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POLYNOMIAL INTERPOLATION METHODS FOR SYNTHESIS OF ELECTRONIC CAM PROFILES

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1 INTRODUCTION

A cam is a mechanical device, which transforms a rotary motion into a linear motion. The cam is widely used in various machines such like piston pumps, packing machines, machine tools or transport systems. A typical example is the camshaft of a car, which operates the intake and exhaust valves of the cylinders and synchronizes their motion with respect to speed of the crankshaft.

The mechanical cam can be replaced by its electronic counterpart in many industrial applications. An electronic control system keeps the synchronization between independently controlled (master) axis and a dependent (slave) axis, whose motion is derived from a prescribed displacement diagram - cam profile, which determines the relation between master and slave position. The master axis can be a real physical drive or a virtual motion generator inside the control system software. The main advantages of the electronic cam are fast and easy change of the cam profile, reliable high-speed and high accuracy operation and no mechanical wear of the cam-follower mechanism.

2 PROBLEM STATEMENT - ELECTRONIC CAM PROFILE SYNTHESIS

Consider a set of user-specified input data points representing the demanded relation between master and slave axis position in form:

$$\{m_i, s_i\}; i = 0..n \tag{1}$$

The goal is to find a proper interpolation function $\varphi(m)$ describing the master-slave dependence $s(t) = \varphi(m(t))$ with following properties:

- The function has to fulfill the interpolation conditions given by the input data points: $s_i = \varphi(m_i); i = 0..n$
- The function $\varphi(m)$ and its three derivatives $\frac{\partial^i \varphi(m)}{\partial m^i}$; $i = 1, 2, 3$ needs to be smooth in order to produce a physically feasible motion trajectory which can be tracked by a feedback controller without any discontinuities and abrupt changes.
- The three derivatives of $\varphi(m)$ have to be equal on the edges of the cam profile to provide a smooth transition during a periodic execution.

The stated requirements led to the choice of a piecewise polynomial interpolation using 5th order polynomials. Three different methods were implemented (Qiu (2005),Mandal (2008),Heng (2008)):

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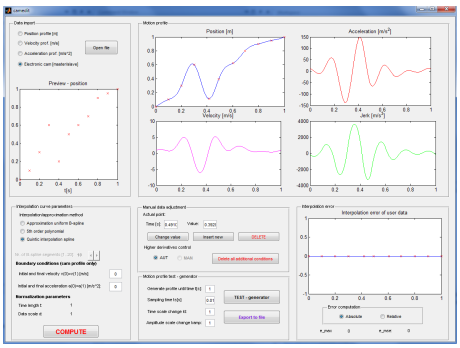

Fig. 1: Electronic cam profile editor - CamEdit

1. *5th order polynomial interpolation* - the profile is divided into n segments bounded by the input data points. Each segment is described by a 5th order polynomial. The user can specify the values of two derivatives of the interpolation curve in each of the input points to adjust the shape of the profile.

2. *Quintic spline interpolation* - the user sets only the input data points and the polynomial in each segment is computed using spline conditions for continuity of four derivatives at the segment boundaries.

3. *Approximation B-spline curve* - the user sets the number of curve segments and the shape of the profile is determined by the location of B-spline control points. Their values are computed by an optimization algorithm using least squares and Lagrange multipliers methods. This approach is useful in case of large amount of input data points.

The proposed methods were implemented in graphical user interface software called *CamEdit*. By using this tool, the electronic cam profiles can be constructed, modified and stored interactively. The output of this software tool is a parametrization of the interpolation curve, which is used for real time trajectory generation in a motion control system.

3 CONCLUSION

This paper deals with methods for electronic cam profile synthesis. The goal is to find a suitable mathematical representation of the cam curve that can be used for real time trajectory generation in a motion control system. Three different methods of piecewise-polynomial interpolation were chosen to obtain the profile. A graphical user interface for an interactive cam profile shaping was developed.

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