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# Design of a Multi-axis Motion Control Platform Based on LabVIEW's Fuzzy Control Algorithm

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**Abstract:** This paper presents a fuzzy control algorithm applied to the position control of a multi-axis motion platform to achieve high precision motion control of the multi-axis motion platform. A LabVIEW-based multi-axis motion control system is designed. This system controls stepper motors using trapezoidal acceleration/deceleration pulse types and fuzzy control algorithms, which effectively avoids mechanical jitter and loss of step in the process of multi-angle motion of the stepper motor, and achieves accurate control of the stepper motor. The TCP/IP (transmission control protocol/internet protocol) communication protocol is used, so that data are output stably and not lost in the process of transmission and communication, achieving the purpose of interconnection of different systems and remote control of equipment. This control system has been tested to maintain a high level of stability and repeatability during actual operation.

**Key words:** LabVIEW, stepper motors, multi-axis linkage, fuzzy algorithms, TCP/IP communication.

## 1. Introduction

Stepper motors are now widely used in a variety of applications because of their simple construction, easy control methods and the ability to achieve precise displacement positioning [1]. With the increasing requirements of production automation, the demand for stepper motor control has gradually increased and the drive methods have become very sophisticated. This paper designs a multi-axis linkage motion control platform which consists of eight stepper motors. The combined motion of these eight stepper motors enables vertical, horizontal, and angular motion control of the platform. The platform's special mechanical structure is designed to carry a weight of around 50 kg and requires that the platform does not fall suddenly during movement or in the event of a sudden power failure. This paper proposes the use of fuzzy control algorithms for accurate displacement control of stepper motors to eliminate errors due to factors such as mechanical vibrations and the environment [2]. The stepper motor produces a return error during the reciprocating motion. The difference between the actual position of the stepper motor and the target position is detected by a sensor, and this return difference can be solved by using a fuzzy control algorithm [3]. In order to design a simple and user-friendly human-machine interface, the system uses LabVIEW software. LabVIEW is the commercial software that is now used in all areas of modern science and technology due to its simple programming, ease of understanding and mastery, as well as being the fastest growing and the most powerful integrated environment for graphical software development.

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## 2. Hardware Structure of a Multi-axis Motion Control System

### *2.1 Structure of the Motion Control Platform*

Fig. 1 shows a schematic diagram of the outline dimensions of the multi-axis motion control platform. This control system uses two multi-axis motion control platforms, each with a platform that can move horizontally fixed on each platform, and each platform is required to carry a load of 50 kg.

