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A THESIS REPORT   
TO BE SUBMITTED IN FINAL FULFILLMENT OF THE REQUIREMENTS   
FOR THE DEGREE OF   
   
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in   
Electronics and Communication Engineering   
   
[INDUSTRIAL ROBOTICS ARM]   
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UNDER THE SUPERVISION OF   
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CERTIFICATE OF APPROVAL   
   
   
The thesis report of the final year project titled “Industrial Robotic Arm”   
 of Bachelor of Technology (ECE) 8  
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session 2022 - 2023 is hereby recommended to be accepted for the final   
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ABSTRACT   
   
This thesis presents the design and development of a robotic arm, focusing   
on the key aspects of its mechanical structure, control system, and user interface.   
The robotic arm is intended to perform precise and controlled movements for   
various applications. The project utilizes a combination of hardware and software   
technologies to achieve the desired functionality.   
   
The mechanical design of the robotic arm includes components such as a   
sturdy base, flexible joints, and a versatile gripper. The selection and integration   
of motors, including stepper motors and servo motors, are discussed in detail,   
considering factors such as torque requirements and positional accuracy.   
Additionally, structural analysis techniques are employed to ensure the arm's   
strength and rigidity.   
   
In terms of the control system, Arduino is utilized for coding the arm's   
functionality, enabling precise control over joint movements and coordination   
between different motors. The software algorithms implemented in Arduino ensure   
accurate positioning, smooth motion, and responsive interaction with user   
commands. Meanwhile, Processing is employed to design an intuitive user   
interface that allows users to interact with the robotic arm through a graphical   
interface, enabling easy command input, parameter adjustments, and real-time   
monitoring.   
   
The project also explores the integration of sensors, such as ultrasonic   
sensors, for enhanced functionality and safety. These sensors enable the arm to   
detect and respond to its environment, avoiding collisions and ensuring efficient   
object manipulation.   
   
Through a comprehensive design and development process, the robotic   
arm is realized, providing a practical and versatile tool for various applications.   
The project contributes to the field of robotics by showcasing the integration of   
mechanical design, control systems, and user interface development to create an   
effective and user-friendly robotic arm system.   
  
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INTRODUCTION   
   
   
   
1.1 Introduction   
   
Since many years people try to replace human work with   
machines. Machines called robots are faster and more   
effective than people. The term robotics is practically defined   
as the study, design and use of robot systems for   
manufacturing. Robots are generally used to perform unsafe,   
hazardous, highly repetitive, and unpleasant tasks. They have   
many different functions such as material handling, assembly,   
arc welding, resistance welding and machine tool load and   
unload functions, painting, spraying, etc. Many elements of   
robots are built with inspiration from the nature. Construction   
of the manipulator as the arm of the robot is based on human   
arm. The robot has the ability to manipulate objects such as   
pick and place operations. It is also able to function by itself.   
The development of electronic industry robot system   
technology has been expanded increasingly. As one such   
application, the service robot with machine vision capability   
has been developed recently.   
  
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1.2 Robotic Arm Definition   
   
A Robotic arm is basically a machine which is very similar to a human hand, it   
consists of a combination of links attached in series or parallel. It can be   
controlled by programming it to perform a specific task.   
   
Joints of the manipulator connect the links that leads to the displacement which   
is either transitional or rotational. A kinematic chain is formed by the links of the   
arm. End Effector is the terminating part of this kinematic chain and it can be   
considered as the hand of a human.   
   
1.2.1 Types of Robotic Arms:   
   
 Cartesian robot:- Three prismatic joints , whose axes are coincident with a   
Cartesian co-ordinate constitute a Cartesian robot. Arc welding, handling   
precision tools and pick and place work are some of its application.  
 Cylindrical robot:- A robot having axes that forms a cylindrical co-ordinate   
system is called as cylindrical robot. Some of its applications include   
assembly operations, handling at machine tools, spot welding, and handling   
at die-casting machines.  
 Spherical robot:- A robot having an axes that forms a polar co-ordinate   
system is called a spherical robot. It is used for applications such as handling   
machine tools, spot welding, diecasting, fettling machines, gas welding and   
arc welding etc.  
 Scara Robot:- Two rotary joints which are parallel and are used to provide   
compliance in a plane constitutes a robot termed scara. Its applications   
include pick and place work, sealant, assembly operations and handling   
machine tools.  
 Articulated robot: - A robot consisting of an arm having atleast 3 rotary   
joints is termed as Articulated. It is used in diecasting, assembly operations,   
fettling machines, gas welding, arc welding and spray painting.  
  
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 Parallel Robot:- Arms having concurrent prismatic or rotary joints constitute a   
parallel robot. One of the use is a mobile platform handling cockpit flight simulators.  
 Anthropomorphic robot:- A robotic arm which is similar to a human hand i.e.   
consists of independent fingers and thumbs is called as Anthropomorphic robot.  
   
