Design Document

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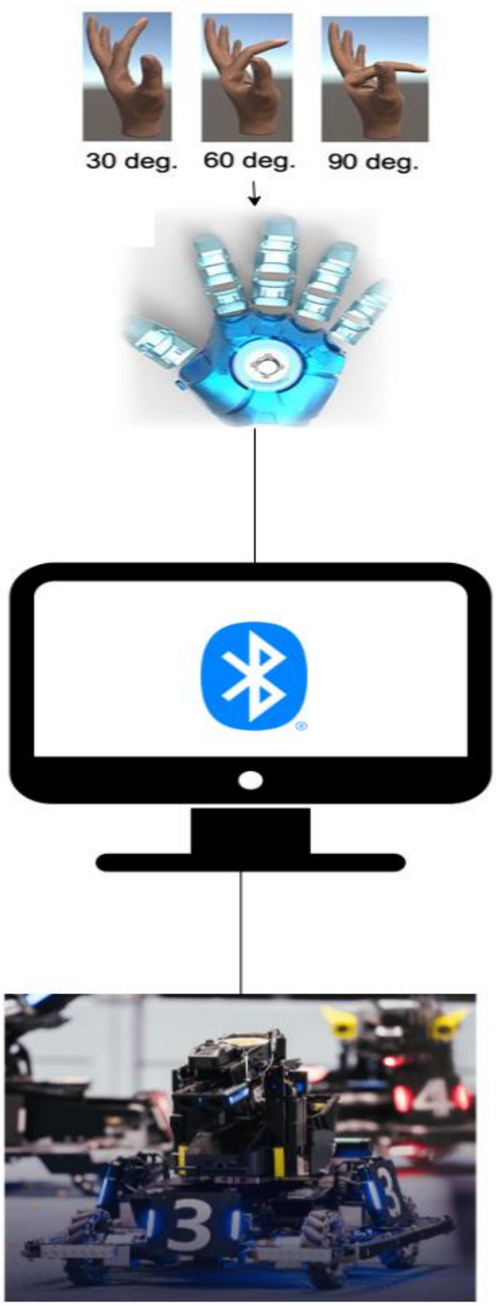
1. Introduction

Problem and Solution Overview

Traditionally, different robots are controlled by their specialized controller from different companies, and it takes time to learn how to use them smoothly and naturally. We propose a gesture control system that builds upon the system, making the process of controlling a robot simple and fun. We plan to design a robot controller which can recognize human gestures and send corresponding commands to robots. The system will have three high-level requirements.

Visual Aid



High-level requirements list

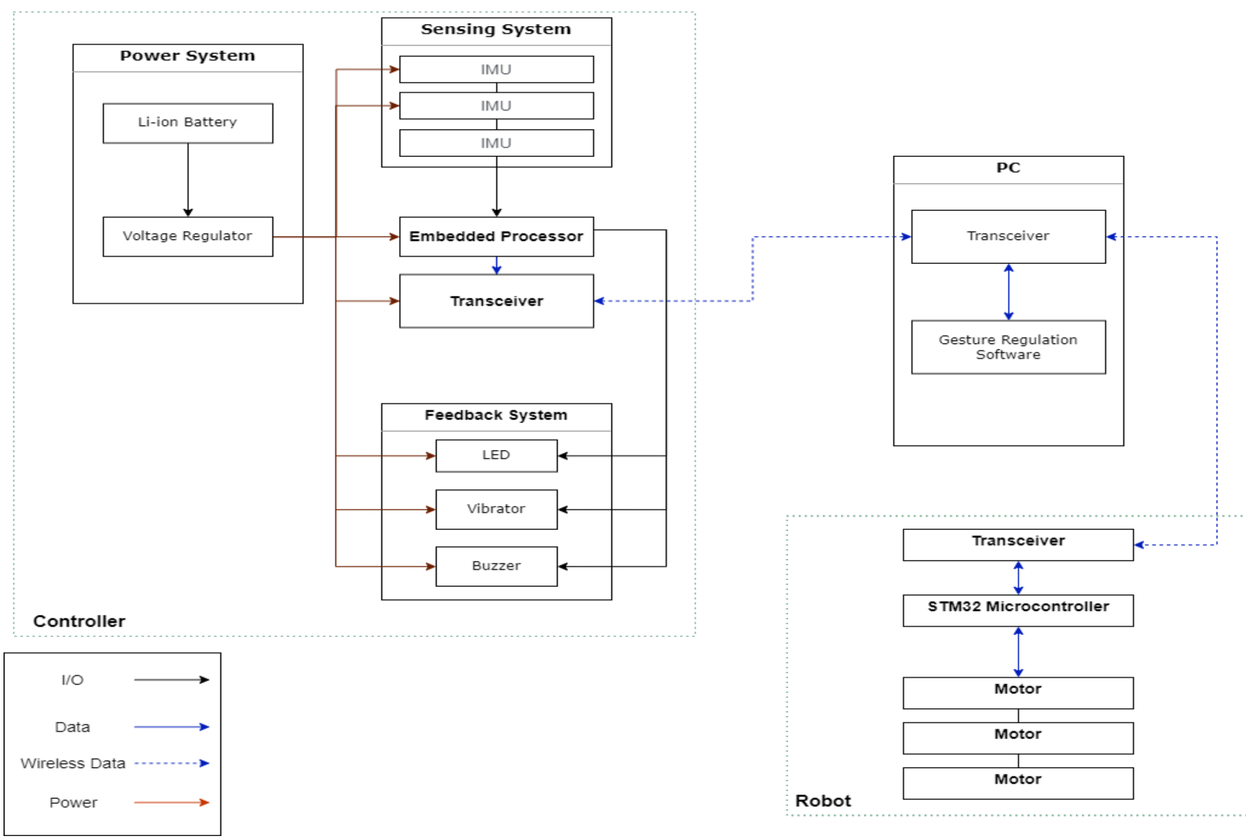
We plan to design a robot controller which can recognize human gestures and send corresponding commands to robots. The system will have three high-level requirements.