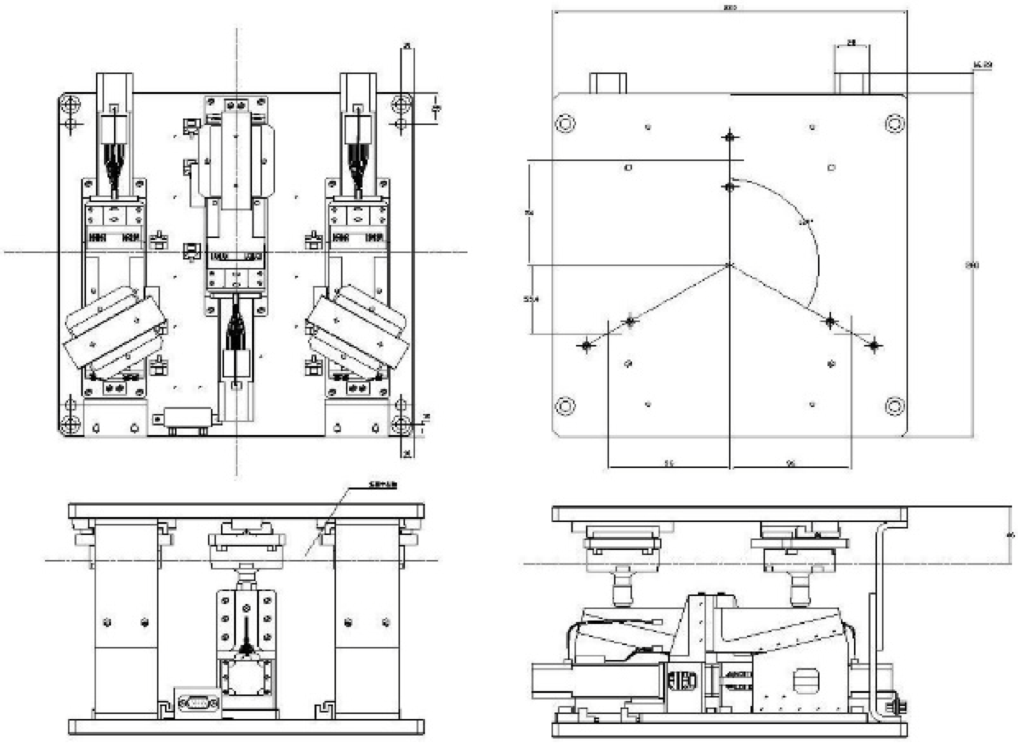

**Fig. 1 Schematic diagram of the multi-axis motion control platform.**

The multi-axis motion control platform has three axes and the stepper motor inside each axis is a two-phase stepper motor. The combined motion of the stepper motors in each axis enables vertical movement and angular adjustment of the platform. The platform is fixed with a sliding table that can be moved horizontally, so that the platform can also be moved horizontally. The control system requires the platform to be able to support a weight of about 50 kg. The mechanical structure of the traditional motion axis is generally designed with a stepper motor located on a screw, and the horizontal, vertical, and angular adjustment of the platform is achieved by controlling the movement of the stepper motor on the screw. This mechanical design is extremely susceptible to sudden falls during movement and standstill when the load is 50 kg. In order to avoid sudden falls when the platform is in motion, at standstill or even when the stepper motor is powered off, a wedge structure has been added to the shaft of each stepper motor movement. As shown in Fig. 2, the movement of the stepper motor drives the movement of the screw, causing the wedge to move in the vertical direction, with a cardan shaft attached to the top of the wedge, thus allowing displacement movement of the individual axes of motion.

This design effectively avoids the sudden fall of the platform due to the heavy load when the platform is in motion or at rest, and this mechanical structure can also maintain the original motion posture when the stepper motor is powered off, effectively improving the stability of the three-dimensional motion platform. The physical multi-axis motion control system is shown in Fig. 3.

### *2.2 Controllers and Drives*

The controller generates pulses and the stepper motor driver converts the electrical pulses into angular displacement signals so that the stepper motor moves at a fixed angle in the set direction. By controlling the number of pulses to control the angular displacement of the stepper motor, the frequency of the pulses can also be controlled to control the speed and acceleration of the stepper motor, thus achieving the purpose of speed regulation and precise displacement

