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Research Article

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Design and Implementation of H-bridge Stepper Motor Driver for Spray Paint Robot

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Abstract

This paper presents the implementation of design of H-bridge using 4N25 isolated driver for stepper motor which is being used in automated spray-painting robot designed for industrial applications. The robot is capable of performing complex paint jobs on various surfaces with high precision and efficiency. The robot's programming allows for customizable settings to achieve desired paint thickness, coverage, and texture. The system utilizes advanced sensors to detect and adjust for variations in surface contours, ensuring a uniform coat of paint. The robot is equipped with a self-cleaning mechanism, reducing the need for manual maintenance. The novelty of work lies in design and simulation of the circuit using proteus software before building the physical prototype. The H-bridge driver with isolated IC is suitable for such heavy application from microcontroller isolation point of view. Overall, this automated spray-painting robot offers a reliable and cost-effective solution for large-scale painting projects in manufacturing and other industrial settings.

Keywords

Automated spray painting, Robot programming, Micro-controller, Motor-controller, H-bridge, Stepper motor

Introduction

Now-a-days the work at height specially related to wall painting becomes hazardous when the task get done with manual approach. Therefore, automation becomes necessary component for completion of such activity without any noticeable hazard. Thus, at an initial research stage of development for such system requires very effective design and development often for the construction industry. The motivation comes from the need for automation and robotic solution which can replace or assist labor intensive and repetitive jobs such as spray painting the medium and high rise external and interior walls of residential buildings.

Tadić et al. [1] explains about the ZED sensor attached with robotics wall paint. This sensor checks the surface area as per applied algorithm and provides the required signal to the microcontroller for initial paint material requirement to spray on the wall. For completion of such task, image processing algorithm with morphological operation is involved for deciding the proper quantity of material to be sprayed.

Miniaturization, reliability, and high performance in IC to control the rotating machine can be addressed using mixing of different ICs and algorithm from application point of view. H-bridge ICs have played an important role in automation and robotics [2-4]. This reduces the number of components required

to run the high torque and high-speed application. Linear quadratic regulator which controls the angular position of the robot where the stepper motor is primary part [5]. For step control of motor, isolated driver IC plays an important role. Synchronization of controller output with driver output to run the motor becomes difficult when it subject to high torque application [2-4].

Kantawong [6] uses RFID and fuzzy logic based PID controller to control the DC stepper motor for tailoring room application where decision tracking range of RFID tag that is relative with robot data system. The main advantage of fuzzy-PID control is to achieve the suitable gain adjustment while operating the dc stepper motor.

Jabeen et al. [7] explained strategy for controlling the stepper motor for smooth transition and uses methodology of equivalence dissimulation refinement for controlling the six types of stepper motor. Abdellatif et al. [8] presented a simple, low weight, low cost, and less painting time conceptual design of an autonomous wall painting robot with an arm, ultrasonic sensors, and a control system. Aris et al. [9] summarized steps for design and construction of a painter robot including hardware, software, and testing.

This paper contains the design and development of wall painting robot which works autonomously which consist of two axes common rail spray paint for the walls which contains following features: (1) It is a mobile robot structural base which covers the painting area as per decided by the micro-controller, (2) An aluminum low cost, low weight frame is fabricated and an Arduino Uno based control system is programmed to give prescribe rotatory motions to lead screws for precise up and down movement as well as left to right moment to cover the area to be painted using a portable spray container with the mobile base in the present prototype, and (c) The novelty in the system is faster painting approach at wall. It is low weight, low cost, and provides faster painting time almost 5 - 10 s for area of 1 sq. m.

Experimentation

System description

The design of system consists of micro-controller, DC stepper motor, A4988 stepper motor driver, MG995 DC servo motor, and power source (Table 1). The system works by using the micro-controller to control the movements of the stepper motor and the position of the MG995 servo motor. The system consists of 3 stepper motor controlled by Arduino and motor controller are fitted, one on the movable horizontal lead screw supported on horizontal slide and two on upper fixed horizontal beam for two vertical lead screw (Table 2). The provision of four wheels may be provided to maneuver in the room area.

