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Design and Fabrication of 6 Axis Robotics Arm: A Systemic Review of the Literature

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ABSTRACT: This review paper examines the design, control, and applications of robotic arms, focusing on their pivotal role in industrial automation and hazardous environment operations. The paper highlights the challenges posed by the complexity and cost of robotic systems and explores strategies for enhancing affordability without compromising performance. Through a comprehensive literature review, the paper analyzes various approaches to robotic arm design, including kinematic modeling, control techniques such as PID controllers and fuzzy logic-based joint controllers, and innovative mechanisms like counterbalance systems. Case studies and experimental results demonstrate the effectiveness of these approaches in improving robotic arm functionality, precision, and safety. By synthesizing findings from diverse research studies, the paper provides valuable insights into the current state-of-the-art in robotic arm technology and identifies promising avenues for future research and development.

KEYWORDS: Robotic arms, industrial automation, hazardous environments, affordability, performance, kinematic modeling, control techniques, PID controllers, fuzzy logic, counterbalance systems, applications

I. INTRODUCTION

Robotic arms have become indispensable tools in industrial automation and hazardous environment operations, revolutionizing processes with their precision and efficiency. However, the complexity of these robotic systems often comes with a hefty price tag, particularly concerning the controllers. The prohibitive costs associated with high-precision actuators and control systems have posed barriers to widespread adoption and hindered the pace of progress in robotics research [1, 2]. Addressing the affordability of robotic arms holds the key to accelerating advancements in the field. By offering heavy discounts on prices, manufacturers can potentially widen access to these valuable tools, catalyzing acceptance and fostering a more rapid evolution of robotic technology. Nevertheless, achieving affordability without compromising quality and performance necessitates careful consideration of design trade-offs across various dimensions.

In the realm of robotic arms, decision-making is multifaceted, involving assessments of factors such as backlash, payload capacity, speed, stability, human safety, and cost. Each dimension plays a crucial role in determining the suitability of robotic arms for different applications, with some considerations carrying more weight in specific contexts. For instance, in tasks requiring precise gripping and manipulation of objects, attributes like repeatability and low backlash are paramount. Additionally, ensuring human safety becomes a critical concern, particularly in environments where robots operate in close proximity to human workers. To explore avenues for affordable yet effective robotic control solutions, this paper delves into the utilization of accessible hardware such as the Arduino UNO A000066 as a controller, complemented by force sensors and potentiometers strategically positioned within the robotic arm's structure. Leveraging earlier models made of lightweight and cost-effective materials like aluminum, this research aims to demonstrate the feasibility of developing economically viable robotic arms without compromising on performance [3]. With a focus on six-axis robotic arms, which offer unparalleled versatility in industrial applications by enabling movement across multiple planes and orientations, this study endeavors to contribute insights into the design and fabrication of cost-effective yet capable robotic systems.

II. OBJECTIVE

The objective of this review paper is to provide a comprehensive analysis of the design, control, and applications of robotic arms, with a specific focus on addressing the challenge of affordability while optimizing performance. The paper aims to:

1. Explore existing literature on robotic arm design, control techniques, and applications, identifying key advancements, challenges, and opportunities.
2. Investigate strategies for reducing the overall cost of robotic arms without compromising functionality, precision, or safety.
3. Evaluate various control techniques, including PID controllers, fuzzy logic-based controllers, and soft computing approaches, to enhance robotic arm performance.
4. Examine innovative mechanisms and design principles, such as counterbalance systems and lightweight materials, for achieving cost-effectiveness in robotic arm fabrication.
5. Provide insights into the integration of affordability considerations into the entire design and fabrication process of six-axis robotic arms.
6. Identify gaps in the literature and propose future research directions to further advance the field of robotic arm technology, particularly in terms of affordability and accessibility.