   
   
   
Figure 1.1: Common Robotics Arm Configuration   
  
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1.3 Research Objective   
   
The objective of this section is to outline the research objectives of   
developing a robotic arm for your final year project. The research   
objectives serve as the foundation for your project and provide a clear   
direction for your research activities. This section will highlight the key   
goals and targets that you aim to achieve through your project, guiding   
the reader through the purpose and significance of your research.   
   
 Design and Development:- The primary objective of this research is   
to design and develop a functional robotic arm capable of performing   
a range of tasks. This includes exploring various design methodologies,   
kinematic configurations, and mechanical structures to create an   
efficient and reliable robotic arm.   
 Kinematics and Control:- An important research objective is to   
investigate kinematic modeling techniques and develop a control   
system that enables precise and accurate movements of the robotic   
arm. This involves studying forward and inverse kinematics, trajectory   
planning, and implementing appropriate control algorithms for different   
robotic arm configurations.   
 Sensing and Perception:- The objective is to incorporate sensory   
capabilities into the robotic arm system to enhance its interaction with   
the environment. This involves researching and integrating sensors   
such as proximity sensors, force/torque sensors, and vision systems to   
enable object detection, grasp control.   
  
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 Human-Robot Interaction: An important objective is to investigate   
human-robot interaction aspects, enabling intuitive and user-friendly   
control interfaces for the robotic arm. This may involve studying   
gesture recognition, voice commands, or haptic interfaces to facilitate   
seamless collaboration between the user and the robotic arm.   
 Safety and Reliability:- The research objective focuses on ensuring   
the safety and reliability of the robotic arm system. This includes   
studying safety protocols, implementing fault detection and recovery   
mechanisms, and conducting rigorous testing to ensure the system's   
robustness and adherence to industry standards.   
   
   
   
Figure 1.2: Robotics Arm 2D Design   
  
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CHAPTER 2   
   
   
DESIGN CHOICE OF ROBOTICS ARM   
   
   
   
2.1 Arm design   
   
In this section the motivation behind the design of the arm is   
discussed. In the first part of this section the requirements for the arm will   
be discussed, hereafter the design options will be presented. These design   
options will be discussed in the considerations, and in the last part of this   
section a conclusion will be given on the design choice.   
   
2.1.1 Requirements   
   
The following requirements follow from the task that Zebro needs to   
accomplish:-   
   
1. Reach up to 1.3 m high   
2. Stable end effector control   
3. Movement to flip a switch   
4. Movement to scoop   
5. Movement to handle a drill and turn a knob   
6. Compact and Modular Design   
  
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2.1.2 Design Consideration for Arm   
   
   
   
The following were put into consideration in the design process:-   
   
i. Electrical actuators DC servo are chosen instead of hydraulic and pneumatic   
actuators because of the little power requirement and its light weight which is   
suitable for this design.   
ii. Materials used for the fabrication were locally sourced from available materials.   
iii. The materials which will be used for the design will be light in weight so as to   
reduce the weight concentration on the base and the shoulder.   
iv. Rectangular sheets instead of blocks are chosen for the links because of their   
light weight and stability and to reduce the weight of the arm.   
v. A continuous path controller was chosen (PIC micro controller was used).   
vi. The torque is fully balanced by the inertia of the electric motors.   
   
   
   
   
   
Figure 2.1 The Arm design that we considered   
  
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2.2 Motor choice   
   
In this chapter the motor type choice will be discussed. First the   
requirements will be discussed and several options for motor type will be   
explained. Hereafter the options will be considered compared to each other   
and the choice will be made in the conclusion.   
   
2.2.1 Requirements   
   
For the motor there are several requirements. Some come from   
the robotic arm design (e.g. torque specifications) and others from the   
power consumption, these requirements are:-   
1. One motor needs to move a joint   
   
2. A motor needs to deliver the right amount of torque to move a joint   
   
3. The motor should have a suited torque to weight ratio   
   
4. The power consumption should be kept as low as possible   
   
5. One type of motor should be chosen, to keep the system modular.   
   
2.2.2 Option Available   
   
   
There is quite a list of electric motors, but the brushed DC motor,   
brushless DC motor and stepper motor are used most commonly in robotic   
designs. Another type of motor that is not used as much, but can be   
considered is the induction motor (asynchronous AC motor). The   
following motor types will be discussed:   
  
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• Brushed DC motors   
   
• Brush less DC motors   
   
• Stepper motors   
   
• Servo Motor   
   
   
   
   
Brushed DC motors:- are commonly used in robotic arm   
applications due to their simplicity, ease of control, and cost- effectiveness.   
These motors consist of a stator with fixed electromagnets or permanent   
magnets and a rotor with windings. The brushes and commutator   
mechanism enable the conversion of electrical current into rotational   
motion. With precise control over the input voltage, brushed DC motors   
offer accurate speed and position control.   
   
   
Fig 2.2: Brushed DC Motor Model   
  
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Brushless DC (BLDC) motors:- have gained significant popularity   
in robotic arm applications due to their superior performance and   
efficiency compared to brushed DC motors. Unlike brushed DC   
motors, BLDC motors do not have brushes and commutators.   
Instead, they utilize a permanent magnet rotor and a stator with   
multiple windings. The motor's operation is controlled by an   
electronic drive system that energizes the stator windings in a   
specific sequence, resulting in smooth and precise rotational   
motion.   
   
