AN ALGORITHM FOR COLLISION AVOIDANCE FOR ROBOTS WITH WORKING SPACE

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Abstract: In this paper an algorithm is presented which serves for collision avoidance between robots with working space. The method is based on the concept of a hierarchical coordinator and permits an on-line application. Computing possible collision points a collision-free trajectory for the robot with no right-of-way precedence is generated. The computations are based on the states of the robots concerned including their practicable accelerations and velocities.

INTRODUCTION

In the paper of the subject of collision avoidance of robots simple realization can be distinguished from complex theoretical approaches. The simple realizations are charaterized by the fact that by entrance of one robot arm the common working space is completely blocked for the other arm in order to avoid collision. These implementations work in practical applications but lack in flexibility,of course, as they are designed for a specific working sequence and therefore not suitable for a broader range of applications. The more complex theoretical approaches are based on time consuming optimization and search methods for planning collision free paths. But owing to the amount of time required for computation these iterative optimization methods in their present form are limited in practical use for automatic on-line collision avoidance in industrial applications. In /1/the collision avoidance is based on various hierarchical strateqies in connection with extremly time efficient evaluation of decision tables. This method allows a simultaneous movement of robots through the collision space and is based on a suitable description of the actual possible collision space. This approach is very effective for two robots however it is quite complicate to handle for for the design of collision avoidance in multi-robot system with three or more robots.A new approach for the solution of the collision avoidance problem is presented in this paper. The collision avoidance strategy applies an analytically described avoidance trajectory which serves for collision avoidance/1/. The strategy is guided by state-feedback to prevent collision between the robots even in case of failure of certain basic control circuits. For the derivation of the collision avoidance trajectory,the structure of the hierarchical overall system is considered first.

ALGORITHM TO THE COLLISION AVOIDANCE

The derivation of the collision avoidance trajectory is shown in the following in general form for two robots j and k out of a system of r robots. These restriction to two robots is chosen for reasons of clearness,the procedure is in principle the same for the other robots involved. Figure 1 shows the arrangement of the robots considered with the common collision space. It is assumed that the main axes of the robots have a cylindrical configuration of the joints. That means,that the robot has a translational joint and a rotational joint in the x-y plane of the world coordinates system. Together with another translational movement. The cylindrical coordinates system is chosen as basic coordinates system for the level of collision avoidance as well, because most robot coordinates can be easily transformed into this system. This allows a general applicability without changes of the algorithms for different types of robots. In figure 1 the robots have cylindrical coordinates, so that no transformations are required in the case considered here.

Inthe configuration in fig.1 the right of way precedence is given to robot k. This means that robot k can follow its desired path described by equations, while robot j has to avoid a collision. The starting point for the derivation of the collision avoidance trajectories is the description of a fictitious permanent collision robot. Relating the position of this fictitious robot to the estimated position of the robot, which has to avoid a collision, two parmanents p and q can be introduced. These so-called collision parameters are the basis for the calculation of the collision avoidance trajectories, where the parameter p is related to translational movement and the parameter q to the rotational movement of the arms. Studies have shown, that in most practical cases the vertical movement is restricted e.q. by conveyor belts, assembly stands etc. It is therefore not meaningful to use the vertical movement for collision avoidance, however it can be treated by the same approach without principle difficulties. For the derivation of the collision avoidance trajectory the configuration of the two robots in fig. 2 is used where the length is the shortest distance between the origins of the robots, which together with the angles denote the relative positions of the robots. To detect now a danger of a collision, the motions of the robot with right of way precedence have to be brought im 4 lation to the other robot. This is done in the approach considered here by describing a fictitious robot. The handpoint of this fictitious robot is permanently colliding with the handpoint of the robot with right of way precedence, as it is shown in fig.2 semidotted lines. Fig.3 shows an implicit description of the collision avoidance trajectory which determinates the allowed range of movement for the robot j in order to avoid a collision. This trajectory depends on the actual movement of the robots and is therefore permanently calculated. If the arm of the robot j does cross this trajectory a collision is detected. On the other hand, this trajectory serves for collision avoidance as well because in case of danger of collision it is obvious to replace the external input of the robot j by the trajectory to assure a safe passing.

