STEPHEN F. AUSTIN STATE UNIVERSITY
COLLEGE OF SCIENCES AND MATHEMATICS

Investigating Inverse Kinematics Through the Construction of a Selective Compliance Assembly Robotic Arm (SCARA)

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Abstract

In the proposed project, we undertook the challenging task of building a Selective Compliance Assembly Robotic Arm (SCARA). This endeavor not only involved the physical construction of the robotic arm but also required students to engage deeply with both mechanical and electrical engineering principles. The project's primary goal was to provide students with hands-on experience in robotics, focusing on the assembly and operational functionality of a SCARA robotic arm. This experience was designed to mirror real-world engineering challenges, allowing students to apply theoretical knowledge in a practical setting.

Introduction

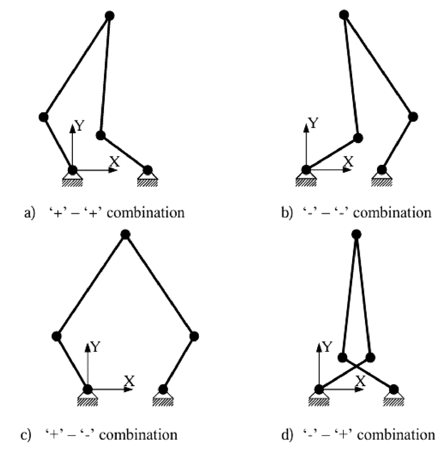
The potential impact and significance of this research project lay in its capacity to equip students with a wide range of practical skills valuable in the private sector, despite not venturing into novel research territory. By constructing and programming a Selective Compliance Assembly Robotic Arm (SCARA), students acquired critical technical abilities, bridging the gap between theoretical knowledge and real-world application, thus preparing them for successful careers post-graduation. Additionally, this project benefited the Department of Physics, Engineering, and Astronomy at Stephen F. Austin State University by providing a demonstration piece that could spark interest in STEM fields among incoming freshmen and impress potential donors during facility tours. This strategic use of the project not only promoted hands-on learning and showcased the department's commitment to innovative education but also played a crucial role in securing financial support, essential for enhancing the university's STEM education quality and resources.

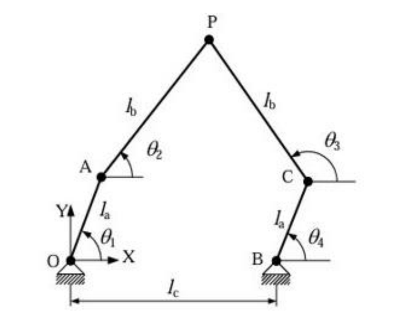
Methods and Materials

The research design for this project centered on the creation of a Parallel Selective Compliance Assembly Robotic Arm (SCARA), leveraging two electronically controlled manipulators to command a singular end effector. This innovative approach was anticipated to streamline the analysis of the system's Inverse Kinematics, simplifying the complex mathematical models that dictated the arm's movements based on specific positional inputs. The initial phase of our design process, spanning over the first few weeks, involved deriving these general kinematic equations essential for manipulating movement. Subsequently, our team undertook a comprehensive workspace analysis to determine the optimal dimensions for each segment and the precise spacing between manipulators. This foundational work was critical, setting the stage for the more detailed design and prototyping phases that followed.

Inverse Kinematics

The different combinations of adding and subtracting the radicals of the angle equations result in 4 different orientations of the 5-bar link as shown below.





$$\begin{cases} \theta_1 = 2\arctan\left(\dfrac{-F_1 \pm \sqrt{E_1^2 + F_1^2 - G_1^2}}{G_1 - E_1}\right) \\ \theta_4 = 2\arctan\left(\dfrac{-F_4 \pm \sqrt{E_4^2 + F_4^2 - G_4^2}}{G_4 - E_4}\right) \end{cases}$$

let $l_a = 24cm$
let $l_b = 36cm$
let $l_c = 24cm$

Where

$E_1 = -2l_a x_P$ $\quad$ $E_4 = 2l_a(-x_P + l_c)$

$F_1 = -2l_a y_P$ $\quad$ $F_4 = -2l_a y_P$

$G_1 = l_a^2 - l_b^2 + x_P^2 + y_P^2$ $\quad$ $G_4 = l_c^2 + l_a^2 - l_b^2 + x_P^2 + y_P^2 - 2l_c x_P$

Conclusions

In this project, participating students and mentoring faculty collaborated closely on several key tasks to ensure the success of the SCARA Robotic Arm initiative. Together, engaging in the design process, part manufacturing, and the construction of the SCARA Robotic Arm, pooling their expertise to tackle each phase of development effectively. Additionally, this team effort extended to the technical implementation of inverse kinematics, a critical component for controlling the arm's output position with precision. Beyond the technical work, students and faculty also dedicated efforts to effectively communicate their project outcomes. This was achieved through the presentation of the completed SCARA Robotic Arm and the dissemination of their findings via a research poster, showcasing the project's achievements and learning outcomes.

