German University in Cairo
Mechatronics Engineering Department
MCTR601

Project Proposal

13/3/2025

Object Classifying Robotic Arm

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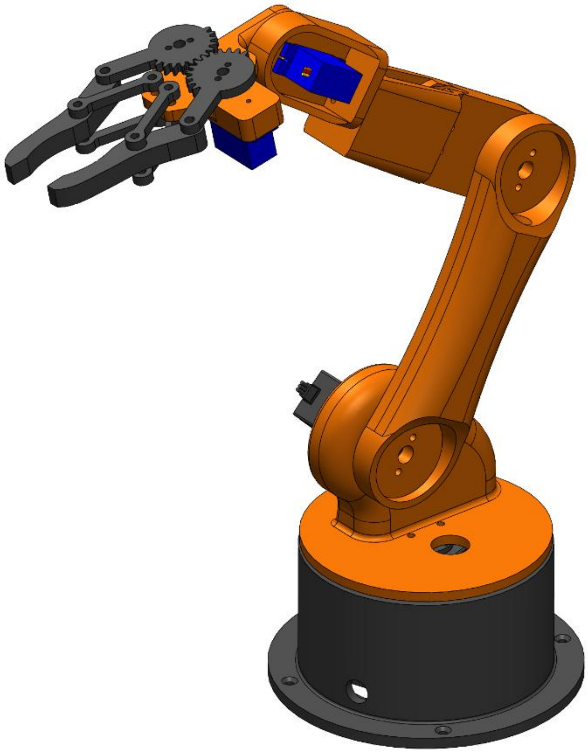
Overview:

This project involves designing and implementing a simple robotic arm capable of classifying and sorting objects based on their color. The robot picks up randomly placed balls from a central basket and places them into designated bins based on their color.



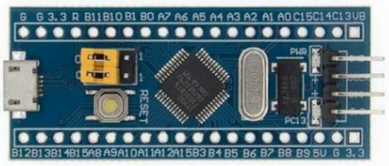
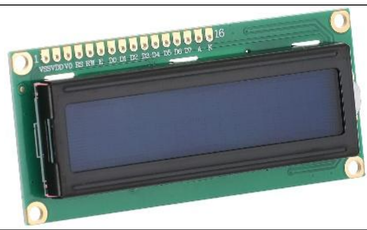
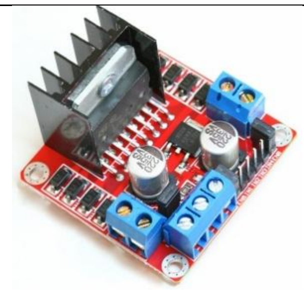
Working Principle

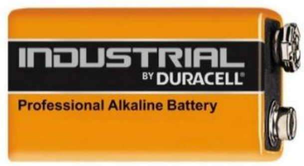
1. The robotic arm picks up a ball from the central basket.
2. A color detection sensor determines whether the ball is blue or red.
3. Based on the detected color, the arm moves and places the ball into the corresponding basket:
    - **Blue ball → Right basket**
    - **Red ball → Left basket**
4. The process repeats for each ball until the central basket is empty.

