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Vision Assisted Robotic Arm Using Arduino

Mr. Khan Mohammad Tahir[1], Mr. Mohammed Yusuf[2], Mr. Chaudhary Shahbaz[3], Mr. Bakhed Avesh[4], Prof. Monika Pathare[5]
Department of Computer Engineering, Theem College of Engineering, Village Betegaon, Boisar Chilhar Road, Boisar (E), Palghar, University of Mumbai

Abstract: ***In the era of automation, the fusion of robotics and computer vision offers promising solutions for sustainable industrial practices. This paper presents the development and implementation of a vision-assisted robotic arm system designed for efficient object sorting by color. Leveraging the integration of robotics and computer vision, the system demonstrates its potential to optimize industrial processes while promoting environmental sustainability. The paper discusses the construction, experimental results, insights gained, and future implications of the project, highlighting its contributions to sustainable development goals.***

Keywords: ***Vision-assisted robotics, sustainable sorting, object manipulation, computer vision, robotics integration, SDGs considerations.***

I. INTRODUCTION

In the age of automation, we invite you to step into a world where machines "see" and "decide." Our project represents an exciting exploration into the integration of robotics and computer vision, with a specific focus on object sorting by color. Picture a robotic arm that can recognize and categorize objects based on their hues, simplifying processes in industries ranging from manufacturing to recycling.

The proposed solution involves the design, implementation, and optimization of an automated system using a vision-assisted robotic arm controlled by Python. By integrating robotics and computer vision, the system offers a sustainable approach to industrial automation, aligning with the objectives of the United Nations' Sustainable Development Goals (SDGs).

This report takes you on a journey through the creation of this ingenious system, revealing the challenges we faced and the solutions we devised. Join us in unravelling the realm of robotics, where technology and vision combine to sort our colorful world.

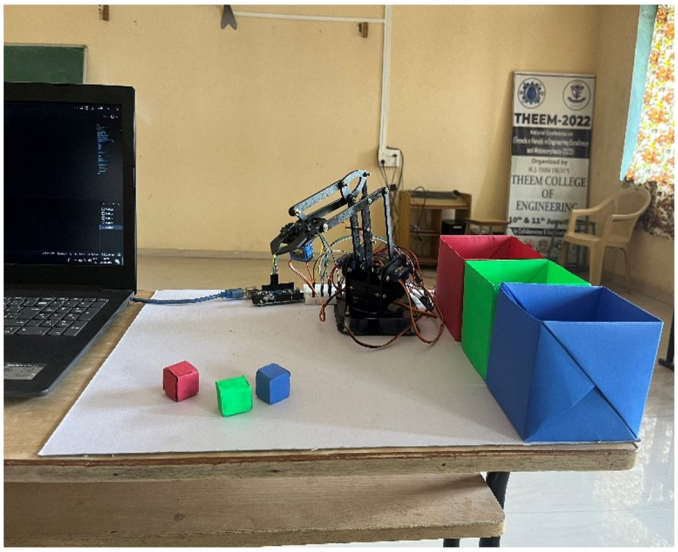

Fig.1. System Overview

II. LITERATURE SURVEY

The integration of robotics and computer vision has revolutionized industrial automation, enabling precise object manipulation and sorting tasks. Previous studies have demonstrated the potential of vision-assisted robotics in enhancing efficiency, reducing waste, and promoting sustainable practices. By leveraging computer vision algorithms for object recognition and color sorting, robotics systems can adapt to dynamic environments and handle diverse objects effectively. This interdisciplinary approach contributes to sustainable development by minimizing resource consumption and optimizing productivity.

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III. IMPLEMENTATION DETAILS

The vision-assisted robotic arm system presented in this paper represents a significant advancement in the integration of robotics and computer vision for sustainable industrial practices. The system is designed to perform object manipulation and sorting tasks efficiently and accurately. This section provides an overview of the hardware components, design considerations, and fundamental formulas utilized in the implementation of the robotic arm system.

A. Hardware Components

The robotic arm system consists of the following key components:

1) *Arduino Board:* The Arduino board serves as the central control unit of the system, facilitating communication between the hardware components and executing control algorithms. It provides the necessary processing power and input/output interfaces for interfacing with peripheral devices.

