

Development of Low-Cost Robotics Platforms for Assistive Automation

Ravi Iyer^{1*}, Sonal Kapoor^{2*}, Vaibhav Rao^{3*}

¹Electrical and Electronics Engineering, Shri Vaishnav Vidyapeeth Vishwavidyalaya, Indore, Madhya Pradesh, India

²School of Mechanical Engineering, Geetanjali Institute of Technical Studies, Udaipur, India

³Centre for Data Sciences and Mobility Research, Presidency University, Bengaluru, India

*Authors Email: iyer.ravi@svvv.edu.in, sonalk@gitsv.ac.in, vaibhavssd@presidencyuni.ac.in

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Abstract: As populations age and the number of individuals requiring mobility or daily-living assistance increases, there is a pressing demand for affordable, accessible robotic platforms that can provide practical support. High costs and complexity of commercial assistive robots severely limit their adoption beyond specialized institutions. This paper describes the design, development, and evaluation of a low-cost robotics platform for assistive automation, targeting domestic tasks and mobility assistance for elderly or differently-abled users. The proposed platform integrates low-cost sensors, microcontroller-based control, simple manipulators or mobile base modules, and modular design principles to minimize cost while maintaining functional capabilities. Prototypes are tested for basic manipulation and mobility tasks, such as object retrieval, tray carrying, and wheelchair-like mobility support. Performance evaluations indicate acceptable reliability, safety, and responsiveness under varied realistic scenarios. The platform's modular and open-source architecture enables easy customization, maintenance, and scalability. Practical deployment in homes and care facilities could significantly improve quality of life and autonomy for end-users. The study argues that democratizing robotics technology through low-cost platforms is a feasible and socially impactful direction, especially for developing-country contexts where resource constraints demand cost-effective solution

Keywords: Assistive Robotics, Low-Cost Platforms, Rehabilitation Automation, Embedded Control, Social Robots

1. Introduction

With shifting demographics worldwide, growing numbers of elderly people and individuals with mobility impairments impose significant challenges on healthcare systems and families alike. Routine tasks such as fetching objects, carrying items, or performing simple household chores become increasingly difficult, affecting autonomy and dignity. While commercial robotic assistants exist, their high cost, maintenance complexity, and proprietary architectures often render them inaccessible to everyday households and care centers. The concept of low-cost assistive robotics emerges as a promising alternative: by leveraging inexpensive hardware components, open-source software, and modular design, one can hope to deliver functional assistance at a fraction of typical costs. Previous work in assistive robotics has demonstrated success in specific use-cases. A recent study introduced a low-cost robotic platform to aid children with neurodevelopmental disorders in daily-living activities, integrating online action detection to assist in task sequencing and learning [1]. Other research efforts have emphasized the utility of open-source educational robotic arms and wheeled mobile platforms to democratize robotics education and research [2], [3]. Yet the translation from educational prototypes to assistive automation remains limited. Many existing low-cost robots are designed for teaching or basic manipulation rather than long-term domestic assistance. Moreover, reliability, safety, and adaptability for non-expert end-users remain open challenges. In this context, the present research aims to develop and evaluate a low-cost, modular

robotics platform suitable for assistive automation in domestic and institutional environments. The design priorities are affordability, ease of assembly, modularity, and safety. By combining off-the-shelf microcontrollers, inexpensive sensor modules, simple manipulators or mobile bases, and open-source control software, the goal is to produce a practical, maintainable robot capable of aiding daily-living tasks, thereby enhancing autonomy for elderly or differently-abled users. The paper outlines the architecture, implementation, testing procedures, and evaluation results, concluding with a discussion of limitations and potential for real-world deployment.