In summary, the automatic spray-painting robotic mechanism is designed to increase efficiency, accuracy, speed, and safety in the painting process, making it an attractive solution for large-scale painting projects in a variety of industries. Painting walls has always been a challenging and time-consuming task, requiring precision and patience. However, with the advent of technology. The spray gun is attached to the servo motor, which allows it to be positioned accurately and precisely. As the system moves along the pre-defined path, the spraycontainer with nozzle applies paint to the surface in a uniform and controlled manner.

Table 1: List of items used in applications design.

S. No.	Component name	Quantity
1	NEMA-17 Stepper	2
2	H-bridge developed at lab scale	2
3	12V power supply	1
4	Spray Bottle and holder	2
5	4N25 Isolated driver IC	10
6	MG995 servo motor	2

Table 2: List of materials used in applications design.

S. No.	Component name	Quantity	Material
1	Frame columns	04	Aluminum
2	Horizontal beam	03	Aluminum
3	Base of frame	01	Aluminum
4	Lead screw	03	SS
5	Screws, clips, and brackets	50, 05, and 14	MS/Al

This process has been revolutionized by the automatic spray wall painting robot. This robot, designed with advanced technology and engineering, is changing the way we think about wall painting. It is a subject of extensive research and study, as it has the potential to revolutionize the field of interior decoration and painting. This research paper explores the technology behind the automatic spray wall painting robot, its applications, advantages, and limitations. By delving into the technical aspects of the robot and examining its real-world applications, this paper aims to contribute to a better understanding of this fascinating and innovative technology.

System design

The material selection is to ensure the system must be designed with light weight material i.e., aluminum is a lightweight material is also a relatively cost-effective material compared to other metals, which makes it a popular choice for the construction of system. Aluminum is also a strong and durable material, which helps to ensure the stability and longevity of the robot. It is a highly machinable material, which means it can be easily formed, drilled, and cut into the desired shape and size. The aluminum system is able to operate efficiently in a variety of environments. Hence aluminum is used for the fabrication of frames. Many other components of system design include.

Micro-controller

Atemega328 micro-controller is implemented in the system which is part of the Arduino mega development board. It contains 28 pin outs. Each pin has specific function like as pin 4, 5, 9, 10, 11, and 12 are PWM pins which provides the necessary operation for speed control using pulse width modulation. Pin 22 to 28 is analog input pins which take care of all analog single from sensors. Rest digital pins are taken for digital signal input from the field or feedback from the field.

DC stepper motor and MG995 servo motor

The DC stepper motor is responsible for moving the spray gun along the pre-defined path. The micro-controller sends signals to the stepper motor driver, which controls the direction and speed of the motor. The speed of DC motor is controlled by variation in the digital signal input to the micro-controller which in turns varies the signal output of the driver circuit, therefore the supply voltage across the dc motor terminal also varies. Such operation is beneficial of critical control of the motor and can also be implemented in fast driving approach in specific application. From robotics to automobiles, small and medium sized motoring applications often feature DC motors for their wide range of functionality.

The MG995 DC servo motor is responsible for controlling the angle and position of the spray gun. The micro-controller sends signals to the servo motor, which rotates the motor shaft to the desired position. The motor's position is measured using feedback signals, which are used to ensure accurate positioning. It is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity, and acceleration.

Results and Discussion

The mechanism of spray-painting is modelled using RoboDK software and simulated for different path planning and motion of horizontal and cross slide (Figure 1). An optimum paint path has been generated and the time required for the paint area to be covered is ascertained.

The Arduino nano open architecture controller is implemented with the double H-bridge driver circuit using 4N25 isolated IC which is from U1 to U10. The IC U9 and U10 enables the supply to both the H-bridge depends on sequence of working of stepper motor programmed in embedded C. The Arduino caries the program for controlling the stepper motor. The stepper motor is used with this driver IC which drive the stepper motor in forward and reverse. direction as shown the simulation circuit in figure 2.

Figure 3 shows that the tracing of channel A, B, C, and D, that is operation of H-bridge driver circuit for stepper motor and switching sequence based on the application requirement. Figure 3 shows the operation for Horizontal Lead Screw Motor (HLSM). Figure 3a shows the enable 1 and enable 2 signal which is basically turning on U19 and U20 in figure 2. When enable 1 is high, the signal E2 and E5 are high and E3 and E4 are low as show in figure 3b, but when enable 2 signal is high, the signals E2 and E5 are low but E3 and E4 are high. Therefore, in this switching sequence, (U11, U14), (U15, U18), (U13, U12), and (U17, U16) operates for forward direction and vice versa for reverse direction. Figure 4 shows the operation for Vertical Lead Screw Motor (VLSM-1 and VLSM-2).

