RexcuBot: An analytical Review of the Robot

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***Abstract*— This paper presents the development process and challenges encountered in constructing the RexcueBot, a robotic platform inspired by the iRobot Roomba. The RexcueBot was designed with an upper casing to house its electronics and incorporated a scoop attachment for specific tasks. Throughout the construction phase, several challenges emerged, including issues related to the placement of the line following sensor and the tilting mechanism of the scoop. However, through iterative testing and design adjustments, these challenges were successfully addressed, leading to a more refined and functional robot. Despite overcoming these initial hurdles, the RexcueBot faced an unexpected setback during the competition due to a battery malfunction, highlighting the importance of robust power management in competitive robotics. This paper underscores the iterative nature of robot development and the necessity of thorough testing to ensure performance under real-world conditions.**

I. Introduction

The field of robotics continues to advance rapidly, with a growing emphasis on enhancing flexibility and minimizing interruptions in robot functionality. Existing literature highlights the importance of robust and adaptable robotic platforms for various applications, from industrial automation to education. This research aims to address these challenges by leveraging insights from prior robots and design concepts, particularly inspired by the Turtlebot 3 platform. By building upon previous work and incorporating innovative strategies, we seek to improve the performance and versatility of modern-day robots.

Drawing inspiration from the Turtlebot 3 platform and its application in educational settings, our research is guided by the goal of enhancing and integrating some mechanisms into the Rexcue Bot. The Turtlebot 3 serves as a foundational reference point, offering valuable insights into hardware and software integration for easy maneuverability and versatility [1]. By analyzing the strengths and weaknesses of previous designs and approaches, we aim to develop a more effective and user-friendly robotic platform tailored to the specific needs of the final competition. Our strategy centers on leveraging line-following capabilities for autonomous navigation, supplemented by manual control to overcome obstacles and manipulate objects using our scoop and arm. Inspired by the Turtlebot 3's versatility, we hypothesize that this hybrid approach will enhance the robot's flexibility and efficiency in completing complex tasks, such as capturing and transporting objects [1]. Through rigorous testing and analysis, we aim to validate our hypothesis and contribute to the advancement of robotics education and technology.

II. Methods

The research methodology commenced with a thorough exploration of existing literature concerning robotics platforms, with a particular emphasis on their integration into educational contexts, notably spotlighting the Turtlebot 3 platform. This endeavor involved a meticulous review of scholarly articles, technical reports, and educational materials spanning various disciplines, including robotics, engineering education, and human-computer interaction. Through a systematic analysis of this diverse body of literature, we aimed to distill valuable insights into the underlying design principles, construction methodologies, and pedagogical frameworks employed in prior initiatives involving different robotics platforms. Our goal was to extract key findings, identify emerging trends, and discern best practices to inform our own design process effectively[1].

This exploration extended beyond the confines of robotics alone, encompassing adjacent fields such as human-computer interaction. By situating our research within this broader interdisciplinary context, we sought to gain a deeper understanding of the complex interplay between technological affordances, instructional strategies, and learner experiences.

In essence, the systematic review of existing literature served as a foundational element of our research methodology, providing a robust framework for comprehending the multifaceted dynamics of robotics education and guiding our subsequent design decisions. Through this rigorous process, we aimed to leverage the collective wisdom of the scholarly community to advance our own endeavors and contribute meaningfully to the field of educational robotics.

When designing robots, several key considerations must be addressed to ensure their effectiveness and suitability for the intended context. Safety is paramount, especially in environments where there is robot-human interaction.

Therefore, prioritizing safety features like emergency stop buttons, and protective enclosures is essential to prevent accidents or injuries.

Moreover, the design should be scalable to accommodate various educational settings, ranging from a small workspace to larger competition boards. Factors such as cost, maintenance requirements, and ease of deployment across multiple locations should be considered to ensure scalability.

Customizability is another critical aspect to consider, as it encourages creativity and allows for robust problem solving. By providing opportunities for customization and experimentation, such as modular design elements and open-source software platforms, we adapted the robot to specific environments, and ensure a modular design. Furthermore, durability is key to ensuring the longevity of the robot in different environments. Choosing materials and components that can withstand wear and tear, as well as being easy to repair or replace, when necessary, will help maintain the robot's functionality over time.

The literature review guided our design process by providing valuable insights and inspiration. By analyzing existing research, we identified common themes and trends that informed our approach. This allowed us to build upon established practices and incorporate innovative ideas into our robotic system, enhancing its effectiveness as the RexcueBot [1].

In the thorough design process of the RexcueBot, each component was carefully selected and integrated to optimize functionality. Our locomotion system featured a dual-wheel configuration, with each wheel driven independently by DC motors. These motors were seamlessly synchronized through a TB6612FNG motor driver, calibrated to ensure precise control over speed and direction, facilitating agile navigation across diverse terrains.

Complementing our locomotion system, a strategically positioned line sensor, hovering 2-3 mm above ground level, facilitated precise path-following capabilities. This sensor, pivotal in our autonomous navigation system, enabled the robot to traverse predefined routes with unparalleled accuracy, crucial for executing complex tasks with efficiency and reliability.

For the manipulation aspect of the RescueBot, our robotic arm was engineered for versatility and precision, featuring two Hitec HS422 servos carefully orchestrated to achieve a wide range of movements. Leveraging an inverse kinematics model, each servo was intricately controlled to ensure precise positioning and orientation. Furthermore, our robot featured a front-mounted scoop mechanism, actuated by a single servo motor, designed to efficiently scoop up objects or dinosaurs. This mechanism, seamlessly integrated into the robot's design, facilitated tasks such as collecting and transporting items within its environment.