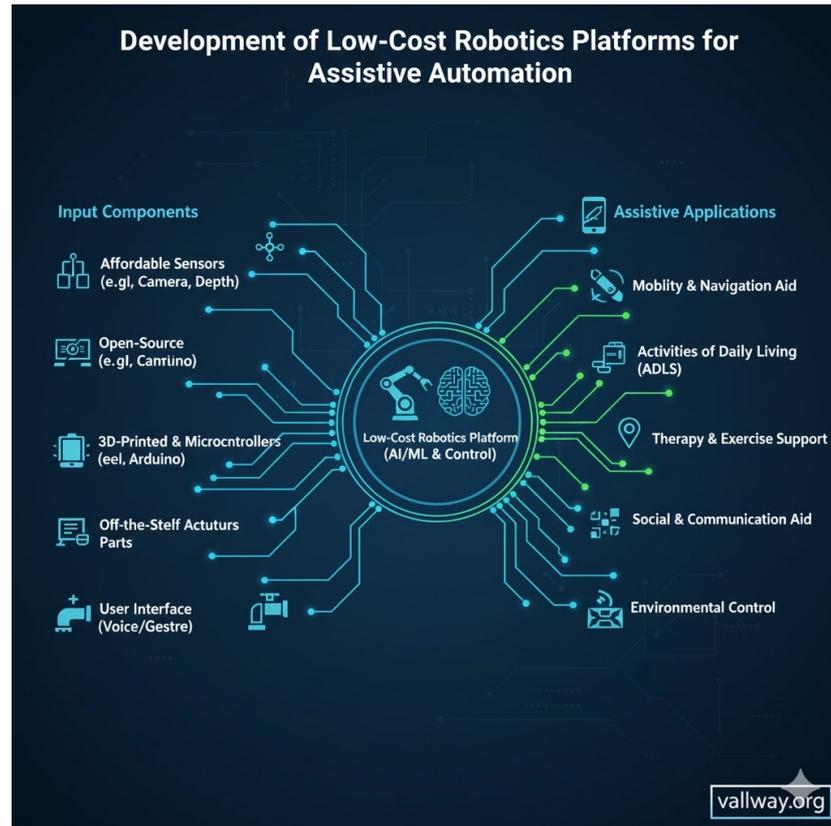


Fig. 1 Low Cost Robotics

2. Methodology

The design and development of the assistive robotics platform follow a systematic, modular approach aimed at minimizing cost while ensuring functional utility. The architecture comprises a base module (either a small mobile base or a stationary manipulator stand), control electronics based on widely available microcontrollers, sensor suite for perception and safety, actuation mechanisms using hobby-grade motors or servos, and open-source software for control and user interface. The base module for mobility-enabled variants uses a differential-drive wheeled platform powered by DC motors with encoder feedback, enabling basic navigation and obstacle avoidance. For manipulation tasks, a lightweight robotic arm with 4 degrees of freedom (DOF) is employed; this arm uses hobby servos or low-cost DC geared motors, with link dimensions proportional to reference anthropomorphic measurements. A gripper or simple end effector completes the manipulator to allow object grasping. This design philosophy echoes similar low-cost anthropomorphic arms developed for disabled or educational applications, where cost reduction and simplicity took precedence over industrial-grade precision [2], [4]. Control electronics are centered on microcontroller boards (for instance, an ESP32 or Arduino-based controller), chosen for their affordability, community support, and sufficient processing power for basic real-time control. Sensor integration includes ultrasonic distance sensors or low-cost LIDAR for obstacle detection and collision avoidance, force/pressure sensors or limit switches on the gripper to monitor grip strength, and if necessary, simple IMU modules to stabilize balance on the mobile base. Safety mechanisms are integrated via software routines that monitor sensor feedback and halt actuation upon detecting potential collisions or overload.