III. LITERATURE REVIEW

Jamshed Iqbal et al. (2012) develop a kinematic model for a six-degree-of-freedom (6 DOF) robotic arm and analyze its workspace. Their research enables precise control of the manipulator to any reachable position and orientation, particularly in unstructured environments. The kinematic models are based on the Denavit Hartenberg (DH) parametric system, providing both forward and inverse kinematic solutions. The forward kinematic model is validated using MATLAB with Robotics Toolbox, while the inverse kinematic model is implemented on a real robotic arm. Experimental results demonstrate that the proposed model allows the robotic arm's end-effector to accurately point at target coordinates within 0.5cm precision. The methodology presented in this paper can be applied to address kinematics challenges in other similar types of robot manipulators.

Rahul Gautam's et al. (2017) review discusses the development of an industrial robotic arm tailored for selective control, particularly useful for tasks such as placing or picking objects distant from workers. The success of the robotic arm lies in its precise movement control. To minimize maintenance costs associated with cable replacement, the design prioritizes reducing friction on the table. This paper highlights the significance of efficient design in enhancing the longevity and performance of industrial robotic arms.

Mahanta G.B et al. (2019) In this paper, the authors explore the use of soft computing approaches for determining the inverse kinematics of a Kawasaki RS06L 6-DOF robotic manipulator in a pick and place operation. They conduct a comprehensive analysis comparing techniques such as artificial bee colony (ABC), firefly algorithm (FA), invasive weed optimization (IWO), and particle swarm optimization (PSO) to assess their effectiveness. Prior to conducting actual experiments, detailed simulations are performed to ascertain the inverse kinematics of the system. The results obtained from the simulations are then applied to the Kawasaki Controller for executing pick and place tasks, demonstrating efficient reversibility. This study highlights the potential of soft computing techniques in enhancing the performance of robotic manipulators for industrial applications.

N.G. Adar et al. (2016) present a study on a two-degree-of-freedom (2-DOF) PID controller method for a six-degree-of-freedom rigid robotic manipulator. Traditional PID controllers are commonly used in industry due to their simplicity, but they can be affected by load disturbances and parametric fluctuations, impacting their robustness. The proposed 2-DOF PID controller is compared with traditional PID controllers in terms of performance. The study implements the proposed method in real-time using the Matlab-Simulink application. Experimental results demonstrate that the 2-DOF PID control outperforms standard PID control in real-time manipulator control applications.

Ankur Bhargava's et al. (2017) paper presents a survey on an Arduino-controlled robotic arm with five degrees of freedom (DOF). The robotic arm, constructed using an Arduino Uno microcontroller, employs a set of potentiometers to accept input signals and control its movements. The arm consists of four pieces, including termination effects and rotary joints for rotational motion, with each link meticulously crafted from a 2mm thick aluminum sheet. Servomotors are utilized to provide rotational motion to the joints, and SolidWorks Sheet Metal Working Toolbox is employed for fabrication. The Arduino is programmed to control the rotation of each servomotor based on the corresponding

potentiometer's rotation, enabling precise and proportional movement of the arm's links. This paper sheds light on the design and fabrication process of the robotic arm, emphasizing the characterization of its movements through relative link motion.

Ashraf Elfasahany's et al. (2011) study focuses on the design and development of a low-cost robot arm with four degrees of freedom (DOF) for performing simple tasks like light material handling. The arm is constructed using acrylic material, with servo motors facilitating the movement between its links. Encoder-equipped servo motors obviate the need for a separate controller. However, the limited rotation range of the motors (less than 180 degrees) constrains the arm's reach and positioning capabilities. The design opts for four DOFs, omitting consideration for an end effector due to the cost-effectiveness and ease of using a commercial gripper. This paper underscores the feasibility of creating competitive yet affordable robot arms suited for basic industrial applications.

Won-Bum Lee et al. (2017) propose a novel six-degree-of-freedom collaborative robot with a multi-degree-of-freedom CBM, as presented in the 2017 IEEE ICRA. Their design incorporates a double parallelogram linkage and a slider-crank mechanism for a compact and durable CBM, which can be seamlessly integrated into the robot linkages. Unlike previous prototypes, where parts of CBMs protruded from the robot body due to their large volume, the suggested CBMs are fully integrated, improving overall aesthetics and functionality. Through dynamic simulation software, the performance of the designed CBM and collaborative robot is verified, showing a reduction in joint torques and enabling the use of low-power motors. This innovation enhances crash safety and energy efficiency in collaborative robots.