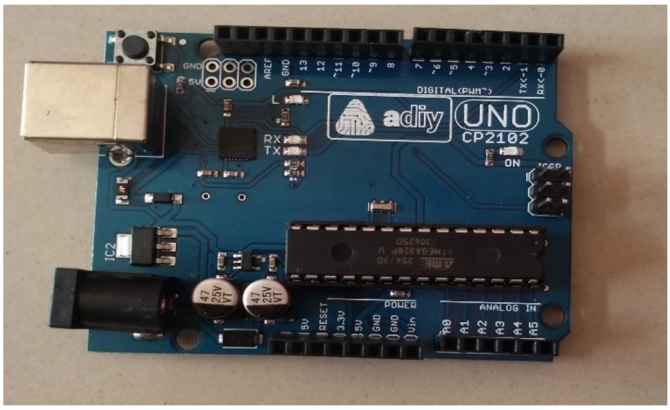

Fig. 2. Arduino Uno R3

2) *The 4-Degree-of-Freedom (4-DOF) Robotic Arm:* It is a robust engineering marvel, crafted from galvanized metal sheets, featuring four rotational joints that grant it exceptional flexibility. With a length of 120 mm, it navigates tasks with precision and versatility, ideal for intricate object manipulation. Whether in assembly lines, manufacturing processes, or sorting tasks, its agility and stability shine. This arm's engineering excellence and adaptability make it a cornerstone of industrial automation, elevating productivity and efficiency in modern manufacturing environments.

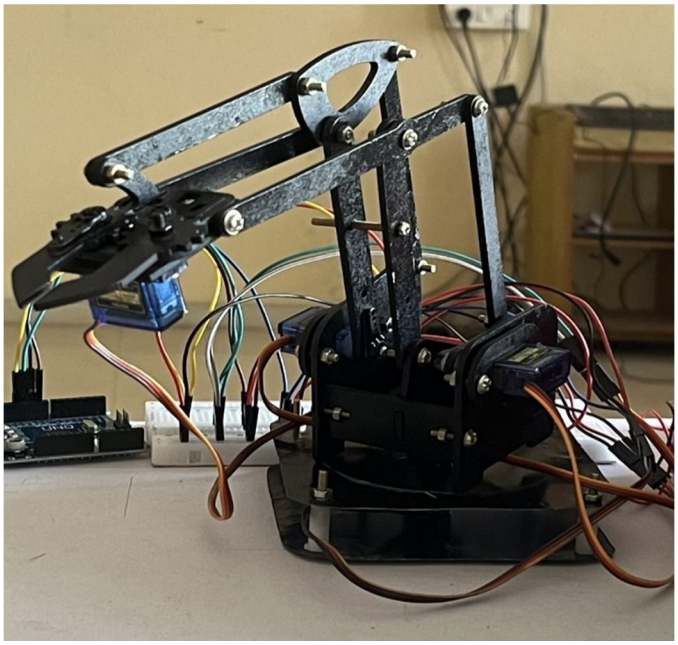

Fig. 3. 4 D.O.F. Robotic Arm

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3) *SG90 Micro Servo Motors:* The robotic arm is actuated by SG90 micro servo motors, which provide precise control over the rotational movement of each joint. These servo motors are lightweight, compact, and capable of generating sufficient torque to manipulate objects weighing up to 200 grams.

Fig. 4. SG90 Micro Servo Motor

4) *Webcam:* A webcam is utilized for capturing real-time images of the workspace. The webcam provides visual feedback to the computer vision system, enabling object recognition and color sorting based on visual cues.

Fig. 5. Camera

5) *Cables and Breadboard:* Various cables and a breadboard are used for electrical connections and interfacing between the hardware components. These components ensure reliable communication and power distribution throughout the system.

