

# Design, Analysis and Fabrication of Pick & Place Colour Sorting Robotic Arm

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**Abstract** - Sorting of packages is the most tedious, labour-intensive and repetitive work in industries. Scanning number of objects and placing them on required conveyor consumes a lot of human effort while in case of heavy and bulky packages it becomes very difficult for worker to ensure smooth process and also some error while sorting might occur. With introduction of automated robotic arm, the human effort can be eliminated at a large extent without any error. The prime objective of this project is to design and develop a robotic arm that sorts the packages and place it at desired location. The heart of this project is Arduino microcontroller which controls the servomotors used in links. An algorithm is developed which runs the microcontroller to deliver desired output. After performing simulations and number of testings, a robotic arm for mentioned application is achieved.

**Key Words:** Arduino, Robotic Arm, Colour Sorting, Analysis of Robotic Arm, SOLIDWORKS

## 1. INTRODUCTION

In today's industry, a robot/robotic arm is found easily. One can find an automated mechanical assistant for the worker in most of the factories. The automation of robotic processes is an essential process for industrial environments in the recent years, since it improves quality while reducing the time needed to accomplish certain tasks. A robotic arm can easily perform numerous tasks that might be laborious for workers.

In this paper, a method is presented to sort the objects based on colour coded system. Colour-based detection captured by the sensor is used as data to create commands through serial communication to the robotic arm controller to pick and reposition the object.

### 1.1 Need

With increasing industrialization and mass production of products, warehouse management has become a major part of the industry but, as this part is mostly labour oriented there are so many short comings. The time consumed is much more, the lifting and placing of objects require much more labour, human error in sorting of different packages, etc are some of such problems. Here automation makes the work easy and efficient. Robotic arm easily sorts and places the package and places it at the desired location, thus making the process more efficient and faster.

In order to assemble products efficiently and quickly, robots are used to pick up the parts from incoming conveyors and assemble them with high precision on the desired conveyor. Robot instantaneously picks and separates different types of parts passing through its vision domain.

## 1.2 Scope

The robotic arms have a wide scope of development. In the near future, robotic arms may perform numerous tasks just as like as humans but in much more efficient way.

It can be really hectic and a tedious task for workers to manually sort number of packages and keep the packages at confined place. Here, a robot / robotic arm plays a major role to overcome different difficulties and mentioned problems. The robotic arm could be designed to sort the packages for the given filter and place it at the desired location. Handling objects of different geometry might be problematic for the time being, but with certain improvements in the design this limitation can be overcome. The robotic arm can further be upgraded by introduction of artificial intelligence which sorts the objects by their physical appearance.

## 2. LITERATURE REVIEW

This content presents the critical analysis of the existing literature which is relevant to the colour sorting robotic arm. Though the literature consists of a lot many research contributions, but here, we have analyzed some of the research and review papers.

According to Mr. Pranay S et al. this paper deals with designing colour sorting robotic arm, which could be used to sort the object by colour. In this paper, a robotic arm is designed to pick object of specific colour and place it in a desired location. To facilitate the lifting objects, Servomotors with servo control board are used. The board is called SSC-32, because it controls up to 32 motors. A microcontroller called the ATMEGA-168 is used for programming, which can communicate with a PC via the RS-232 interface and interpret SCPI (Standard Commands for Programmable Instruments) commands sent from the PC. The microcontroller along with pins is soldered on a PCB board. The colour sorting application was made in Lab Windows/CVI from National Instruments. In this paper, they choose this programming language; because it's a standard ANSI C programming

language, but it has many drivers for the specific computer interfaces.

Mr. Aji Joy proposed to separate the objects from the pile of objects based on the objects colour. As an application, it could be used to categorize the objects moving on a conveyor belt. The proposed method uses the colour of the objects to categorize them. In this paper, it was used to categorize balls of three different colors. A light intensity-to-frequency converter is used to detect the particular colour. The TCS3200 colour sensor exhibits almost stable behavior under a wide variety of sunshine conditions. A microcontroller-based system controls the robotic arm's DC servo motor. There are standard software programs available for controlling a robotic arm. A CAD drawing is used to manipulate the robotic arm's movements, and a CAM program can translate the drawing into movement code. In this paper, we present the design, development, and construction of robotic arm that can pick up and sort objects of various colors. Aluminum brackets were used to form the mechanical structure, thereby reducing the weight without sacrificing mechanical strength.