Dino Dominic Ligutan et al. (2018) presents the design, simulation, and implementation of a fuzzy logic-based joint controller (FLJC) on a six-degree-of-freedom (6-DOF) robotic arm equipped with machine vision feedback for object manipulation tasks. Implemented on a four-degree-of-freedom M100RAK robotic arm with a two-degree-of-freedom gripper, the FLJC operates within a closed-loop system, receiving inputs such as joint angles, gripper coordinates, and target object coordinates. Utilizing an MPU6050 Six-Axis sensor for measuring joint angles and a machine vision system comprising a Kinect camera and open-source Processing software for gripper and target object coordination extraction, the FLJC computes joint angles and communicates them to an Arduino microcontroller for servo control via network protocols packets.

Pragathi Praveena et al. (2019) present an offline method for generating smooth and viable motion for robot arms, specifically targeting the end-effector posture goals of a 6-DoF path within user-defined acceptable limitations. Their approach aims to closely match the position and orientation goals of a given path while allowing deviations to avoid self-collisions, joint-space discontinuities, or kinematic singularities. By generating multiple alternative trajectories and selecting the optimal one based on sparse user input regarding acceptable deviations, their method achieves smooth, achievable motions that closely approximate the provided posture goals and adhere to user specifications. Through application to various demanding pathways, they demonstrate the effectiveness of their approach in producing satisfactory solutions for robotic motion planning.

Hwi-Su Kim et al. (2014) introduce a novel counterbalance system designed to completely offset the gravitational torques induced by the robot mass. Their approach employs a 3-degree-of-freedom (3-DOF) counterbalance system based on the double parallelogram mechanism, offering reference planes to each joint for effective counterbalancing, especially pertinent for 6-degree-of-freedom (6-DOF) robots with three vulnerable pitch joints. Demonstrating the system's performance, they created a 5-DOF balancing robot arm. The proposed mechanism significantly reduces the torque necessary to support the robot mass, paving the way for the use of low-cost motors and slower speeds in future applications, as evidenced by simulation and experimental results. Model and Material which are used is presented in this section. Table and model should be in prescribed format.

IV. LITERATURE GAP

While the existing literature provides valuable insights into various aspects of robotic arm design, control, and applications, there remains a notable gap in research focusing on the integration of affordability and performance optimization. Many studies discuss advanced control techniques, such as PID controllers and fuzzy logic-based controllers, along with innovative mechanisms like counterbalance systems. However, few studies explicitly address the challenge of reducing the overall cost of robotic arms without compromising their functionality and efficiency. Additionally, there is limited exploration of design strategies that leverage accessible hardware and lightweight materials to achieve cost-effectiveness while maintaining high performance standards.

Furthermore, while some studies investigate specific components or subsystems of robotic arms, such as end effectors or counterbalance mechanisms, there is a lack of comprehensive approaches that consider the holistic design and fabrication process of six-axis robotic arms. Integrating affordability considerations into every stage of the design process, from material selection to manufacturing techniques, is essential for developing economically viable robotic arm solutions. Therefore, there is a clear need for research that bridges the gap between advanced robotic arm technologies and affordability, offering practical insights and guidelines for designing and fabricating cost-effective yet capable six-axis robotic arms.

V. CONCLUSION

In conclusion, this review paper has provided a comprehensive overview of the design, control, and applications of robotic arms, with a particular emphasis on addressing the challenge of affordability while maintaining performance standards. Through the analysis of existing literature and case studies, various strategies for enhancing affordability without compromising functionality, precision, or safety have been explored. From innovative control techniques to novel mechanisms and design principles, this paper has highlighted the diverse approaches available for achieving cost-effectiveness in robotic arm fabrication. By synthesizing findings from a range of research studies, valuable insights into the current state-of-the-art in robotic arm technology have been presented, along with promising avenues for future research and development. Ultimately, the integration of affordability considerations into the entire design and fabrication process of six-axis robotic arms is crucial for advancing the field and facilitating their broader adoption in industrial automation and hazardous environment operations.

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