A Novel Approach to the Generation and Implementation of Motion Profile for a Multi Axis Motion Control System

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Abstract

This article presents a novel motion control method which aims to generate and implement a motion control profile with reduced jerk. To implement an architecture which can deliver jitter free trajectory scalable to 18 axes at an update rate of 5KHz.Actual hardware is designed to realize a 6 axes controller and experiments are performed on this setup. While analysis and trajectory generation are performed for 6 axes control, motor control is evaluated on a mechanical system with two motors. Comparisons are made based on the results obtained using various DSP controllers. The motion profile of a circle is implemented and tested in this article.

Keywords: Motion control, Ethernet, Vibration analysis, DSP controllers.

Introduction

Necessity of Path Planning

Motion control system's purpose is to control anyone or the combination of the following parameters: Position, velocity, acceleration and torque. Velocity control needs to be quantified with respect to several issues like what is the speed required to do the application. Torque control suggests the need to control the torque or force in a system independent of speed. Position control entails the control of motion displacement which is the change of motion with respect to time. This includes command, control and the monitoring of motion. The acceleration rate will affect the force in the system since torque is the product of inertia and acceleration rate. Position control requires flexibility regarding the need to change certain parameters of the required motion.

Motion planning computes a collision-free and continuous path from the initial point to the destination point. Motion planning is breaking down a desired path into discrete motions. Smaller the distance between two movements smoother will be the curve. The objective of a path planning is to dynamically create a path position reference for the control movement from initial point to destination point.

Motion Profile Planning

PVT Approach

The PVT (Position Velocity Time) algorithm fits a jerk (non-constant acceleration) profile between user specified "Position, Velocity, and Time" points. The PVT algorithm guarantees that the trajectory calculator will hit the specified position, with specified velocity and at the specified time. For each point, PVT algorithm calculates the acceleration and jerk values to exactly reach the specified position and velocity at the next point. PVT allows the continuous motion between different points since the point-time pairs are calculated in advance and are loaded into the motion frames that create real-time command positions at each sample during time intervals between the point-time pairs.

The objective of the path planning is to create a position reference that results in a controlled move from position A to position B. In some cases, it is not important what the actual profile is between point A and point B. In general, reference position x(t) from Fig. 1 can be any mathematical formula, continuous or piece-wise continuous. For example, a trapezoidal move is a piece-wise continuous curve. It is the velocity that has a trapezoidal shape, not the position.

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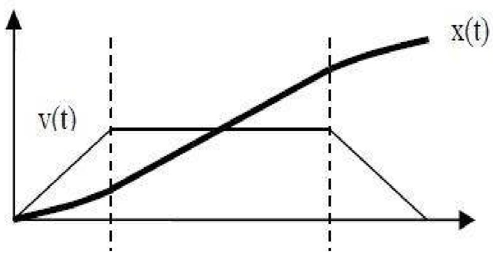

Figure 1.Path x (t)

In this approach, the profile path is segmented into smaller pieces and those smaller pieces are approximated with polynomial. Thus the original curve is sampled and then reconstructed.

The path experimented is a circle of various radii. For a circle in an X-Y plane, the position along X is continuous.

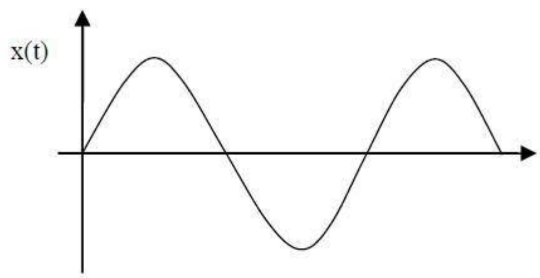

Figure 2.X axis path of a circle

For path planning purposes, position profiles are expressed as polynomials.

One of the better approaches is to segment the profile into smaller pieces, and approximate those smaller pieces with a polynomial.

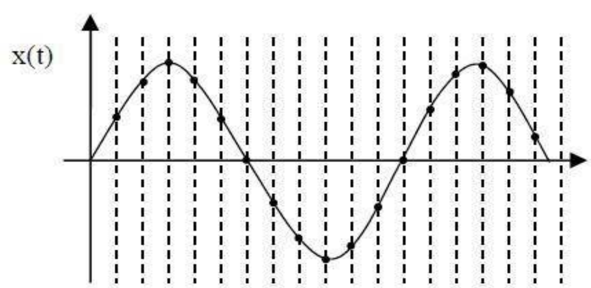

Figure 3.Sampled X axis path

Controller Implementation

Various controllers were experimented and implemented. The first board experimented is the SC04 with a Microchip controller MCS9845CV-BA which has an operating frequency of 80MHz.

A path of a circle is created and is fed through the controller to the motor drive. The motors are made to run at various different speeds. The objective is to achieve smoothness and accuracy throughout the movement.

A circle of 10mm radius is loaded into the controller. The parameters loaded are the speed and the steps required for the total movement. These parameters are fed in a queue to the controller. Motors were tested at various speeds. The analysis of the smoothness of the motors was done using Vibration sensors.

The sensors were mounted on the motors and tested. A protection circuit is connected between the sensor and the controller. The vibrations of the motor were recorded and stored.

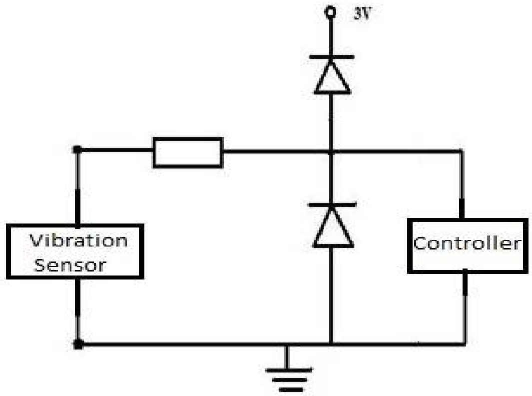

Figure 4.Protection Circuit between sensor and controller

The controller used for ADC is F28069 which has a 12 bit ADC. A total of 512 samples were taken and recorded as voltages (0-3.3V).RMS of these values at different speeds is found.

Result

The recorded result of the SC04 controller is as follows:

SC04 controller MCS9845	
Speed	**RMS value**
200	1.0587
600	0.9302
700	0.9043
800	0.8664
1000	0.5543

Table 1.Recorded result of SC04 controller

The RMS value decreases as the speed increases. The vibration at a minimum speed is found to be the largest. The next experiment was done on the TIVA TM4C129NCPDT by Texas Instruments which operates at 120MHz.

TIVA controller TM4C1294NCPDT	
Speed	**RMS value**
200	0.113
600	0.0694
700	0.0599
800	0.0584
1000	0.0572

Table 2.Recorded result of TIVA controller

The results clearly show that the vibrations of the motor are very less than SC04 controller. At a speed of 1000 the RMS value is as small as 0.0572.

Conclusion

This article describes the development of a motion generation approach using PVT method. This delivers a novel motion profile generation strategy that is proposed to reduce the motion-induced jerk and vibration. The motion profile tested was a circle of 10mm radius. The motion profile was tested on two DPS based motion controllers. Vibration analysis was done and the best smoothness and accuracy was observed in Texas Instruments TIVA129 controller.

Industrial Importance

The proposed motion control method can be applied to a wide range of precision machines in electronics manufacturing industry which uses high-speed high- precision motion stages, such as pick-and- place manipulator, industrial robots, positioning systems, CNC machine for various applications.

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