Semi-Autonomous Control of mBot Neo Robots Using Physiological Signals and PID Wall following Systems

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***Abstract*— The integration of robotics with physiological signals represents an emerging frontier in human-robot interaction research. This study, conducted within the framework of a Research Experience for Undergraduates (REU) program at the University of Alabama, embarked on a multifaceted exploration of this evolving field. Our primary objective was to enhance the capabilities of Makeblock's mbot neo robots by forging a semiautonomous control system that ingeniously merged both physiological controls and advanced programming techniques. At the heart of our research was the implementation of a Proportional-Integral-Derivative (PID) control system, designed to impart precision and responsiveness to the mbot neo robots. This endeavor unfolded in tandem with the development of a wall following algorithm, illuminating our journey with lessons in perseverance, innovation, and problem solving. We navigated the labyrinth of challenges, transforming the robots into autonomous entities capable of navigating their environment with elegance and precision. The study's evolution culminated in the fusion of the PID control system with the Emotibit, an emotive sensor, enabling the robots to respond dynamically to physiological data obtained from users. This integration empowered the robots to engage in a nuanced dance with users, adapting their actions based on real-time physiological signals, thus fostering a new dimension of human-robot interaction.**

I. INTRODUCTION

The integration of robotics and physiological signals represents a dynamic and promising area of research with the potential to transform human-robot interaction. This study, conducted as part of an immersive Research Experience for Undergraduates (REU) program at the University of Alabama, aims to contribute to this evolving field by developing a semi-autonomous control system. This system incorporates physiological controls and advanced programming techniques, harnessing the capabilities of Makeblock's mbot neo robots and the Emotibit. This ambitious endeavor ventures into uncharted territory at the intersection of robotics and human physiology, pushing the boundaries of what is currently achievable in the realm of human-robot interaction.

II. PID-BASED CONTROL SYSTEM DEVELOPMENT

The PID control system served as the bedrock of our research endeavors, aiming to imbue the mbot neo robots with a remarkable level of precision in their actions, whether following user commands or responding to their environment's dynamic changes. Our use of the PID control system was to have automous wall following. The ambitious goal of creating a wall-following system tasked us with designing a complex algorithm that would enable the mbot neo robots to autonomously traverse their environment while maintaining a consistent distance from walls. This seemingly straightforward task posed numerous intricacies that tested our problem-solving abilities. Our initial attempts were marked by a dance of trial and error. We adjusted parameters, fine-tuned algorithms, and conducted rigorous testing, only to be met with erratic and unpredictable robot behavior. It was a frustrating phase, where it seemed as though the robots had a mind of their own, often veering off course or hesitating when faced with corners and obstacles. We meticulously analyzed each failure, seeking insights that would lead us toward success. Each setback was an opportunity to refine our approach, to question assumptions, and to experiment with novel solutions.(see Figure 1)

After countless iterations, our efforts bore fruit in the form of an elegantly functioning wall-following system. The mbot neo robots finally demonstrated the ability to autonomously navigate their environment with precision. Their movements became a harmonious dance along the walls, a testament to the power of perseverance and ingenuity. The successful development of the wall-following system marked a significant milestone in our research. It represented the realization of autonomy a stage where the robots could operate independently, responding to their surroundings in real time without human intervention. It was a moment of triumph, where our robots evolved from mere tools to autonomous entities capable of making

