments cognition. For the classical task "Safety browsing of environment" (applicable for unknown environment) is used the local navigation whilst for the task "Coordinated movement between two points of environment" (applicable for known environment) is used the global navigation. For complex solution of mobile robots movements control is therefore using both navigation methods. In literature it is possible to occur with the difference interpretation of terms "local navigation" and "global navigation". Under these terms we will be mean following:

Local navigation (reaction navigation) – It is based on execution of elementary steps, which provide a collision-free robots path within the environment. The movement is executed without considering to global goal point. For the local navigation are using data from different kind of sensors (optical, ultrasonic), most frequently in the form of the information about obstacles presence or absence in assumed course. The avoidance of obstacles is the typical example of local navigation. The control system is in this case focused only to solving of current situation in local environment.

Global navigation – It is the control of mobile robots movement between entered global "Start" and "Goal" position. In compare with the local navigation, by the global navigation is the importance of goal position markedly greater. The basic task in this case is the determination of global path. This kind of navigation we can call "The planning". There are same degrees of planning: from simple generators of trajectory, to the optimizing modules, which search the optimal path in the view to length of trajectory, time or the value of acceleration.

Category of global navigation:

a) *Tactic level* – solving of simple task of robots movement from one start to one goal position.
b) *Strategic level* – robot navigation between many reference points. For example one task: Robot is moving from room A to room B, where is it grasping the object O_i, and then is moving to room C. The tasks are formulated more freely in this case.

3. APPLICATION OF POTENTIAL FIELDS FOR MOBILE ROBOTS PATH PLANNING

Tactic level of mobile robots global navigation (the path planning) is often solving with method of potential fields, which is based on principle of collaboration called attractive and repulsive fields (or forces). Generally, the metric map (usually 2D- or 3D-raster representation or quadtree representation) is useful for generating these fields. Specific selection is dependent on the size of map, character of obstacles, etc. [3, 4, 5].

3.1. General way to generate of potential fields

General method is described in many of sources (for example [1, 3, 4, 5]) and it is dependent on our choice between continuous and discreet forms of potential fields.

By the generating of continuously potential field we are generally proceeding follows: For described space, "a scalar function called the potential is constructed that has a minimum, when the robot is at the goal point, whilst a high value on obstacles. Everywhere else, the function is sloping down toward the goal, so that the robot can reach the goal point from any other point following the negative gradient of the potential. The high value of potential prevents the robot from running into obstacles." [3]. Therefore is AMR moving as a ball, which is rolling downward in the conic surface – robot is leading to one point (goal position).

It is more practically, the process of potential fields' generating, divide to three basic steps, for its simplification and for easy modification of goal point (Fig. 1):

- Generating of „Obstacles' Potential field",
- Generating of „Goal potential field",
- Generating of „Final potential field".

By the development of simulation software on our department [5], we were concentrated on metric forms of environment representation, concretely on 2D-raster maps (grid representations). The discreet kind of potential fields is most frequently used for the application on raster kind of environments representation. Then, on this kind, we are also focused in our paper. Principle of generation is the same in both cases.

Potential field of obstacles (Obstacles potential field) - (Fig. 1a and Fig. 2a)

The first type of potential field is created by the sequential generating of particular waves about all of obstacles which are situated within the space. In the neighbourhood of obstacles' boundaries, the first wave (or waves) of field is generating. Consequential are constructed the next waves about all of the previous (they envelopes the previous), until all free-space is filled with waves. So we get to an array of values (note in suitable form – most frequently the matrix), which are represented the distance between the watched point and the nearest obstacle, or obstacles. The same scalar value of potential is associated to all cells belong the same wave of potential field so that the first wave have the maximal value and the each next wave have about a step lower. Contrary, the minimal value of potential have the cells, which are represented the obstacles. Following these values, robot can stay out of the obstacles - in safely area. It is sufficient watch the neighbourhoods' cells for robots navigation. Robots behaviour is like as the behaviour of two magnets, which are turned with like poles to one another.

