DESIGN OF A LOW-COST ROBOT MOBILE PLATFORM FOR ASSISTING ELDERLY PEOPLE

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Abstract: This paper develops a low-cost assistive robotic mobility platform for the visually impaired individuals and elderly people, addressing high cost and functional fragmentation. Its hybrid wheeled-legged structure enables flat-ground navigation and stair climbing. The prototype which weighs 1.9 kg and costs about €400 uses low-cost components and meets design specs.
Keywords: Service Robots, Mobile Robots, Hybrid Wheeled-legged Robots, Prototype, Assistance of elderly people.

1. Introduction

The global population is aging at an unprecedented rate, with adults aged 65 and above, exceeding 850 million [1]. This demographic shift amplifies age-related physical decline (e.g., lower-limb weakness, visual impairment) and thus drives urgent demand for assistive robots targeting mobility support [2]. The burgeoning potential for assistive robots to mitigate these challenges and to enhance the quality of life for older adults is widely recognized [3]. This potential is directly reflected in the rapid growth of the global market, which research indicates has been valued at nearly $3 billion in 2024 and is projected to expand further [4].

Current research and development in assistive robotics for elderly can be broadly categorized into three distinct types, each addressing different aspects of mobility and independence. The first category encompasses large mobility aid robots based on wheelchairs or walkers, which provide fundamental walking assistance and stability. For example, Nagasawa's team has developed a walking assistive robot integrated with advanced functionalities like GPS navigation for use in outdoor environments [5]. Complementing this, the work of Hamza's team has focused on a critical aspect of user comfort by rigorously analyzing and mitigating vibration in elderly-robot coupled systems during transport [6]. Furthermore, Kim's team has designed a novel two-wheeled robotic wheelchair featuring a slidable seat, achieving impressive mechanical performance with a minimal turning radius and a high load capacity, tailored for users with lower-limb disabilities [7]. Additionally, the BIT wheelchair, developed by Huang's team, combines a four-bar linkage leg exoskeleton with an electric wheelchair. It supports active, passive, and active-passive operation modes to meet users' independent mobility needs during rehabilitation or exercise [8].

The second category includes medium-sized mobile guiding robots, which prioritize autonomous navigation to assist the elderly, particularly those with visual impairments, in wayfinding. Beyond wheeled platforms, legged robots like the HexGuide hexapod offer superior mobility on rough terrains and are equipped with capabilities like traffic signal detection to safely guide users in urban environments [9]. Similarly, research by Xiao et al. on quadruped robots has shown remarkable progress in dynamic obstacle avoidance and path planning in unstructured settings, making them highly suitable for accompanying elders on varied outdoor routes [10]. A prominent example is the work of Lu's team, who developed a guidance robot utilizing Deep Reinforcement Learning, integrated with UWB/voice beacons and semantic feedback, demonstrating advanced capabilities in complex navigation tasks [11].

"JetHexa" demonstrates strong adaptability to various complex terrains; however, the platform itself has limited load-bearing capacity. It is an open-source hexapod robot based on the ROS operating system and produced by Hiwonder. Its composition includes a Jetson Nano, LiDAR, a camera, a circular microphone array, an internal sensor system, and among other components [12]. The core challenge in this category lies in achieving robust and real-time environmental perception and decision-making under real-world conditions.

The third category is exoskeleton robots, which are wearable robotic systems designed to augment, reinforce, or restore the physical capabilities of the user [13]. These

systems range from full-body suits to targeted joint assistance (e.g., hip, knee, or ankle). Christensen et al. have contributed to this field with the design and validation of a powered full-body exoskeleton specifically intended for the physical assistance of elderly individuals [14]. Among the most prominent commercial systems is the ReWalk exoskeleton. This powered lower-limb system is designed for individuals with spinal cord injuries (SCI), enabling them to stand, walk, and climb stairs through a combination of robotic joints and sophisticated motion algorithms. While the ReWalk exoskeleton demonstrates strong potential for restoring mobility, its high cost and primary focus on SCI present barriers to broader geriatric application [15]. Beyond full-body systems, significant research focuses on lower-limb exoskeletons. For example, Harvard's soft exosuit represents a paradigm shift from rigid structures, using textile-based actuators to provide gait assistance with a lightweight and non-restrictive design, thereby reducing metabolic cost and improving natural mobility [16]. The primary hurdles for exoskeletons include ensuring safety and stability, achieving intuitive and comfortable human-robot interaction, and, crucially, reducing their high weight and cost.