3D Model Exploded View

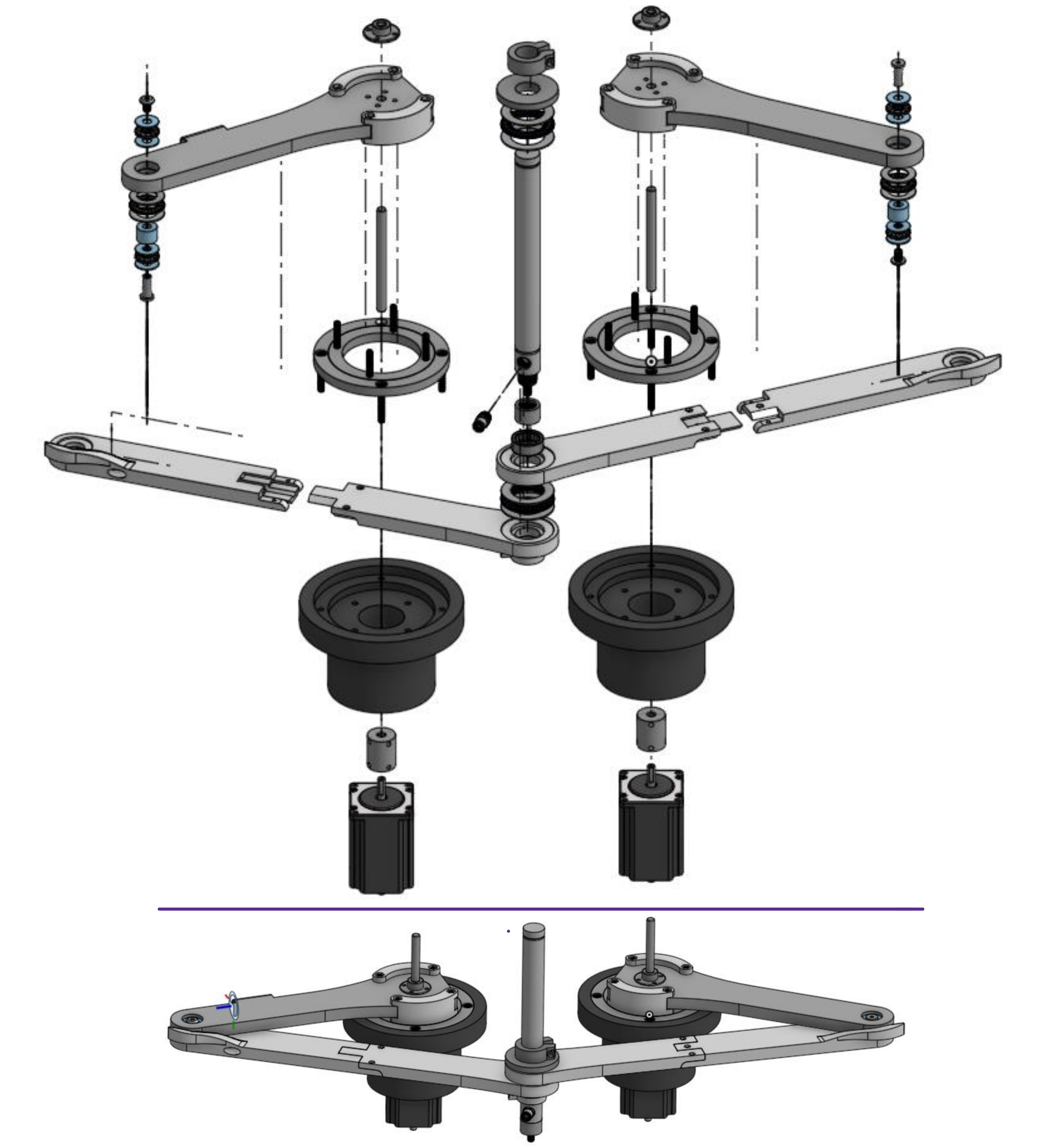
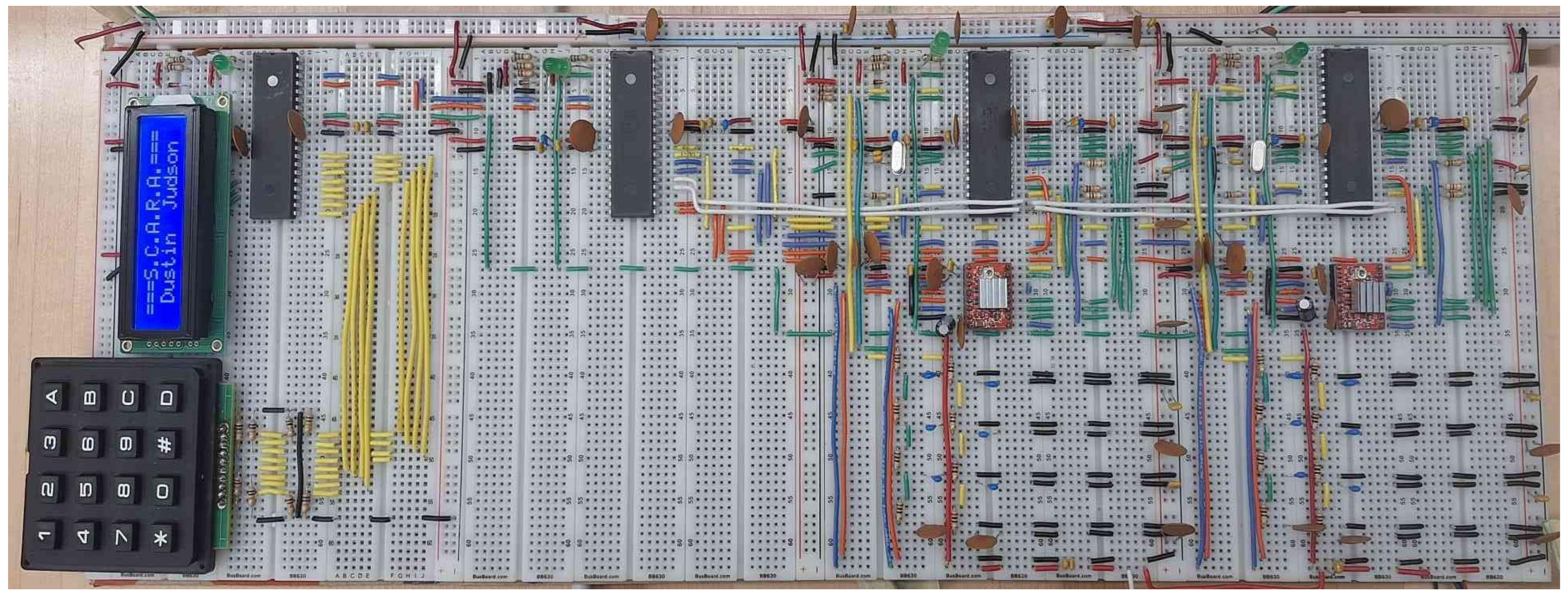