Applications

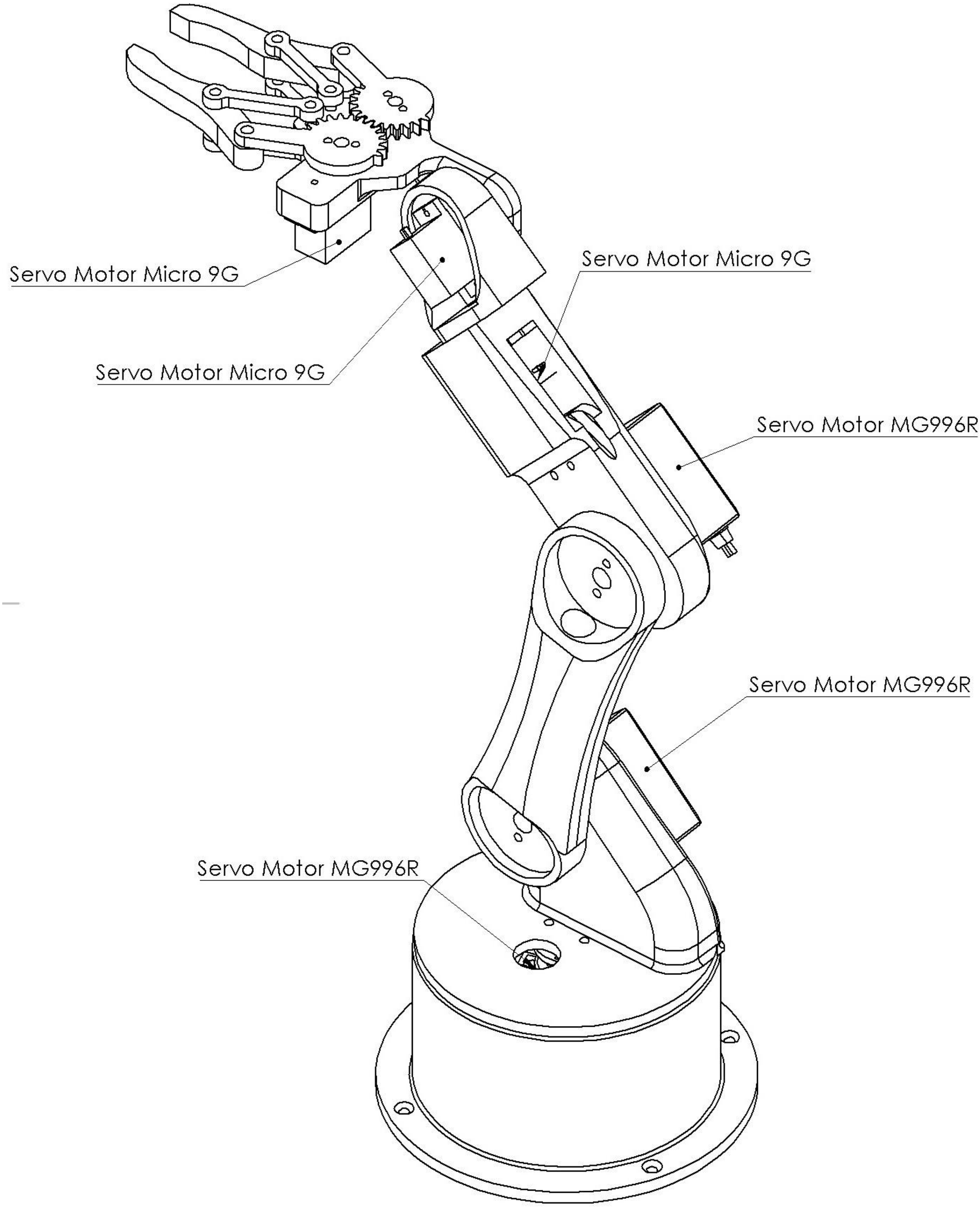
- **Automation and Sorting Systems:** This project simulates basic industrial sorting applications.
- **AI & Machine Learning Integration:** Can be expanded by integrating machine learning for improved object recognition.
- **STEM Education:** Provides a hands-on experience in robotics, sensors, and automation.

Components List:

Component	Number	Picture
STM32F103C8T6 Microcontroller	1	
16x2 LCD	1	
Servo Motor MG996R	3	
Servo Motor Micro 9G	3	
l289 h-bridge driver module	2	
Color Sensor TCS3200	1	

Ultrasonic Sensor HC-SR04	1	
AC/DC 5A Current Sensor Module ACS712-5A	1	
9 VDC Batteries	6	
Push Buttons	5	
Potentiometer	1	
Blue & Red LEDs	2	

Motors Distribution:

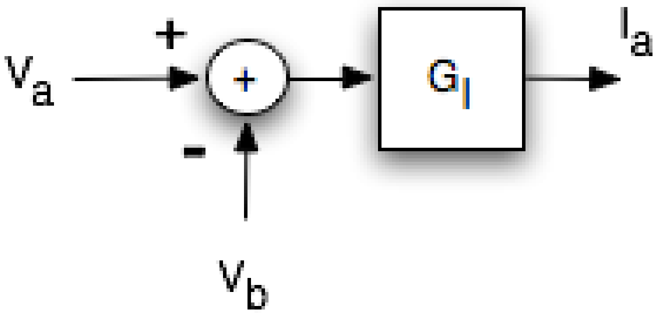


Dynamic Model:

The DC servomotor transfer function block diagram can be created through an examination of the armature current equation. Ohm's law for impedances is used to write the armature current equation in the s-domain. Note that the equation includes both real and imaginary parts of the impedance. The reactance is inductive.