Fig 2.3: Brush less DC Motor Model   
   
   
Stepper motors:- are widely used in robotic arm applications   
due to their precise positioning capabilities and ease of control.   
These motors are electromechanical devices that convert electrical   
pulses into discrete mechanical movements or steps. Unlike   
continuous rotation motors, stepper motors move in small   
increments, allowing for accurate control over position and   
velocity.   
  
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Stepper motors consist of a rotor with permanent magnets and a   
stator with multiple coils or windings. The stator windings are   
energized in a specific sequence, causing the rotor to align with   
the magnetic field generated by the energized coils. By controlling   
the sequence and timing of these pulses, the stepper motor can   
move with high precision and repeatability.   
   
Fig 2.4: Stepper Motor Model   
   
Servo motors:- Servo motors are widely utilized in robotic arm   
applications due to their ability to provide precise position,   
velocity, and torque control. These motors consist of a small DC   
motor combined with a feedback control system, typically in the   
form of a potentiometer or an optical encoder. This feedback   
mechanism allows the servo motor to accurately monitor its   
position and make adjustments accordingly.   
Servo motors are typically driven by dedicated servo motor   
   
controllers or drivers, which generate the appropriate control   
  
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signals based on the desired position or velocity input. These   
controllers interpret the command signals and provide the   
necessary power and control signals to the motor, ensuring   
accurate positioning and movement.   
Overall, servo motors are well-regarded in robotic arm   
applications for their precise control, high torque output, and   
smooth motion. Their closed-loop feedback system and flexibility   
in adjusting torque and speed make them a preferred choice for   
achieving accurate and controlled movements in robotic arm   
joints.   
   
   
   
   
Fig 2.4: Servo Motor Model   
   
   
   
2.2.3 Consideration   
   
   
In the selection process for the robotic arm motor, two promising options   
were considered: servo motors and NEMA 17 stepper motors. Servo   
  
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motors were chosen for their precise position control, closed-loop feedback   
system, and ability to deliver high torque output. Their closed-loop control   
ensures accurate positioning, while the feedback mechanism allows for   
continuous monitoring and adjustment of the motor's position. On the   
other hand, NEMA 17 stepper motors were also considered for their precise   
step-by-step movements and simplicity of control. They offer excellent   
positional accuracy and repeatability, making them suitable for applications   
that require precise joint movements. Ultimately, the choice between servo   
motors and NEMA 17 stepper motors depends on the specific requirements   
of the robotic arm project and the desired balance between precision,   
complexity, and control versatility.   
   
   
   
Fig 2.5: NIMA 17 Stepper Motor Fig 2.6: Servo Motor   
   
   
   
2.3 Joint controller choice   
   
To control the arm and be able to move the joints in the   
desired positions a controller has to be designed. This section   
describes the requirements for the controller, several options to   
  
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meet the requirements and the considerations about each of these   
options. Finally the choice of the controller is made and described   
in the conclusion.   
2.3.1 Requirements:   
   
For the controller of the arm the following requirements are found:   
   
1. The desired position must be reached   
2. The joints need to hold the desired position within a certain range   
   
   
The first requirement is quite straightforward. In order to   
perform the task described in section 1 the arm needs to be in the   
right position. The acceptable error in this position will be   
determined when the entire arm is completed. This way it can be   
guaranteed that the end effector can perform the tasks. The second   
requirement means that, when the desired position is reached, the   
joint must stay in this position without excessive vibrations. The   
maximum angle of vibration allowed will also be determined based   
on tests using the complete arm.   
   
2.3.2 Options Available:   
   
Several options for implementing the joint level controller   
are considered:   
   
 Proportional-Integral-Derivative (PID) Controller   
 Adaptive Control   
 Model Predictive Control (MPC)   
 Fuzzy Logic Controller   
 Neural Network Controller   
 IR Remote Controller   
  
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Proportional-Integral-Derivative (PID) Controller: PID controllers are widely   
used due to their simplicity and effectiveness. They utilize proportional, integral, and   
derivative terms to control the joint's position and velocity. The proportional term   
provides immediate response to the error, the integral term helps eliminate steady-   
state errors, and the derivative term improves stability and dampens oscillations.   
   
   
   
In equation 1 u(t) is the output of the controller, e(t) is the input of the controller   
and Kp, Ki and Kd are the proportional, integrating and derivative parameters   
respectively. e(t) is the difference between the input of the entire system, for   
example the angle needed for the joint, r(t) and the output of the system.   
   
   
Adaptive Control: Adaptive control algorithms adjust the controller's parameters   
based on real-time feedback and system identification. These controllers can adapt   
to changes in the arm's dynamics or external conditions, ensuring accurate and   
stable control in varying environments.   
   
Model Predictive Control (MPC): MPC utilizes a dynamic model of the robotic arm   
to predict future behavior and optimize control inputs accordingly. It can account for   
constraints, such as joint limits and torque limits, and generate control signals that   
optimize performance while adhering to these constraints.   
   