Figure 2. Mechanical Design of the SCARA Robot Arms

Prototype Circuit on Breadboard



Functional SCARA

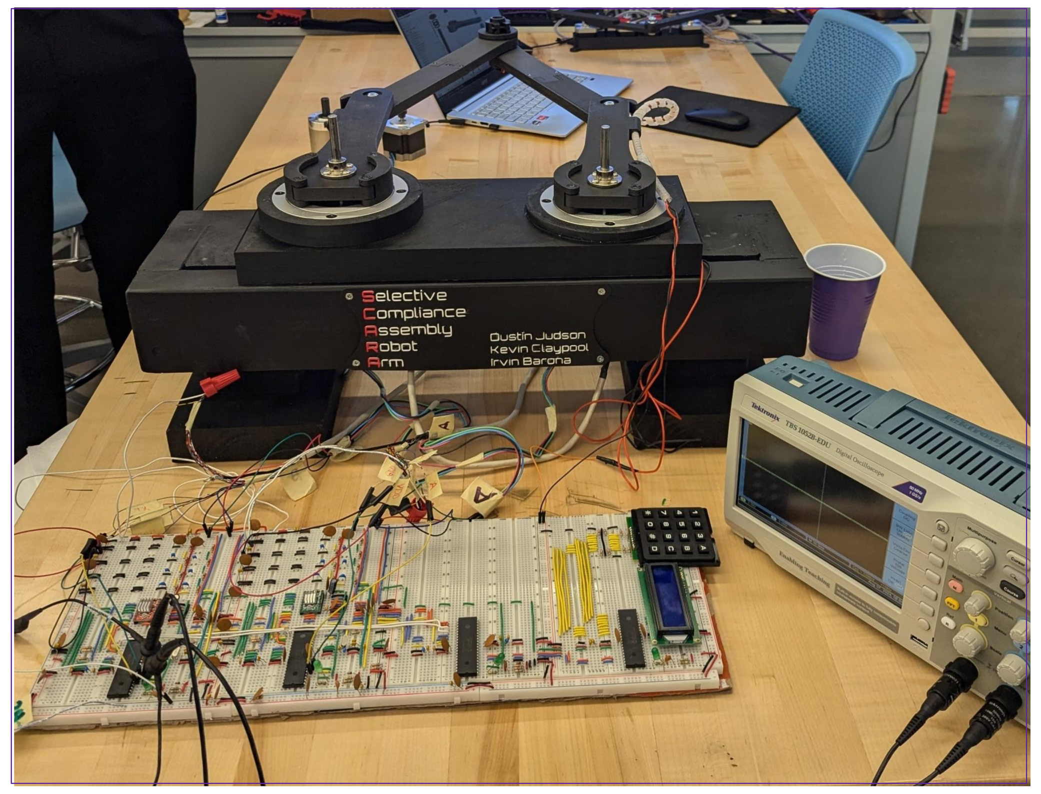


Figure 1. Electronics Design of the SCARA Robot.

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