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Avoidance of Possible Collisions of Mobile Robots

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Introduction

When one robot is on the run in the known environment, there is possibility of conflicts with static obstacles (columns, walls, screens), i.e. with objects, which do not change its position. Those conflicts are solve the most effectively when using vector marks [1] and identifying the possible shortest motional trajectories evaluating overall dimensions of the robot [4]. The tree of vector marks formed using the algorithm of vector marks forming, according to which the coordinates of motion to goal is determined for the robot [3]. The goal of using these methods is to seek the get of shortest and fastest way

When many mobile robots are moving in the same environment, possible dynamic obstacles appears and the risk of its conflicts is more probable when the overall dimensions of mobile robots are bigger and when there are more of those robots. It is necessary to predict collision in advance and confine the provided rules to choose the suitable solutions on purpose to avoid them [2]. It is possible to take a bypass or to pass the arisen obstacle, to slow down or stop according to accredited rules, but in such way, the task completion time extends. The possible collision of few robots at the same time requires even more rules that are complex. The probabilities of collisions are supposed to be forecasted, what can be effectively realized by modeling the motional trajectories. The most effective way is to do it with robot navigation equipment, created in color Petri networks program base, operating as ISS (intellectual supervisor system), executing all the calculations in virtual time, solving the conflict situations and able to forecast possible collisions (conflicts).

The robot navigation successfully realized using color Petri networks base programming packet Centaurus CPN by the shortest way searching method, given various complexity static obstacles, long and narrow hallways, narrow holes and changeable overall dimensions of robot with transportable object [5]. The search of shortest way performed by ISS, which manages the robots; the vector marks trees in advance generated for known environment are used as database. The vector marks trees contain information about possible movement directions towards the goal in shortest way. Knowing the original coordinates, overall dimensions and the goal coordinates of robot, ISS forms the guidelines, according to which the robot will seek the goal in shortest way. The deviation from movement route, formed by ISS, in any place of the route, does not guarantee that the robot will not interfere with static obstacle on his way.

In order to avoid such situation, when the robot has started to realize his ISS formed movement route, the ISS is keeping in bidirectional link with robot in real time in order to correct and accompany the robot to the goal destination in case if robot would deviate from his way for various accidental reasons. If the robot does not transport anything, or the transportable object does not change the setting configuration, which taken by robot with his object, the bypass of static obstacles may be performed according to local navigation principles, when it is done by itself robot management system, using the available sensors for distance until the obstacle determination. When the profile of obstacle successfully passed, the further robot movement is controlled by ISS. If robot profile overall dimension are bigger, his local navigation system is not able anymore to take a bypass of static obstacle successfully without readjustment. In this case, ISS forms route parameters so, that the obstacles passed by in safe distance and the robot does not use local navigation equipment. In such a way, herein described robot navigation problems are solved [5].

Very different problems arise if there is more than one robot in the territory, and it predicted that there would be so many robots, as the manufacturing process system requires for ensuring manufacturing process without derangement. The question arises, according what principles and rules to organize robot navigation in order to avoid collisions. Only the one problem is clear, that for successful functioning of such system it is necessary to forecast possible collisions and to organize management so, that it would be possible to avoid it.

It is remarkable, that such system already exists; it is already available car traffic with strict rules. The difference is that roads and traffic trail regulate car traffic. It is not purposeful to organize in such way in flexible manufacturing system because the mobile robot navigation doctrine would be denied.

It is possible to apply the standard car traffic rule for mobile robots in the equivalent crossroads „priority from right side“. In addition, it needed to evaluate additional qualification: forthcoming robot speed, oncoming angle and task execution priority. For this reason, the car traffic rules cannot be applied to robot navigation without changes.

Solutions of conflict situations

There are formed 20 possible rules in the table 1, which are used by robot in real time when calculating route to the goal when moving in the rooms, where other robots move without rules. The distance in the table is determined by four values (LA) very close, (A) close, (T) far and (LT) very far, the direction is determined by five values – (K) in the left, (TK) directly more left, (T) directly, (TD) directly more right and (D) right.