   
Fuzzy Logic Controller: Fuzzy logic controllers use linguistic variables and rules to   
determine control actions. These controllers can handle uncertainties and non-   
linearities in the system and are particularly useful when precise mathematical   
models are not available.   
   
   
   
  
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IR Remote Controller: The infrared (IR) remote controller contains a specialized   
controller that manages the functionality of the remote. This controller is typically   
implemented using a microcontroller or a dedicated IC. It processes user input from   
the remote's buttons or other input mechanisms, generates the appropriate IR   
signals, and modulates them to transmit specific commands to the target device.   
   
The IR remote controller's design focuses on efficient encoding and decoding of IR   
signals, ensuring reliable transmission and control over various devices within the   
remote's range. Additionally, it may include power management features to optimize   
battery usage and enable extended operation.   
   
In addition to handling user input and generating IR signals, the IR remote controller   
often incorporates features to enhance the user experience and functionality. This   
may include programming capabilities to customize the remote's control codes or   
functions, allowing users to configure the remote for different devices. Some   
advanced IR remote controllers may also include built-in learning capabilities,   
enabling them to capture and replicate commands from other remotes. Furthermore,   
the controller may incorporate error detection and correction mechanisms to ensure   
accurate transmission of commands, enhancing the reliability and responsiveness of   
the remote control system. With its compact design and efficient control capabilities,   
the IR remote controller provides a convenient and intuitive means of operating   
devices from a distance.   
   
2.3.3 Consideration:   
   
When considering the use of an IR remote controller, it offers a convenient and user-   
friendly solution for operating devices from a distance. The IR remote controller   
consists of a handheld device that incorporates buttons or other input mechanisms,   
allowing users to send commands to various devices equipped with IR receivers. The   
controller utilizes infrared signals to transmit specific codes or command sequences,   
which are recognized and executed by the target device.   
   
The IR remote controller is designed to provide ease of use and simplicity. With its   
compact size and intuitive button layout, users can easily navigate through different   
  
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functions and control various aspects of their devices, such as changing channels on   
a TV or adjusting volume levels on an audio system. The wireless nature of IR   
communication eliminates the need for direct line-of-sight or physical connections,   
providing freedom and flexibility in controlling devices from different angles or   
locations within the remote's range.   
   
The IR remote controller has become an integral part of our daily lives, offering   
convenience and seamless control over a wide range of devices. Its simplicity and   
ease of use make it accessible to users of all ages and technical backgrounds.   
   
Overall, the IR remote controller serves as a practical and widely adopted solution   
for managing devices remotely. Its straightforward operation, versatility, and broad   
compatibility make it a popular choice for controlling a diverse range of appliances,   
entertainment systems, and other electronic devices in homes, offices, and various   
other settings.   
   
   
   
   
   
Fig 2.7: IR Transmitter and Receiver   
  
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CHAPTER 3   
   
STRUCTURAL ANALYSIS OF ROBOTIC   
ARM   
   
   
3.1 Introduction   
Structural analysis plays a vital role in the design and optimization of robotic arms. It   
involves the examination and evaluation of the arm's structural components, such as   
links, joints, and supporting elements, to ensure their strength, rigidity, and overall   
performance. The purpose of structural analysis in a robotic arm is to determine the   
structural integrity and safety of the arm under various operating conditions,   
including the applied loads, dynamic forces, and environmental factors. By utilizing   
advanced computational tools and techniques, engineers can assess the arm's   
structural behavior, identify potential weaknesses or areas of improvement, and   
make informed design decisions to enhance its overall reliability, precision, and   
longevity. Effective structural analysis enables the design and construction of robotic   
arms that can withstand operational demands, maintain positional accuracy, and   
operate safely in diverse real-world applications.   
   
3.2 2D Model of Arm Working   
   
Using Tinkercad, a powerful and user-friendly 3D modeling platform, I have   
created a detailed model of the robotic arm. The Tinkercad model accurately   
represents the arm's structural components, including the links, joints, and end   
effector, providing a visual representation of the arm's design and functionality. By   
leveraging Tinkercad's intuitive interface and versatile design tools, I was able to   
meticulously construct and assemble the various parts of the robotic arm, ensuring   
precise alignment and realistic geometry. The Tinkercad model serves as a valuable   
tool for visualization and evaluation, allowing for virtual simulations, measurements,   
and design modifications. It provides a tangible representation of the robotic arm's   
  
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form and enables a comprehensive understanding of its overall structure and spatial   
relationships. With the Tinkercad model as a reference, further analysis and   
optimization can be conducted to refine the arm's design and enhance its   
performance prior to physical implementation.   
   
   
   
Fig 3.1: 2D Model of Arm Working   
   
   
   
3.3 Block Diagram of Robotic Arm   
   
The block diagram of the robotic arm encompasses the key components   
and subsystems involved in its operation. The diagram includes two stepper motors   
(Stepper Motor 1 and Stepper Motor 2) responsible for controlling the arm's joint   
movements. These motors provide precise angular positioning and allow the arm to   
move in discrete steps. Additionally, three servo motors (Servo Motor 1, Servo Motor   
2, and Servo Motor 3) are employed to actuate specific functions, such as gripping   
and manipulating objects.   
   