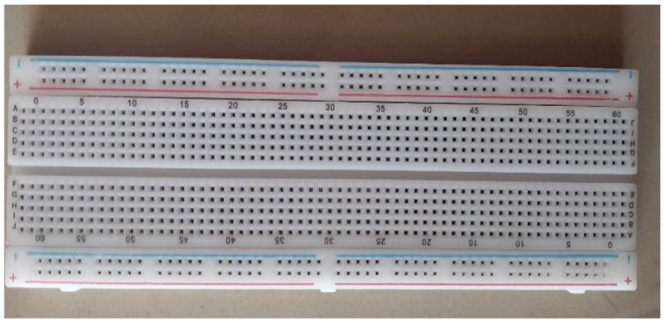

Fig. 6. Breadboard

B. Design Considerations

In designing the robotic arm system, several factors were considered to ensure optimal performance and reliability:

1) *Length of Robotic Arm:* The length of the robotic arm was chosen to be 120 mm to provide sufficient reach and workspace coverage for object manipulation tasks. This length allows the arm to access objects placed within a wide area while maintaining stability and precision in movement.

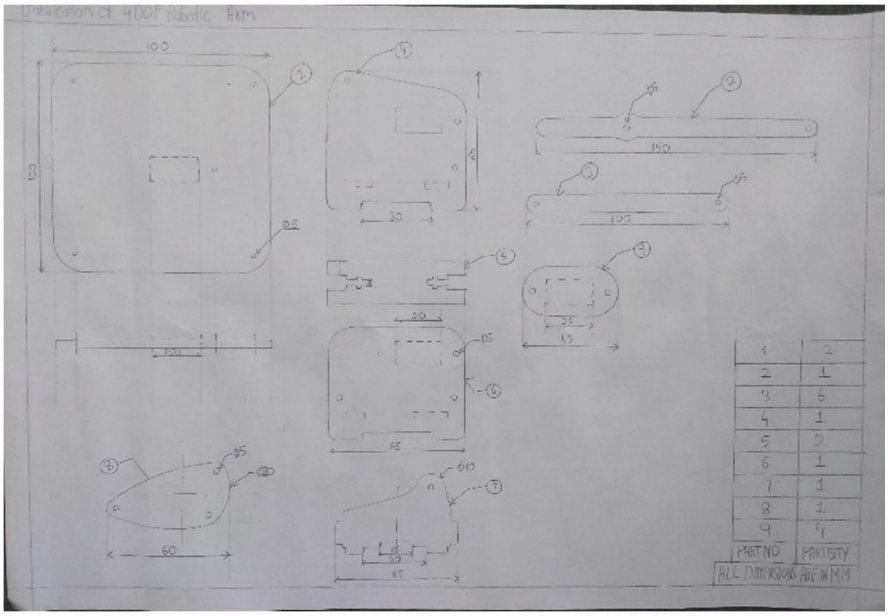

Fig. 7. Arm Design

2) *Selection of SG90 Servo Motors:* The selection of SG90 micro servo motors for the robotic arm system was deliberate due to their compact size, lightweight construction, and adequate torque output. These motors ensure minimal space consumption, maintaining the arm's agility and efficiency. Their precise control facilitates accurate rotational movements, enhancing object manipulation. The SG90 motors strike a balance between size, weight, and performance, making them an ideal choice for the robotic arm's operational requirements, thereby contributing significantly to its overall reliability and effectiveness in executing various tasks with precision and smoothness.

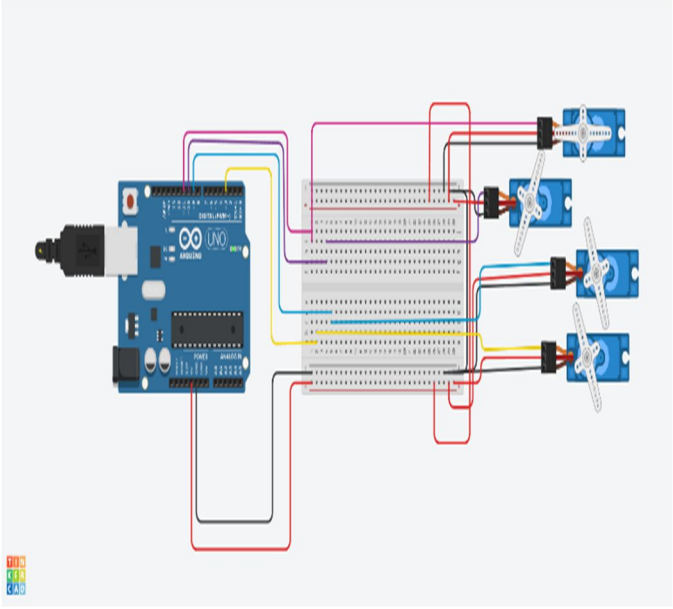

Fig. 8. Circuit Diagram of SG90

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3) *Integration of Computer Vision:* The system incorporates computer vision techniques for object recognition and color sorting. By integrating a webcam and implementing image processing algorithms using OpenCV, the system can identify and categorize objects based on their visual characteristics.