Despite these advancements, significant challenges impede the widespread adoption of these technologies. A primary barrier can be considered their high complex development and unit cost [17]. Specifically, the prices of electric wheelchairs range from 2,000 to 25,000 euros, while the base price of quadruped robot products such as Unitree Go2 starts at 1,300 euros [18], and high-end rehabilitation exoskeletons like ReWalk are priced at approximately 72,000 euros [19]. Secondly, there exists a functional gap. Most solutions excel in providing either physical support (like walkers and exoskeletons) or intelligent navigation (like guiding robots) but rarely integrate both core functions into a cohesive system. Thirdly, achieving an optimal form factor that balances mechanical stability with maneuverability in domestic environments remains a design challenge. Among the three types of designs, the relatively compact quadruped robot products have an operating weight of approximately 18 kg. If the robot runs out of power during use, it is almost impossible for elderly users to carry it independently.

It is to these three interconnected problems—cost, functional integration (support and navigation), and form factor—that this work is directed at. This work aims to present a novel assistive robotic solution that addresses these limitations to better meet the comprehensive needs of the aging population as from activity within a teaching program with design projects for service robots.

2. Requirements and Design

When designing assistive robots for the elderly, key aspects must be comprehensively addressed: mainly core functions, user adaptability, environmental perception, ease of use, safety, and economy. This leads to specific design requirements in three directions: hardware design, software design, and physical parameters. This paper proposes that elderly-assistive mobile platforms should feature moderate size and weight to ensure versatility across environments. The load capacity must provide essential support for assisted walking, while endurance should sufficiently cover daily activities. Finally, cost minimization remains critical to ensure broad accessibility. Figure 1 summarizes the main requirements that need to be considered when designing an assistive robot for elderly people. Such assistive robot must meet the main design requirement mobility summarized in Table 1.

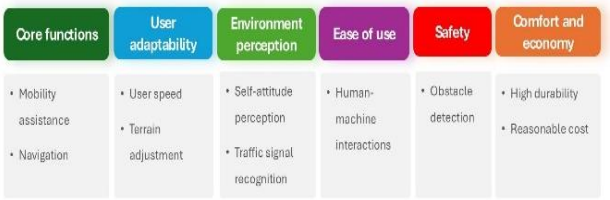


Fig. 1. Main requirements for mobility assistance of elderly people.

Tab. 1 Design requirements for main design parameters for elderly people assistance, Figure 1.

Physical parameters	Reference values
Size [mm]	600~800 in length 400~600 in width 300~700 in height
Weight [kg]	3~5
Load capacity [kg]	2~3
Travel speed [m/s]	0.3~1.0

To ensure the robot's obstacle-overpassing ability, such as climbing stairs, a specific design can be proposed. The front wheels are positioned on adjustable front legs, extending away from the main platform. A solution can be proposed as in the conceptual design as in Figure 2. However, the adjustment of the front legs' length and angle presents challenges related to dimensional. The wheelbase of the middle passive wheels is extended. Therefore, the front, middle, and rear wheels are placed on different axes. When climbing stairs, the platform can rely solely on the middle and rear wheels for support. The front wheels are lifted off the ground, while the front legs adjust their angle and length to help the robot to climb. The rear and middle wheels work together to ensure stability on flat surfaces. The overall six-wheeled platform provides high load capacity and strong terrain adaptability. The control system and sensors are installed on the main platform, enabling precise navigation and real-time environmental awareness. Figure 2 shows a conceptual design of the hexapod robot with additional equipment for proper assistance and interaction with elderly users. This robotic platform assists visually

impaired individuals and elederly peoply by interacting by speaking relations with users using feedbacks from the the vision equipment.