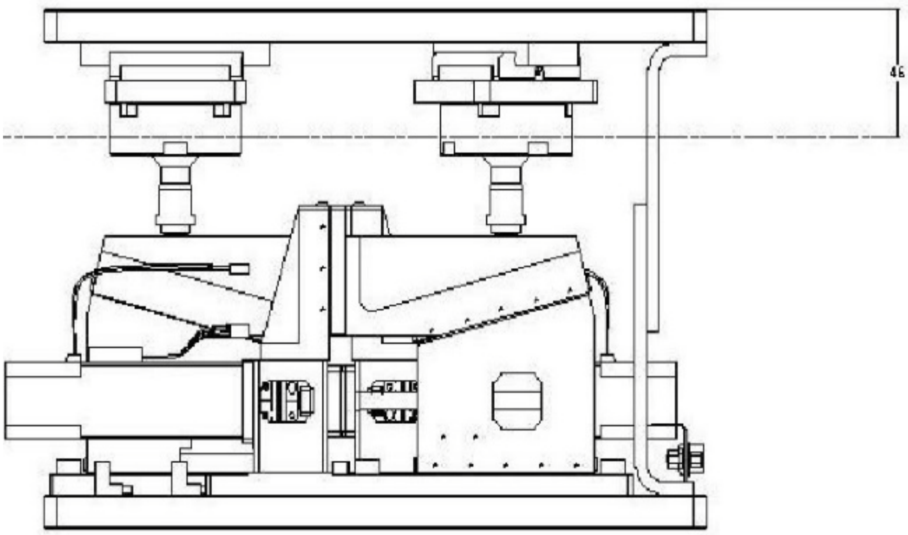

**Fig. 2 Schematic diagram of the wedge mechanism.**

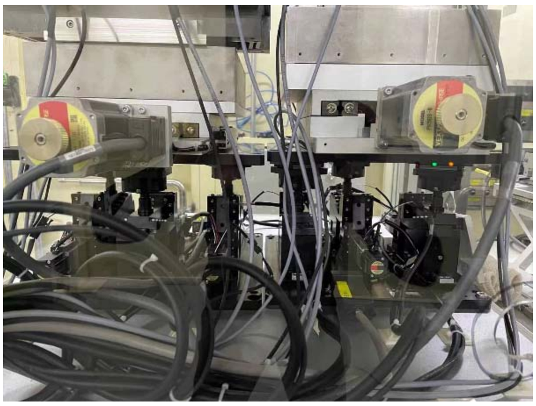

**Fig. 3 Physical view of the multi-axis motion control platform.**

**Fig. 4 Integrated controller and drive cabinet.**

control. The number of pulses sent by the controller controls the number of steps the stepper motor moves, the greater the number of pulses, the more steps the stepper motor moves; the frequency of pulses sent by the controller controls the speed of the stepper motor movement, the greater the frequency of pulses, the faster the stepper motor movement.

The signal transmission of this control system uses TCP/IP (transmission control protocol/internet protocol) communication protocol to ensure the stability and accuracy of the signal transmission. In this paper, the driver and controller of the stepper motor are designed to be installed in a cabinet, which improves the integration of the control system and provides convenience for the operator, as shown in Fig. 4.

The controller uses the PM16C-16 from TSUJI, Japan. This controller can output 16 pulses in a stable manner, with a large range of output pulses, a high degree of adjustability and the possibility of adjusting the type of pulse. For different pulse frequencies can control the controller output different types of pulse, and thus control the stepper motor more stable operation, to a certain extent effectively avoid the stepper motor in the process of movement of mechanical vibration phenomenon.

The driver is a Melec model 750V1-01 from Japan, which is perfectly adapted to the controller and has a drive current range of 0.30-1.35 A up to 4,000 subdivisions and a holding current of about 40% of the drive current. The circuit design of the drive uses conventional electronic components rather than integrated circuits, increasing operational reliability. The internal design of the circuit contains limit switch signal processing and hardware protection functions.

## 3. Control Algorithms

### *3.1 Movement Algorithms for Multi-axis Motion Control Platforms*

Define the coordinates of the center position of the platform as (0, 0) and the coordinates of the U-axis, V-axis, and W-axis tilt cores as (0, 84), (-96, -55.4) and (96, -55.4) respectively. Since the screw diameter and screw pitch for each axis are 6 mm and 1 mm, it is possible to calculate the amount of movement per unit pulse corresponding to the axis. It is assumed that the target breaking energy is $[a]$ µm/pulse, the screw pitch is $[b]$ mm and the drive breaking energy is set to $[d]$ pulse/rev. The reduction ratio (wedge ratio) of the mechanism is 1/4. Then in the linear direction we get:

$$[b]\ mm \div [d]\ pulse/rev = [d]\ mm/puse \tag{1}$$

Vertical:

$$[d]\ mm/pulse \times 4\ = [f]\ mm/pulse \tag{2}$$

From the above equation it is possible to calculate the displacement of each axis of motion in real space when the controller sends a certain number of pulses. The values of $Z$, $\theta_x$ and $\theta_y$ can be obtained according to the mechanical structure of the control platform and for the definition of the coordinates of each axis of the control platform.