Snehal Shirgave et al. in this paper deals with colour sorting robot. There are four main components in this system: colour sensor module, servo motor, Arduino UNO, and LCD display. TCS3200, the colour sensor detects the light reflected by an object, and to generate a frequency. Servo motors move the slider in response to the colour detected. The Arduino UNO microcontroller controls both input and output, and a LCD displays the detected output color and the count of each coloured object.

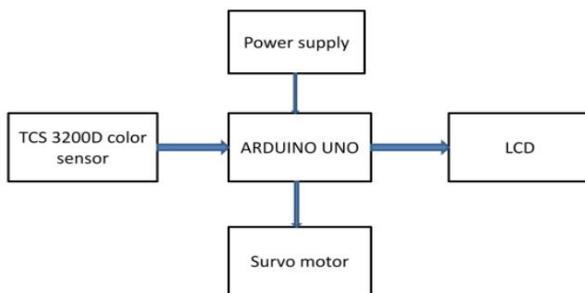


Fig -1: System Block Diagram

According to Prof. D. B. Rane et al. automation is the key to growth of industry. For more efficient and precise working of robots, complex sensors are needed. An object sorting system based on colour is presented in this paper, using machine vision and operations in image processing. The object grouping is completed with a robotic arm. With camera-based machine vision, the proposed work aims to develop simple, compact, and accurate objects sorting machines that use real-time colour image processing to continuously evaluate and inspect color deformities. The inspected object is sorted into predefined quality groups post evaluation by the robot. If the inspected object violates

the quality norms, it is rejected from the system. In many fields that require continuous evaluation of quality, the proposed system will be of great use. It has been developed successfully because the robot's movement can be controlled precisely. It is expensive to change the cable and therefore the designing to reduce the friction on table, is crucial to increase time between maintenance.

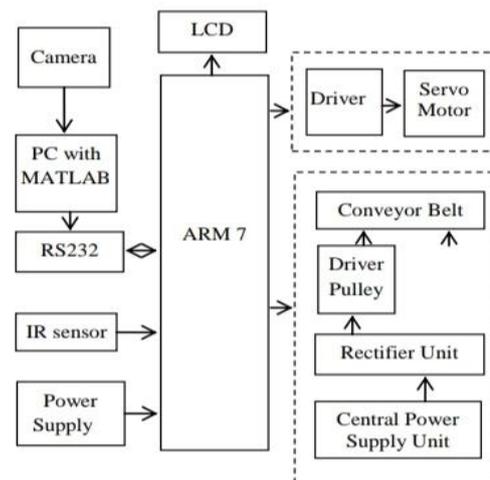


Fig -2: Block Diagram at Control Room

### 3. METHODOLOGY

In this chapter, a method is presented for development of package sorting robotic arm that is based on colour sensing. This also includes explanation for material selection based on various engineering parameters that made those materials suitable for application.

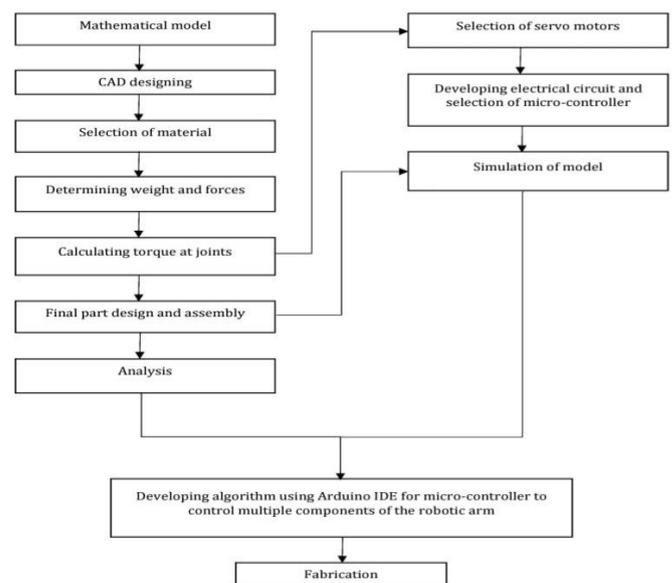


Fig -3: Methodology Flow Chart

### 3.1 Modelling

CAD modelling is highly significant as it portrays better understanding of envisioned system clearly. Through electrical design, a brief idea is generated about required connections which would process desired motion for the robotic arm.