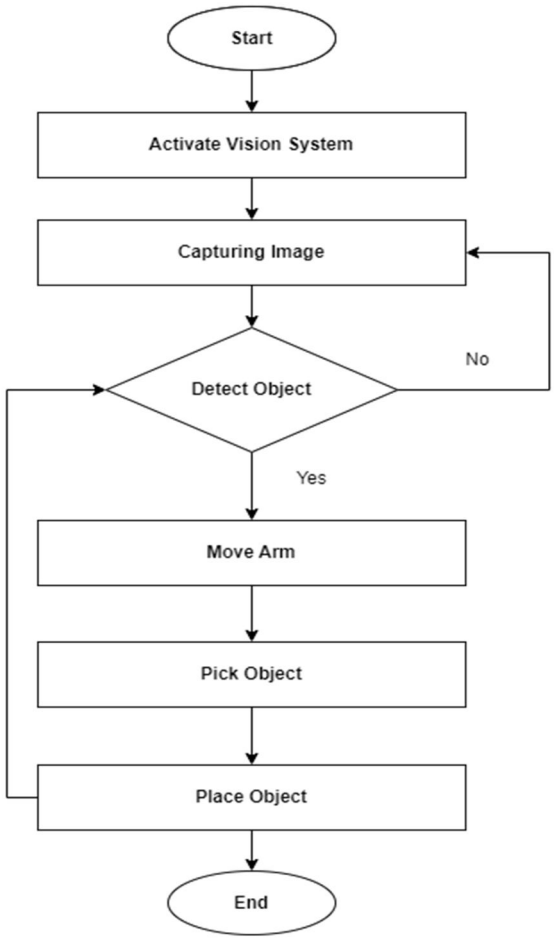

Fig. 9. Integration of Computer Vision

4) *Payload Capacity:* The robotic arm's payload capacity of 200 grams was meticulously chosen based on the torque capabilities of the SG90 servo motors and the structural robustness of the arm. This weight limit ensures optimal performance without straining the motors or compromising the arm's stability. By aligning the payload capacity with these technical considerations, the robotic arm system can effectively handle objects up to 200 grams, guaranteeing reliable and precise object manipulation while maintaining operational efficiency longevity.

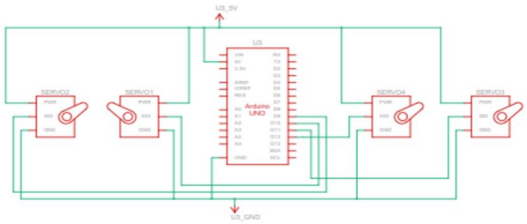

Fig. 10. Pin Diagram

C. Fundamental Formulas

1) *Torque Calculation:* Torque(T) can be calculated using the formula ($\Gamma = Fr$), where F represents the force applied perpendicular to the point of rotation, and r denotes the distance from the point of rotation to the line of action of the force.
2) *Forward Kinematics:* Forward kinematics determines the end-effector position and orientation based on the joint angles of the robotic arm. It can be expressed as a transformation matrix T obtained through successive matrix multiplications representing the rotations and translations of each joint.
3) *Inverse Kinematics:* Inverse kinematics solves for the joint angles required to a $T = \bar{\lambda}R$e a desired end-effector position and orientation. It involves the use of geometric and trigonometric relationships to determine the joint angles corresponding to a given end-effector pose.

