Purdue Polytechnic School of Engineering Technology, TEAM 30

Smart DIY Exoskeleton

PURDUE UNIVERSITY

Polytechnic Institute

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OBJECTIVE

To develop a low-cost, modular, and sensor-integrated DIY exoskeleton designed for educational use at Purdue University. The goal is to enhance passive exoskeletons with smart features for measuring force distribution, muscle activity, and joint angles that provide a hands-on tool for students to study human factors, ergonomics, and workplace safety.

CUSTOMER PROBLEM AND BACKGROUND

Purdue's Human Factors and Ergonomics courses offer a strong foundation in theory and small-scale electronics projects but lack access to fully functional wearable exoskeleton systems. This limits students' ability to study ergonomic interventions and mechanical variability through real-time data collection. Current passive exoskeletons used in academia are not designed for sensor integration, reducing their instructional value for applied learning in human-centered design and workplace safety.

The existing prototypes cannot measure critical mechanical parameters like force exertion, hip angles, or full-body orientation. Additionally, they are often bulky, lack modularity, and provide no wireless data capabilities. Faculty in Purdue Polytechnic are seeking a low-cost, educationally effective, and easy-to-assemble system that delivers accurate and actionable data for lab-based instruction.

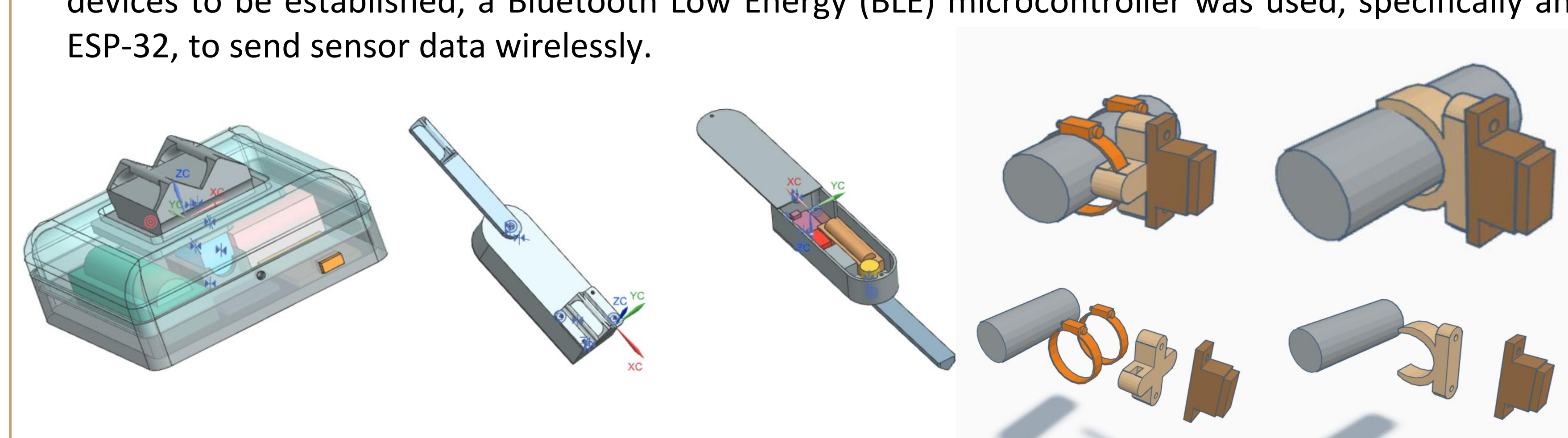
Our smart DIY exoskeleton addresses these gaps with a modular, sensor-integrated platform equipped with **force sensors**, **angle sensors**, and an **Inertial Measurement Unit (IMU)**. Force sensors capture load distribution across the chest and thighs, angle sensors track hip and torso flexion to study posture and movement, and the IMU provides real-time orientation data. These elements enable hands-on analysis of ergonomic performance, offering students a deeper understanding of mechanical feedback and human variability.