$$S_t(U) = Z + (-1) \times U_y \times \tan\theta_x - U_x \times \tan\theta_y \tag{3}$$

$$S_t(V) = Z + (-1) \times V_y \times \tan\theta_x - V_x \times \tan\theta_y \tag{4}$$

$$S_t(W) = Z + (-1) \times W_y \times \tan\theta_x - W_x \times \tan\theta_y \tag{5}$$

$S_t(U)$: Z-directional movement of the U-axis;
$S_t(V)$: Z-directional movement of the V-axis;
$S_t(W)$: Z-directional movement of the W-axis;
$U_x$: 0 mm, $U_y$: 84 mm;
$V_x$: -96 mm, $V_y$: -55.4 mm;
$W_x$: 96 mm, $W_y$: -55.4 mm.

Therefore, according to the above movement control algorithm to obtain the spatial position of the motion platform, each platform can achieve the displacement and spatial angle adjustment, and then from the spatial position to convert the number of pulses issued by the controller, to achieve the multi-axis motion control platform attitude adjustment.

### *3.2 LabView Algorithm and Implementation*

The motion control of this system is mainly the motion control of the stepper motor, and the motion of the stepper motor will generate errors, which is caused by the internal structure of the stepper motor and the control means, therefore, reduce the error generated by the stepper motor in the process of motion of this control system control algorithm research focus [4]. Due to the special internal structure of the stepper motor, when the stepper motor is started, the pulse frequency generated by the controller is too fast or the frequency issued during deceleration is too slow, which may cause the stepper motor to oscillate or lose steps. The phenomenon occurs mainly during the acceleration and deceleration phases of stepper motors, where the loss of step or oscillation is related to the type of pulse output from the controller [5]. Fig. 5 shows the pulse type of a conventionally controlled stepper motor, which is a rectangular wave. When the controller outputs rectangular wave, due to the sudden rise and fall of the rising and falling edges of the rectangular wave, it is very easy to make the stepper motor out of step phenomenon, when the controller output signal frequency is too fast, the out-of-step phenomenon will be more obvious. In order to avoid this phenomenon in stepper motor, this paper uses a trapezoidal acceleration and deceleration pulse signal, as shown in Fig. 6. In contrast to rectangular waves, trapezoidal acceleration and deceleration pulse signals have a slow rise and a slow fall on both the rising and falling edges. The trapezoidal acceleration and deceleration pulse signal allows the stepper motor to have a slow increase in frequency during the start-up phase and to have a slow decrease during the deceleration phase. Take the stepper motor movement for a period of displacement, for example, in the

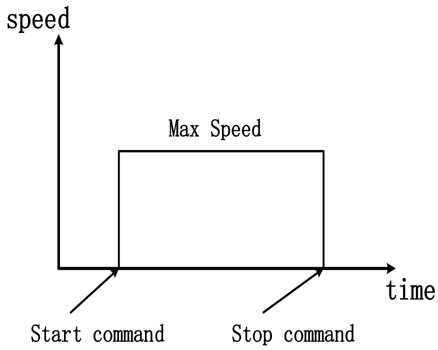


**Fig. 5 Rectangular wave pulse signal.**

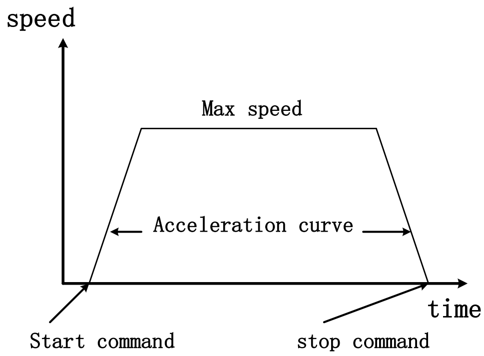


**Fig. 6 Trapezoidal acceleration/deceleration pulse signal.**

stepper motor start-up phase, the motor first low-speed start, followed by a certain acceleration gradually speeding up, and then uniform motion, when the movement is about to reach the specified position, take a certain acceleration deceleration movement, and finally to the target position to stop the movement. This prevents the stepper motor from not recognizing the pulse signal and losing steps.