4) Torque-Force Calculation of Model

T-F calculation of Gripper Motor-D:
Total weight for gripper =145 gram
F1 = m1* a1 N
= 0.145 * 9.8 = 1.42 N …..... (1)
T1 = F1 * L1
= 1.42 N * 0.01m = 0.14 kgcm …… (2)
T-F calculation of Motor A, B, C:
Total weight for Motor A, B, C = 250 gram
F2 = 0.25 * 9.8 = 2.45 N…… (3)
T2 = 2.45 N * 70m = 1.75 kgcm…….. (4)

TABLE I
Torque- Force calculation

Motor - Axis	Motion	Mass (kgcm)	Length (mm)	Torque (kgcm)	Force (N)
A-Y	Base rotation	0.250	15	0.36	2.45
B-Z	Up-Down	0.250	25	0.62	2.45
C-X	Forward & backward	0.250	70	1.75	2.45
D-Linear	Gripper Opening	0.145	10	0.14	1.42

IV. EXPERIMENTAL RESULTS

Experimental testing of the vision-assisted robotic arm system yielded promising results, showcasing its efficiency, accuracy, and sustainability. Through rigorous testing and evaluation, the system demonstrated its capability to perform object manipulation and sorting tasks with precision and reliability. This section provides an overview of the experimental setup, key findings, and implications of the results.

A. Experimental Setup

The experimental setup involved testing the vision-assisted robotic arm system under various conditions to assess its performance. The setup included:

1) *Object Recognition and Sorting:* For evaluating the system's prowess in object recognition and sorting, a diverse range of objects featuring various colors and shapes was meticulously selected. These objects were strategically placed within the system's workspace. Utilizing a high-resolution webcam, real-time images of these objects were captured, ensuring precise visual data acquisition. Subsequently, advanced computer vision algorithms were deployed to analyze these images comprehensively. The algorithms were specifically engineered to discern intricate details such as color variations and distinctive shapes, enabling the system to accurately identify and categorize objects based on their unique visual characteristics.

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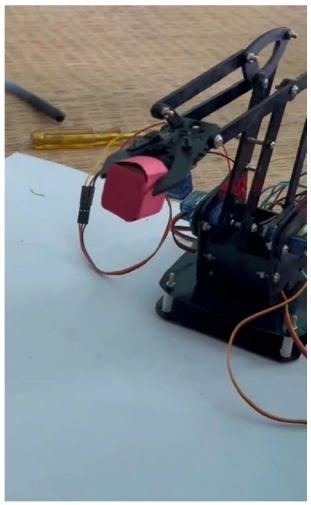

Fig. 10. Robotic Arm Pick Up the Object

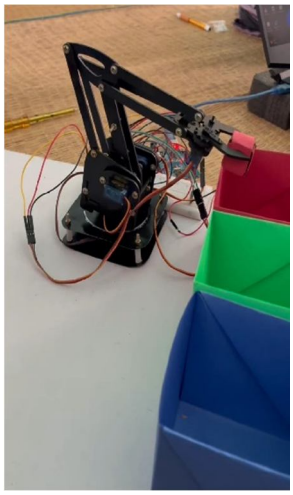

Fig. 11. Robotic Arm Successfully Determine

2) *Torque Measurement:* To gauge the system's robustness and mechanical proficiency during object manipulation tasks, a series of torque measurements were meticulously conducted. Diverse objects, each varying in weight and physical properties, were affixed to the end-effector of the robotic arm. Subsequently, a precision torque sensor was employed to measure the torque exerted by the servo motors while manipulating these objects. This comprehensive torque measurement procedure provided invaluable insights into the arm's ability to effectively handle varying loads and execute precise manipulation.
3) *Efficiency Testing:* The system's overall efficiency and operational efficacy were rigorously evaluated through comprehensive efficiency testing procedures. A diverse array of sorting tasks was meticulously designed and executed to assess the system's performance metrics comprehensively. Key performance indicators such as sorting speed, error rate, and throughput were meticulously measured and recorded throughout the testing phase. The time taken by the system to complete each sorting task was meticulously logged, providing valuable insights into its operational speed and efficiency. Furthermore, the accuracy of object recognition was rigorously scrutinized to ensure precise sorting capabilities. Through meticulous data collection and analysis, the system's efficiency, reliability, and overall performance were meticulously assessed, highlighting its ability to streamline industrial processes and optimize productivity effectively.

