

Reconfigurable Robot Base

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Abstract: This paper presents a reconfigurable robot base capable of adjust to changing environmental circumstances, the robot base shown in this research may change its configuration. This reconfigurable robot base features a dynamic framework capable of expanding and shrinking to adapt to various tasks and environments. Utilizing a microcontroller, relays, servomotors, and a screw rod mechanism, the system enables precise structural adjustments. The base can modify its dimensions in real-time, allowing for improved maneuverability in tight spaces and stability during high-payload operations. Servomotors drive the expansion mechanism, while relays control power distribution to various components. The integration of a payload platform ensures functional versatility. This adaptive design enhances operational efficiency, making it ideal for applications in exploration, industrial automation, and environments with variable spatial constraints.

I. INTRODUCTION

This project presents a reconfigurable robot base with a changeable framework that can expand and shrink dynamically to adapt to various operational needs and environments. By enabling real-time size and structural modification through the use of mechanical and electronic components, the main goal is to increase the robot's adaptability and efficiency. The ESP32 microprocessor, which powers the system, acts as the central control unit and permits sensor integration, wireless connectivity, and accurate control over the mechanical parts. Servomotors and a screw rod mechanism work together to drive the expansion and contraction mechanism. The robot's frame can stretch or retract based on operational needs to this configuration, which permits smooth and regulated linear mobility. Relays ensure effective energy distribution and system protection by controlling the flow of power to the servomotors and other parts. Because of its unique payload portion, which can hold a variety of tools or sensors, the robot can be used for a variety of tasks, including terrain investigation, object transportation, and surveillance. It can expand for greater stability and load capacity in open areas or contract to navigate through narrow passages and confined spaces. The modular design

also allows for easy maintenance and component replacement, improving the overall lifespan and adaptability of the system.

II. LITERATURE REVIEW

The efficiency, variety, and adaptability of reconfigurable robotic systems in dynamic situations have drawn a lot of interest in recent years. Reconfigurable platforms that can alter their physical dimensions and configurations in real-time have been developed because traditional fixed-frame robots frequently encounter restrictions in confined or unpredictable settings. Mechanical reconfiguration mechanisms, including screw rod systems, scissor lifts, and sliding rails, have been the subject of several research. Because of its accuracy, ease of use, and capacity to support loads, the screw rod mechanism has been frequently used among them. To improve stability and load handling, researchers have successfully integrated screw-driven actuators onto robotic platforms to accomplish linear motion for expansion and contraction. Because of its precise control and simplicity of integration, servomotors have been the subject of much research on robotic reconfiguration. Servomotors can be accurately controlled to regulate mechanical transformations when paired with microcontrollers such as the ESP32. In robotic systems, relays are commonly used for high-current component switching and power control. They are essential to reconfigurable robots because they regulate the power supply to servomotors and other actuators in response to microcontroller commands. The significance of payload management in adaptive robots is also emphasized in the literature. In addition to supporting a variety of sensors and instruments, a well-designed payload section enhances the system's overall usefulness and balance.

III. METHODOLOGY

The reconfigurable robot base utilizes a screw rod mechanism powered by high-torque servo motors to enable reconfiguration of modular frame the

microprocessor activates relays to turn on the motors when it detects a restricted gap, which causes the frame to compress. The system extends for improved load support and stability in open area that shown in figure.1.

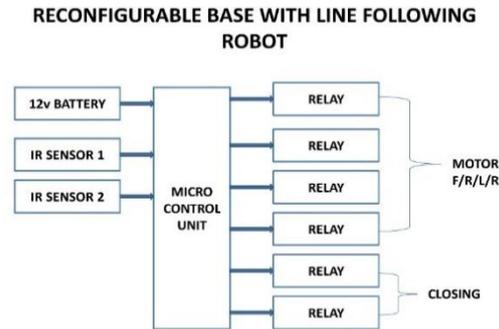


Figure.1. Methodology

IV. SYSTEM ARCHITECTURE

The system architecture of the suggested reconfigurable robot foundation is scalable and modular, allowing for accurate motion, and adaptability in a range of operating settings. A screw rod mechanism for linear actuation, servo motors for rotational movement, an ESP32 microcontroller for control and communication, infrared sensors for obstacle detection, a relay circuit for power management, and a steel bar framework for structural integrity are some of the system's essential parts. The robot's hardware architecture at the system level.