SIMULATION OF COLLISION AVOIDANCE

In order to prove the efficiency of the method of automatic on-line collision avoidance as described in the foregoing paragraphs, simulations were made using the digital block oriented simulation language/2/. These simulations are based on the configuration of two robots in fig.4, that shows the arrangement of the robots and the collision space in principle.

Fig.4(a) and 4(b) show the trajectories of the two robots if no collision avoidance strategy is provided. Robot 1 collides with robot 2 after 0.952 time units.

Applying now the described collision avoidance strategies for the robots, where the approach for robot 3 is extended in order to avoid a collision with two robots at the same time, the resulting collision free trajjectories provided by on-line path correction are given in fig.4(c) and 4(d). Robot 1 and 2 cannot pursue their original proposed paths but reach the target points. The deviations from the original paths can be extended by the safety factors but are of mainly a function of the position and the speeds of the robots.

CONCLUSIONS

A new approach for the solution of the collision avoidance problem is presented in the paper. Based on the description of a fictitious permanent collision robot, the collision avoidance trajectory which serves for collision avoidance. The strategy is guided by state feedback to prevent collision even in case of failure of the basic control of the robot with right of way precedence. Simulations of a system of robots as well as an estimation of the required amount of computational time show that the approach is well suited for on-line collision avoidance. The method itself is of a general form and holds for a larger number of robots involved.

In the present treatment of the problem of collision avoidance,a distinction is made between methods for collision avoidance for robots.Considering an obstacle as a special type of a robot,the described collision avoidance strategy for robots can be applied without changing the algorithm. Therefore,this approach can be used for the solution of the collision avoidance problem between mobile robots and obstacle as well as between robots and moving obstacles,too.

"Die Eule der Minerva fliegt erst bei Nacht".

REFERENCES

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/2/ Mehner,F. Users Manual SIMAIT. FernUniversität Hagen,1984

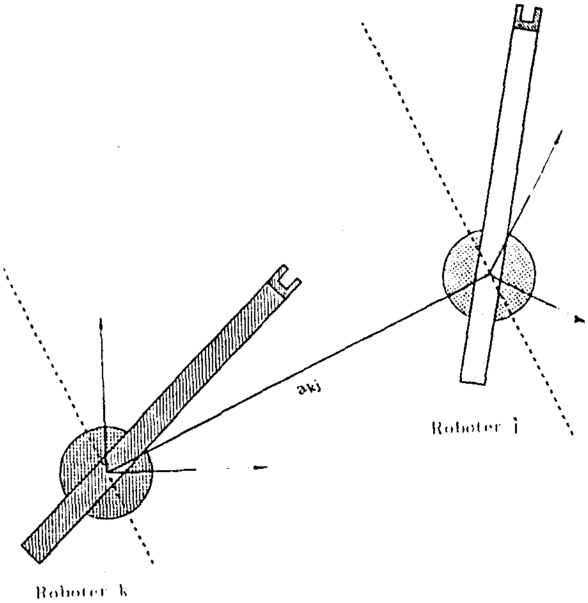


Fig. 1 Arrangement of the robots

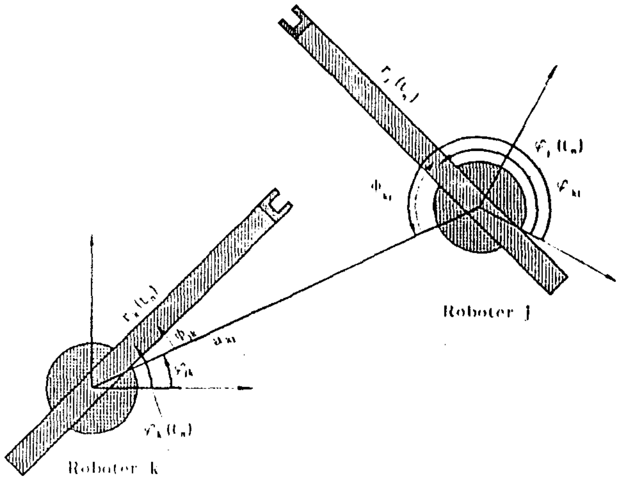


Fig. 2 Geometrical configuration of the robots k and j.