Goal potential field - (Fig. 1b and Fig. 2b)
The second type of potential field is constructed by generation particular waves about entered goal point placed in the action space. The first wave is generated in the neighbourhood of goal point. Consequential are constructed the next waves about all of the previous so that they envelopes the previous, until all free-space is filled with waves. So we get to an array of values, which are represented the distance between the watched point and the goal point. In this case, like in the first case, is associated the same scalar value of potential for all cells included in one wave. Contrary to first type of potential filed is in this case for first wave associated the minimal value and for each next the value is incrementing about one step. To cell, where is placed the goal point, is associated globally minimal value. Following these values of potential is AMR navigated (goal point is "attract" for robot) to goal point by the shortest trajectory.
The collision-free path planning (global navigation) of AMR in action space is then founded on ***Final potential field***, which is constructed by using proper combination of both fields (Fig. 1).

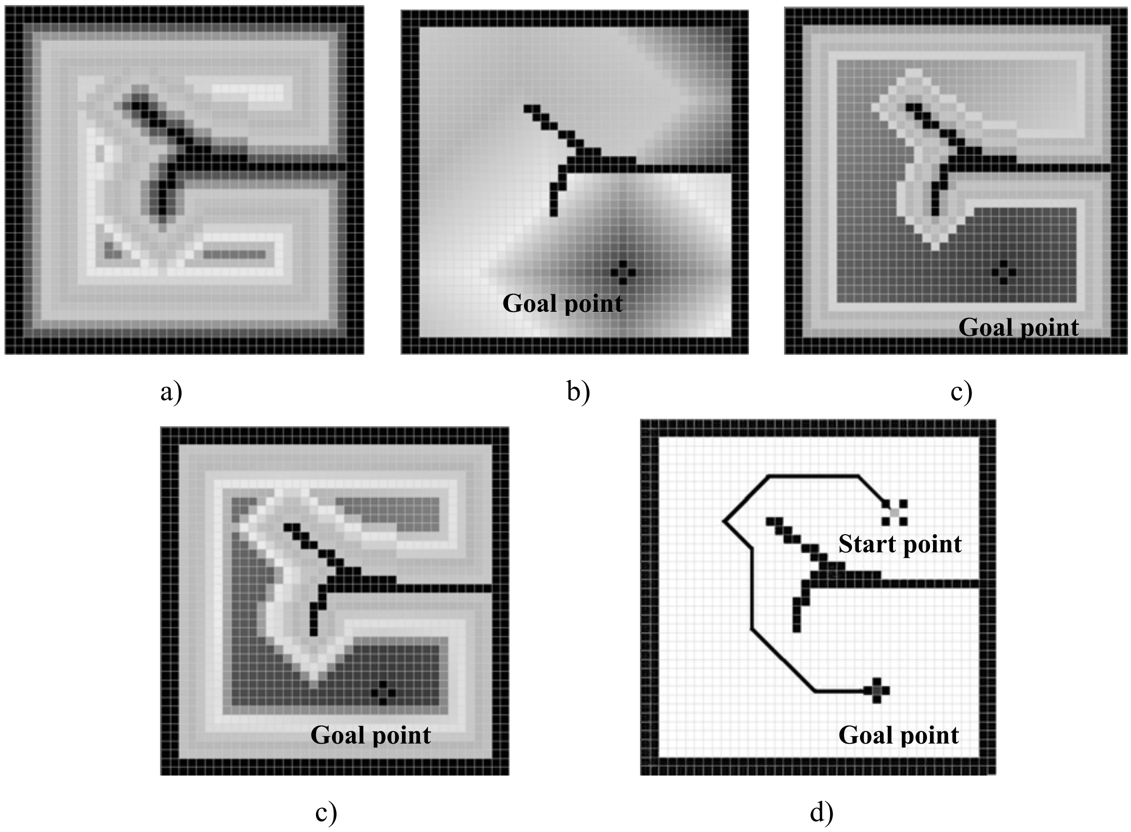


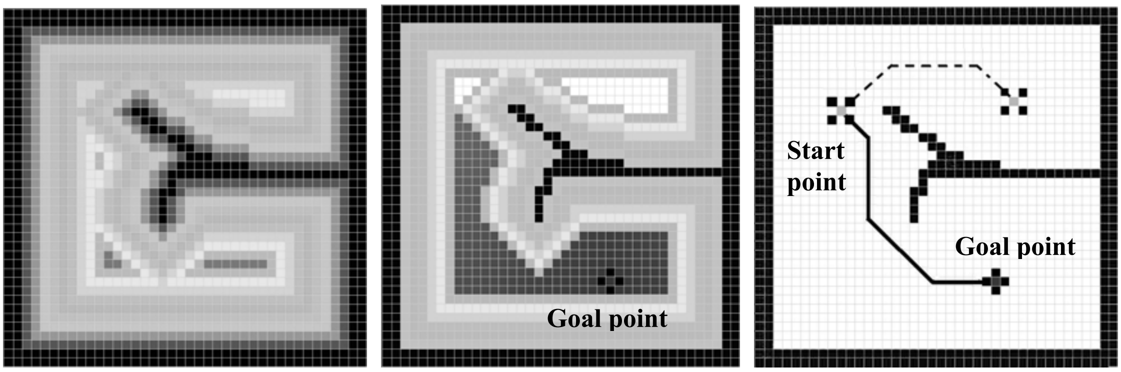
Figure 1. Classical process of Final potential fields generating:
a) Obstacles potential field, b) Goal potential field, c) correct Final potential field, d) incorrect Final potential field – partition of action space(robot can't reach goal point) e) planned path

3.2. Analysis of collisions by potential fields constructing

Problems starting up in case that the scene contains many obstacles and the Final potential field is generating by direct combination of information extracted from both potential fields. In this case both of "attractive" and "repulsive force" can work against each other. Then AMR is deadlocking in a part of action space, and it can't reach the goal point (the problem of "paths bottle-neck"). The second collision situation is created, when AMR is navigated by Goal potential field along the boundary line of two waves in Obstacles potential field. Two or many neighbourhoods cells have the same value, and the trajectory planning is aborted. The separation of process of potential fields' generation into two steps (instead of three steps) both situations can solve:

- At first it is generated the obstacles potential field (process is described on top).
- At the second hand, on the basis of data extracted from obstacles potential field, it is generated the goal and final potential field (both in the same time).

After this modification, it is possible in case of the scene with many obstacles to start up of interaction of waves and then it can create the discontinuity of field [3, 5]. This discontinuity (inhomogeneity) showed the trafficability of action space by certain settings (robots dimensions, radius of curve, etc.) and same places, which aren't available (Fig. 2 – white areas).



a) b) c)

Figure 2. The collisions' solving by the modification of Final potential field generation process a) Obstacles potential field, b) Goal (and also Final) potential field, c) planned path

4. CONCLUSIONS

Potential fields can relatively easy and reliably used for the tasks of mobile robots' global navigation – navigation in known environment. The problems can start by the certain configurations of obstacles and certain strategy of generation the final potential field, when the field includes more local minimums. In this case robot can deadlock in one of them – out of the goal point [4, 5]. One of possible solutions is described in our paper. It is founded on the difference of potential fields' generation process. The other possible solutions are the recording of done trajectory and the reduction of safety distance from obstacles. In simulation software, which is developed on our department, we deal with testing both of these methods. We were come to conclusion that the method based on change of fields' generating process is more effectively. The disability of this method is that the cutting of action space (areas, which aren't available) is enabled. The other methods we can use as the auxiliary data or objects for testing. The combination of more methods is shown as the best way to solving of mobile robots' global navigation.

5. ACKNOWLEDGEMENT

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