As discussed earlier the package sorting robotic arm has 4 degrees of freedom. A CAD design of the arms was designed using SOLIDWORKS software. The modelling process was divided into different sections like, mathematical modelling, part design, assembly design, and drawings. During mathematical modelling, the calculations are performed considering workspace dimensions and thus the links for robotic arm were designed. Further, different designed components were assembled to get the final model of the robotic arm. The output of the design was a scaled down model.

Another design required consists of electrical connections between various components to be done so as to get the desired motion from mechanical model. This design gives us clear idea about connections between sensors, servo motors and Arduino micro-controller as shown in fig (4.12). The colour sensor used for the project is TCS3200. This sensor can sense mainly three prime colours. This data is then acquired by the micro-controller and based on received data, the program runs multiple servo motors to pick and sort the packages.

### 3.2 Material Selection

After thorough research about different properties about materials the most feasible material is selected for the robotic arm. Different parameters are taken into the account like strength, weight, durability, availability, machineability and cost of the material.

To ensure that the links of the robotic arm don't fail under load imposed, the material with suitable strength is selected. For the project, Aluminium Alloy is selected. Refer below table for properties of Aluminium.

Table -1: Material Properties

Sr. No.	Properties	Values
i.	Tensile Yield Strength	$2.05 \times 10^8$ Pa
ii.	Tensile Ultimate Strength	$2.5 \times 10^8$ Pa
iii.	Shear Strength	$2.05 \times 10^8$ Pa
iv.	Density	2680 Kg/m <sup>3</sup>

## 4. DESIGN AND ANALYSIS

### 4.1 Mechanical Design

Mechanical Design gives a virtual representation of the different parts and assembly of a robotic arm. To determine the dimensions required for the links, the workspace dimensions are considered. Angles between links are calculated for the maximum stretch and minimum stretch conditions using basic mathematical relations.

#### a. Mathematical Model

Mathematical model gives an idea about the lengths and size required for the robotic arm in 2D form. The working area of the robot can be determined in the mathematical model. Angles between links at different condition is also derived through mathematical calculation.

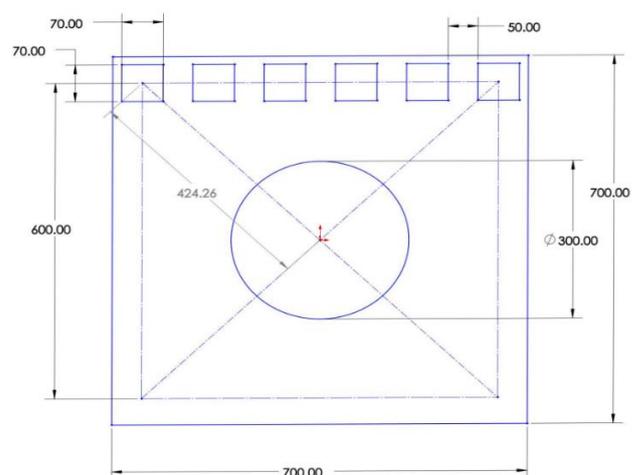


Fig -4: Workspace

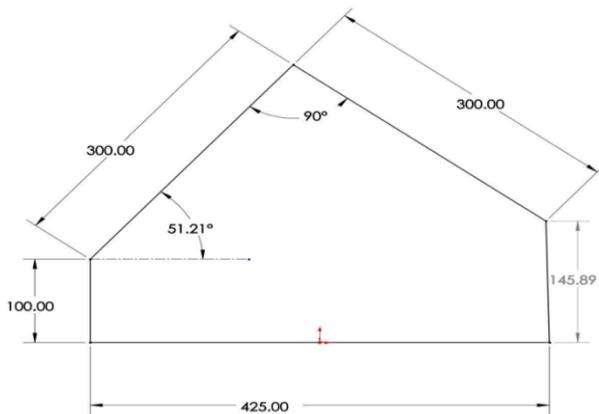


Fig -5: Maximum Arm Stretch

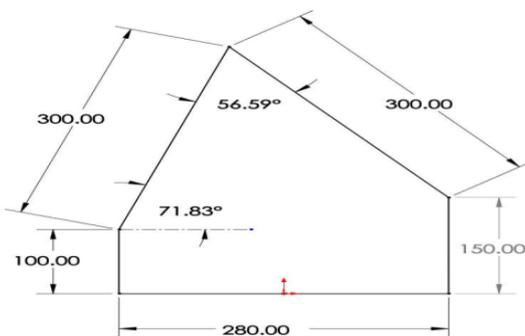


Fig -6: Minimum Arm Stretch

### b. Part Design

Parts are designed using SOLIDWORKS software. It gives an idea about all different components that are used to assemble the robotic arm. The 3D presentation of each component gives us a virtual representation of every component of the project.