Table 1. 20 possible rules for collision detection

		Direction				
		K	TK	T	TD	D
Distance	LA	T	TD	TK	TK	T
	A	TK	T	TK	T	TD
	T	TK	T	TK	T	TD
	LT	T	T	TK	T	T

Dependently on other robots movement conditions, there are formed following solutions in the table [4]:

1. If the obstacle is in left (K), movement directly;
2. If the obstacle is in front more left (TK), movement directly more right (TD);
3. If the obstacle is in front (T), movement directly more right (TD);
4. If the obstacle is in front more right (TD), movement directly more left (TK);
5. If the obstacle is in right (D), movement directly (T).

There arises the other problem, how to determine the priority of robot, because it has to be compared with the obstacle's priority what means that all robots will have to keep in touch with all other robots in real time, to keep in touch with ISS and to solve the local navigation system. The question arises, it is not worth to give out solving of dynamic conflicts to ISS, which already follows all robots, and would have additionally to forecast possible conflict situations, would take needed decisions and would adjust robot routes. Mobile robots would not receive any additional tasks except manufacturing process service and local navigation problems solving. After detailed analysis of this task, it has chosen two possible solutions for analyzed problem, which allow successful implementation of task, ensuring successful mobile robots navigation in the environment with static and dynamic obstacles:

a) avoiding conflicts by bypass,
b) by stopping or slowing down the speed.

Conflict situations forecasting

For the conflict situations, forecasting ISS is optional, which controls and adjusts movement of all mobile robots and keeps in touch with manufacturing process dispatcher. The manufacturing process dispatcher, as a rule, is DNC system, which ensures CADCAM process. It well organized by technical means and managing programs steady or constantly improving system, so any invasion to such a well functioning system is unwanted. ISS managing mobile robots navigation would receive information from DNC system about what and from which coordinates needs to transport to another position. ISS at the moment free mobile robots choose the one, which is at the nearest distance down the point from which the product needs to take. In such way, it is evident that the task will be executed in the fastest way.

Following discussed mobile robots navigation problems are already implemented [5] in ISS.

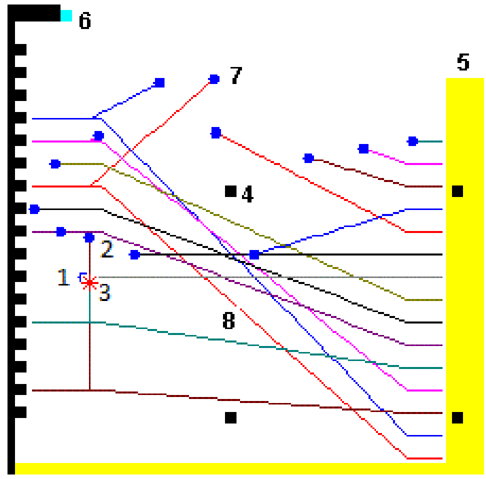

Fig. 1. A fragment of production system with seventeen mobile transportation robots, tasks received from the ISS to carry out shows and track their movement trace. Asterisk shows the two robots (3 and 1) collision.: 4 – static object (a column), 5 – static object (zone forbidden for robots), 6 – static object (production center), 7 – dynamic object (mobile robot), 8 – trace of a mobile robot

ISS mobile robots navigation problems solves in virtual modeling time, i.e. the time needed for this problem solving is incomparably shorter in comparison with mobile robot real navigation.

In justice to contemporary computer system possibilities, all particular robot navigation problems may be solved just after the robot starts to move through forecasted route. So ISS may be used for conflict situations solving, i.e. for possible collisions forecast. Fig.1. shows possible collision of two robots, if no any remedies are taken. If ISS is realized with CENTAURUS colored Petri nets program packet and allow to enter possibility to come back few seconds till the collision in virtual time, as shown in Fig. 2. In addition, adjust movement trajectories that would allow avoiding collision, and executing mobile robots navigation further in virtual time until the next forecasted collision, which would be adjusted in parallel.