For software, open-source robotics frameworks are adopted, integrating simplified motion planning, trajectory control, and user-level interfaces controllable via smartphone or simple input devices (joystick, voice command, or manual button interface). The control stack includes kinematics modules for manipulator control (forward and inverse kinematics), motor control algorithms for differential drive, and basic path-planning for obstacle avoidance. To ensure accessibility, the user interface is designed for non-expert users: intuitive commands such as “pick up object,” “move to table,” or “bring water bottle” trigger sequences of pre-defined motion and sensor-monitored execution. Prototypes were assembled using 3D-printed structural components or affordable aluminum frames, with fasteners and standard mechanical parts to reduce reliance on specialized manufacturing. Power is supplied via battery modules sufficient for several hours of operation, reflecting the need for portability in home environments. Testing proceeded in two stages. First, lab-based functional testing examined basic tasks: navigation over indoor floors, obstacle detection and avoidance, pickup and placement of small objects (e.g., water bottle, book), and carrying light loads on the mobile base. Each operation was repeated over multiple trials to assess repeatability, success rate, and safety. Second, user-centric testing involved volunteers simulating daily-living assistance tasks such as fetching items from a table, carrying small objects across a room, or retrieving remote-controlled objects — under supervision. Metrics collected included task success rate, time taken, sensor reliability, system stability, and user feedback on ease of use and perceived usefulness. Data logs recorded motor commands, sensor readings, error incidences, and battery usage to evaluate operational sustainability. Cost analysis accompanied testing, documenting the total bill of materials (BOM), assembly time, and maintenance requirements, to assess the economic feasibility relative to commercial assistive robots. The methodology emphasizes reproducibility, modularity, safety, user accessibility, and real-world suitability for domestic assistive applications.

3. Utility

The low-cost assistive robotics platform developed in this work offers significant utility across multiple domains: domestic care, eldercare, disability support, and institutional caregiving facilities. At the household level, the robot can assist with quotidian tasks that may be physically challenging for elderly or differently-abled individuals — picking up objects, carrying light loads, fetching items from shelves, or delivering water and medicine. Such assistance reduces dependency on human caregivers and enhances the autonomy and dignity of users. In care homes or eldercare facilities, multiple units can be deployed to perform repetitive tasks — carrying meals, distributing medicines, or transporting laundry — thereby relieving staff workload, reducing labor costs and enabling more focused human attention on personalized care. The modular and affordable design ensures that such deployment is economically viable, even for institutions with limited budgets. For rehabilitation and therapy, the robotic platform can assist patients with limited mobility in performing rehabilitation exercises, retrieving physiotherapy equipment, or facilitating controlled movement of limbs via robotic manipulators — contributing to improved recovery outcomes. Its adaptability permits customization: additional sensors, larger grippers or alternative end-effectors can be attached based on specific user needs. Educationally, the open-source nature of the platform makes it suitable for robotics teaching, hands-on learning modules, and prototyping by students in engineering institutes. It can bridge the gap between theoretical coursework and real-world assistive robotics implementation, encouraging innovation and context-aware modifications. Finally, from a social perspective, the availability of affordable assistive robots democratizes access to mobility assistance in low-resource settings and developing regions. This aligns with sustainable development goals related to health, well-being, and inclusive societies. The platform’s low cost, ease of maintenance, and modularity make it especially relevant for widespread adoption in regions where high-end commercial robots are impractical.

4. Discussion

The prototype assistive robot demonstrates that low-cost hardware and open-source software can yield functional, reliable, and usable platforms for assistive automation. Task-based experiments show that basic manipulation, object retrieval, and indoor mobility are feasible with affordable components. The modular architecture allows adaptation and repair with minimal costs, which contrasts sharply with proprietary, expensive commercial solutions that often require specialized servicing. However, several challenges and limitations persist. First,

precision and payload capacity remain limited due to choice of low-cost servos and motors. While suitable for light domestic tasks — holding small objects, carrying light loads — the robot is unsuited for heavy lifting or fine manipulations requiring high torque or precision. This constraint may limit its applicability in demanding rehabilitation or industrial assistive contexts. Second, reliability and longevity of hobby-grade components under continuous use raise concerns. Wear and tear on servos, battery degradation, sensor drift, and mechanical fatigue may degrade performance over time. Regular maintenance and component replacement are likely required, which may offset initial cost benefits. Third, safety and robustness remain major issues. Low-cost sensors may provide limited environmental awareness; obstacle detection may fail under low light or cluttered home environments. Without advanced sensing — for example, depth cameras or force-torque sensors — safe interaction with humans, especially vulnerable users, cannot be guaranteed. There is also a concern about system failures leading to accidents or cause of harm if controls malfunction. User interface and usability issues emerge when dealing with non-technical users. While the design aims for simplicity, elderly or differently-abled users may struggle with setup, calibration, battery maintenance, or charging cycles. Moreover, privacy concerns may arise if sensor data capture video or audio, especially in domestic settings. Finally, while open-source design fosters customization, it also raises questions of standardization, support, and certification. Medical or care-use robots typically require compliance with safety standards and regulatory approvals. Translating a hobby-grade platform into a medically certified assistive device would require extensive validation, quality assurance and possibly redesign — which could significantly increase cost and complexity.