Figure 4a shows the enable 1 and enable 2 signal which is basically turning on U9 and U10 in figure 2. When enable 1 is high, the signal E2 and E5 are high and E3 and E4 are low as show in figure 4b but when enable 2 signal is high, the signals E2 and E5 are low but E3 and E4 are high. Therefore, in this switching sequence, (U1, U4), (U5, U8), (U3, U2), and (U7, U6) operates for forward direction and vice versa for reverse direction.

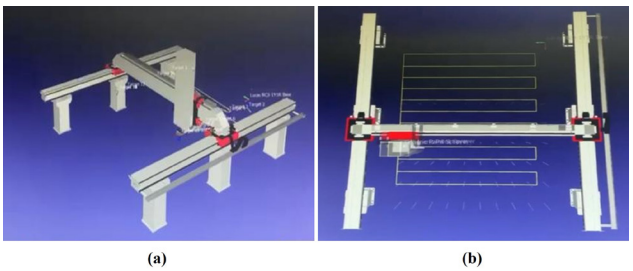

Figure 1: (a) Top view and **(b)** Front view of application simulation.

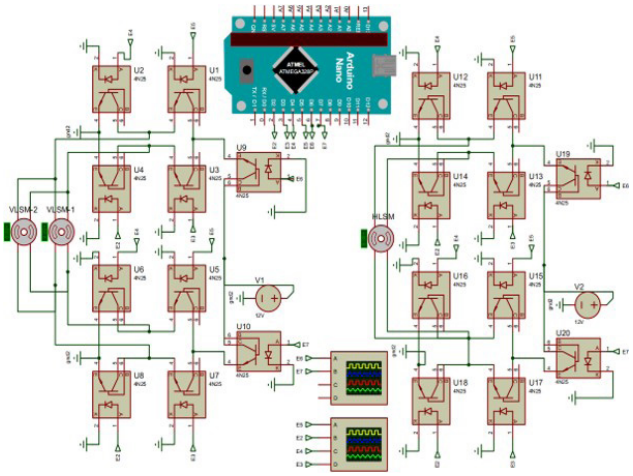

Figure 2: Designed H-bridge driver circuit simulation with vertical and horizontal lead screw stepper motor (VLSM and HLSM).

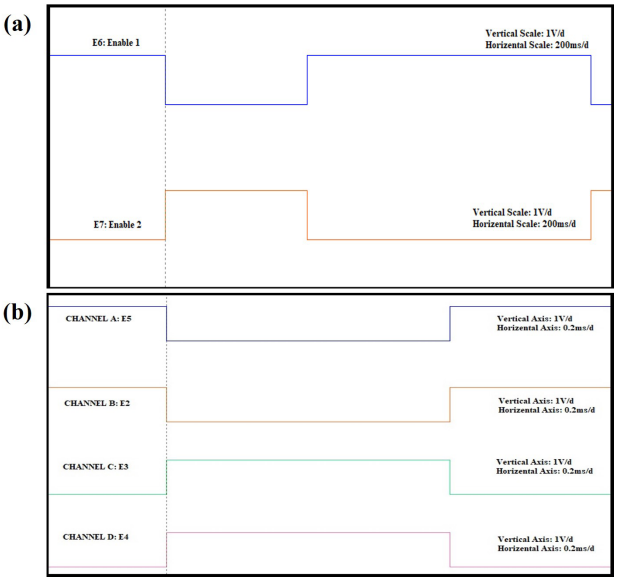

Figure 3: DSO output with stepper motor for four channels for forward direction of HLSM **(a)** Enable signal and **(b)** Channel A, B, C, and D.

The proposed automatic spray-painting robotic mechanism prototype shown in figure 5, where figure 5a shows vertical lead screw supported on vertical pillars and base, figure 5b shows horizontal lead screw with micro-controller, figure 5c shows horizontal and vertical slide assembly with motors and controllers.