The processing software, Arduino, forms a crucial part of the block   
diagram. It serves as the control center for the robotic arm, handling the   
interpretation of user commands and generating control signals for the motors. The   
Arduino software facilitates the coordination and synchronization of motor   
movements, ensuring precise and coordinated actions of the arm.   
  
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Incorporated within the block diagram is an ultrasonic sensor. This sensor   
plays a vital role in the arm's operation, providing proximity detection and distance   
measurement capabilities. By emitting ultrasonic waves and analyzing their   
reflections, the sensor enables the arm to detect objects in its vicinity and perform   
obstacle avoidance or object recognition tasks.   
   
Together, the stepper motors, servo motors, processing software   
(Arduino), and ultrasonic sensor create a comprehensive block diagram that   
illustrates the core elements and their interactions within the robotic arm. This   
diagram serves as a foundational reference for understanding the control and   
operation of the arm and forms the basis for further development and refinement of   
its functionalities.   
   
   
   
   
   
   
  
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3.3 3D Model of Robotic Arm’s Components   
   
In Tinkercad, a 3D model of a robotic arm has been created, incorporating different   
components such as a solid base, a flexible shoulder joint, a versatile gripper, and a   
movable elbow joint. The model showcases the intricate details and interconnections   
of these components, providing a comprehensive representation of the robotic arm's   
physical structure.   
   
This Tinkercad model serves as a valuable tool for visualizing and evaluating the   
design, ensuring proper alignment and functionality before considering physical   
implementation. It enables the refinement of the arm's construction, optimization of   
its performance, and the exploration of its potential applications in real-world   
scenarios.   
   
   
   
   
Fig 3.2: 3D View of Base Fig 3.3: 3D View of Shoulder   
  
33   
   
   
Fig 3.4: 3D view of Elbow   
   
   
Fig 3.5: 3D view of Gripper   
  
34   
   
   
   
3.3 Actual Images of Robotic Arm   
   
An actual image of the robotic arm reveals a tangible representation of its physical   
form and components. The image provides a concise visual depiction, showcasing   
the arm's mechanical structure, joint configurations, and end effector.   
   
It allows for a quick assessment of the arm's size, shape, and overall design. By   
observing the actual image, one can gain a better understanding of the arm's   
physical capabilities, potential range of motion, and the integration of various motors   
and sensors. This image serves as a valuable reference for evaluating the arm's   
aesthetics, functionality, and potential applications in real-world environments.   
   
   
   
   
   
Fig 3.6: Robotics Arm Body   
  
35   
   
   
   
   
Fig 3.7: Robotics Arm Electronic Components   
   
   
Fig 3.8: Robotics Arm Shoulder and Elbow   
  
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Fig 3.9: Complete Robotic Arm   
  
37   
   
CHAPTER 4   
   
MATHEMATICAL ANALYSIS OF   
ROBOTIC ARM   
   
   
4.1 NONLINEAR MATHEMATICAL MODEL OF THE INDUSTRIAL   
ROBOT MANIPULATOR   
The industrial robot manipulator M20P for robotic complex is considered. The robot   
manipulator is shown in Figure 1 consists of a base, the stand, hands, the gripping   
device and actuators for moving and turns.   
   
   
   
Fig 4.1: The industrial robot manipulator M20P   
   
   
The industrial robot manipulator M20P has two translational and two rotational   
kinematic pairs. The elements of manipulator are numbered starting with fixed   
element - the base with number of zero. The motion of clamp-unclamp for the   
gripping device is not considered. The kinematic scheme for industrial robot   
manipulator is shown in Figure 2 and consists of four moving parts. We introduce   
the relative coordinate system associated with elements, with the origin at the   
points: O  
1  
, O  
2  
, O  
3  
, O  
4   
. The initial coordinate system O  
0   
we correlate with the fixed   
element.   
   
For generalized coordinates we accept: the angle of rotation around the rack -q  
1   
,   
lifting height -q  
2   
, the length of arms -q  
3   
, the angle of gripping device -q  
4   
   
The system of dynamic equations of industrial robot manipulator is obtained.   
  
38   
   
We apply the matrix method and dynamic Lagrange equations in matrix form to   
produce the equations of motion [5-7].   
   
The transition from the coordinate system O  
0   
to O  
1   
occurs by rotation around z axis   
at an angle q  
1   
.  
   
   
The transition from the coordinate system O  
1   
to O  
2   
occurs by rotation around z axis   
at an angle π , by displacement along z axis on q  
2   
and by rotation around x   
axis at   
an angle π /2 .   
   
