Robotic Spray Painting System

Authored by:

Amir Mohammad saffar (40006783)

&

Alireza Yahaghi (40010413)

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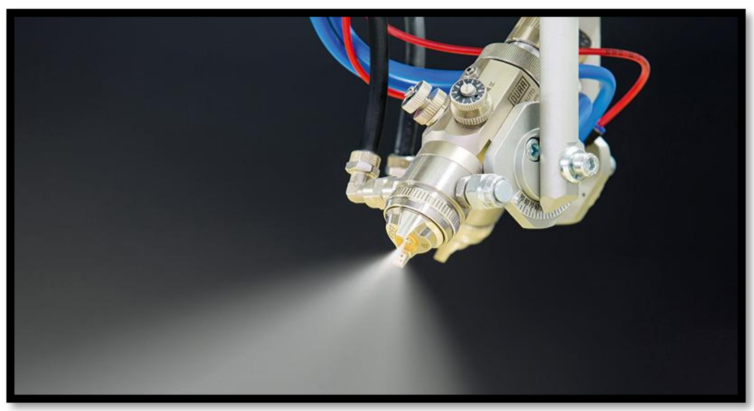
K. N. Toosi University of Technology

Faculty of Electrical Engineering - Department of Control

Preface and the reasons

The system we choose to work on for this semester is robotic-spray painting system. control systems in this robot use in different ways; like pump speed, articulated robots &…

We were interested in this subject because of its various usage. For example, you can easily change the tip of the system and make another system like an electric screw driver for manufacturing factories.

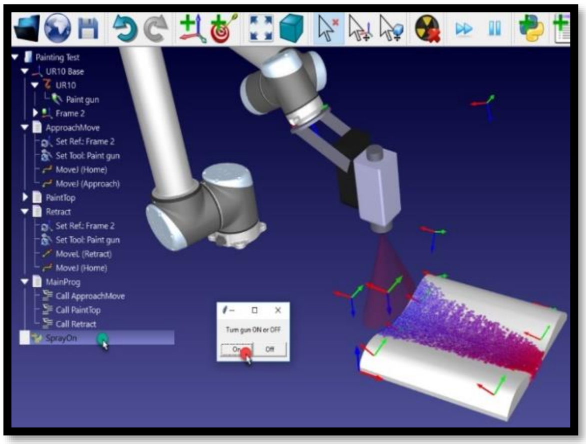


Usage:

A robotic spray-painting system uses spray and robotic arms to apply paint to various surfaces & objects for the benefits part we can mention:

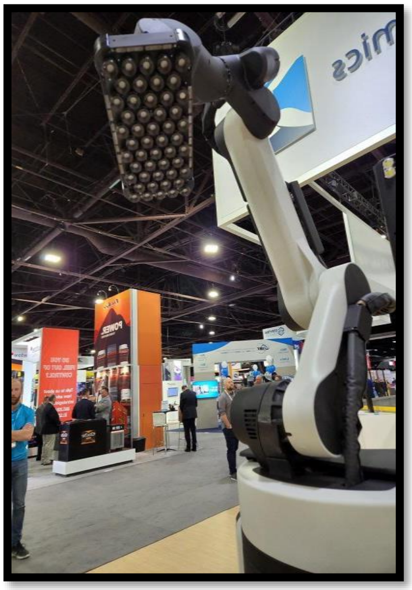
1. **Higher accuracy of the painting application.**
2. **Less material & energy consumption.**
3. **Faster production speed.**

4. Increase safety level.
5. Easier coordination with other components.
6. Color uniformity.



Now lets talk about the industries which use this system in their factories:

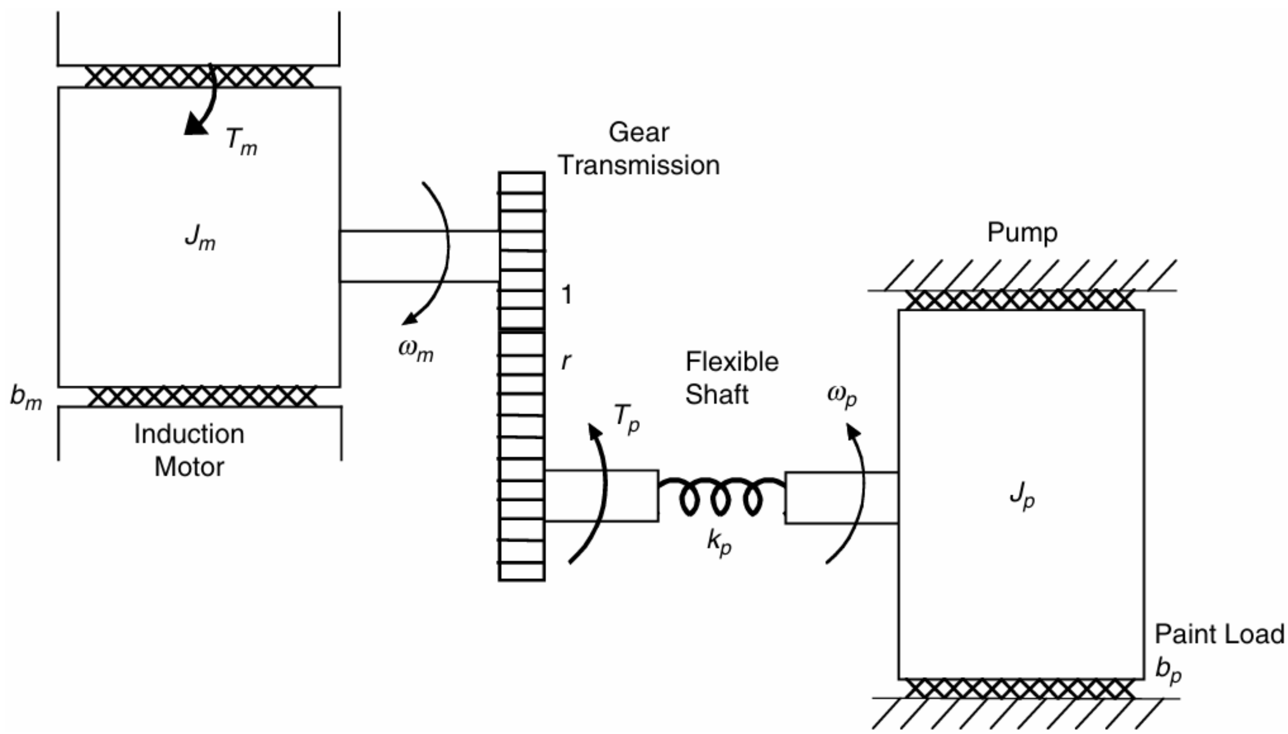
1. **Automotive (of course!)**
2. **Furniture**
3. **Metal fabrication**



The output of an induction motor & pump combination working together provides 15 g/min for the cluster of spray paint heads in all painting booths. Not all the parts like booths or painting heads work at the same time.

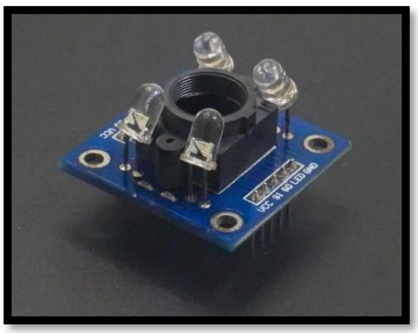
We can change pressure level to our desired number by controlling pump speed; here we choose 275 psi.

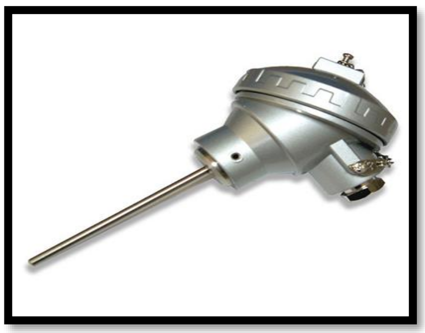
Beneath we have an approximal model for our systems.

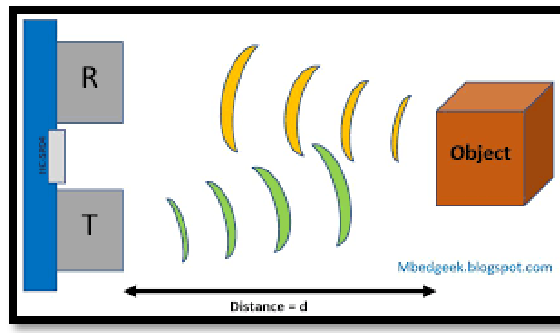


Robotic spray-painting system’s sensors:

- **Proximity sensor: Detects objects near it without physical contact. These sensors use electromagnetic fields, sound waves, or light rays to detect objects.**
- **Color sensor: Detects the surface's color and adjust the paint accordingly.**
- **Temperature sensor: Monitors the ambient and paint temperature, adjusting the painting process as needed.**
- **Motion sensor: Detects robot movement and adjust its speed and direction.**