An all-aluminum low-cost low-weight frame has been fabricated aluminum section due to its light weight and easy workmanship. the conceptual design of an autonomous spray-painting robot is described as it consist of two axis common rail spray paint for the walls which is fitted on a mobile robot base to give the lateral feed motion to cover the painting area. The design objective is to satisfy the criteria of simplicity, low-weight, low-cost, and fast painting time. An Arduino Uno based control system is programmed to give prescribe rotatory motions to lead screws for precise up and down movement as well as left to right movement to cover the area to be painted using a portable spray container with the mobile base in the present prototype. The control system consists of 3 stepper motor controlled by Arduino and motor controller are fitted, one on the movable horizontal lead screw supported on horizontal slide and two on upper fixed horizontal beam for two vertical lead screw. The spray nozzle is operated using a MG995 high torque motor. The mechanism offers several benefits, including increased efficiency, accuracy, reduced labor, enhanced safety, professional finish, applicable in various industries, reduced material waste, customizable, and cost-effective.

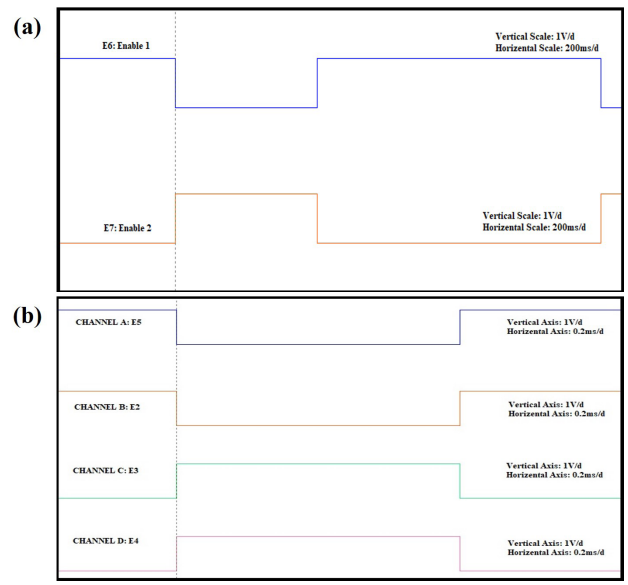

Figure 4: DSO output with stepper motor for four channels for forward direction of **(a)** VLSM-1 and **(b)** VLSM-2.

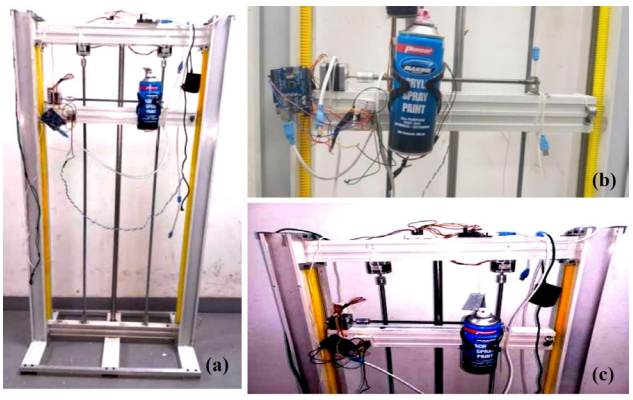

Figure 5: Prototype of spray-painting mechanism. **(a)** Vertical lead screw supported on vertical pillars and base, **(b)** Horizontal lead screw with micro-controller, and **(c)** Horizontal and vertical slide assembly with motors and controllers.

Conclusion

The H-bridge driver is developed using isolated 4n25 driver circuit embedded with the automatic wall spray-painting robots. Proposed driver circuit control the whole mechanism of the system. The system becomes beneficial for painting the chemicals on wall. The system is fast enough, it paints the wall of 1 sq. m. within 2 to 3 s with the vibration limit under the limit of 4 mils. Therefore, the hazard due to machine sufficiently reduced and also the indirect hazard due to human manual approach for wall painting also reduces. With this mechanism it will be possible to reduce the risk in painting tall building at elevated height.

Future Scope

The H-bridge driver is needed to be fast enough when synchronization with the micro-controller IC. This delay in the system to be addressed from system efficiency point of view. In future, lot more to be worked in the area of system improvement for deployment of such more drivers in the automation and robotics engineering.

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Conflict of Interest

None.

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