   
   
   
   
   
   
Fig 4.2: The kinematic scheme   
  
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44   
   
   
   
Fig 4.3: The dynamics of the generalized coordinates: q  
1  
, q  
2  
, q  
3  
, q  
4   
   
   
  
45   
   
   
   
   
   
4.1.1 Conclusion of Mathematics Model   
   
The mathematical model of industrial robot manipulator with four degrees of   
freedom is developed. The robot manipulator is designed to create automated   
systems for service devices, for removing and installing the equipment,   
change details and tools. For creation of the equations of robot manipulator   
we used the method of matrices and matrix Lagrange equations of the second   
kind.   
The mathematical model is presented nonlinear system of four ordinary   
differential equations of second order. The analytical solution of the nonlinear   
system is obtained by polynomial transformations method. The kinematic   
structure and dynamic characteristics of robot manipulator are defined. The   
power of actuators and generalized forces generated by actuators for moving   
the gripper at a given point in space are found.   
  
46   
   
   
CHAPTER 5   
   
ROBOTIC ARM CONTROLLING CODE   
   
   
5.1 INTRODUCTION   
   
In the development of the robotic arm project, Arduino has been utilized for coding   
the arm's functionality, while Processing has been employed for designing the user   
interface (UI). Arduino, an open-source electronics platform, provides a user-   
friendly environment for programming the robotic arm's movements and   
coordinating the actions of its motors and sensors. By writing code in Arduino, the   
arm's behavior, such as position control and object manipulation, can be precisely   
defined and implemented.   
   
On the other hand, Processing, a programming language and development   
environment, is used to create an interactive and visually appealing UI for the   
robotic arm. Through the Processing (.pde) files, an intuitive interface is designed   
to facilitate user interaction. The UI incorporates graphical elements and interactive   
controls that enable users to send commands, adjust settings, and monitor the   
real-time status of the robotic arm.   
   
The combination of Arduino for coding and Processing for UI design allows for   
seamless integration between hardware control and user interaction. It enhances   
the overall user experience by providing a user-friendly interface for commanding   
and monitoring the robotic arm's actions.   
   
5.2 ARDUINO CODE   
   
   
#include <IRremote.h>   
#include <Servo.h>   
#include <AccelStepper.h>   
   
const byte IR\_PIN = 2;   
IRrecv irrecv(IR\_PIN);   
   
decode\_results results;   
  
47   
   
#define base\_dir 6   
#define base\_step 7   
   
   
#define solder\_dir 4   
#define solder\_step 5   
   
   
const int gripperPin = 12;   
const int elbowPin = 11;   
   
#define GRIPPER\_SERVO\_MAX 75 // 10 opened to 75 closed   
#define GRIPPER\_SERVO\_MIN 15   
#define ELBOW\_SERVO\_MAX 100   
int gripperHome = 50; // initial value - half opened   
int gripperPos = gripperHome;   
   
int elbowHome = 50;   
int elbowPos = elbowHome;   
   
   
Servo gripperServo;   
Servo elbowServo;   
   
AccelStepper nema1(1, base\_step, base\_dir); // type 1, step, dir to arduino   
pin   
int stepNema1 = 4; // for quarter step resulation   
int gearNema1 = 1.8; // for 36 teeth pulley gear ratio with 20 teeth is   
1.8   
int nema1Home = 0;   
int nema1Pos = nema1Home;   
int NEMA1\_MAX = gearNema1 \* stepNema1 \* 80; // for 80 right   
int NEMA1\_MIN = gearNema1 \* stepNema1 \* (-80); // for 80 left   
int nema1Increment = gearNema1 \* 50; // 4 \* 200 (for 1 rotation) = 800/50   
= 16 (baar me 1 rotaion)   
   
   
AccelStepper nema2(1, solder\_step, solder\_dir);   
int stepNema2 = 4;   
int gearNema2 = 4;   
int nema2Home = 0;   
int nema2Pos = nema2Home;   
  
48   
   
int NEMA2\_MAX = gearNema2 \* stepNema2 \* 50;   
int NEMA2\_MIN = 0;   
int nema2Increment = gearNema2 \* 20;   
   
   
#define nema1Left1 4113   
#define nema1Left2 6161   
#define nema1Right1 4112   
#define nema1Right2 6160   
   
   
#define nema2Up1 4128   
#define nema2Up2 6176   
#define nema2Down1 4129   
#define nema2Down2 6177   
   
   
#define elbowServoUp1 4150   
#define elbowServoUp2 6198   
#define elbowServoDown1 4148   
#define elbowServoDown2 6196   
   
   
#define gripperOpen1 6182   
#define gripperOpen2 4134   
#define gripperClose1 6203   
#define gripperClose2 4155   
   
   
void setup() {   
Serial.begin(115200);   
IrReceiver.begin(IR\_PIN, ENABLE\_LED\_FEEDBACK);   
   
   
irrecv.enableIRIn(); // Start the receiver   
while (!Serial) // Wait for the serial connection to be establised.   
delay(50);   
Serial.println();   
Serial.print("Now waiting for IR message");   
   
   
pinMode(base\_dir, OUTPUT);   
pinMode(base\_step, OUTPUT);   
  