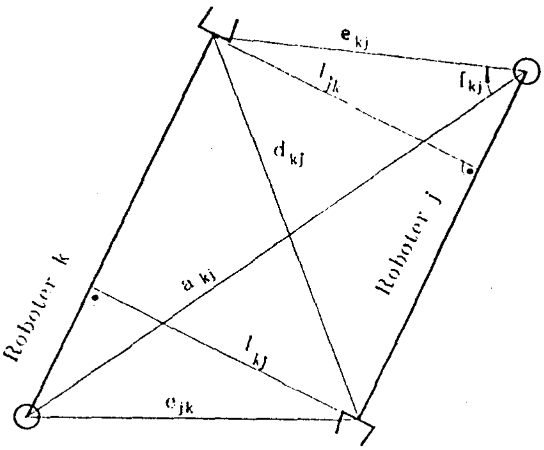
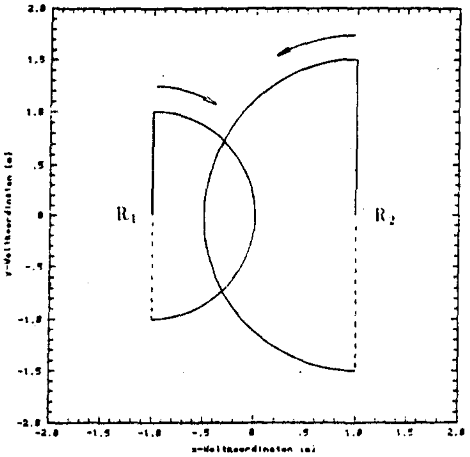
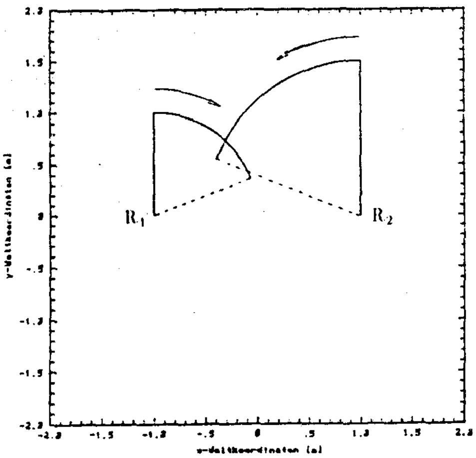


Fig. 3 The collision avoidance trajectory

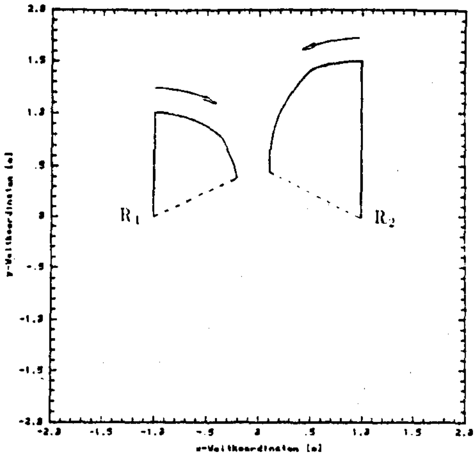


a) Programmierte Bahnen in der xy-Ebene

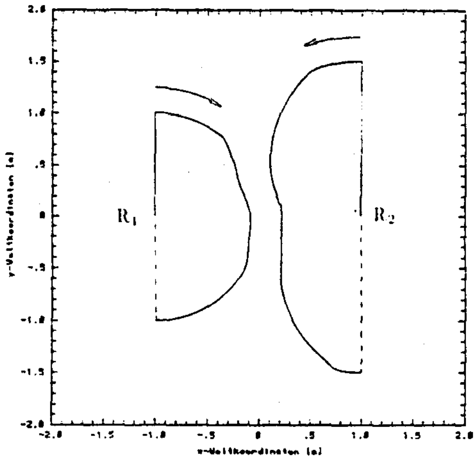


b) Kollision bei programmierter Bewegung (t=0,952)

Fig. 4 (a) and (b) Collision of two robots



c) Kollisionsfreie Bahnen bis zur Zeit t=0,952



d) Kollisionsfreie Bahnen bis zum Zielpunkt

Fig. 4 (c) and (d) collision avoidance of two robots.