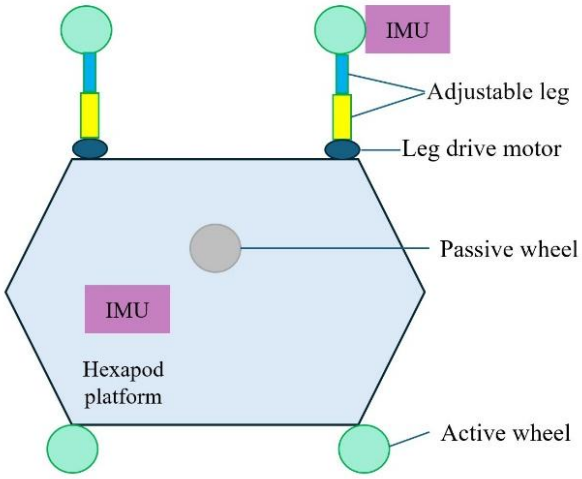


Fig. 2. Conceptual design of a wheeled mobile robot for elderly people's mobility assistance.

3. Prototype

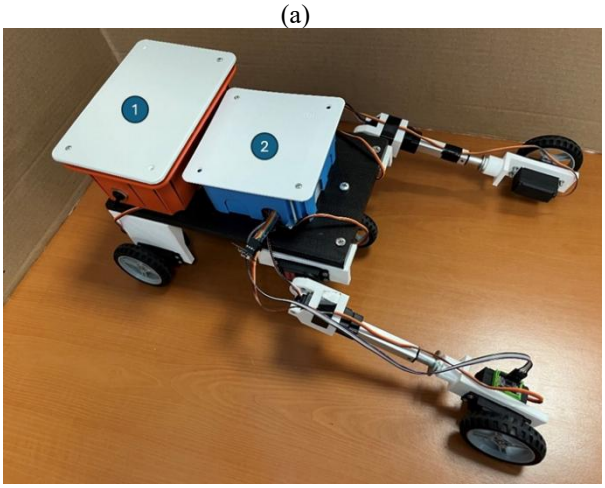
To address requirements outlined in Section 2, a novel hybrid wheeled-legged mobile platform is proposed with a solution as in the prototype shown in Figure 3. This design synergizes the stability and energy efficiency of a wheeled base with the enhanced terrain adaptability of an articulated leg mechanism.

The core of the proposed solution is a five-wheeled platform. The front pair of wheels is mounted on actively controlled, adjustable legs, enabling modifications to both their length and angular orientation. The middle wheel is passive wheel, ensuring stability and load-bearing on flat surfaces. The rear pair are driven wheels, providing the primary propulsion force. This configuration ensures that the front, middle, and rear wheels are positioned on distinct axes. During stair-climbing or obstacle negotiation, the platform can stabilize on its middle and rear wheels. Simultaneously, the front legs retract and adjust their angle to elevate the front wheels onto the obstacle, effectively guiding the entire platform over the impediment. This integrated design guarantees high load capacity on flat ground while offering robust adaptability to uneven terrain. The main control system and sensor equipment are centrally located on the platform to facilitate precise navigation and real-time environmental perception. The central wheel and a pair of rear wheels form a triangular structure, ensuring the stability of the platform.

The hardware implementation carefully balances performance with economic viability. The locomotion system is driven by MG996R servo motors for wheel propulsion and leg articulation [20], complemented by Actuonix L12 linear actuators for precise leg extension and retraction [21]. An Arduino Nano serves as the central microcontroller [22], coordinating inputs from a BMI160 IMU for attitude perception and an ACS712 sensor for current monitoring [23] [24]. Motor control is managed through a PCA9685 16-channel servo driver [25], which efficiently handles multiple actuators. A separate, handheld wireless joystick unit [26], built around an Arduino Uno and a nRF24L01 transceiver module [27], provides intuitive remote control, offering multiple human-machine interaction options. Figure 4 presents the detailed electrical design for the mobile robot.



(a)



(b)

Fig. 3. The built prototype: a) front view; b) skew view.

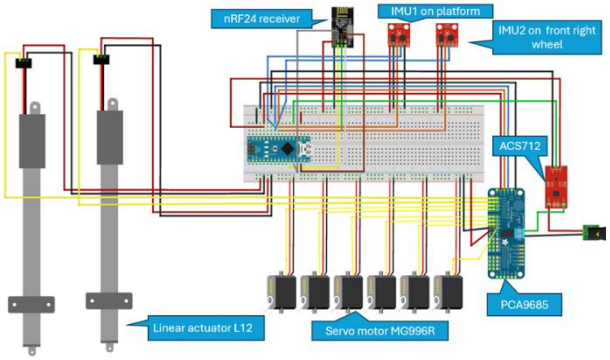


Fig. 4. Electric design for a wheeled mobile robot for elderly people assistance, Figure 2 and 3.

