

Low Cost Industrial Paint Bot

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Abstract - This project aims to create an economical robotic arm system for painting parts in a manufacturing process line. The robotic arm system has 3 degrees of freedom (DOF) with an atomizing spray nozzle tip as its end effector. There are two different computers – one for the workstation to operate the robotic arm and another for the Human-Machine Interface (HMI) to take user inputs from a remote location. The user provides the pattern for the paint job and the robot performs the task over a 2D space. The overall process is simple and rugged along with small footprint which makes the system ideal for deployment in large scale production line.

Key Words: robotic arm, 3DOF, paint robot

1. INTRODUCTION

The advent of robotics in manufacturing industry has revolutionized the products developed today. Paints can be classified into two distinct categories – architectural, for buildings & structures and industrial for automobiles, defense and powder coatings. The industrial paints are the protective and heavy-duty coatings. These industrial paints can be harmful for human workers on factory floor and could lead to many health problems and diseases. To encounter this problem, we have implemented this robotic system which could be deployed in a closed chamber and can be operated remotely.

2. METHODOLOGY

The Figure 1 shows the overall idea behind the robotic system for the painting process.

The user provides the desired pattern of motion. The pattern could be provided in terms of consecutive points on the 2D plane. Python script runs on Computer 1 to get input co-ordinates processed using conversion factors on computer 1 to map the actual co-ordinates in the 2D workspace of the robotic system and Computer 1 sends the co-ordinates to Computer 2 through serial communication. Next, another Python script is running on computer 2 which will extract the co-ordinates and store them in an array. The code is configured with inverse kinematic equations to tabulate the angle of rotation for each joint motor. Then the drivers drive the motors simultaneously based on multithreading function running in the python code. There is no feedback mechanism required because of the structured code with failure proof functions, except the proximity sensors to detect the end points for the rotation of each joint motor.

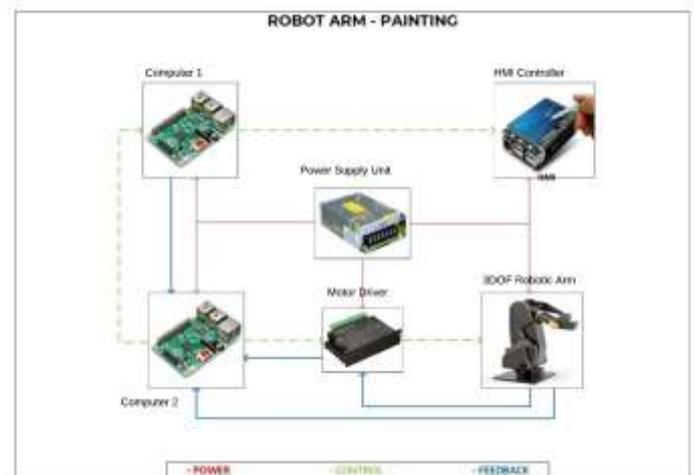


Fig -1: Block Diagram

The power supply unit, which consists of one 12V, 10A SMPS (Switched Mode Power Supply) box and three 12V transformers, provides sufficient power required by the system.

3. COMPONENTS USED:

1. Raspberry Pi 3 B+: For computer 1 & 2
2. Nextion NX3224T028 HMI Panel
3. PILOT WA 900 Automatic spray gun
4. Relay Board
5. Aluminium Sheets
6. Chromium plated Stainless Steel Rod: 2x12 feet, 8mm
7. Stainless Steel Gears: No. of Teeth – 10
8. Nut and Bolts: M3, M5, M8
9. NEMA 34 Stepper Motor: 3 Stepper motors are used for each joint.
10. Leadshine DM542 Digital Stepper Motor Driver
11. Mounted Ball Bearing: 8mm
12. Other components include: Mouse, Keyboard, Display, Wires, etc.

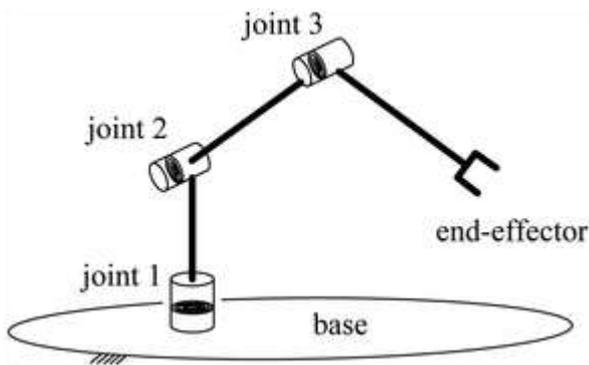


Fig -2: 3DOF Robotic ARM

4. INVERSE KINEMATICS

The Figure 2 shows the overview of the 3DOF Robotic Arm which has 3 joints across 3 links from the base to the end effector. The angle at each joint is θ_1 , θ_2 and θ_3 . To move the end effector to a particular co-ordinate in 3D space, say (x,y,z) , we need to find the angle of rotation for each motor through inverse kinematics. Let's consider length of each links from base as p , q and r cm respectively. The following are the equations for the present system:

$$\theta_1 = \text{atan}\left(\frac{y}{x}\right)$$

$$\theta_3 = \text{acos}\left(x^2 + y^2 + z^2 - p^2 - q^2 - r^2 - \left(\frac{p(z-p)}{qr}\right)\right)$$

$$\theta_2 = \text{atan}\left((z-p)\left(\frac{\cos\theta_1 - \sin\theta_1}{x-y}\right)\right) - \text{atan}\left(\frac{r\sin\theta_3}{q+r\cos\theta_3}\right)$$

5. MECHANICAL STRUCTURE

Figure 3 shows the structure for the 3DOF robotic arm which has a footprint of 550x600 mm and 500mm of height. The curb weight of 30 Kg. While the control panel is placed within 400x400x200 mm (LxBxH) box with the curb weight of 15 Kg. Materials used for chassis is Aluminium while the Gears were made from Stainless Steel. To support the structure, stainless steel rods and circular bearings were used. Maximum reach of the Arm is 920mm. It can carry a payload of around 6 Kg. The spray gun is actuated through pressurized air maintained at 6 Bar from the compressor. The outer body is made up of fiber reinforced plastic.



Fig -3: Paint Bot

5.1 Gears

The gears are the most distinct feature on this robotic arm since the other sophisticated robots generally use high precision, zero backlash Harmonic drive gears. But we have used Spur gears which are used in automobile and are already mass manufactured to reduce the cost of product.

5.2 Structure

The structure is designed based on a pair of four bar mechanism cascaded together for efficient and smooth transmission of drive from the motors to the links.

5.3 Drive

Stepper motors were used instead of servo for drive in order to reduce cost. High torque NEMA 34 stepper motors enables higher payload applications at competitive resolution which is sufficient for painting purpose.

6. EMBEDDED SYSTEM

The overall system can be divided into two segments – One for the operation of the robotic arm and other for the control panel. Both can be operated simultaneously at different location while communicating through a serial communication channel.

6.1 Robotic Arm

At the heart of the system is the single board computer 2 which is basically a Raspberry Pi 3 for computing the code for the manipulation of the arm. The General-Purpose Input Output (GPIO) pins are used sending control signals to the motor drivers as well as the relay board for the actuation of pneumatic valves for switching spray gun on-off and

receiving feedback from proximity sensors. Float level sensor is being used to measure the of paint present in the storage tank and indicate when it crosses the threshold limit.

6.1.1 Sensors

Infrared proximity sensors are used as limit conditions for the arm. Due to its fast response and non-invasive nature they can run for long time without failure in industrial conditions.

6.1.1 Actuators

Two relay channels are used to trigger the actuation of the spray gun for a required amount of time. High precision drivers with encoder feedback are used to drive the stepper motors to achieve accurate angle of rotation.

6.2 Control Panel

The user has two options for input – Area or Pattern. In Area option, more than two points forming an enclosed area needs to be selected for which the code will create a to & fro pattern while in the Pattern option, the exact pattern of the points selected will be processed for the paint job. The option for multiple number of repeat operations is there which can be based on sensor feedback on conveyor belt for a manufacturing facility.

6.2.1 Display Interface

The display is a resistive touch-based interface to select the points for paint operation. A python coded GUI displayed on the touchscreen allows user input of mode, run times and number of cycles the process should repeat while also displaying continuously updated system information.

6.2.2 Manual

In addition to automated control, the user also has the option to manually control the system with the physical switches on an external panel with LEDs that serve as a visual indicator of system status.

5. CONCLUSION

A low cost, robust industrial paint bot is developed which will significantly improve working conditions and reduce labor intensity in a factory floor. It will be beneficiary for Small scale industries to undertake mass production with the advantage of easy operation and low cost. It will help them raise their production rates and improve the quality. The proposed robot is specially used for spray painting interior and exterior surfaces of heavy vehicles with complicated shape and construction.

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