Prosthetic arm using Arduino and Arduino sensors: An Exploration of convenience, affordability and reliability

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Abstract - **Prosthetic limbs play a crucial role in enhancing the quality of life for amputees, yet high costs and limited accessibility remain significant barriers. This research presents a cost-effective prosthetic arm designed using Arduino and flex sensors to achieve precise and responsive movement. By leveraging Arduino's open-source nature and affordability, the proposed design provides a customizable and scalable alternative to existing market solutions. A comparative analysis highlights the prosthetic arm's advantages in terms of cost reduction, functionality, and adaptability compared to commercial models like KalArm. The modular construction enables future upgrades, ensuring long-term usability. This study outlines the development process, testing methodology, and performance metrics, demonstrating how the proposed design bridges the gap between affordability and advanced functionality in prosthetic technology**

I. Introduction

The ability to perform basic physical tasks is integral to daily living. Yet, millions of individuals worldwide face challenges due to the loss of limbs caused by accidents, diseases, or congenital conditions. Prosthetic limbs have long been instrumental in addressing these challenges, providing users with restored mobility and functionality. However, the high cost and limited accessibility of advanced prosthetics significantly restrict their availability, especially in lowend middle-income regions. Existing commercial prosthetics, such as the KalArm, Symbionic, Grippy, and other bionic models, offer advanced features like multi-grip control and responsive movement. Despite their technological sophistication, these solutions often come with prohibitive costs, proprietary systems, and limited adaptability to individual user needs. This creates a gap in the market for affordable, customizable, and efficient prosthetic devices. Arduino, an open-source microcontroller platform, has emerged as a transformative tool in various fields due to its affordability, ease of use, and compatibility with a wide range of sensors and actuators. These features make Arduino an ideal candidate for developing cost-effective prosthetic solutions. This research focuses on designing a prosthetic arm using Arduino and flex sensors, aiming to balance functionality with affordability. The primary goal is to demonstrate that an Arduino-based design can achieve comparable performance to existing market solutions while being significantly more accessible and adaptable. This paper explores the development process, key design features, and testing methodologies, followed by a comparative analysis to highlight the advantages of the proposed design over existing alternatives.

II. Current Status

Prosthetic arm technology has seen significant advancements in recent years, with a growing emphasis on functionality, aesthetics, and user adaptability. High-end commercial prosthetic devices, such as the Kalarm, Symbionic, Grippy and other bionic limbs, incorporate advanced features like multi-grip control, lightweight materials, and responsive movement mechanisms. However, these devices are often associated with substantial costs, typically ranging from Rs80,000 to Rs41,00,000, depending on customization and functionality. This high price point makes them inaccessible to a large population, particularly in low-income regions. Meanwhile, open-source and DIY approaches have gained traction, leveraging platforms like Arduino for prototyping and low-cost manufacturing. These projects aim to bridge the accessibility gap by providing cost-effective alternatives to commercial solutions. Despite this progress, many such prototypes lack scalability, robustness, and the polished functionality seen in professional-grade prosthetics. Developing a prosthetic arm using Arduino and flex sensors addresses these limitations by combining affordability with practical functionality. By employing readily available components, the proposed design focuses on creating a modular, lightweight, and customizable solution that meets users' essential needs while remaining cost-efficient. This approach reduces production costs and provides a scalable foundation for future enhancements, such as wireless connectivity and advanced control systems. The global robotic prosthetics market size was valued at USD 1.4 billion in 2022. It is anticipated to progress at a compounded annual growth rate (CAGR) of 8.8% from 2023 to 2030. The market is primarily driven by the high rate of innovation in the field of robotics by deploying artificial intelligence, 3D printing, and increased demand for custom-made bionic prostheses.

III. Findings and Analysis: A Comparative Perspective

The The current prosthetics market offers a diverse range of options, from advanced highcost models to basic low-cost alternatives. While products like KalArm, Symbionic, and Grippy have carved their niches, they each have limitations that our Arduino-based prosthetic arm effectively addresses.

1. Cost Efficiency
   • KalArm: A premium product with cutting-edge technology, but the cost remains a significant barrier, limiting accessibility to users with substantial financial resources or insurance coverage.
   • Symbionic: Priced moderately, yet still unaffordable for many, especially in underserved regions.
   • Grippy: Offers a budget-friendly option but compromises on functionality and durability.

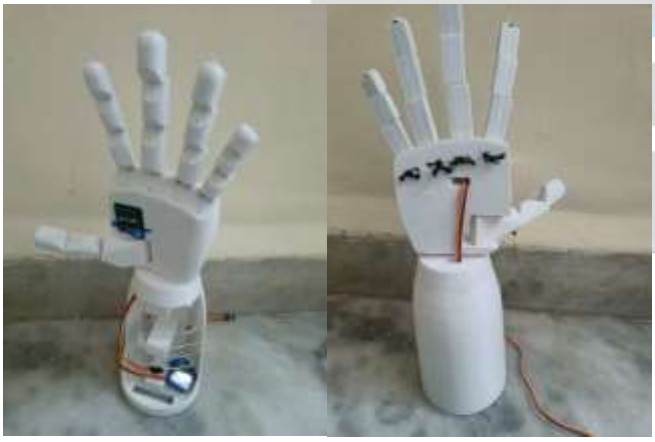
• Prosthetic Arm using Arduino and Arduino Sensor: Designed with affordability as a core principle, it delivers essential functionalities at a fraction of the cost. By leveraging open-source Arduino technology, production costs are estimated to be lower than most of the bionic arms available on the market, making it an ideal choice for costconscious users.

