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Extended Abstract nnn

Title:

A potential field approach for collision avoidance in 5-axis milling

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Keywords
5-axis machining, Collision detection, Potential field, tool paths optimization

Introduction

5-axis surface machining is an essential process in the field of aerospace, molds and dies industries. 5-axis milling is required for the realization of difficult parts such as blades and impellers and is also very convenientto improve quality for the machining of deep molds in plastic injection and casting by reducing tool length. Despite the evolution of CAM software, 5-axis tool path programming requires advanced skills and collision detection remains a challenge during the tool path computation. One can distinguish two kinds of tool collision when addressing machining issues. The first one is local and only involves the active part of the tool, the second one is global and in that case the whole body of the tool, the tool holder and even the spindle can be considered.

Literature shows that collisions are often avoided using a geometric point of view. Indeed, the study traditionally starts with a representation of the tool geometry [1][2], then by a geometrical representation of the environment [3][4], thirdly by a collision test between the obstacle and the tool [5][6] and finally by a correction and optimization of the tool axis direction to avoid the obstacle [7]. In the field of robotics, other methods based on potential fields virtually attached to the obstacle are developed. These fields emit a repulsive force on the robot when it enters the neighborhood of the obstacle [8][9]. The aim of this paper is to show the benefit of using potential fields in order to prevent collisions during the computation of the tool axis orientation along a given tool path followed by the center of a ball-end milling tool.

Main idea

In the proposed approach, 5-axis collision avoidance is managed thanks to repulsive forces deriving from a potential field. The tool is considered as a rigid body moving in 3D space on which repulsive and attractive forces are acting. Repulsive forces are due to potential fields attached to check surfaces and an attractive force exerted by a spring is introduced to restore the tool axis orientation in the programmed configuration. Moreover, a viscous damper is used to allow the system returns to steady state without oscillating. The tool center follows the programmed path on the part surface whereas the tool axis orientation is modified to avoid the obstacle by resolving the fundamental principle of dynamics. Differential equations of the tool motion are solved using an Ordinary Differential Equation solver (ODE).

The repulsive force comes from robotics [9] and is formulated as follows:

$$\begin{cases} \vec{F}_{rep} = h.(\frac{1}{r} - \frac{1}{r_0})^2.\frac{1}{r^2}.\overrightarrow{grad}(r) & r < r_0 \\ \vec{F}_{rep} = \vec{0} & r \geq r_0 \end{cases}$$

with

- η: Repulsive force coefficient
- r: Distance between obstacle and tool gravity center
- r_0: Programmed neighborhood for the obstacle

Two different applications are proposed. First, a tool moving along a straight line enters successively two spherical potential fields created by two single points. The tool axis orientation is automatically modified to avoid the collision and go back to its programmed orientation as fast as possible with a smooth response. This first case allows tuning simulation parameters such as mass, spring constant and damping as well as tool velocity during simulationto avoid oscillations.

The second study deals with a 5-axis open pocket application such as impeller machining. Part surface and check surfaces are modeled as Bezier patches. The check surfacesare discretized and every point of the mesh is considered as a repulsive point. The main purpose is to avoid oscillations by choosing an optimum mesh size and by programming the return in the initial orientation with a critical or over damped behavior. Fig.1 and Fig.2 illustrate the results of both studied cases.

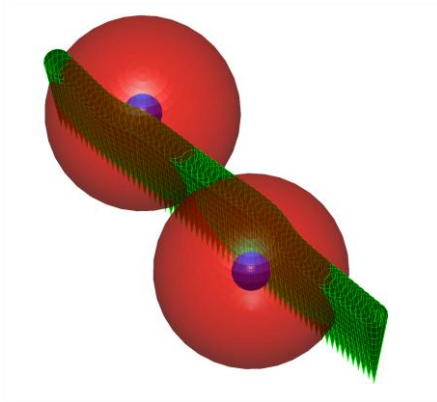

Fig. 1: Avoidance of 2 spheres neighborhood

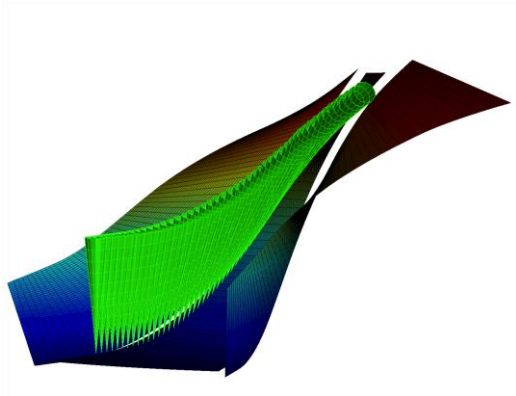

Fig. 2: Avoidance of anImpeller-type surface

Conclusions

Research works introduced in this paper show an original method for 5-axis collision avoidance by using potential fields commonly used in robotics. Using potential fields allows to be sure that no collision will ever occur with the obstacles as the neighborhood emits a repulsive force growing to infinity when the tool gets closer to the obstacle. As the tool behaves like a damped harmonic oscillator, investigations are carried out to prevent the tool axis orientation from oscillating. Numerical investigations show that the proposed approach is efficient and perspectives brought by these works are numerous. In particular, the reduction of the tool length to minimize tool deflection and the smoothness of the tool axis orientation variation to ensure High Speed Machining are under investigations.

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