# Self-Navigating Mobile Robot for Assisting with Load Transportation for Physically Limited Users

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***Abstract*—Robotics is an expanding field that aims to automate tasks traditionally performed by humans using machines. Mobile robotics involves using mechanical system dynamics to execute tasks, with sensors gathering environmental data to navigate and perform these tasks. Assistive robotics uses autonomous robots to aid individuals with disabilities or limitations, such as transporting loads for pregnant women and the elderly. This paper details the development of a low-cost autonomous mobile robot capable of following its user and avoiding obstacles, analogous to a leader-following robot. The system employs a fuzzy controller and a state machine. A simulation and a prototype were created, demonstrating the ability to track a target and avoid obstacles in real time. The study concludes with recommendations for future research**.

***Keywords-Technological applications in social environments; Service robotics; Autonomous robotics.***

## I. INTRODUCTION

For many researchers, robotics can be divided into two main areas: programmed and artificial intelligence. Programmed robotics involves systems that require reprogramming whenever the task changes [9]. In contrast, intelligent robotics integrates aspects of Artificial Intelligence (AI), enabling robots to learn and adapt autonomously. This integration allows machines to emulate human reasoning, analyze situations, and make decisions, ultimately aiming to mimic or even surpass human intelligence [5].

The application of robotics in medicine has evolved significantly from performing early repetitive tasks to providing substantial patient benefits. Surgical robots enhance precision during operations, reducing trauma to patients and extending the capabilities of surgeons [1]. Beyond surgical applications, mobile nursing robots have been developed to assist elderly patients with minor physical and cognitive limitations, thereby supporting patients and the nursing staff [3].

The work in [11] introduces a robust and flexible control system for mobile robots, leveraging motion description language in behaviours-based robotics. This approach effectively manages the control of mobile robots by describing the interactions between discrete and continuous dynamics within a robotic system. Additionally, it quantitatively measures the complexity of the steering a robot. The study focuses on the problem of object-following by nonholonomic wheeled mobile robots using this method. The effectiveness of the proposed approach is validated through MATLAB simulations, demonstrating its capability to handle the object-following task successfully.

In [10], clinical and healthcare Knowledge Management (KM) has garnered significant global attention as an emerging discipline in recent years. This approach integrates a broad spectrum of interconnected themes, including clinical informatics, clinical governance, artificial intelligence, privacy and security, data mining, genomic mining, information management, and organizational behaviour. This paper presents critical manuscripts exploring case studies and KM applications in healthcare and clinical settings.

By employing motion description language, the system captures the intricate dynamics of robot behaviours and provides a structured framework for implementing and assessing control strategies. This method offers a significant advancement in the control of mobile robots, particularly in environments requiring precise navigation and object tracking. The MATLAB simulation results confirm the practicality and efficiency of this control approach, showcasing its potential for broader applications in mobile robotics.

The integration of motion description language in behaviours-based robotics presents a comprehensive solution for controlling nonholonomic wheeled mobile robots, with proven effectiveness in object-following tasks, as demonstrated by simulation results. Future work could explore the application of this method to more complex robotic systems and dynamic environments.

Initially, mobile robotics focused on guided object transportation within production lines. However, contemporary advancements have enabled autonomous mobile robots to operate effectively in both factory settings and open environments. These robots employ sophisticated processes such as perception, localization, trajectory planning, and movement execution [2]. To navigate and track targets within obstacle-rich environments, they utilize various sensors, including ultrasonic sensors and cameras, to gather positional data essential for trajectory planning [8].

The primary aim of this study is to develop an autonomous robot capable of transporting small loads, such as luggage, for individuals with physical limitations, such as the elderly and pregnant women. This goal is aligned with applications in service and assistive robotics, which aim to alleviate physical strain on these individuals. Additionally, the study underscores the ergonomic benefits of adjusting working conditions to enhance human efficiency and well-being. By mitigating ergonomic risks, such as physical strain, improper posture, and repetitive tasks, the study highlights the potential for robotics to improve overall human health and productivity in various settings [10].

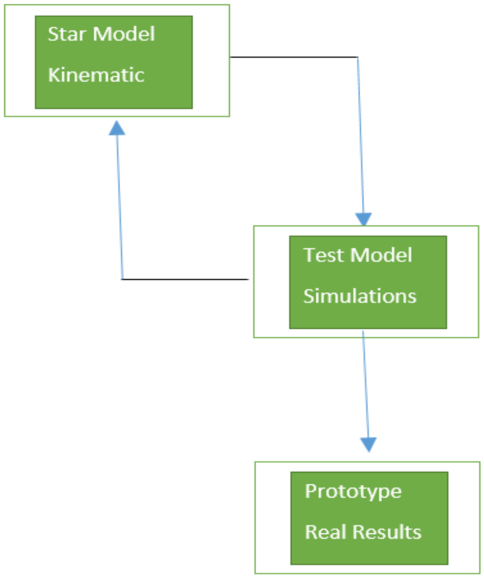

Figure 1. Development Prototype.

