Virtual simulation system for collision avoidance for medical robot

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For the collision avoidance with a medical robot with 6 DOF a virtual simulation system is presented. Manipulator and obstacles are modelled by geometric primitives. Collisions are detected in the Cartesian workspace by hierarchical distance computation based on the given CAD model. The application initially being addressed is maxillofacial surgery, where the safety of the patient is the main requirement, because of the closeness to vital parts. The simulation system allows the surgeon to check up the trajectory of the robot before the current operation begins.

1. Introduction

Virtual simulation has proved to be a cost-effective tool in path planning avoiding costly errors in judgement. Computerised systems for path planning have been developed for redundant manipulators [1] and for 6-DOF industrial robots [2], but are not used in medical applications where high precision of moving control is required.

This work focuses on the use of 3D simulation for collision detection and avoidance. The 3D simulation has been developed using ROBCAD.

2. Background

The goal of our medical application is to support the surgeon in maxillofacial surgery doing sawing, drilling, and milling jobs placed on the human skull.

The simulation system accepts the data file from the trajectory planning application and according to these data initial position of the robot is defined. The optimal relative position and the start configuration of the robot are determined by using the simulation system preoperatively.

Before the current operation begins, the physicians or assistants move the robot to the initial calculated position. For more convenience, the personal is guided using the navigation system. Nevertheless, the position will differ from the preoperative planned, so that the current position is handed over to simulation and collision check once more.

Figure 1 illustrates the operation sequence. The following steps will be the patient registration and the operation itself.
3. The Collisions Detection

Collisions are detected by a fast, hierarchical distance computation in 3D workspace, based on the polyhedral model of the environment and the robot provided by special ROBCAD system [3]. The Cartesian distances are then transformed into joint angles in order to define the state (“free” or “prohibited”) of the regarded configuration. For obtaining similar joint intervals, thus implicating an efficient distance exploitation, the optimal joint discretization is automatically computed based on the method presented in [4]. Collision are detected in the explicit workspace by computing the minimum distance between robot R and obstacles W_i (Figure 2).

4. The Collisions Avoidance

A frequent approach to collision avoidance is the calculation of a penalty function, which value is increased in case of the robot removal from the goal [1]. Other approaches work in the explicit representation of the free C-space [2].

Here a method “the hypothesis–test” is presented. The first step is definition of possible collisions as non-zero geometrical crossing between models of the manipulator and obstacles. The second step is modification of the trajectory. Updating occurs at first on axis z, which keeps upward orientation of the trajectory. If it is a necessary, then the path is modified on the other axes.

5. The Simulation System Realization

The system was implemented on a SGI IRIX in the programming language C.
The 3D simulation model provides a robust visualisation tool helping reveal and prevent a potential collision.

The application of results, obtained by the present work, was carried out at the Institute for Process Control and Robotics (University of Karlsruhe, Germany) in the form of a software package for control of the 6-DOF manipulator.

6. Conclusion and Future Goals

The virtual simulation system for collision avoidance of medical robot has been presented. The paper shows the use of 3D graphics for support of the visualisation of the planned robot motion along the trajectory. The collision detection is done in the Cartesian workspace by distance computation. This avoid the time and memory consuming obstacle transformation and C-space calculation. The collision avoidance is based on the “the hypothesis–test” method and provide the supervising surgeon a good overview over all robot activities. Based on these results, we focus next on developing means of communication between the robot control system and the developed simulation system.

References