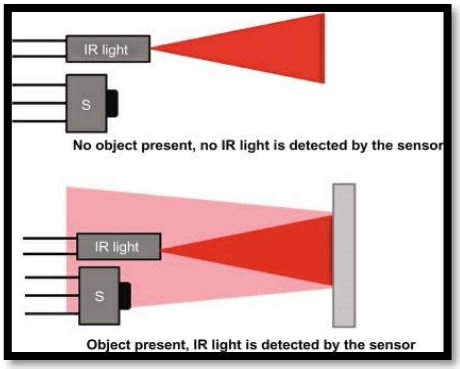


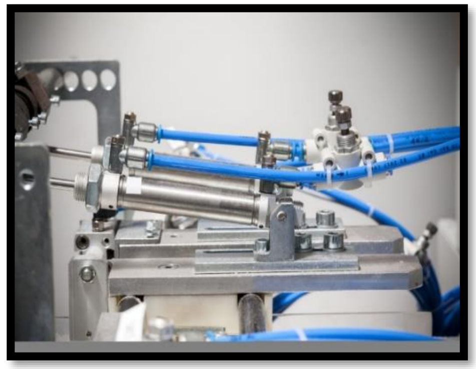


Actuators:

- **Ultra-sonic sensor: Uses sound waves for distance measurement. Affordable and reliable, but less precise than laser sensors.**
- **Leaser sensor: Uses a laser beam for precise distance measurement. More expensive than ultrasonic sensors but offers higher accuracy.**
- **Optical sensor: Uses light to detect color and other surface features. Suitable for complex designs and multiple colors.**
- **Servo motors: A type of electric motor that rotates with high precision at various angles. Used for robot arm movement and painting tool control.**
- **Pneumatic systems: Uses compressed air to move the robot's arms. Powerful and fast but can be noisy.**

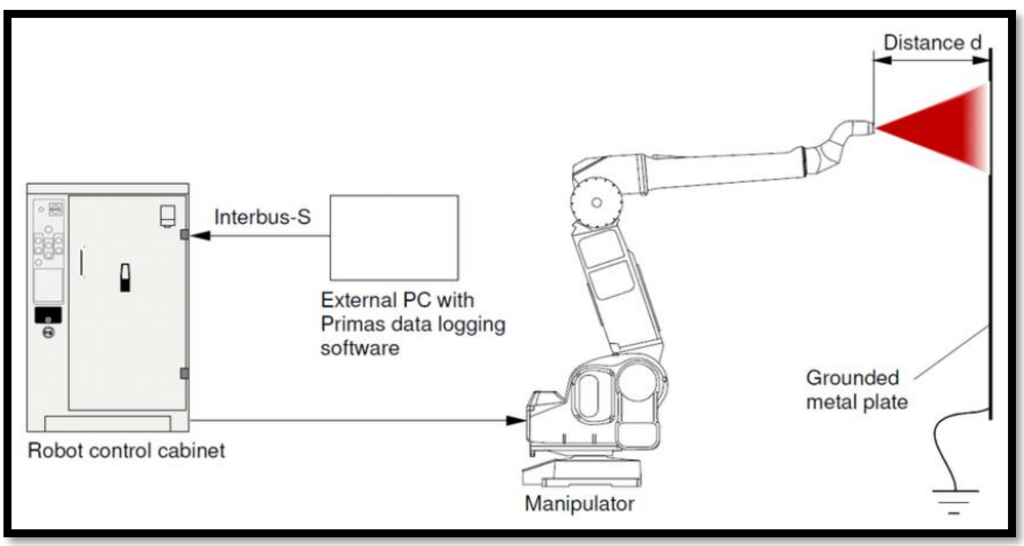
- **Hydraulic systems: Uses pressurized oil to move the robot's arms. Offers high power and torque but can be complex and expensive.**





Advanced Control Systems in Car Painting Robots:

- **Motion Control: Guides robot movements with precision.**
- **Paint Control: Adjusts painting parameters for optimal results.**
- **Safety Control: Ensures the safety of the robot and operator.**
- **Machine Vision: Allows the robot to see and understand its surroundings.**
- **Artificial Intelligence: Empowers autonomous learning and task execution.**



On this following page we have pages from Mechatronics: An Integrated Approach by Clarence silva which totally explains the questions we have here:

a) **What are the inputs to the system?**
b) **What do the motor parameters and T0 represent, with regard to motor behavior?**

I put the exact pages of book here to convey the meaning in the best way!

A.