The most important question is how to solve this problem, that the route, formed for mobile robot, would be successfully realized in solving possible conflict situations.

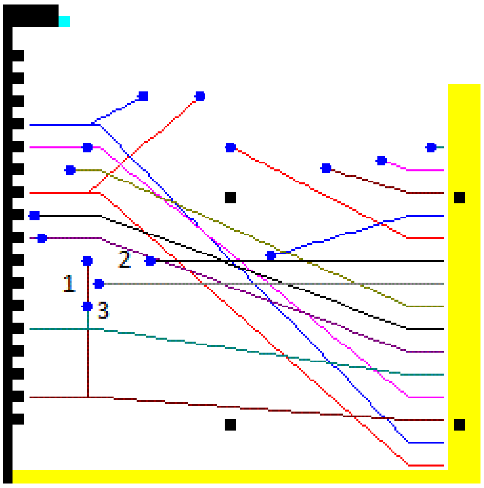

Fig. 2. The situation in a few seconds what in Fig. 1., where 1 and 3 shows a mobile robot collision

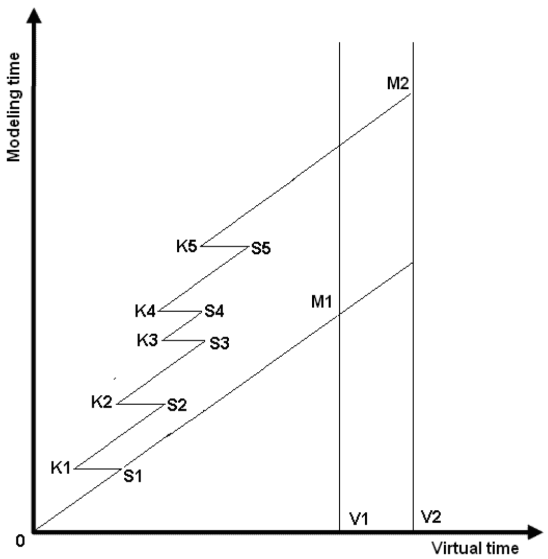

Fig. 3. Mobile robot tracks the formation of predicting possible collisions with other mobile robots

The time additionally spent for ISS functioning and conflict solving is show in Fig.3. If the robot does not have conflict situations, its route implementation in modeling time is M1, what corresponds to virtual time V1. If there are conflicts, as shown in Fig. 3., S1 – S5, and this is ISS collision forecast, according to accredited strategy we move back for few seconds in virtual time (points K1 – K5), perform the adjustment of movement route and again move towards destination point. Analyzing common case, it is possible to state that the movement route may lengthen (everything depends on chosen conflict solving strategy), but the virtual time spent will always be longer. Fig. 3. it corresponds to virtual time V2, as the outcome of this the modeling time pause lengthens until managing information is given to mobile robot. There are possible two variants: managing information is given outright, when the conflict situations are not solved yet, and it is updated on every moment when the route change is made. Other variant – mobile robot is standing and waiting until the movement route fully formed. For this a very powerful ISS needed, that the time spent for route estimating would be very trivial because otherwise ISS mobile robots relations are violated

It is not so important which robot should have the priority assigned when evaluating conflicts solving conditions because it should be determined by DNC system, and ISS should implement that. Only in case when the ISS system itself is left to decide this, the most effective algorithms should be used that as less time as possible would be spent for conflicts solving.

Two ways for conflict solving may be used the most effectively, when the conflict is forecasted:

1. One of mobile robots changes the trajectory, according to particular rules, not slowing down the speed,
2. One of mobile robots stops or slows down the movement speed not changing the movement trajectory.

Avoiding conflict by bypass

The situation when the conflict is avoided by passing obstacle from right side showed in Fig. 4., where at the beginning when the robot 3 is avoiding collision with robot 1, the route change is performed according discussed algorithm, and later the same is performed when avoiding collision with robot 2.