The first one is that the controller mounted on the user would be able to read the sensors placed on the body of the user and calculate the position of different body parts of the user and broadcast through Bluetooth.

The second one is that it would enable the gestures and movements of the user to be translated to actual robot controlling actions through a software running on a powerful device (like PC) after receiving data using Bluetooth, and it would also have the capability of commanding the robot using another Bluetooth link.

The third one is that it would be able to transmit the warnings of robots to signals that can be sensed by humans through actuators placed on the user, like lights (LEDs), vibration motors, and buzzers.

2. Design



Physical Design

Subsystem Overview

Human Positioning System

The system consists of a power source, an embedded processor, multiple IMUs, and a transceiver. Firstly, the IMUs are placed on the user's body, and the user will input the locations of these sensors to the embedded processor. The embedded processor will constantly read data from the IMUs using the I2C protocol, then it will calculate the position of these IMUs in the space. Together with the user predefined IMU position, it will work out the positions and orientations of the user's body parts. After that, the transceiver will output these raw data to PC through a 2.45GHz Bluetooth data-link.

Gesture Control System

The system would be a software program resides on the PC. It will take in the raw data transferred by the transceiver of the Human Positioning System and detect gestures using those data. Ideally, it can recognize many gestures such as the motion of and leg, including making a fist, waving arms, shaking head, etc., depending on the positions of the IMUs placed on the user. Then the system will generate controls based on these gestures and send them to the robot using another 2.45GHz Bluetooth data-link.

Robot Feedback System

The system would be a program resides on both PC and embedded processor of the controller. It will be used to transfer some signals generated by the robot back to the user through the actuators placed on the user. It will also use the same 2.45GHz Bluetooth data-link that the controller used to communicate with PC, sending the signals to trigger vibration motors, LEDs, and buzzers on the controller.

Subsystem Requirements

Human Positioning System

- It should be able to read the data from 9-axis IMUs through IIC protocol.
- It should be able to translate the readings into angles or other easy-to-understandable parameters
- It can transmit the results of calculation to PC or robot controller for them to interpret the data.

Gesture Control System

- It should be able to recognize at least the gestures of users listed below
    - Making a fist to stop the robot from moving
    - Extend the fingers, then the robot will move in a direction where the user's palm is directed to.

- It would be able to translate these predefined gestures to robot movements.
- It can transmit the corresponding robot commands to the robot using a Bluetooth data-link.

Robot Feedback System

- It should be able to receive signals sent from PC or controller on the robot.
- It should be able to interpret the feedback signals from the robot and control the following devices mounted on the user.
    - LED (array) blinking
    - Buzzer play predefined sound sequence
    - Vibration motor turning

Tolerance Analysis

The IMUs will be measuring the magnetic field strength to calculate the angle of the unit. However, if the IMU is placed near a powerful external magnetic field source other than the earth (e.g., motors, large block of conductive metal, wall power cable/outlet), then the reading might be affected and produce garbage result. We will be examining the reasonable tolerance of data error and the real motion range of human finger.

3. Cost and Schedule

Cost Analysis

Labor Costs: According to the average annual salary of an electrical engineer, the hourly salary for each team member is $36/hour. And we expect to work 8 hours per week on this project. The total labor cost would be: $36/hr × 2.5 × 8 weeks × 8hrs/week = $5, 760 per partner The total cost of our team would be $17, 280.

Component Costs:

Schedule

4. Discussion of Ethics and Safety

Ethical and Safety Issues

User Safety

1. Since our product will directly contact human skin, it is important to separate the skin from electricity and make sure that no hazardous components will put users in danger. The wearable component in our design does not pose a threat to the user, and we will keep it operating under a low voltage that reduces energy consumption.

2. When power is low, the product should notify the user and shut down the system automatically to prevent the battery from starvation. If the system is not in use for a long time, it should also shut down by itself. Our product utilizes Bluetooth protocol for wireless communication between the controller and the robot. We commit to protect and respect user privacy, complying with section 7.8.I-1 of IEEE's guidelines.

Build Safety

1. Always power off the battery before any hardware changes. Rubber gloves are required before touching any electric components. We will treat all persons fairly and with respect, and to not engage in discrimination based on characteristics such as race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression. We will also not engage in harassment of any form, including sexual harassment or bullying behavior.

Procedures to Mitigate Concerns

5. Citations

[1] "IEEE code of Ethics," IEEE. [Online].
Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 21-Feb-2022].

[2] M. Zhu, Z. Sun, Z. Zhang, Q. Shi, T. He, H. Liu, T. Chen, and C. Lee, "Haptic-feedback smart glove as a creative human-machine interface (HMI) for virtual/augmented reality applications," Science Advances, vol. 6, no. 19, 2020.