To orchestrate the seamless interaction between locomotion and manipulation systems, we developed a sophisticated control algorithm. This algorithm, crafted through kinematic modeling, and trajectory planning, ensured fluid movement and precise manipulation of objects. Through rigorous testing and optimization, we refined the control algorithm to achieve optimal performance, ensuring the robot's reliability and effectiveness in educational contexts.

The final design of the robot was made in Fusion 360, it can also be seen in Figure 1. Additionally, the electrical schematic was made with the goal of making the RexcueBot as customizable as possible, this can be seen in Figure 2. The overall dimensions of the robot were 350 mm long and 180 mm wide, as seen in Figure 3 & Figure 4 respectively, with a total print volume of 14.62in^3. The design incorporated 0% MDF, as it was discussed that the whole robot would be 3d printed.

Figure 1 - Final Design of the RexcueBot

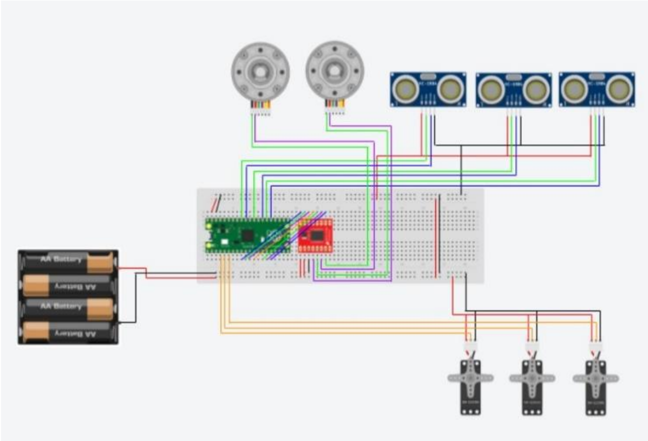

Figure 2 - Electrical Schematic of the RexcueBot

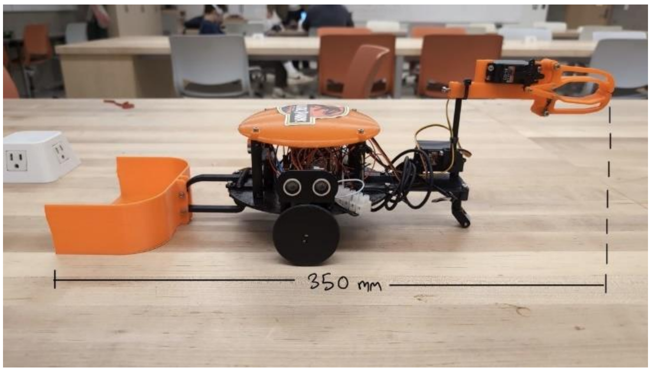

Figure 3: Side view of the RexcueBot

Figure 4: Top view of the RescueBot

III. Results

After completing the project, the robot worked as it was intended to, however, it was slightly less efficient than expected. Initial testing showed the gripper to work consistently and after a few modifications, our scoop worked well too. The biggest drawback we faced by adding the scoop to our design was that it made the entire robot bigger and harder to drive around. This however, just required our driver to keep these new conditions in mind and sometimes having to take the longer route around obstacles (mainly the rocks).

Our gripper, seen in Figure 5, also worked well during initial testing. During the design of the gripper, our main concern was keeping the arm short enough that the servo at the base had enough torque to lift the Ken doll up. However, it turned out to be more than strong enough with fully charged batteries. The gripper itself also went through a couple design iterations. Most of these changes were made before any of it was printed and came mostly from our team meetings and discussions. The only parts of the gripper that had to be reprinted were the small links connecting the servo to the gripper. Thankfully these took close to no plastic.

The base of the robot gave us the best results out of any part of the project. The parts were only printed once and were the most reliable. A concern from the base design was the swivel wheel being loose enough (bottom of Figure 5) to not cause resistance on the main two wheels. This however was never a problem. The base also held all the electronic components needed including the breadboard, ultrasonic sensors, and batteries. Holes along the plastic base were added in anticipation for this and resulted in a clean look.


Figure 5 - Gripper up close

In the qualifying round, our robot had an about average run. It successfully completed the autonomous part and transitioned into manual mode as expected, it managed to place 2 dinosaurs into the bin but did not have time to get the Ken doll. This run was better than most groups.

Unfortunately, for the main competition, the robot's batteries were not sufficiently charged which greatly affected the scoop and speed. Despite designing the robot scoop to have a 1-centimeter clearance above the bin, the low batteries caused the servo be to unable to lift it high enough with the dinosaurs in it. The low batteries also caused the autonomous mode to slow down greatly. Overall the combination of these unexpected obstacles lead the robot to be unable to get any dinosaurs.

IV. Discussion

The performance of the robot in the recent competition demonstrated its strong potential, despite not being fully charged. Each of its components, including the scoop and gripper, operated effectively on an individual basis, showcasing the robot's well-engineered design and functionality. The issue with the charging did not overshadow the fact that the robot could perform its tasks efficiently when power levels were optimal. This experience highlights the importance of ensuring full in future competitions.

Throughout the course of this project, the team gained substantial insights and knowledge, particularly in the areas of robotics and 3D printing. One significant challenge encountered was with the robot's connectivity, which occasionally disrupted the coordination between its various components. This issue provided a valuable learning opportunity for troubleshooting and refining the communication protocols within the robot's system.

Addressing these challenges has not only improved our technical skills but also emphasized the importance of thorough testing and contingency planning in real-world applications.

[1] R. Amsters and P. Slaets, “Turtlebot 3 as a robotics education platform,” Robotics in Education, pp. 170–181, Aug. 2019. doi:10.1007/978-3-030-26945-6_16