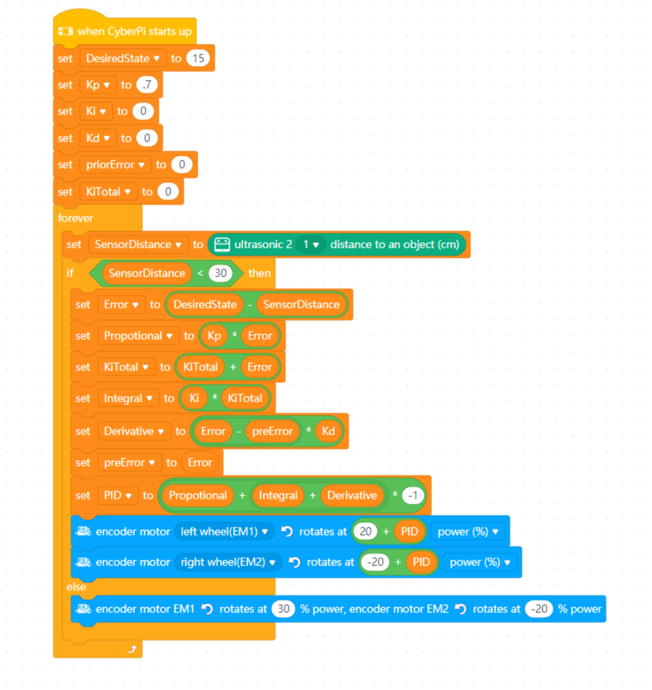

Fig. 1. The Wall following algorithm in block-based programming form.

decisions based on their perception of the world.

III. Transition to Python-Based Control: Embracing Open Source

Our transition to Python represented more than just a change in programming language; it marked a profound shift from the confines of closed, block-based programming to the open, expansive world of Python. This transformation endowed us with a level of flexibility and adaptability that was pivotal in our quest to break free from the limitations of block-based programming. Python, with its innate versatility and adaptability, became our new digital canvas Figure 2. It offered us the freedom to sculpt tailored solutions, enabling our robots to adapt, evolve, and respond with precision to the multifaceted challenges we encountered. Yet, this transition came with its share of challenges. Navigating the open-source realm was akin to embarking on a quest. It required a substantial investment of time, filled with trial and error, as we searched for the elusive documentation that would serve as our guide through this new landscape. We explored a multitude of resources, dived into forums, and sought the collective wisdom of the dated open-source community. We felt as though we had discovered a hidden region of untapped potential when we eventually discovered the open-source documentation. The key to linking our Python environment with the mbot neo robots is included within this documentation. Despite its relative obscurity, the code's intuitive and straightforward nature astonished us. In our journey through open source, Visual Studio Code (VSCode) emerged as our workshop of innovation. Its user-friendly interface, extensive extensions, and powerful debugging capabilities became indispensable tools. They streamlined our development process, enhancing our productivity and enabling us to seamlessly integrate Python with the mobility of the mbot neo robots. Having connected Python to the mbot neo robots, we faced the enigmatic challenge of integrating the central nervous system of the mbot neo robots the CyberPie. This central hub connected all the vital parts, from the motors to the sensors. However, Understanding how to connect and command this intricate network required further exploration. The CyberPie, much like the brain of our robots, was a complex enigma that demanded our attention. We embarked on an expedition into its depths, exploring its intricacies, and deciphering its language.

IV. Electrodermal Activity (EDA) and Emotional Interpretation

With the foundation of Python-based control in place, we sought to enrich the human-robot interaction by introducing emotional intelligence into the equation. To achieve this, Electrodermal Activity (EDA) sensors were seamlessly integrated into the control system through the Emotibit device. This integration opened up new horizons, enabling us to collect physiological data intricately linked to emotional states. Our journey into emotional intelligence began with the Emotibit, a device designed to capture physiological signals that mirror the user's emotional responses. Python code was meticulously crafted to process and visualize the EDA data in real-time. This innovation allowed us to peer into the user's emotional world during interactions with the robot, offering a dynamic and unfiltered view of their emotional responses. The ability to interpret EDA data in real-time was a transformative leap forward. It meant that our robots were not just responding to commands but also to the subtle nuances of human emotion. This profound capability opened avenues for dynamic adaptation. The robots could now gauge the user's emotional state and respond accordingly, infusing a new dimension of empathy and responsiveness into human-robot interactions. However, our journey didn't stop at emotional intelligence. We aimed for a higher degree of autonomy, where our robots could navigate their environment intelligently. Leveraging the Proportional-Integral-Derivative (PID) control system, we engineered semiautonomous behaviors for the mbot neo robots. These behaviors empowered the robots to navigate autonomously while maintaining a consistent distance from walls and avoiding obstacles.

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