49   
   
pinMode(solder\_dir, OUTPUT);   
pinMode(solder\_step, OUTPUT);   
   
gripperServo.attach(gripperPin);   
elbowServo.attach(elbowPin);   
   
gripperServo.write(gripperHome);   
elbowServo.write(elbowHome);   
   
nema1.setMaxSpeed(1000); // set the max speed achivable by driver   
nema1.setAcceleration(500);   
nema1.setCurrentPosition(nema1Home);   
   
   
nema2.setMaxSpeed(1000); // set the max speed achivable by driver   
nema2.setAcceleration(500);   
nema2.setCurrentPosition(nema2Home);   
}   
   
   
void loop() {   
   
   
if (irrecv.decode(&results)) {   
// print() & println() can't handle printing long longs. (uint64\_t)   
// serialPrintUint64(results.value);   
   
   
Serial.print(results.value);   
Serial.println(" --- ");   
   
if(results.value == gripperOpen1 || results.value == gripperOpen2){   
gripperPos-=2;   
if(gripperPos <= GRIPPER\_SERVO\_MIN) {gripperPos = GRIPPER\_SERVO\_MIN;}   
gripperServo.write(gripperPos);   
}   
   
   
if(results.value == gripperClose1 || results.value == gripperClose2){   
gripperPos+=2;   
if(gripperPos >= GRIPPER\_SERVO\_MAX) {gripperPos = GRIPPER\_SERVO\_MAX;}   
gripperServo.write(gripperPos);   
  
50   
   
}   
   
   
if(results.value == elbowServoDown1 || results.value ==   
elbowServoDown2){   
elbowPos-=2;   
if(elbowPos <= 0) {elbowPos = 0;}   
elbowServo.write(elbowPos);   
Serial.print("elbow position ");   
Serial.println(elbowPos);   
}   
   
   
if(results.value == elbowServoUp1 || results.value == elbowServoUp2){   
elbowPos+=2;   
if(elbowPos >= ELBOW\_SERVO\_MAX) {elbowPos = ELBOW\_SERVO\_MAX;}   
elbowServo.write(elbowPos);   
Serial.print("elbow position ");   
Serial.println(elbowPos);   
}   
   
   
if(results.value == nema1Left1 || results.value == nema1Left2){   
nema1Pos -= nema1Increment;   
if(nema1Pos <= NEMA1\_MIN) {nema1Pos = NEMA1\_MIN;}   
nema1.moveTo(nema1Pos);   
nema1.runToPosition();   
Serial.print("nema1 position ");   
Serial.println(nema1Pos);   
}   
if(results.value == nema1Right1 || results.value == nema1Right2){   
nema1Pos += nema1Increment;   
if(nema1Pos >= NEMA1\_MAX) {nema1Pos = NEMA1\_MAX;}   
nema1.moveTo(nema1Pos);   
nema1.runToPosition();   
Serial.print("nema1 position ");   
Serial.println(nema1Pos);   
}   
   
   
if(results.value == nema2Down1 || results.value == nema2Down2){   
nema2Pos -= nema2Increment;   
  
51   
   
   
if(nema2Pos <= NEMA2\_MIN) {nema2Pos = NEMA2\_MIN;}   
nema2.moveTo(nema2Pos);   
nema2.runToPosition();   
Serial.print("nema2 position ");   
Serial.println(nema2Pos);   
}   
   
   
if(results.value == nema2Up1 || results.value == nema2Up2){   
nema2Pos += nema2Increment;   
if(nema2Pos >= NEMA2\_MAX) {nema2Pos = NEMA2\_MAX;}   
nema2.moveTo(nema2Pos);   
nema2.runToPosition();   
Serial.print("nema2 position ");   
Serial.println(nema2Pos);   
}   
   
   
delay(30);   
irrecv.resume(); // Receive the next value   
}   
}   
  
52   
   
   
   
CHAPTER 6   
   
CONCLUSION And FUTURE ASPECTS   
   
   
6.1 CONCLUSION   
   
In conclusion, the development of the robotic arm presented in this thesis has been   
successfully realized, showcasing a comprehensive integration of mechanical   
design, control system implementation, and user interface development. The   
project focused on achieving precise and controlled movements through careful   
selection and integration of components such as stepper motors, servo motors, and   
sensors.   
   
The mechanical design of the robotic arm incorporated key elements such as a   
sturdy base, flexible joints, and a versatile gripper. Structural analysis techniques   
ensured the arm's strength and rigidity, while considering factors such as torque   
requirements and positional accuracy. The integration of motors allowed for precise   
and coordinated movements, enabling the arm to perform tasks such as reaching   
specific positions, manipulating objects, and executing predefined sequences of   
actions.   
   
The control system, implemented using Arduino, provided the necessary coding for   
the arm's functionality. Through the software algorithms developed, accurate   
positioning, smooth motion, and responsive interaction with user commands were   
achieved. The user interface, designed in Processing, facilitated an intuitive and   
visually appealing interaction between the user and the robotic arm. Users were   
able to send commands, adjust settings, and monitor real-time arm status through   
a user-friendly graphical interface.   
   
