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New Challenges and Opportunities for Industrial Engineers after the Economic Recession

The Institute of Industrial Engineers Asian Conference 2011

Edited by Zhibin Jiang, Feng Chen, Fugee Tsung, and Xiangtong Qi

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MESSAGE FROM THE GENERAL AND PROGRAM CHAIRS

It is our great pleasure to welcome you to the Institute of Industrial Engineers Asian Conference 2011 (IIE Asian'2011).

IIE Asian'2011 is being held in the city of Shanghai, China. Shanghai, the hub of the Yangtze River Delta area, is becoming one of international business centers. With its splendid past, Shanghai will have a more brilliant future, and is on the fast track to become an international metropolis. Shanghai, the Oriental Pearl of the new century, warmly welcomes participants from all over the world.

Asia is nowadays the biggest manufacturing centre in the world, which calls for a broad range of applications of Industrial Engineering techniques. Emerging economy, such as service and environmental industries, also brings new challenges and opportunities for Industrial Engineers after the economic recession.

The Institute of Industrial Engineers (IIE), the world's largest professional society, is dedicated solely to the support of the Industrial Engineering professionals and individuals. IIE will hold the first regional conference in Asian, IIE Asian Conference 2011, in 10^{th}-12^{th}, June 2011 in Shanghai. The conference will gather scholars and industrial experts together to show their views at Industrial Engineering research and applications in Asia in the new era.

On behalf of the Organizing Committee of IIE Asian'2011, we heartily appreciate the arrival of all the participants from all over the world and your presentations on the sessions.

Zhibin Jiang
Fugee Tsung
General Chairs

Feng Chen
Xiangtong Qi
Program Chairs

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Computer Aided Design

Multi-Pass Progressive Tool Path Planning in 5 – Axis Flank Milling by PSO Algorithms

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Abstract

This paper proposes a novel planning method of multi-pass tool path in 5 – axis flank machining of ruled surfaces. The path planning task is transformed into an optimal curve matching problem. The objective in the optimization is expressed as a weighted sum of the errors induced by overcut and undercut respectively. Evolutionary computing algorithms based on Particle Swarm Optimization are applied to search for optimized tool path. Running the algorithms multiple times produces multi-pass tool motion that progressively improves the machining quality. Different optimized results can be generated for each pass by properly adjusting the weights in the objective. Simulation results show that our approach produces smaller machining errors compared to traditional planning of single tool path. It offers a planning flexibility that was never conceived in the past.

Keywords 5 – axis machining, flank milling, particle swarm optimization, multi-pass tool path

1 Introduction

5 – axis machining offers superior shaping capability and high productivity with extra rotational degrees of freedom in tool motion. This milling operation can be categorized into two types: point milling and flank milling. In the point milling operation, material is removed by the cutter end, similar to that in traditional 3 – axis surface milling. In contrast, the action of material removal mainly occurs along the peripheral of the cutter. Tool collision and machining error control are two major concerns in 5 – axis flank milling [1]. The cutter is likely to collide with other objects existing in the machining environment such as machine tools, fixtures, and stock material. Simulation functions based on computer graphics have been developed to avoid tool collision. It is highly difficult to completely avoid machining error in 5 – axis flank milling when a cylindrical cutter is used.

The design surface cannot be precisely created except for simple geometries such as conical, cylindrical, and developable surfaces [2]. The machined surface is considered acceptable in practice given that the amount of machining error is limited within a given tolerance.

Previous studies proposed to reduce the machining error in 5 - axis flank milling by global (or near global) optimization methods [3 - 5]. Such an optimization approach provides an effective and systematic mechanism of the machining error control. Wu et al. [3] transformed the tool path planning task into an optimal curve matching problem. The total error on the machined surface was used as an objective in the optimization process. Dynamic programming was applied to search for the optimal solutions. Chu et al. [4] solved the problem using Ant Colony Systems algorithms. The computation time in the optimization process can be significantly reduced with a minor deterioration of the final solution. Hsieh and Chu [5] relaxed the constraint in the two previous studies that the cutter is only allowed to contact at pre-defined discrete points on the boundary curves of the design surface. The optimal tool path generated from such a larger solution space produces a smaller machining error.

All the past studies only handled generation of single tool path. In practice, multiple machining operations are often required to achieve the design specification. Secondary operations such as polishing are employed to improve the dimensional accuracy and/or to correct machining deviation created by the primary machining operation. However, no tool path planning methods have been developed for 5 - axis flank milling that can generate multi-pass tool motion. The only way of producing multiple tool paths is to offset the design surface with different amounts of allowance and apply the same algorithm to the offset surfaces (see Figure 1). This may serve the different needs of tool path planning in rough, semi-finish, and finish cuts. However, such an approach cannot be used multiple times for progressively improving the machining quality in the finish cut.

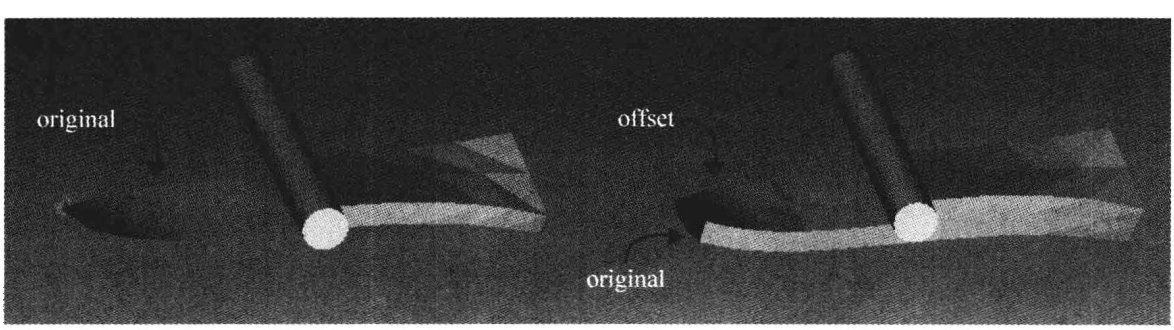

Figure 1 Multiple tool path generation by offsetting the design surface

Global (or near global) optimization based tool path planning provides a solution to overcome this limitation. As shown in Figure 2, through proper transformation, the path planning task becomes a curve matching problem, which can be systematically solved by existing optimization schemes. Such planning methods also allow generation of multiple tool paths in a progressive manner. This work presents a computational scheme for realizing this idea. We propose to use a new representation of the objective in the optimization.