Table 2 summarizes the key characteristics of the primary components used in the mobile platform. Table 3 lists components in the joystick subsystem in Figure 5, based on Arduino Nano, nRF24L01 submitter and receiver. A cost-analysis was conducted based on the selected components, so that total material cost for the prototype was optimized to approximately €400, successfully meeting the predetermined economic requirement of remaining below €500. This cost-effective component selection demonstrates the feasibility of developing a high-functionality assistive robot without prohibitive expense. The final assembled prototype, shown in Figure 3, has a compact form factor and its main operational characteristics are summarized in Table 4.

Tab. 2 Characteristics of components for the prototype in Figure 3 and 4.

Name	Ref	Weight [g]	Size [mm]	Power [W]	Cost [€]
Arduino Nano	[22]	5	45x18	0.8	21.49
MG996R	[20]	55	40.7x19.7x42.9	3	7.9
L12-100-50-6-R	[21]	40	152x18x14.9	0.5	115.9
BMI160	[23]	1	16.5x13x1.6	<0.006	1.59
PCA9685	[25]	5.5	62.5x25.4x3	<0.06	19.9
ACS712	[22]	2	31x13	<0.006	5.98
nRF24L01	[27]	2	15x29	<0.03	4.87

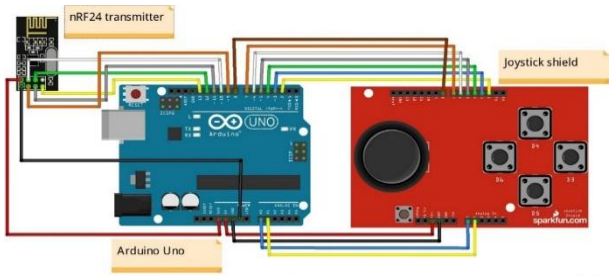


Fig. 5. Electrical design for a wireless joystick.

Tab. 3 Characteristics of components in the joystick controller in Figure 5.

Name	Ref	Weight [g]	Size [mm]	Power [W]	Cost [€]
Arduino Uno	[22]	25	68.6x53.4	0.8	28.85
Joystick shield	[26]	36	87x54x40	0.2	8.99
nRF24 with antenna	[27]	16	15x40	0.4	18.3

Tab. 4 Main characteristics of the prototype of wheeled mobile robot, Figure 3.

Platform size [mm]	150x250	**Box 1 size [mm]**	165x110x78
Wheel diameter [mm]	65	**Box 2 size [mm]**	115x115x55
Height [mm]	105	**Max height [mm]**	185
Leg length [mm]	[118,168]	**Power [W]**	6
Weight [kg]	1.9	**Total cost**	€ 400.76

4. Experimental validation

Equations will be edited aligned left and separated with 8 mm free space.

To evaluate the prototype's adaptability under varying terrain conditions, three operational modes are designed. Mode 1 involves maintaining straight-line motion for 20 seconds, during which the motion stability and operating speed of the prototype are tested. Mode 2 consists of unidirectional turning for one full cycle, aiming to measure parameters such as the turning radius of the prototype.