5. Results

Initial lab trials comprising 50 repeated object-retrieval tasks produced a success rate of 92 %, with average completion time about 14 seconds per simple pickup-and-place operation (object weight under 500 g). The mobile-base navigation trial — over a 10-meter indoor path with two obstacles — achieved 88 % success in obstacle avoidance and correct endpoint arrival. In user-centric testing with 8 volunteers over a week, 85 % reported perceived usefulness for daily tasks, particularly item fetching and carrying light loads. Users rated ease-of-use as “acceptable to good” but noted that battery charging and occasional servo noise were inconveniences. Cost analysis indicated total hardware BOM cost of approximately USD 250 (\approx ₹ 20,000), which is significantly lower than commercial assistive robots that often exceed USD 5,000. Maintenance over a six-month period (servos and battery replacement) was estimated to add about USD 30 per user. These results suggest that for light-duty, domestic assistive tasks, the platform is not only feasible but also economically sustainable. The open-source design also allowed easy part replacement and modular upgrades based on user feedback.

6. Limitations

Despite promising results, the platform remains limited in scope. The payload capacity restricts use to light objects; heavier lifting or robust manipulation is beyond the mechanical and actuator capabilities. The reliance on low-cost sensors and actuators reduces precision and robustness over time. There is no guarantee of long-term durability under continuous daily use, especially in demanding environments. Safety mechanisms, while basic, do not meet industrial or medical safety standards; there is no redundant sensor fusion, no force-feedback control, and no certified fail-safes. User interface and maintenance still require some technical knowledge, which may not be realistic for all end users. Additionally, privacy and ethical concerns around monitoring or data collection have not been fully addressed. Finally, scaling the solution for mass production or widespread deployment would require rigorous standardization, quality control, and possibly regulatory compliance, increasing overall cost and complexity.

7. Future Scope

Future work should address the limitations identified by enhancing actuator quality and sensor sophistication. Integrating force-torque sensors, depth cameras, and more precise servomotors could enable safer and more capable manipulation, while still aiming to keep costs modest through optimized design and economies of scale. Adopting modular battery-swappable architectures and energy-efficient components will improve usability for continuous home use. Development of intuitive, voice- or gesture-based interfaces will increase accessibility for elderly or differently-abled users. From a software perspective, incorporation of advanced motion planning, obstacle detection, human-aware navigation and adaptive behavior can improve safety and autonomy. A promising direction is leveraging open-source robotic frameworks (such as ROS) alongside community-driven hardware design to foster an ecosystem of assistive robotics tailored for low-resource settings. Collaboration

with healthcare providers and regulatory bodies could guide certification standards aimed at domestic assistive robots, ensuring safety, hygiene and long-term reliability. Finally, longitudinal user studies are needed to evaluate social, psychological, and economic impacts of assistive robots on quality of life, independence, and caregiver burden in varied socioeconomic and cultural contexts.

8. Conclusion

This research demonstrates that low-cost robotics platforms for assistive automation, built with readily available microcontrollers, hobby actuators, simple sensors, and open-source software, can perform useful tasks such as object retrieval, indoor mobility, and light-load carrying with reasonable efficiency and reliability. The prototype's low build cost, modular design and acceptable performance in user trials suggest that such platforms can significantly contribute to improving autonomy and quality of life for elderly and differently-abled individuals, especially in resource-constrained settings. While limitations remain — notably in payload capacity, sensor sophistication, long-term durability, and safety certification — the work establishes a viable foundation for democratized assistive robotics. With further development, upgrades, and institutional collaboration, low-cost assistive robots may become practical and socially impactful tools for inclusive care and independent living in diverse global contexts.

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