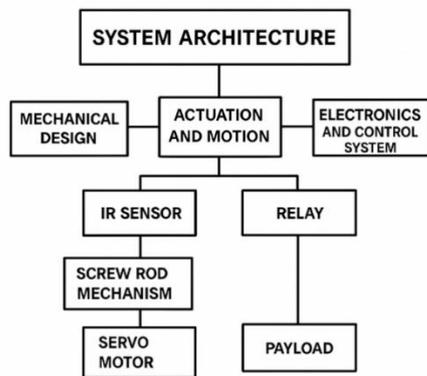


Figure.2. System Architecture

A. MECHANICAL DESIGN:

Modularity and adaptability for a range of robotic applications were made possible by the changeable robot base's SolidWorks design. The base may be easily resized and reconfigured thanks to its telescopic structure and movable arms. Options for

tracked or omnidirectional mobility are supported by integrated quick-release joints and modular wheel mounts. Slots for standardized sensor and actuator attachments are incorporated into the design to guarantee smooth integration. In order to blend portability and robustness, a lightweight alum steel bar was used. The stability of the structure under dynamic loads was confirmed by SolidWorks simulations. In a variety of operational settings, this reconfigurable foundation facilitates flexible deployment and quick development, making it an ideal platform for industrial robotics and research.



Figure.3. Reconfigurable Robot Base

1. MECHANICAL FRAMEWORK:

The robot has a modular, high-strength stainless steel structure with movable joints and reconfigurable connection brackets. The framework can easily extended to accommodate big loads or confined places. Axial and angular adjustments are made possible via servo motors and a screw rod system. This robust, flexible design improves performance in automation, dynamic jobs, and search and rescue by supporting sensors, actuators, and payloads.

2. SCREW ROD MECHANISM:

The robot's precision linear actuation is powered by a lead screw rod mechanism and a high-torque DC motor, allowing for dynamic base expansion and contraction. It is integrated into the steel framework and provides smooth, steady movement as well as mechanical support. Its self-locking technology ensures positional stability without requiring continual power, improving energy efficiency, adaptability, and performance over a wide range of terrain and payload circumstances.

B. ACTUATION AND MOTION CONTROL:

1. Servo Motor Control:

Servo motors at crucial joints provide accurate rotational motion for dynamic structural modifications. They are controlled by PWM

impulses from the ESP32 microcontroller and provide precise, real-time positioning. The ESP32's multi-channel PWM enables synchronized servo control, which improves flexibility, stability, and mobility. This approach simplifies mechanics while allowing for seamless reconfiguration for navigation, load handling, and adaptive environmental interaction.

2. Payload Handling:

The reconfigurable robotic base has an adaptive actuation system that uses servo motors and a screw rod mechanism to dynamically modify structural dimensions and balance in response to changing payloads. Servo motors accurately drive ball or lead screws, making it easier to extend or retract structural components. This mechanism allows for real-time change of the robot's center of gravity, assuring maximum stability and performance across a wide range of operating conditions. The use of servo-driven screw rods allows for precise, smooth linear motion, increasing the robot's flexibility to changing load circumstances and work requirements. This arrangement enhances the robot's adaptability, efficiency, and dependability in difficult situations.

C. ELECTRONICS AND CONTROL SYSTEM:

1. Microcontroller:

The ESP32 microcontroller controls the robot's hardware, including power, motion, and sensors, making it a suitable choice for the system due to its processing power and wireless capabilities. It creates PWM signals to operate the lead screw motor for linear actuation and coordinates several servo motors at pivot points, allowing for accurate structural reconfiguration and smooth operation.

2. Sensor Integration:

Infrared (IR) sensors allow robots navigate by generating light and detecting reflections to determine object proximity, allowing for collision avoidance and efficient mobility. They may struggle with black surfaces, which absorb infrared radiation and are sensitive to ambient light interference. Calibration and testing are required to provide consistent performance in different environmental conditions.

V. POWER MANAGEMENT AND EFFICIENCY

Reliable power management is critical to the efficiency and lifetime of a reconfigurable robotic system. The system's primary power source is a 12V lithium-ion battery. Buck converters are used to efficiently scale down voltage for low-voltage components like the ESP32 microcontroller and IR sensors. The ESP32 controls servo motors and relay circuits, as well as monitoring battery characteristics for intelligent power distribution. The steel bar structure supports the cargo, and its design effects overall power consumption, particularly during movement aided by the screw rod mechanism. Implementing adaptive power management strategies ensures optimal performance while conserving energy, thereby enhancing the robot's operational lifespan.

VI. TESTING AND PERFORMANCE EVALUATION

The reconfigurable robot the base was tested and integrated by confirming each subsystem, which included the screw rod mechanism, servo motors, ESP32 microprocessor, and IR sensors. The steel bar structure offered structural integrity, while the servo-driven screw rods allowed for seamless reconfiguration. The ESP32 effectively regulated servo operations and relays while also controlling power to different components such as the 12V lithium-ion battery and sensors. IR sensors enabled obstacle detection during mobility and base modification. Load testing demonstrated a payload capability of up to 3.5 kg without structural deformation. Overall, the integrated system performed consistently in terms of mechanical reconfiguration, sensor response, and power economy.