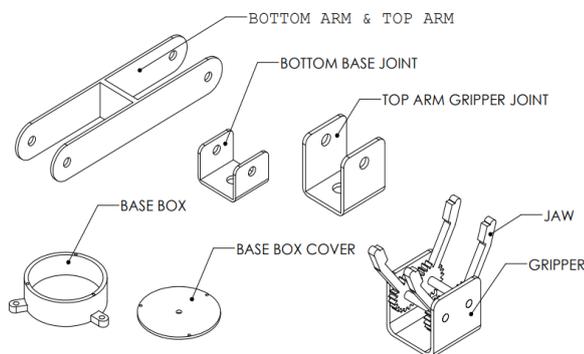


Fig -7: Parts Design

### c. Assembly

Assembly of the project combines all the part models and gives a computer model of the robotic arm. It gives an idea of how the robotic arm will look on ground after all the processes are completed.

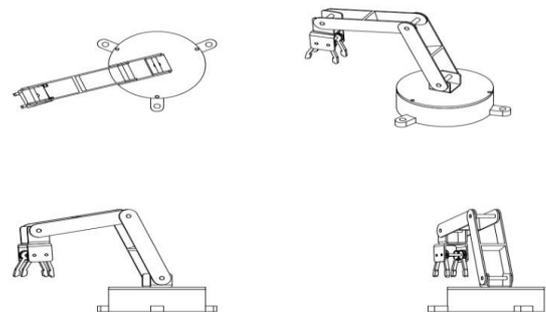


Fig -8: Assembly



Fig -9: Rendered Image

## 4.2 Electrical Design

Electrical design gives an idea about the different connection between various component used in a robotic arm. In this project different component are used like Arduino Uno, servomotors, TCS3200 colour sensor, breadboard, battery and jumper wires.

### a. Arduino UNO

Arduino is an open source electronics platform which is easy to use hardware & software based. The Arduino board is capable of reading inputs from sensors, buttons, or tweets and turning them into outputs, such as moving a motor, switching on LED, or generating an online message. Setting instructions for microcontroller to get what's required can be accomplished through the Arduino IDE (based on Processing), which uses the Wiring programming language.

The Arduino Uno microcontroller is selected for this project, as it provides the best processing capabilities necessary to manage the components, while avoiding the complexities

present in other high-grade controllers. It contains ATMEGA328P microcontroller. It has 14 digital I/O pins (6 are PWM outputs, 6 analog inputs). Connect the microcontroller to a computer by using a cable, else power it using an adapter or a battery.

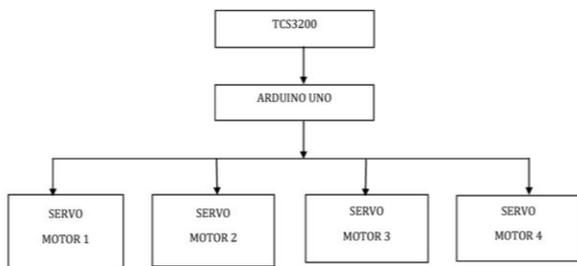
**b. TCS3200 Color Sensor**

For this project, there were many color identification sensors available in the market place, sensor TCS3200 was selected because of its cost effectiveness, capability and well formatted output. The TCS3200 produces a square wave with frequency directly related to light intensity. This frequency is received by the ATmega328P microcontroller for interpretation.

A colour sensor consists of TCS3200 RGB sensor chip and 4 white LEDs. The TCS3200 is capable of detecting and measuring a virtually unlimited range of visible colors. With the TCS3200, each photodetector either has a red, green, or blue filter, or no filter at all (clear). The red, green, and blue filters are distributed evenly among the array to minimize location bias in the three colours. Also, an oscillator built into the device produces square waves whose frequency depends on the intensity of the selected colour.