The diagram in Figure 1 outlines a process beginning with the "Star Model Kinematic" as the initial phase. This is followed by the "Test Model Simulations," where simulations will be executed exhaustively. The next step is the "Prototype Real Results" stage, which focuses on implementing and validating the prototype. It is important to note that the prototype testing should include a maturation period to ensure that no unexpected behavior occurs. Additionally, there is a feedback loop between "Test Model Simulations" and "Star Model Kinematic," suggesting iterative refinement based on the simulation results.

The results are preliminary, obtained through a simulated experiment, and a second phase will likely be implemented, incorporating another knowledge base with fuzzy logic in a smaller search space. The aim at the end of the first search is to obtain initial results from this research and then proceed to the second phase, at which point the development of the prototype will begin.

## II. DEVELOPMENT

This work aims to create a low-cost mobile robot capable of transporting loads up to 10 kg for individuals with physical limitations. The robot must follow the user, avoid obstacles, and prevent collisions in real time. The development involves building the robot's structure, including chassis, wheels, motors, and its electronics—comprising H-bridge, microcontroller or computer, and sensors (ultrasonic sensor or camera). Programming will interpret sensor data and make decisions.

The system will determine the distance between the robot and the target using ultrasonic sensors or a camera. This distance will inform the pulses sent to the robot's motors, adjusting speed based on proximity to the target. Fuzzy or multivalued logic will control the output, simplifying the modeling compared to Proportional-Integral-Derivative (PID) controllers, especially for multivariable systems [7].

Target identification may use markers based on color and shape, like in the approach in [4]. A safety system will be developed to avoid obstacles, either by manoeuvring around static obstacles or waiting for dynamic obstacles to clear. The embedded system must handle the computational demands, with options like Arduino for simplicity and cost or Raspberry Pi for higher computational capacity.

## III. RESULTS AND DISCUSSIONS

### A. *Simulation*

Control model validation involved MATLAB simulations, comparing fuzzy and multivalued logic controllers—the fuzzy controller determined wheel pulses based on the Euclidean distance between the robot and the target. Simulation results showed satisfactory performance for target tracking with acceptable computational complexity. Table I presents the functions used as the basis for the rules of the developed fuzzy controller: the Euclidean distance between the robot and the target and the increment given to the pulse sent to the robot's wheels.

TABLE I. RULE BASE OF THE FUZZY CONTROLLER

| |
|---|
| **1. If (hi is close) then (const is close)** |
| **2. If (hi is medium) then (const is medium)** |
| **3. If (hi is medium far) then (const is medium plus)** |
| **4. If (hi is far) then (const is medium)** |

Figure 2 shows the structure of the fuzzy system. Figure 3, in turn, presents the surface generated by the fuzzy controller. In Figure 2, the inputs are, a priori, the distance of the person in the x and y-axis, and the outputs are the pulses given to both wheels of the kinematic model.

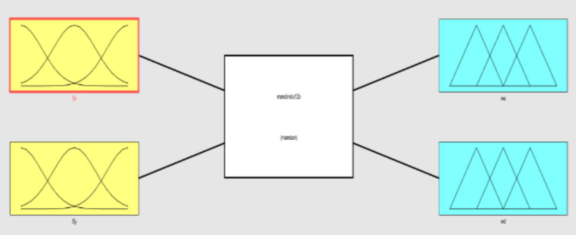

Figure 2. Fuzzy Controller Structure.

The diagram illustrates a process where two input signals (labeled 1 and 3, represented by sine waves) are fed into a central module, labeled "network", which then outputs two results (labeled 2 and 4, represented by triangular waves). The inputs and outputs are connected to the network through lines, indicating data flow or signal processing.

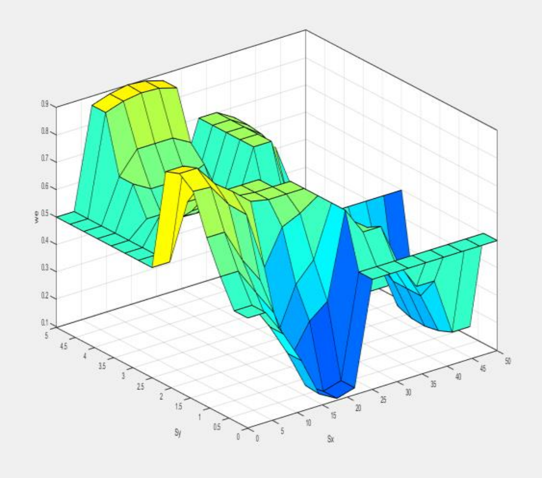

Figure 3. Fuzzy Controller Surface.