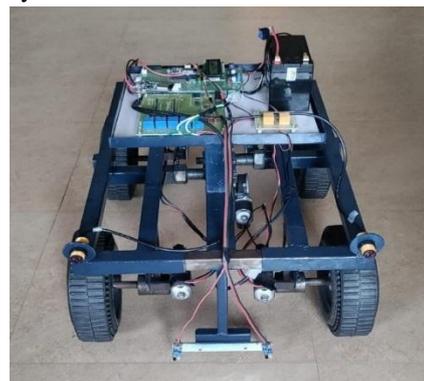


Figure.4. Prototype of Reconfigurable Robot Base

VII. CHALLENGES AND SOLUTIONS

Reconfigurable robotic systems face several obstacles that require novel solutions. Precision machining and advanced control algorithms can help with mechanical complications such as screw rod alignment and servo motor calibration. While the ESP32 microcontroller is flexible, it may have processing power and I/O restrictions; however, incorporating supplementary microcontrollers or increasing I/O ports can help to alleviate these constraints. Payload capacity problems, particularly when employing steel bar frames, necessitate structural optimization to balance strength and weight. Relay circuits and infrared sensors are subject to electrical noise and environmental interference; using shielding techniques and signal filtering can improve dependability. Developing strong reconfigurable robots requires a comprehensive design strategy that takes into account mechanical, electrical, and software issues.

A. Payload And Mobility Testing:

The system underwent mobility tests with varied loads. The robot remained stable and maneuverable on smooth and slightly sloping surfaces while carrying weights of up to 3.5 kg, demonstrating its applicability for light industrial and inspection applications.

B. System-Level validation:

Following satisfactory subsystem testing, complete system integration was carried out. The synchronization of the servo-driven reconfiguration mechanism and the ESP32 control logic was verified. Test findings revealed that the robot could rearrange its base size automatically, recognize obstacles, and transport payloads within the set limitations.

VIII. PAYLOAD CALCULATION:

- Torque (T) = 2 Nm (servo motor)
- Lead screw pitch (l) = 8mm
- Efficiency (η) = 0.3
- Gravity g=9.81 m/s²

Step 1: Calculate force

$$F = 2\pi \cdot T \cdot \eta / l$$

$$F = 2\pi \cdot 0.2 \cdot 0.3 / 0.008 = 0.377 / 0.008 = 47.12N$$

Step 2: Convert to mass

$$\text{Payload} = F/g = 47.12/9.81 = 4.6 \text{ kg}$$

IX. SCHEMATIC CIRCUIT DIAGRAM

The reconfigurable robot base's schematic circuit diagram incorporates a number of crucial elements to guarantee reliable operation and adaptability. The central processing unit of the system is an ESP microcontroller, which coordinates input and output signals throughout the robot. To govern power distribution and isolate high-current components, like motors, from the microcontroller's low-power control logic, a relay circuit is utilized. The motion system's screw rod mechanism, which is powered by a servo motor, enables precise linear movements and customizable robot base configurations. Infrared sensors are incorporated for path-following and obstacle identification to facilitate autonomous operation.

The robot's construction is supported by a robust steel bar framework that is intended to provide strength and durability when supporting a range of loads. A 12V lithium-ion battery powers the robot, offering a portable and effective energy source. Depending on the application, the robot can handle tiny to medium-sized tools or components thanks to the overall design's modest payload capacity. This configuration makes the robot base flexible and customizable, making it appropriate for jobs demanding exact control and adaptability.

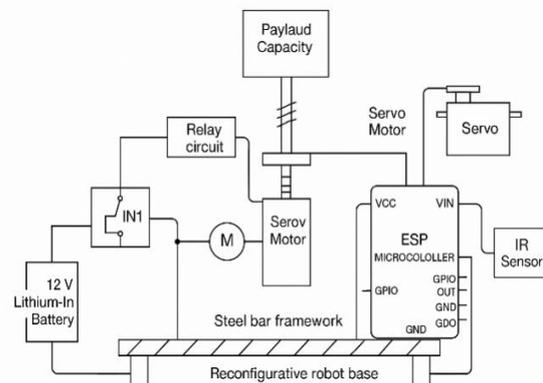


Figure.5.schematic circuit diagram:

X. CONCLUSION

The system was designed with modular components, allowing for real-time structural changes like as height control, wheel-to-track conversion, and axis flexibility. The trials took place on flat indoor surfaces. In each situation, the robot improved its mobility, stability, and adaptation to task-specific

needs. This reconfigurable robot provides a strong and adaptable platform for a variety of robotic applications. Its capacity to change physical configurations eliminates the need for many specialized robots, increasing productivity and decreasing deployment costs. Advantages include task-specific adaptability, enhanced terrain negotiating, and operational continuity under changing conditions.

Despite these benefits, obstacles persist, notably in handling greater mechanical complexity and establishing more sophisticated control systems. Future improvements should focus on incorporating AI-driven autonomous reconfiguration using lightweight materials to increase energy efficiency, and designing user-friendly interfaces for ease of deployment. As a consequence, customizable robot bases provide a promising future for robotics in fields such as search and rescue, industrial automation, and exploratory missions.

XI. REFERENCES

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