**c. Servo Motor**

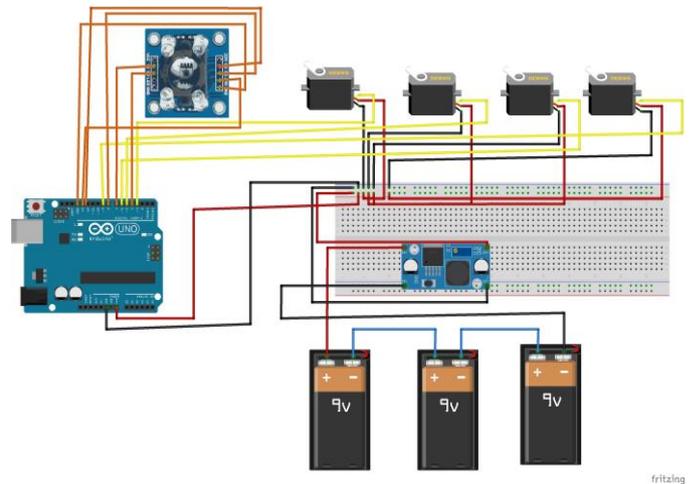
A servo motor is DC motor that is has servo mechanism for the purpose of controlling precise angular positions with an error-sensing feedback control. Based on the figure, servo motors are DC motors with error-sensing feedback control. Typically, the maximum rotational angle of these motors ranges 90° to 180°. However, the disadvantage is that servos cannot rotate continuously. They can rotate only between fixed angles. Thus, precision positioning is also possible using servos. Robotic arms, RC airplanes and many more of other applications use servos. Thus, in this project servo motors are applied for movement of links of robotic arm



**Fig -10:** Electrical Connection Block Diagram

As shown in above fig, external battery is used in a circuit diagram for motion of 4 servo motors because Arduino uno board only provides 5v supply which is not sufficient for motion of more than 2 servo motors. Thus, external battery is connected with Arduino uno board and breadboard using jumper wires. The breadboard is used for reducing complex

connection between various component easily. With jumper wires, 4 servo motors are connected to Arduino uno board after the battery is connected. The TCS3200 color sensor is connected to the Arduino uno board after the battery is connected. The following table shows which servo motor is used for different joint according to their need in the project.



**Fig -11:** Electrical Connection Diagram

**Table -2:** Servo Motor Specifications

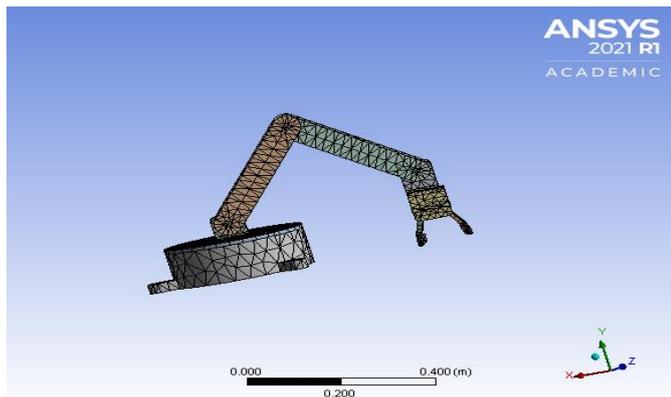
S/N	JOINT	SPECIFICATION	SERVO MOTOR
1.	Base	Torque of 9.4 kg/cm at 4.8v	Tower pro MG 996R
2.	Base joint	Torque of 9.4 kg/cm at 4.8v	Tower pro MG 996R
3.	Elbow joint	Torque of 9.4 kg/cm at 4.8v	Tower pro MG 996R
4.	Gripper	Torque of 1.8kg/cm at 4.8v	Tower pro SG 90

**4.3 Analysis**

A structural analysis is carried out to examine the reaction of the different parts and materials of the robotic arm to the different loads applied to it. In load analysis the design of the model is analyzed to conclude so that it can resist the different weight situations considered. Loads, forces, and moments are calculated by using the weight and length of different components. Many conditions are selected under which different loads are given on the body to see corresponding reactions on the body.