B. *Key Findings*

The experimental results revealed several key findings, highlighting the capabilities and performance of the vision-assisted robotic arm system:

1) *Precise Object Recognition:* The computer vision algorithms implemented in the system accurately identified objects based on their colors, enabling reliable sorting and manipulation.
2) *Efficient Sorting Process:* The system demonstrated high sorting speed and throughput, effectively reducing the time required to complete sorting tasks. This efficiency is essential for optimizing production processes and enhancing productivity in industrial settings.
3) *Sustainable Operation:* Torque measurements confirmed the arm's ability to handle moderate loads, indicating its suitability for industrial applications. The system's sustainable operation aligns with the objectives of Sustainable Development Goals (SDGs) related to sustainable production and consumption.
4) *Low Error Rate:* The system exhibited a low error rate in object recognition and sorting, minimizing the occurrence of misclassifications and errors. This reliability is crucial for maintaining high-quality standards in industrial processes.

C. *Implications and Future Directions*

The experimental results have significant implications for various industries, particularly in manufacturing, logistics, and recycling sectors. The vision-assisted robotic arm system offers a sustainable and efficient solution for automating object manipulation and sorting tasks, thereby reducing labor costs, minimizing errors, and improving overall productivity.

Moving forward, further research and development efforts can focus on:

1) *Optimizing Algorithm Performance:* Continuously refining and optimizing computer vision algorithms to enhance object recognition accuracy and speed.
2) *Scaling Up for Industrial Deployment:* Expanding the system's capabilities to handle larger volumes of objects and integrating it into industrial production lines for real-world deployment.
3) *Exploring New Applications:* Exploring new applications and use cases for the vision-assisted robotic arm system in diverse industries, such as agriculture, healthcare, and warehouse automation.

V. INSIGHTS AND OBSERVATIONS

The development and implementation of the vision-assisted robotic arm system have provided valuable insights into the potential of robotics and computer vision technologies for sustainable industrial practices. This section discusses key insights and observations gleaned from the project, highlighting its significance and implications.

A. Scalable and Adaptable Solution

The integration of robotics and computer vision technologies has resulted in a scalable and adaptable solution for object sorting and manipulation tasks. The vision-assisted robotic arm system can be easily customized and deployed across various industries, offering a versatile platform for optimizing production processes and enhancing efficiency.

B. Alignment with Sustainable Development Goals (SDGs)

The project aligns closely with the objectives of Sustainable Development Goals (SDGs), particularly those related to sustainable production and consumption, innovation, and industry growth. By automating object sorting and manipulation tasks, the system contributes to reducing waste, conserving resources, and promoting sustainable practices in industrial settings.

C. Potential for Innovation and Industry Growth

The vision-assisted robotic arm system represents a promising avenue for innovation and industry growth. Its integration of cutting-edge technologies opens up new possibilities for streamlining operations, improving productivity, and driving economic development. Moreover, the system's adaptability allows for continuous innovation and refinement, ensuring its relevance in a rapidly evolving industrial landscape.

D. Future Research and Development

The vision-assisted robotic arm system offers a promising future. We anticipate integrating advanced sensors, AI, and machine learning to enhance object recognition and sorting precision. Multi-object sorting, industry-specific adaptations, and collaboration with human operators are on the horizon. Improvements in energy efficiency, safety features, and remote control capabilities are priorities. Market expansion, user interface refinements, and international collaborations will further its reach and impact. This system remains poised for dynamic growth, adapting to evolving technologies and market demands across various sectors.

The fusion of vision technology and Arduino-driven robotics holds immense promise for the future. In the forthcoming years, we anticipate a deeper integration of these technologies into Industry 4.0, with fully autonomous manufacturing systems. Healthcare will benefit from vision-assisted robotic surgery, remote monitoring, and telemedicine, increasing precision and accessibility. In agriculture, smart farms equipped with vision systems will optimize crop management, and autonomous vehicles will revolutionize transportation. Personal robotics, including smart appliances and assistive devices, will become commonplace. Ethical considerations and robust regulations will be essential, and interdisciplinary collaborations will drive progress. Continuous research and innovation will remain pivotal, ensuring that the potential of these technologies is harnessed to shape a more intelligent and adaptive world in harmony with human needs.

