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Accurate Interpolation of Machining Tool-paths Based on FIR Filtering

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Highlights

A novel online trajectory generation scheme is developed for motion systems using FIR filters.
It enables generation of non-stop contouring motion along machining tool-paths.
Both contour errors and frequency spectrum of reference trajectories are controlled.
The method is computationally efficient for real-time implementation.

Abstract

This paper presents a novel real-time (online) interpolation algorithm based on Finite Impulse Response (FIR) filters to generate smooth and accurate reference motion trajectories for machine tools and motion systems. Typically, reference tool-paths are composed of series of linear (G01) or circular (G02) segments. Basic point-to-point (P2P) feed motion can be generated by interpolating each segment with trapezoidal or S-curved velocity profile. However, smooth and accurate transitions between path segments are necessary to realize non-stop contouring motion. In this study, FIR filters are utilized, and the reference tool-path is filtered to interpolate a non-stop rapid feed motion. By using a chain of FIR filters, acceleration and jerk continuous motion profiles are generated from velocity pulse commands. A segment interpolation timing technique is developed to control the contour errors during non-stop real-time interpolation of tool-paths. Furthermore, by utilizing FIR filters for interpolation, frequency spectrum of the interpolated motion profiles is controlled. The time constant (delay) of the filter is tuned to create notches around the lightly damped vibration modes of the motion system, which allows mitigation of unwanted vibrations and thus enables delivering accurate feed motion. Simulation studies and industrial scale experimental validations are provided to illustrate effectiveness of the developed interpolation technique.

1. Introduction

Reference trajectory generation plays a key role in the computer control of machine tools and motion systems. Generated trajectories must not only describe the desired tool path accurately, but must also have smooth kinematic profiles in order to maintain high tracking accuracy, and avoid exciting natural vibration modes of the mechanical structure or servo control system. As a matter of fact, most machining tool-paths are defined in terms of series of linear (G01) segments or circular (G02) arcs [1][2]. This imposes serious limitations in terms of delivering a non-stop smooth and rapid motion for productivity, and to achieve the desired final part geometry.

There are several challenges associated with interpolating a smooth motion along these discrete tool-paths. Consider interpolation on a single path segment; feedrate (tangential velocity) profile needs to be planned with smooth acceleration and decelerations to avoid excitation of the machine tool's structural modes [3] and at the same time respect kinematic limits, i.e. torque, acceleration and jerk, of the drives [4][5][6]. Polynomial based feed profiles, such as trapezoidal velocity [1], acceleration [4] and jerk profiles