2. Functionality and Features
   • KalArm: Excels in advanced motion control and signal processing but requires complex calibration and extensive power, making it less user-friendly for everyday use.
   • Symbionic: Focused on natural movement through advanced control systems but lacks the flexibility to meet specific user preferences. • Grippy: Limited to basic grip-and-release functionality, suitable only for simple tasks.
   • Prosthetic Arm using Arduino and Arduino Sensor: Strikes a perfect balance between simplicity and functionality. Powered by flex sensors, it offers intuitive and responsive grip control, ensuring reliable performance for daily activities. While not as sophisticated as KalArm or Symbionic, it surpasses Grippy by offering greater precision and usability.
3. Customization and Adaptability
   • KalArm: Proprietary systems restrict user modifications, leading to high maintenance and repair costs.
   • Symbionic: Offers limited customization options, often requiring professional technical support.
   • Grippy: Lacks modularity, with fixed designs that cannot be adapted to diverse needs.
   • Prosthetic Arm using Arduino and Arduino Sensor: Built with a modular design, it allows users to replace, upgrade, or adapt components easily. This level of personalization empowers users to tailor the prosthetic to their unique requirements, a feature unmatched by competitors.
4. Accessibility
   • KalArm: Targets affluent markets with advanced features, often out of reach for users in developing regions.
   • Symbionic: Moderately accessible but still beyond the financial means of many in lowincome communities.
   • Grippy: Affordable, yet its lack of durability and limited features make it less suitable for long-term use.
   • Prosthetic Arm using Arduino and Arduino Sensor: Designed to break accessibility barriers, it combines affordability, durability, and essential features, making it an excellent solution for underserved populations and resource-constrained settings.
5. User Experience
   • KalArm: Offers premium features but can feel bulky and power-intensive, impacting long-term comfort.
   • Symbionic: Prioritizes ease of use but requires regular maintenance, which can be inconvenient for users.
   • Grippy: Lightweight and simple, but its limited control reduces its practicality for complex tasks. • Prosthetic Arm using Arduino and Arduino Sensor: Prioritizes user comfort with a lightweight and intuitive design. Flex sensor technology ensures natural and responsive control, making it easy for users to perform everyday tasks with minimal effort.

IV. Conclusion of Comparison

Arduino-based prosthetic arm emerges as a game-changer by addressing the gaps left by existing market players: • Affordability: The most cost-effective solution, reducing financial barriers significantly. • Functionality: Balances practicality and usability, offering reliable performance without unnecessary complexity. • Customization: A modular approach ensures adaptability, making it user-centric and future-proof. • Accessibility: Ideal for resource-limited settings, bringing advanced prosthetic technology within reach for underserved communities.

Design Of the Prosthetic Arm using Arduino and Arduino Sensor:



V. Cost Comparision of the Bionic Arms

nKalArm:

• Approximate Cost: ₹25,00,000–₹41,00,000
• Reason: Premium features, advanced functionality, and high-quality materials significantly contribute to the cost.

Symbionic:

• Approximate Cost: ₹8,00,000–₹16,50,000
• Reason: Mid-range pricing with a balance between advanced features and affordability.

Grippy:

• Approximate Cost: ₹80,000–₹4,00,000
• Reason: Positioned as a budget-friendly option with basic functionalities and limited

durability.

Prosthetic Arm using Arduino and Arduino Sensor:

• Approximate Cost: ₹5,000–₹15,000 (estimated based on Arduino and flex sensor components).

• Reason: Relies on open-source technology and cost-effective components, making it an affordable yet functional solution.

VI. CONCLUSION

This research demonstrates the potential of Arduino-based technology in addressing the critical challenges of affordability and accessibility in prosthetic arm design. By utilizing Arduino and flex sensors, the proposed prosthetic arm achieves precise and responsive functionality while significantly reducing production costs compared to existing market alternatives. The modular and open-source nature of the design not only enhances adaptability for individual users but also provides a scalable platform for future advancements. Through comparative analysis, the proposed design has shown promising results in terms of cost-efficiency, functionality, and user-centric adaptability. These attributes make it a viable alternative to expensive commercial prosthetics, especially in underserved regions where access to advanced medical devices remains limited. While the prototype demonstrates significant advantages, there are areas for further improvement. Enhancements such as incorporating haptic feedback, improving power efficiency, and adding advanced control mechanisms like gesture recognition can elevate the prosthetic's functionality to a higher level. In conclusion, this project serves as a step toward democratizing prosthetic technology by delivering a practical, affordable, and scalable solution. With further refinement and broader testing, the proposed design has the potential to make high-quality prosthetics more accessible, ultimately improving the lives of amputees worldwide.

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