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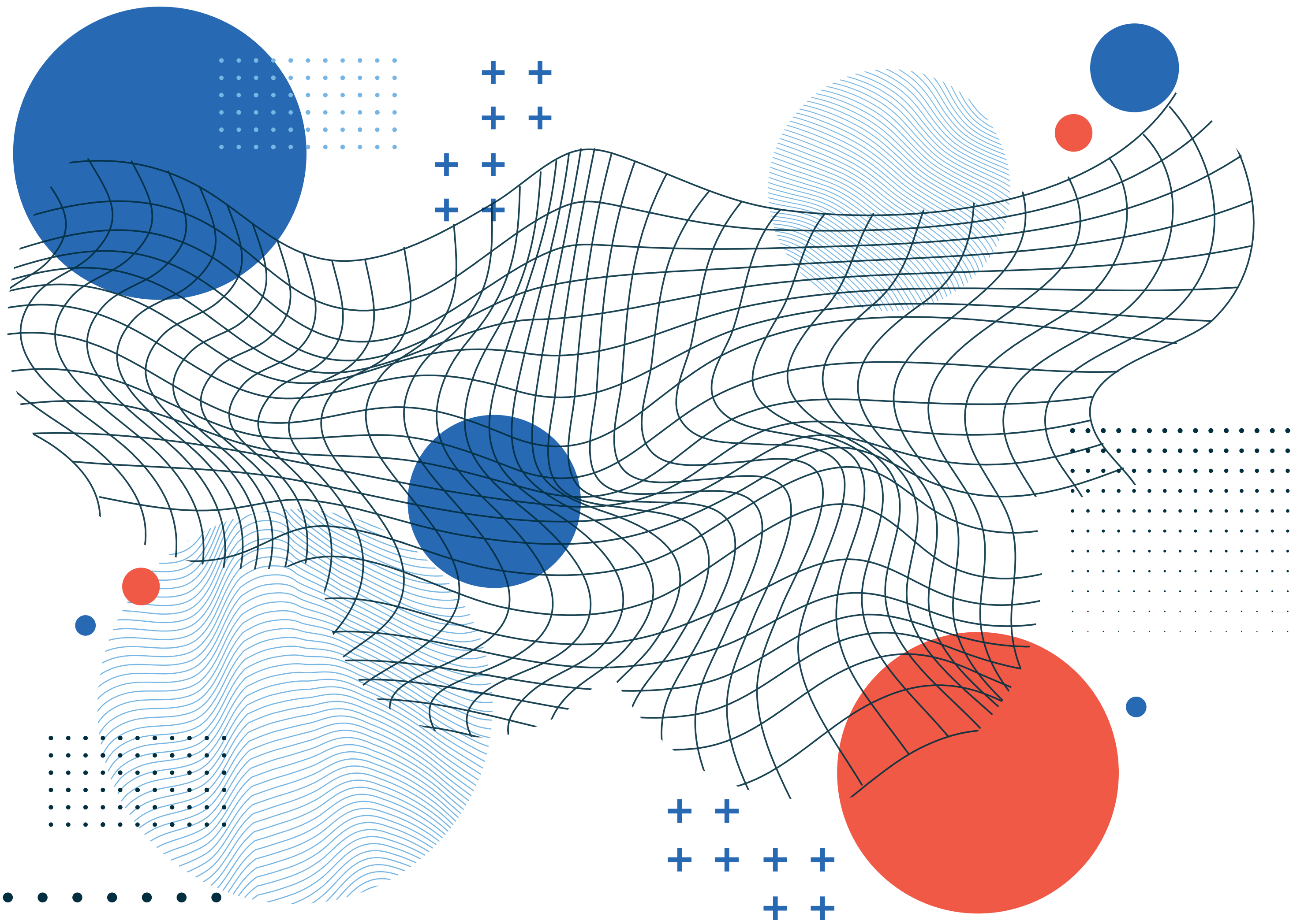

Exploring the Enhancement of All-Terrain Adaptability – A Case Study of Structural Design and Optimization of Forklift Robots
探討全地形適應能力－以堆高機機器人之結構設計與最佳化為例

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Abstract

This project designs and modifies an all-terrain forklift robot. During real-world testing, the robot needs to move objects quickly and accurately while maintaining balance to avoid tipping over. Therefore, stability and power are crucial.

To tackle these challenges, we came up with two key features. The first is a wheel-switching system — the robot can swap between tracks and tires depending on what the situation calls for. The second is an extra power system: we added two batteries to the back of the robot. This does double duty — it boosts total battery capacity and extends how long the robot can run, while also acting as a counterweight to keep the robot steady when it's carrying heavy loads.

We conducted numerous experiments comparing different configurations, including stability, endurance, and mobility tests. The experimental results clearly demonstrate that the extra power systems significantly improve the robot's balance and operating time. Simultaneously, the wheel-switching design makes the robot more flexible and better adaptable to different terrains and competition requirements.

Keywords: Forklift robot, modular design, stability, power system, all-terrain mobility

I. Introduction

With the rapid advancement of automation and robotics, forklift robots have become increasingly important in logistics, manufacturing, and competition-based engineering challenges. These robots are required to transport heavy objects efficiently while maintaining stability and maneuverability. However, achieving both stability and mobility remains a key challenge, especially when dealing with varying terrain conditions and load weights.