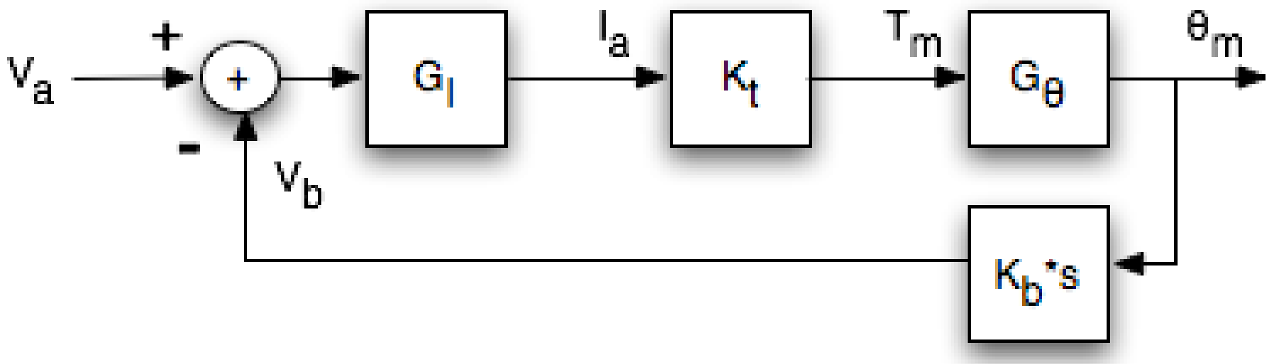
$$I_a = \frac{V_a - V_b}{R_a + s * L_a} = \left(\frac{1}{R_a + s * L_a}\right) * (V_a - V_b) = G_I * (V_a - V_b)$$

The block diagram model of this equation:

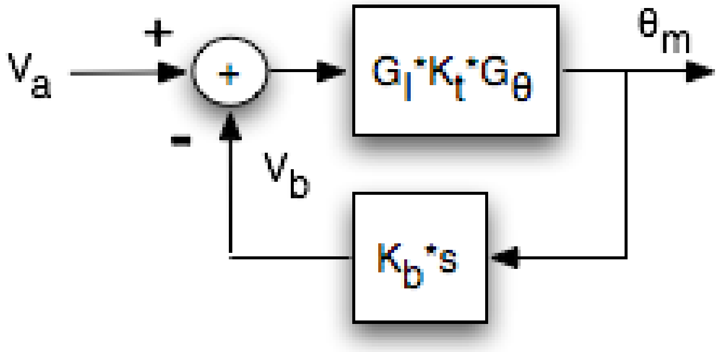


Similarly, the equations of motion can be used to relate the armature current to torque, torque to angular displacement, and angular displacement to the back-emf.

The complete block diagram:



Note that this actuator is a feedback system that can be reduced to the standard form for derivation of the gain. The series gain path is reduced to an equivalent gain through multiplication. The reduced block diagram is shown in the following figure. The forward path gain is traditionally called G while the feedback path gain is H.



The gain can be calculated directly from the reduced block diagram:

$$TF = \frac{\theta_m}{V_m} = \frac{G}{1+GH} = \frac{G_I * K_t * G_\theta}{1 + (G_I * K_t * G_\theta)(K_b * s)}$$

Note that the denominator contains a + sign because the block diagram has negative feedback at the summation node. The denominator would contain a - sign if the block diagram used positive feedback.

Color Detection System:

The **TCS3200 color sensor** converts the light intensity from the RGB color filters into a frequency output. We can model the sensor's output as follows:

- The TCS3200 outputs a frequency proportional to the intensity of the color detected. The higher the intensity of a specific color (e.g., red or blue), the higher the frequency.

We can model the color sensor's output frequency $f_{color}(t)$ based on the intensity of the color:

$$f_{color}(t) = K_{color} . I_{color}(t)$$

Where:

- $f_{color}(t)$ = Frequency output of the TCS3200 sensor.
- K_{color} = Calibration constant for the specific color
- $I_{color}(t)$ = Light intensity of the color detected (which corresponds to the ball's color).

For color detection:

- If $f_{color} > Threshold_{blue}$, classify as **blue**.
- If $f_{color} > Threshold_{red}$, classify as **Red**.

This means the system classifies the ball based on the frequency of the sensor output and compares it to predefined thresholds to decide which color is detected.

Ultrasonic Sensor:

The **HC-SR04 ultrasonic sensor** measures distance based on the time of flight of the ultrasonic pulse. The distance d to the object is given by:

$$d(t) = \frac{c.t}{2}$$

Where:

- c = Speed of sound in air (~343 m/s).
- t = time taken for the pulse to travel to the object and back).

This sensor will be used to determine the position of the balls in the basket, helping the robot decide where to pick up the balls.

System Identification:

1. Servo Motor Parameters

For MG996R Servo Motor:

- Motor Constant K_m = **0.3 N·m/A**
- Moment of Inertia J = **1.0 × 10^{-6} kg·m²**
- Damping Coefficient b = **0.01 N·m·s/rad**

For Micro 9G Servo Motor:

- Motor Constant K_m = **0.1 N·m/A**
- Moment of Inertia J = **5.0 × 10^{-7} kg·m²**
- Damping Coefficient b = **0.005 N·m·s/rad**

2. Ultrasonic Sensor (HC-SR04) Parameters

For the **HC-SR04 ultrasonic sensor**, the key parameter to identify is the **speed of sound c**, which is 343 m/s at room temperature.