**a. Meshing**

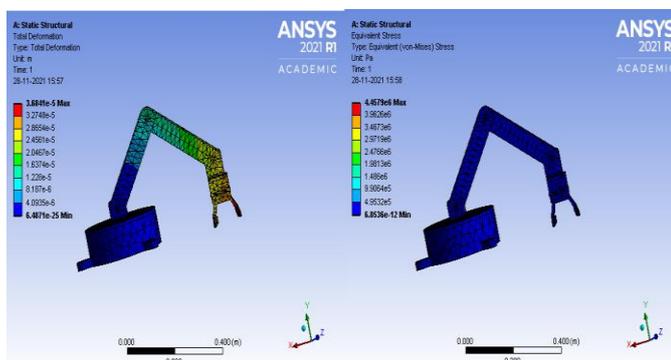
Mesh means that the model is separated into several elements so that when a load is applied to the model, it distributes it evenly. It is necessary to discretize the continuum into a finite number of elements. In FEA, an element's size and number of elements can essentially change the results. The meshing is shown in the figures below.



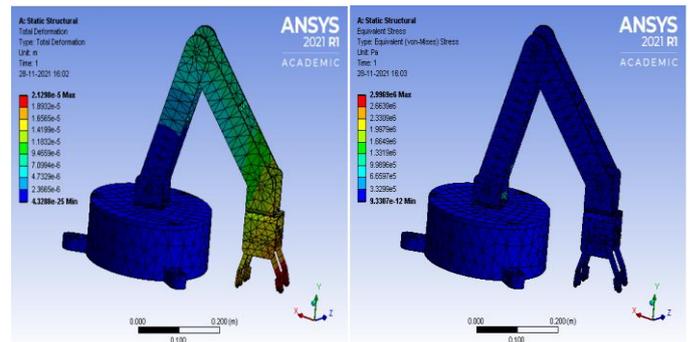
**Fig -12:** Meshed Model

**b. Static Structural Analysis**

Loads calculated earlier are applied on the body parts in the structural analysis. The effect of loads and moments is applied on the mesh body giving out the different results. The direction and location of each load input to the component define the loading. Assembly file from SOLIDWORKS is converted to STEP file for analysis into ANSYS. Different results like deformation and stress effect on the assembly is obtained. Results at two different condition is obtained.



**Fig -13:** Analysis at Maximum Stretch



**Fig -14:** Analysis at Minimum Stretch

**5. FABRICATION**

After selection of material for the prototype which would be light in weight, great in strength and easily available i.e. Aluminium, the material is procured and different machining operations are carried out. Different parts are manufactured like link arms, base plates, brackets, supports, etc. Different operations are carried out on links arms like slots for motors and holes for shaft. The claws of end effector are prepared using laser cutting operations. Thin aluminium sheet is laser cut into the desired shape. After different parts are ready, they are assembled together into a robotic arm.

**6. CONCLUSION**

The system has been successfully designed and it has the capability to rotate 360° and handle the required task. It can take RGB coloured object, hold it and put it to a particular station using RGB colour sensor. TCS3200 gives precise output. It can also be more efficient by using different colour sensors and micro-controller. Colour sensing section performed two main tasks; object's detection and colour recognition. System is fully automated and can pick objects of 1 kg weight approximately. The cost-effective system was designed to perform the continuous and reliable tasks without human errors using the simplest concepts. The robotic sorting systems are useful in industries and different household activities. Since this system is mainly controlled by the PIC Microcontroller, the results obtained are more reliable and faster.

**7. FUTURE SCOPE**

A good effort is put in design and analysis of this system, but this cannot be taken for granted. There are many other parameters that determine the quality of a model. This document explains and describes the simplest way to design and analyze a robotic arm. A lot of it has to do with the degree of perfection you can achieve.

It is necessary to optimize this model. We need to understand in depth what effect could occur if a parameter is

changed, especially design parameters such as volume, thickness, and material. Also, the cost study is needed to be performed in a detailed way. After all, a good machine is also judged on how affordable it can be. There is always more room for innovation in any study. During this project, we came across many modern innovative automation techniques. If given a chance to do this project again, we are very much interested in applying those techniques. Independent component analysis is one such technique. A machine learning technique called Independent Component Analysis or ICA, provides the separation of independent signals from mixed signals. Independent component analysis, on contrary to principal component analysis, focuses on the independence of data points, i.e., independent components.

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### BIOGRAPHIES



Kunal Palasdeokar, a Final Year student pursuing his Bachelors in Mechanical Engineering. With enthusiasm and strong technical foundation, he wishes to acquire deeper insights in Mechatronics & Robotics by contributing his skills to real world applications.



Abhishek Ashok Chavan currently pursuing final year of bachelors of Mechanical engineering. He is eager to work in the automobile industry and to learn more about it. Additionally, he is highly detailed oriented, accurate, and has experience completing technical drawings.



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