The successful integration of the mechanical, control, and user interface   
  
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components in the robotic arm resulted in a functional and versatile tool for various   
applications. The project's contributions to the field of robotics lie in demonstrating   
the effectiveness of an integrated approach, showcasing the importance of   
considering mechanical design, control systems, and user interface development in   
creating an efficient and user-friendly robotic arm system.   
   
The project's experimental results validated the arm's functionalities and   
highlighted its potential for further enhancements and applications in real-world   
scenarios. Future work may involve the incorporation of advanced control   
algorithms, expansion of the arm's range of motion, and integration with additional   
sensors for improved functionality and versatility.   
   
Overall, the development of the robotic arm presented in this thesis represents a   
significant achievement, demonstrating the successful integration of mechanical   
design, control systems, and user interface development to create an effective and   
user-friendly robotic arm system. The project's outcomes contribute to the   
advancement of robotics and provide a foundation for further research and   
development in this field.   
   
6.2 Ethical view on a possible usage of the arm   
   
From an ethical perspective, the potential usage of the robotic arm raises   
important considerations regarding its responsible and appropriate application.   
While the arm's capabilities offer opportunities for increased efficiency,   
productivity, and assistance in various tasks, it is crucial to ensure that its use   
aligns with ethical principles and safeguards against potential misuse.   
   
One key ethical consideration is the impact on human employment. As the robotic   
arm automates certain tasks, it may lead to job displacement for human workers.   
It is essential to address the potential consequences by providing appropriate   
training and support for affected individuals, facilitating their transition to new roles   
or industries. Additionally, ethical guidelines should be established to prioritize   
human well-being and ensure that the introduction of the robotic arm does not   
contribute to unjust social or economic inequalities.   
  
54   
   
Another ethical consideration relates to the arm's interaction with humans. If the   
arm is designed for collaborative tasks alongside humans, safety measures must be   
implemented to prevent harm and injury. Ensuring proper risk assessments,   
implementing robust safety protocols, and adhering to industry standards are   
essential in guaranteeing the well-being and physical integrity of individuals   
working alongside the robotic arm.   
   
Furthermore, privacy and data security must be addressed when considering the   
arm's potential usage. If the arm collects and processes sensitive information   
during its operation, appropriate measures should be in place to safeguard   
personal data and ensure compliance with relevant privacy regulations.   
Transparency and informed consent should be emphasized, and mechanisms for   
data protection and responsible data governance should be established.   
   
Ultimately, responsible and ethical usage of the robotic arm requires continuous   
evaluation, dialogue, and adaptation. Stakeholder engagement, including input   
from affected individuals and communities, can help shape policies and guidelines   
that prioritize ethical considerations and ensure that the arm's deployment aligns   
with societal values, promotes human welfare, and fosters equitable outcomes.   
  
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6.3 KINEMATICS MATRICES   
   
   
  
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6.4 FUTURE ASPECTS OF ROBOTIC ARM   
   
Looking ahead, the future of robotic arm technology holds promising possibilities   
for further advancements and enhancements. Here are a few key areas that present   
potential future aspects for robotic arms:   
   
1. Advanced Control Algorithms: Future developments in control algorithms can   
significantly enhance the capabilities of robotic arms. By leveraging machine   
learning, artificial intelligence, and adaptive control techniques, robotic arms can   
acquire the ability to learn from experience, optimize their movements, and adapt to   
dynamic environments. This can lead to improved precision, efficiency, and   
versatility in performing complex tasks with increased autonomy.   
   
2. Human-Robot Collaboration: The field of human-robot collaboration offers   
exciting opportunities for the future of robotic arms. Advancements in safety systems,   
sensing technologies, and ergonomic design can enable closer and safer interaction   
between humans and robotic arms. Collaborative robots, also known as cobots, can   
work alongside humans, assisting in tasks that require a combination of human   
dexterity and robotic strength or precision. This collaboration can enhance   
productivity, improve safety, and open new avenues for automation in various   
industries, such as manufacturing, healthcare, and logistics.   
   
3. Soft Robotics and Biomimicry: The integration of soft robotics and biomimicry   
principles in robotic arm design holds immense potential. Soft robotic arms, inspired   
by the natural flexibility and adaptability of biological organisms, can offer enhanced   
dexterity and versatility in interacting with delicate objects or performing tasks in   
unstructured environments. By mimicking the characteristics of muscles,   
  
57   
   
tendons, and compliant materials, soft robotic arms can exhibit safe and efficient   
interactions, expand their range of motion, and enable novel applications in areas such   
as healthcare, exploration, and human-assistive robotics.   
   
These future aspects of robotic arms demonstrate the ongoing potential for innovation   
and advancement in this field. As technology continues to evolve, incorporating   
cutting-edge control algorithms, fostering human-robot collaboration, and exploring   
nature-inspired designs, robotic arms have the potential to become even more capable,   
adaptive, and integrated into our daily lives. Continued research, interdisciplinary   
collaboration, and ethical considerations will be essential in realizing the full potential   
of robotic arm technology and unlocking its benefits for various industries and   
societal needs.   
  
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