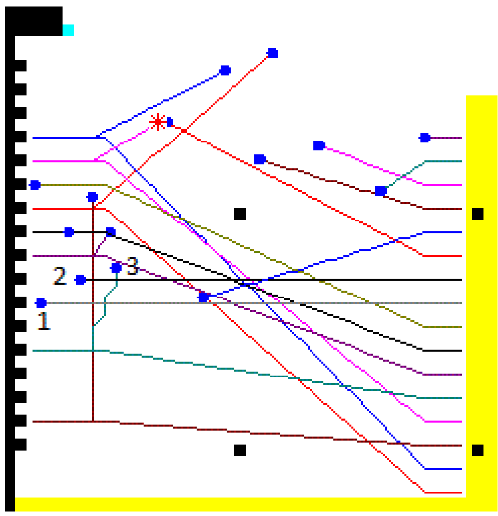

Fig. 4. The situation when the robot 3 to avoid a collision with robot 1 then the robot 2

Avoiding conflict by stopping or slowing down the speed

When slowing down or stopping Fig. 5, the movement trajectory is not changed and only the task executing time, where the additional time is spent for deceleration, movement in minimal speed or standing, and afterwards because of acceleration till the initial speed is achieved.

When robot slows down the speed or stops, the possibility of collision cannot ignore because it can come to other robot movement trajectory.

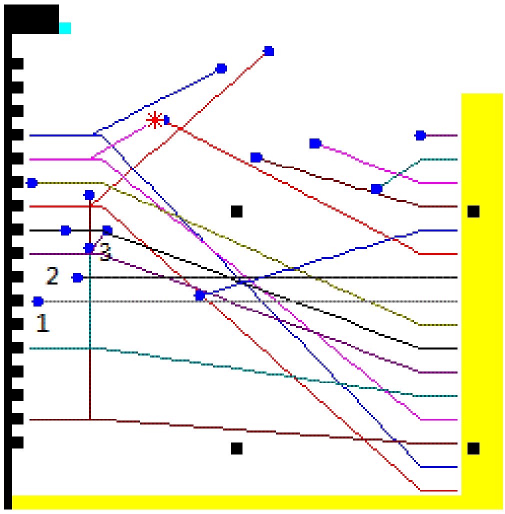

Fig. 5. The situation when the robot stops before 3 predicted collisions and to avoid a collision with robot 1

When comparing one and the other conflict avoiding ways, we can state, that slowing down should be more effective because from Fig.4. and Fig. 5. we can see, that in the second case the third robot appears closer destination goal. If there is no deviation from initially formed route, there is no need any more for solving additional problems about possible conflicts with static objects.

Conclusions

The internecine conflicts can solved by creating set of universal robot movement rules. The choice of correct avoidance format gives the shortest possible task execution time. The correction performed in virtual time simplifies problem solving. The conflict situation can avoid of two means: passing the trace or slowing in short time movement speed.

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Known environment is moving more than one mobile robot to a certain point in time to confront the inevitable conflict between robots and the more robots in one room collisions increases. Possible solution to the conflict – preconflict rules, movement correction, introduction. Correction carried out in a virtual time, so all the movement trajectory of the robot, taking into account all possible collisions, are counted against before transfer of the movement paths to the robots. Ill. 5, bibl. 5, tabl. 1 (in English; abstracts in English and Lithuanian).

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Pažįstamoje aplinkoje judant daugiau nei vienam mobiliajam robotui, tam tikru laiko momentu neišvengiama robotų susidūrimų, ir kuo daugiau robotų yra vienoje patalpoje, tuo daugiau įvyksta susidūrimų. Galimas konfliktų sprendimo būdas – sukurti taisykles, kurios leistų išvengti konfliktų, ir koreguoti judėjimą. Korekcija atliekama virtualiu laiku, todėl visos robotų judėjimo trajektorijos, įvertinant visus galimus susidūrimus, apskaičiuojamos prieš perduodant judėjimo trajektorijas robotams. Il. 5, bibl. 5, lent. 1 (anglų kalba; santraukos anglų ir lietuvių k.).