The controller also generates errors in the process of sending out pulse signals. Factors such as the sensitivity of the controller’s internal electronics and the environment can cause errors in the number of pulses sent out by the controller. For example, when the controller receives a command to issue 10 pulses, it is possible that the controller will issue more than 10 pulses or less than 10, and the stepper motor will take one more step or one less step in the process of movement, which makes the stepper motor produce a displacement error. In order to eliminate the effect of this error on the motion control system, for the design of this control system, a fuzzy control algorithm, commonly used in the control field, can be used.

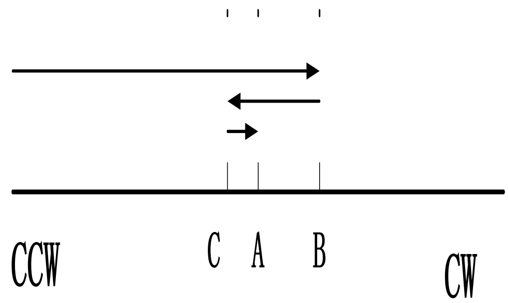


**Fig. 7 Logic diagram of the fuzzy control algorithm.**

The logic of the fuzzy control algorithm in this paper is similar to the infinite approximation approach, as shown in Fig. 7. Suppose that point A is the target position of the stepper motor movement, but the controller sends a few extra pulses to make the motor move to point B. At this point the sensor will detect the actual position of the motor and calculate the difference in distance between the actual position and the target position. The program will convert the number of pulses that the controller should output based on this displacement difference. The controller receives the command to move towards point A again, but the actual position of the motor moves to point C. The above action will then be repeated until the motor moves to point A and the motor stops moving.

The fuzzy control algorithm can well solve the problem of controller internal chip and electronic circuit causing the controller to mis-trigger pulses. The trapezoidal acceleration/deceleration pulse waveform and fuzzy control algorithm can ensure the smooth motion of the motion control platform to achieve the control accuracy and stability of this system.

## 4. LabVIEW Control Interface

Fig. 8 shows the LabView control interface of this system. The control interface is simple and easy to operate, and the operator can be familiar with the control logic of the multi-axis motion control system without much understanding, which improves the efficiency of work.

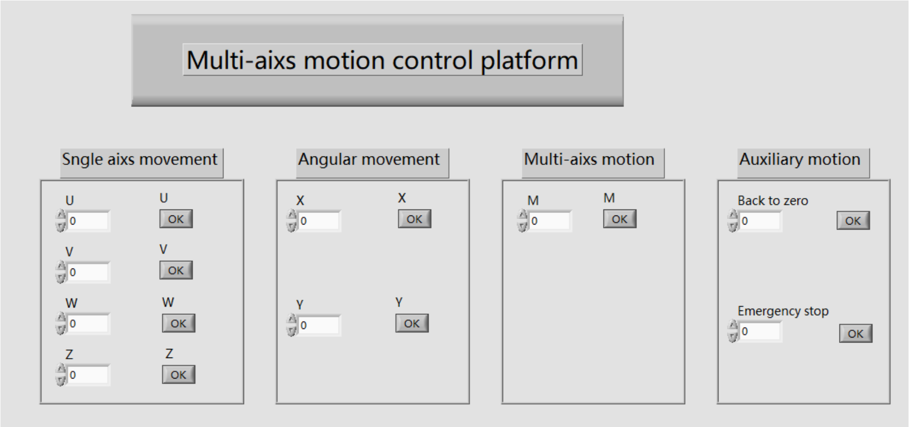


**Fig. 8 LabView control interface.**

## 5. Conclusions

This paper introduces the design of a multi-axis motion control system platform based on LabView language. The hardware composition of this system is mainly introduced, and the trapezoidal acceleration and deceleration waveforms and fuzzy control algorithms are used to make the motion control platform move smoothly and reduce the motion errors. And the use of the TCP/IP communication protocol allows the system to be integrated with other control systems. The controller and driver can also be used for motion control of other stepper motors, reducing the cost of stepper motor control. In practical tests the system also maintains a high level of stability and accuracy of movement, providing an important reference for future multi-dwelling stepper motor control.

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