VI. CONCLUSION

In conclusion, the fusion of vision technology and Arduino-driven robotics has paved the way for intelligent and adaptable automation solutions. Vision-assisted robot arms hold the promise of transforming industries and revolutionizing how we interact with and harness the power of robotics in our daily lives. Within the manufacturing sector, these vision-assisted robotic arms are poised to optimize production lines, streamline assembly processes, and deliver consistent quality while reducing the risk of errors. The potential for cost savings and enhanced productivity is nothing short of revolutionary.

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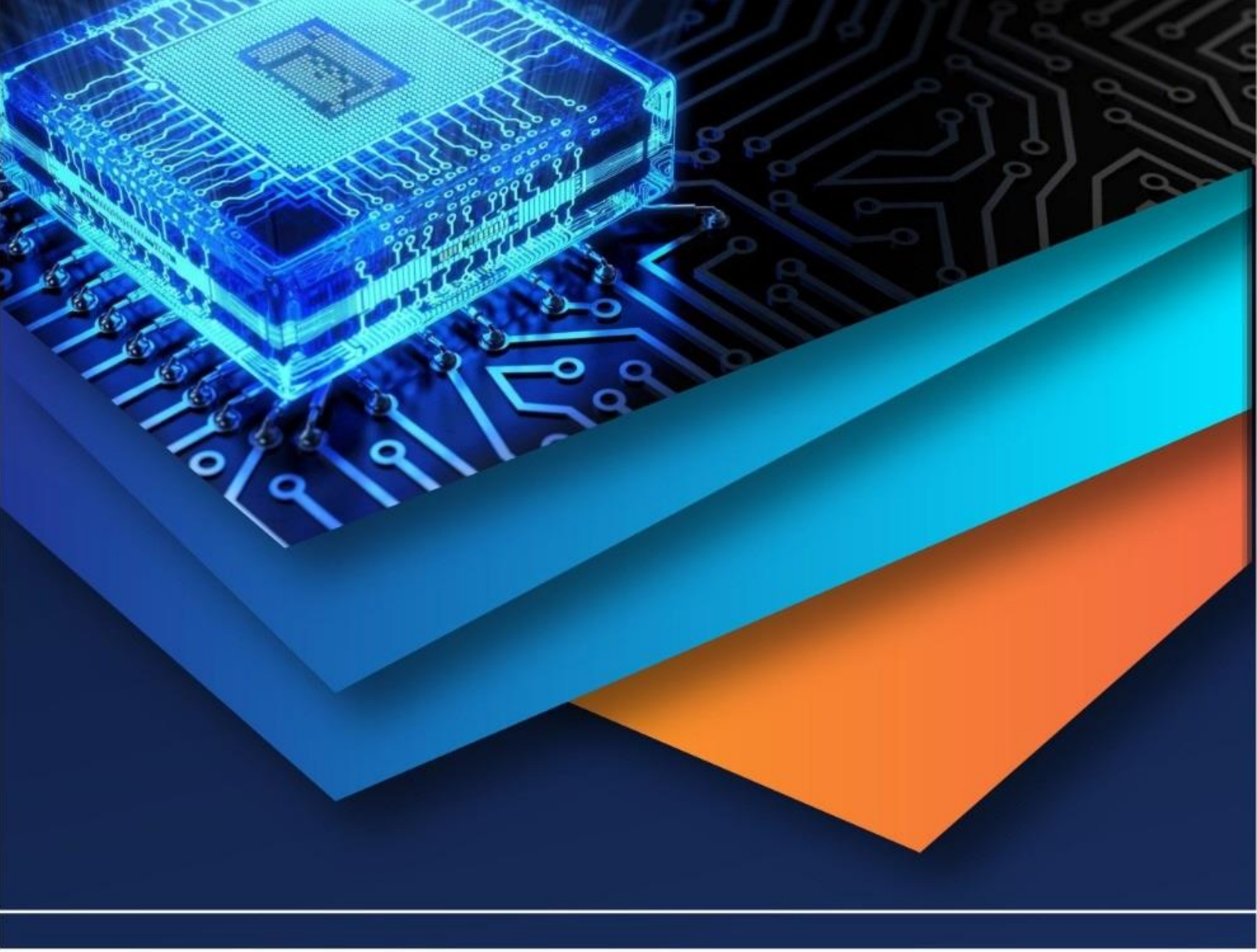

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