REQUIREMENTS

1) Fabrication and assembly of multiple exoskeletons for testing and education purposes
2) Simple for users to wear and collect data from smart exoskeleton
3) Non-invasive, modular design that does not impede movement or discomfort user
4) Collects data related to users' movement (angle of user's legs relative to torso, force against chest, orientation of user)
5) Wireless transfer of data over long period of time

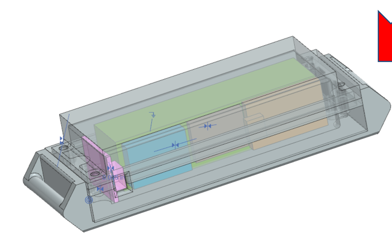
CONCEPTS AND EXPERIMENTATION

Requirements for the smart exoskeleton system lead initial concepts in the direction of a decentralized system, with custom 3D printed parts to attach and contain the sensors and components that allow for the wireless collection of data. Custom printed 3D parts allows for a modular design that, at the same time, keeps invasive geometry to a minimum. To keep the sensors active and communicating with devices for a long period of time, a charging port and rechargeable lithium-ion battery were integrated into sensor modules. For communication with devices to be established, a Bluetooth Low Energy (BLE) microcontroller was used, specifically an ESP-32, to send sensor data wirelessly.

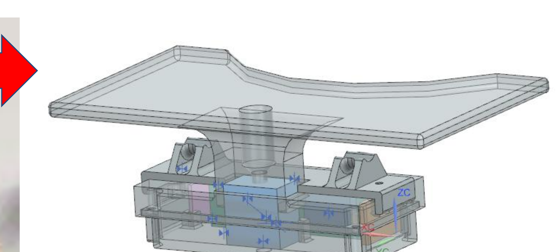


Initial designs for sensor modules and attachment parts

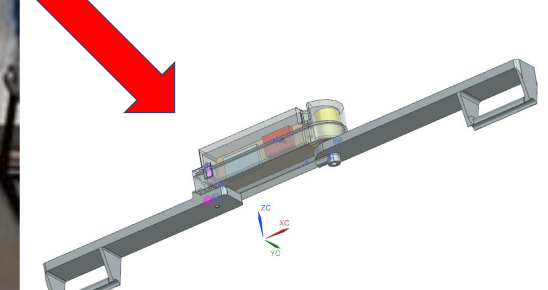
FINAL DESIGN



IMU Sensor Module



Force Sensor Module

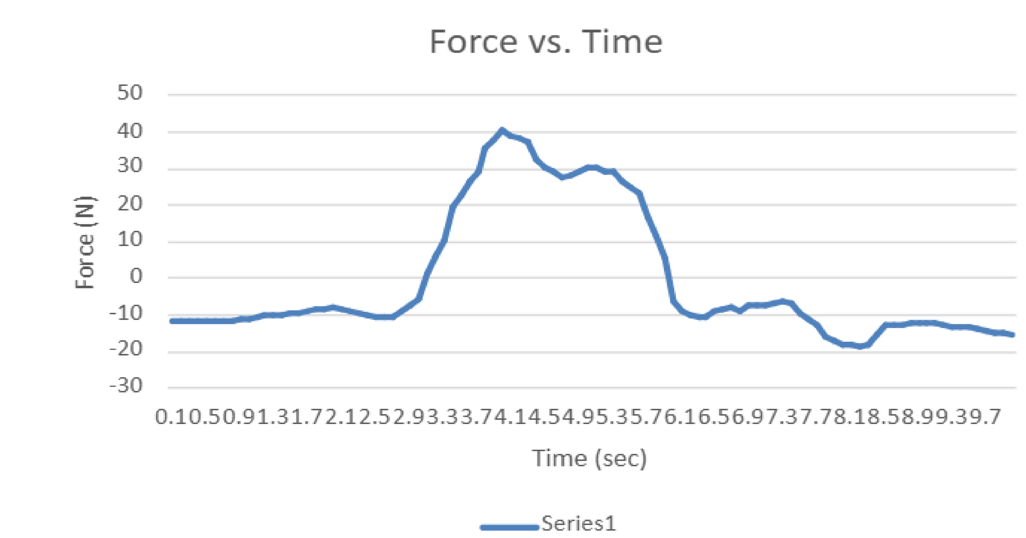


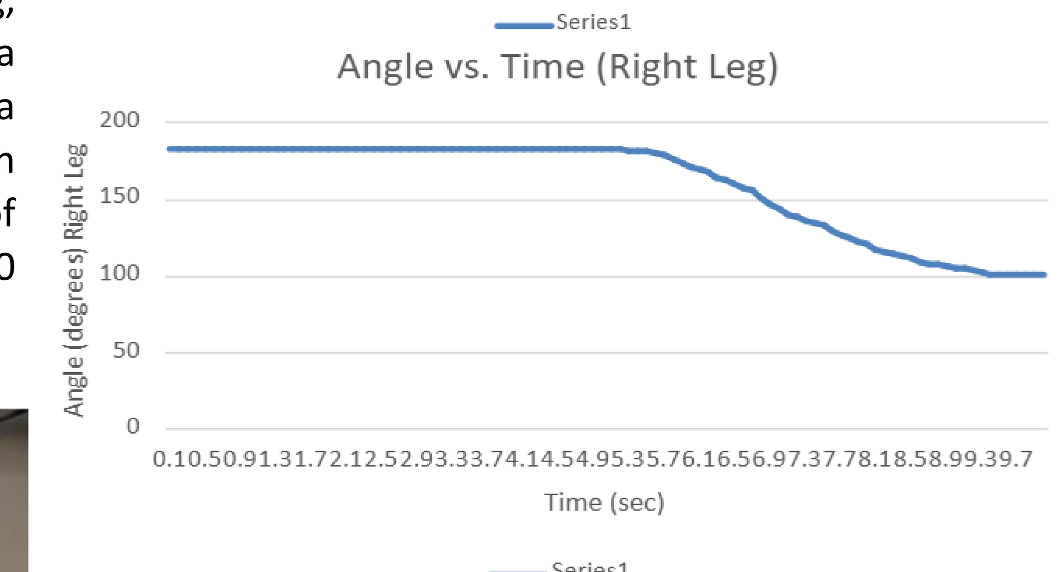
Angle Sensor Module

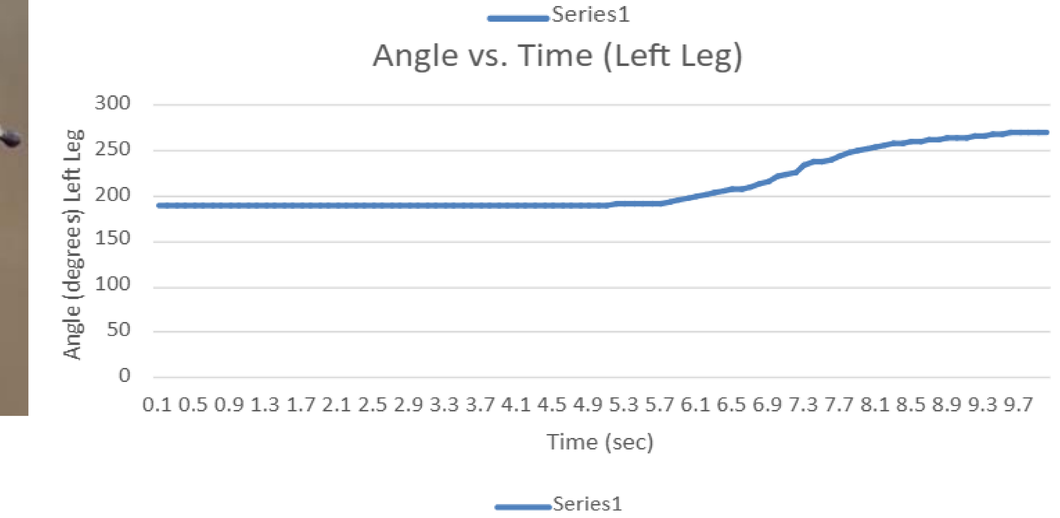
TESTING RESULTS

Testing results include multiple graphs showing information such as force against users' chest and angle of each leg. Information gathered during testing procedures where user was asked to stand still for 5 seconds, then bend down then back upright again in a motion totaling 3 seconds. Three separate graphs were made from the user's movement, Force vs. Time, Angle vs. Time for the right leg, and Angle vs. Time for the left leg. Angle data points are recorded in degrees, Force data points in Newtons, and time in seconds. Each data point was recorded at a time interval of 0.1 seconds, over a total amount of 10 seconds.

Bending over motion user was asked to make







CONCLUSION AND RECOMMENDATIONS

During the time that this team has worked toward completing project requirements and beyond, most base requirements have been met by the final design. EMG sensor data collection was omitted due to time constraints, as well as force readings for each leg. Other requirements have been met. Recommendations for the future of this project are the **inclusion of EMG sensor and force sensors for each leg**, involving the development of sensor circuits, sensor casings, and wireless communication and data integration with other sensor information. Possible **fabrication and assembly of additional exoskeletons** if needed for testing or education purposes, **additional fabrication also applies to sensor modules if more data is needed** on a single exoskeleton or including data collection on multiple exoskeletons.