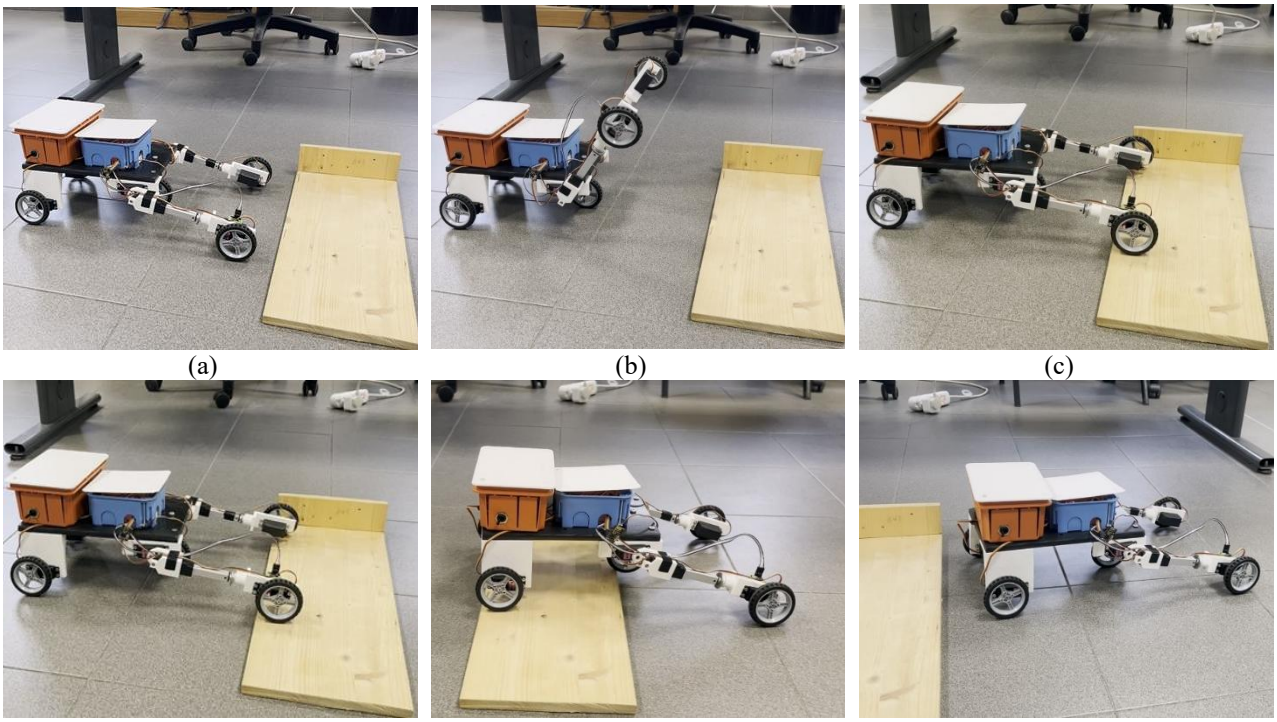
For obstacle overpassing mode 3, the motion sequence is designed as follows:

1) The prototype advances straight and stops near the obstacle.
2) It lifts its front legs, then extends the front legs to elevate the front wheels onto the obstacle.
3) The prototype lowers the front legs, leaving the front wheels on the obstacle.
4) It resumes motion, allowing the middle and rear wheels to sequentially climb the obstacle under the guidance of the front wheels.
5) The prototype completes traversal once all wheels clear the obstacle.

A snapshot of test mode 3 is the sequence from 1 to 5 in Figure 6. In this test, obstacle is a 20 mm high wooden board.

5. Conclusions

This paper presents a low-cost mobile robot platform for elderly assistance as result of a design project within a teaching program on robot design at the mechatronic engineering Master program of University of Rome Tor Vergata. Centered on Arduino Nano, the proposed robot design integrates multi-type actuators and sensors (with rigorous circuit validation). Autodesk Inventor 3D modeling and dynamic simulations confirmed it meets motion specs. A prototype has been made via hybrid 3D-printing and using market components.



(a) (b) (c)

(d) (e) (f)

Fig. 6. Acquire snapshots of prototype during test of mode 3, Table 6: (a) sequence 1; (b) sequence 2; (c) sequence 3; (d) sequence 4; (e) sequence 5; (f) end.

Tests show 100% success on obstacles which are lower than 3cm. For higher obstacles such as stairs, the design enables the adjustable front legs to extend firstly to reach the stair surface, with the leg drive motors lifting the platform. With the leg drive motors maintaining the specified angle, the active wheels are activated until the central middle wheel also reaches the stair surface. Subsequently, the platform is pulled onto the stairs under the drive of the front wheels. But insufficient torque (peak 1N·m) of leg motors limited performance on larger obstacles. Specifically, the standalone replacement of high-torque leg drive motors is expected to significantly enhance the robot's obstacle-surmounting capability for higher obstacles. Experiments verified the platform achieves cost-effective manufacturing, enhanced terrain adaptability, and meets core elderly-assist needs. Its design provides a scalable framework for affordable, functional assistive robots.

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