In robotics competitions, such as the one this project is based on, the robot must lift and transport relatively heavy objects within a limited time frame. During the development process, several issues were identified, including insufficient power capacity, instability when lifting heavy loads, and limitations in mobility depending on the chassis design.

To address these challenges, this project aims to develop a modular forklift robot that can adapt to different operating conditions. The robot is designed with interchangeable tracked and wheeled chassis systems, as well as an enhanced power system that improves both energy capacity and stability. The objective of this study is to evaluate the effectiveness of these design features through performance testing and comparison.

II. Literature Review

According to the literature, one of the key design considerations for an all-terrain robot is the ability to operate effectively on a wide variety of surfaces and overcome obstacles. To achieve this, the robot should be equipped with a sufficient number of drive wheels, high-torque motors, appropriate motor drivers, and a reliable power supply system. Adequate motor power and electrical capacity provide the traction and driving force required to travel across challenging terrains such as sand, snow, and rubble while carrying additional payloads. Therefore, ensuring sufficient power and energy availability is essential for improving mobility, obstacle-climbing capability, and overall terrain adaptability in all-terrain robot design.

III. Methodology

A. Overall Robot Design

The forklift robot is constructed using a modular aluminum frame combined with a gear-driven lifting mechanism. The lifting system uses a series of gears to provide stable and controlled vertical motion, allowing the robot to lift objects with precision. The overall structure is designed to be durable while maintaining flexibility for modifications. (image 1)

B. Modular Chassis System

A key feature of this robot is its modular design, which allows the lifting mechanism to be detached and mounted onto different chassis systems. Two types of chassis were developed:

1. **Tracked chassis** – provides higher stability and better traction on uneven surfaces. (image 2)
2. **The wheeled chassis** offers faster movement and improved maneuverability.

This modular approach enables the robot to adapt to different competition scenarios and environmental conditions.

C. Dual-Function Power System

To improve performance, an additional power system was implemented by installing two extra batteries at the rear of the robot. This system serves two main purposes:

1. **Power enhancement** increases total energy capacity, allowing a longer operation time. (image 3)
2. **Counterweight function** – shifts the center of mass backward, improving stability when lifting heavy loads.

This dual-function design plays a critical role in preventing the robot from tipping forward during operation.

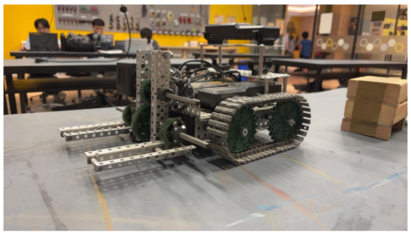
D. Experimental Design

To evaluate the robot's performance, several tests were conducted:

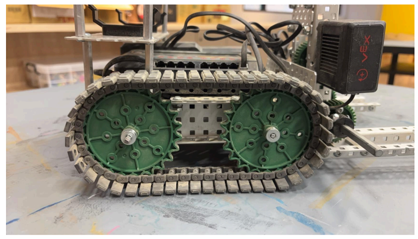
1. **Stability Test**
   The robot was tested with and without the additional batteries while lifting objects of increasing weight.
2. **Power Endurance Test**
   The operational time was measured using different battery configurations.

3. Mobility Comparison

The performance of tracked and wheeled chassis systems was compared under different surface conditions.



(image 1)



(image 2)

(image 3)

IV. Results

The experimental results indicate significant improvements in performance with the enhanced design.

First, the stability test showed that the robot without the additional batteries was more prone to tipping when lifting heavier loads. In contrast, the robot with the dual-function power system maintained balance even under higher weight conditions.

Second, the power endurance test demonstrated that adding extra batteries extended the operational time considerably, allowing the robot to complete tasks more efficiently without interruption.

Finally, the mobility comparison revealed that the tracked chassis provided better stability and traction, particularly on rough surfaces, while the wheeled chassis offered higher speed and flexibility on smooth surfaces.

V. Discussion

The results confirm that the integration of a dual-function power system is highly effective in improving both stability and operational efficiency. By serving as both an energy source and a counterweight, the additional batteries address two critical challenges simultaneously.

Furthermore, the modular design significantly enhances the adaptability of the robot. Instead of building separate robots for different conditions, the interchangeable chassis system allows for quick reconfiguration based on specific requirements.

The comparison between tracked and wheeled systems highlights an important engineering trade-off between stability and speed. This finding suggests that selecting the appropriate chassis depends on the specific task and environment.

Overall, the combination of modular design and power optimization provides a practical and efficient solution for robotics competitions and real-world applications.

VI. Conclusion

This study successfully developed a modular forklift robot with improved stability and power efficiency. The implementation of a dual-function power system effectively enhances both energy capacity and balance, while the interchangeable chassis design allows flexible adaptation to different environments.

The results demonstrate that integrating mechanical design with power optimization can significantly improve robot performance. Future work may focus on incorporating sensors and automated control systems to further enhance functionality and efficiency.

References

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