The preliminary outcomes from the first simulation conducted on the mobile robot are illustrated in Figure 4. This figure visually represents the robot's movement within the designated environment. Figure 5, correspondingly, presents the results derived from the second simulation, offering a comparative analysis of the robot's performance under modified conditions. In both figures, the black point represents the mobile robot's current position, while the orange triangle denotes the target or goal location. The blue line traces the robot's trajectory as it navigates the environment. The graph's axes indicate distances measured in centimeters; however, the scale can be adjusted to meters when applied to larger environments. This flexibility in scale ensures the applicability of the simulation results across a range of spatial domains, enabling robust analysis in both confined and extensive operational settings.

These graphical depictions illustrate not only the robot's efficiency in path planning and execution, but also provide a foundation for further adjustments in navigation algorithms, should the need arise based on environmental complexity or task demands.

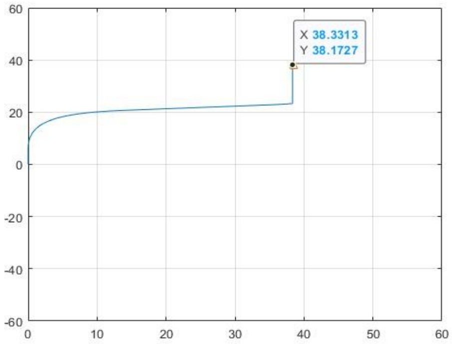

Figure 4. First robot simulation.

The results obtained, although preliminary, were satisfactory for target pursuit. For small, stipulated error values, the computational complexity was not compromised. Subsequently, this control logic will be implemented in the prototype mentioned in introduction section.

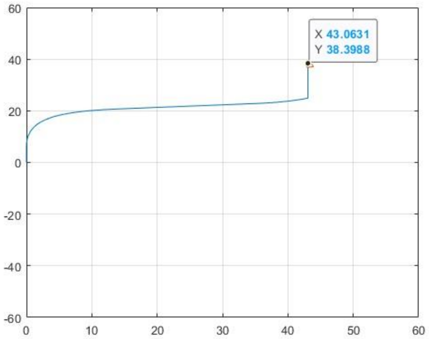

Figure 5. Second robot simulation.

### B. Prototyping

A prototype was developed using Arduino UNO R3 and an ESP-32 camera. Initial tests demonstrated satisfactory target detection capabilities; however, software stability issues were identified, indicating a need for further improvements to enhance system robustness. Figure 6 showcases the initial prototype.

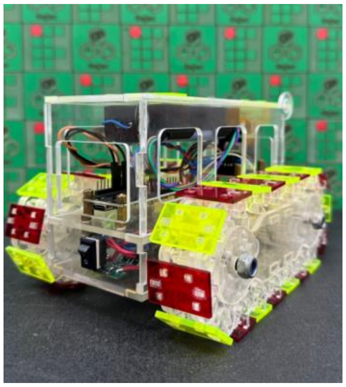

Figure 6. Mobile robot prototype.

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The marker detection tests are illustrated in Figure 7 and Figure 8. These tests involved assessing the system's ability to accurately identify and track predefined markers. While the results were promising, the observed software instabilities highlight the necessity for additional refinement and optimization.

Future efforts will focus on addressing these stability issues and improving the overall robustness of the system. This includes optimizing the software algorithms and potentially upgrading the hardware components to ensure more reliable performance in real-world applications. Enhancing the system's stability and reliability is crucial for its effective deployment in various practical scenarios.

Figure 7. Marker filtering.

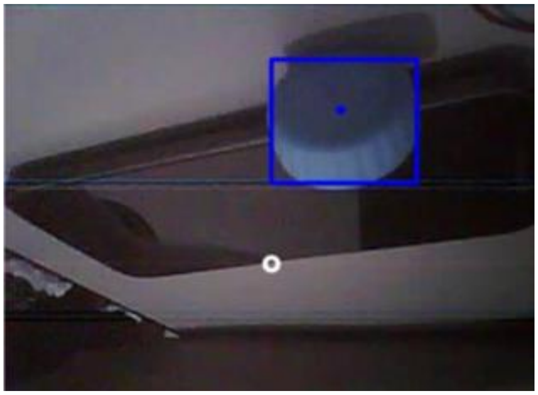

Figure 8. Marker detection.

## IV. CONCLUSION

This study proposed the development of an autonomous robot designed to transport loads. The system integrated a camera and ultrasonic sensors to identify targets effectively, ensuring the prototype responded accurately to control commands. This combination of sensors facilitated precise navigation and obstacle avoidance, demonstrating the robot's potential for real-world applications.

Future work aims to enhance the system's robustness by implementing embedded systems with higher processing power. This upgrade will allow for more complex computations and faster data processing, improving the robot's efficiency and reliability. Additionally, further research will explore advanced algorithms for better decision-making and adaptive learning capabilities, enabling the robot to operate in more dynamic and unpredictable environments.

By leveraging state-of-the-art technologies and continuously improving the system, this autonomous load-transporting robot holds promise for various applications, including logistics, healthcare, and personal assistance, significantly enhancing productivity and quality of life.

## V. ACKNOWLEDGMENT

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