Motor speed $\omega_m = \frac{d\theta_m}{dt}$

Load (pump) speed $\omega_p = \frac{d\theta_p}{dt}$

where
θ_m = motor rotation
θ_p = pump rotation.
Let T_g = torque transmitted by the motor to the gear. By definition, gear efficiency is given by

$$\eta = \frac{T_p r \omega_m}{T_g \omega_m} = \frac{\text{output power}}{\text{input power}}$$

Note that since r is the gear ratio, $r\omega_m$ is the output speed of the gear. Also power = torque × speed. We have

$$T_g = \frac{r}{\eta} T_p \quad \text{(i)}$$

Newton's second law (Torque = inertia × angular acceleration) for the motor:

$$T_m - T_g - b_m\omega_m = J_m\dot{\omega}_m \tag{ii}$$

Newton's second law for the pump:

$$T_p - b_p\omega_p = J_p\dot{\omega}_p \tag{iii}$$

Hooke's law (Torque = torsional stiffness × angle of twist) for the flexible shaft:

$$T_p = k_p\left(\frac{\theta_m}{r} - \theta_p\right) \tag{iv}$$

Equations ii through iii, and the derivative of Equation iv are the three state equations. Specifically, substitute Equation i into Equation ii:

$$J_m\dot{\omega}_m = T_m - b_m\omega_m - \frac{r}{\eta}T_p \tag{v}$$

Differentiate Equation iv:

$$\dot{T}_p = k_p\left(\frac{\omega_m}{r} - \omega_p\right) \tag{vi}$$

Equation iii:

$$J_p\dot{\omega}_p = T_p - b_p\omega_p \tag{vii}$$

Equations v through vii are the three state equations. Note that this is a nonlinear model with the state vector $[\omega_m \quad T_p \quad \omega_p]^T$. The input is T_m. Strictly,

$$T_m = \frac{T_0 q\omega_0(\omega_0 - \omega_m)}{\left(q\omega_0^2 - \omega_m^2\right)} \tag{viii}$$

There are two inputs: ω_0 (the speed of the rotating magnetic field, which is proportional to the line frequency) and T_0 which depends quadratically on the phase voltage.

B.

When $\omega_m = 0$ we note from Equation viii that $T_m = T_0$. Hence T_0 = starting torque of the motor.

Also, from Equation viii we see that when $T_m = 0$, we have $\omega_m = \omega_0$. Hence, ω_0 = no-load speed.

This is the synchronous speed—Under no-load conditions, there is no slip in the induction motor (i.e., actual speed of the motor is equal to the speed ω_0 of the rotating magnetic field).

Differentiate Equation viii with respect to T_0, ω_0, and ω_m. We have

$$\frac{\partial T_m}{\partial T_0} = \frac{q\omega_0(\omega_0 - \omega_m)}{\left(q\omega_0^2 - \omega_m^2\right)} = \beta_1 \text{ (say)} \tag{ix}$$

Note that β_1 is positive.

$$\begin{aligned}\frac{\partial T_m}{\partial \omega_0} &= \frac{T_0 q\left[\left(q\omega_0^2 - \omega_m^2\right)(2\omega_0 - \omega_m) - \omega_0(\omega_0 - \omega_m)2q\omega_0\right]}{\left(q\omega_0^2 - \omega_m^2\right)^2} \\ &= \frac{T_0 q\omega_m\left[(\omega_0 - \omega_m)^2 + (q-1)\omega_0^2\right]}{\left(q\omega_0^2 - \omega_m^2\right)^2} = \beta_2 \text{ (say)}\end{aligned} \tag{x}$$

Note that β_2 is positive.

$$\begin{aligned}\frac{\partial T_m}{\partial \omega_m} &= \frac{T_0 q\omega_0\left[\left(q\omega_0^2 - \omega_m^2\right)(-1) - (\omega_0 - \omega_m)(-2\omega_m)\right]}{\left(q\omega_0^2 - \omega_m^2\right)^2} \\ &= -\frac{T_0 q\omega_0\left[(q-1)\omega_0^2 + (\omega_0 - \omega_m)^2\right]}{\left(q\omega_0^2 - \omega_m^2\right)^2} \\ &= -b \text{ (say)}\end{aligned} \tag{xi}$$

Note that b is positive.

You may also like:

https://www.youtube.com/watch?v=yfzYUCZM3fE&ab_channel=PaintingRobot

https://www.youtube.com/watch?v=iSc-oCt8SD0&ab_channel=ConceptSystems%2CInc

https://www.youtube.com/watch?v=gUWCljX7oa0&ab_channel=CMARobotics

https://www.youtube.com/watch?v=ab-XvpG5PBM&ab_channel=APEXCars

https://www.youtube.com/watch?v=YTwsWrpy_zo&ab_channel=BrombalWindows%26Doors

https://howtorobot.com/expert-insight/painting-robots

Sources:

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