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Design of a Sensor System for a Semi-Autonomous BCI Controlled Mobility Device

M. Kerr McNutt[1◇*], A. Berezowski[1◇], L. Workman[1], H. Scheirman[1], D. Jourdain[1], P. Madill[1], A. Kirton[1], E. Kinney-Lang[1]

[1] *University of Calgary, Calgary AB, Canada*

[◇]*Co-Authors with equal contributions to the work set forth below.*

[*]2500 University Drive NW, Calgary AB, T2N 1N4, Canada. E-mail: morgan.kerr@ucalgary.ca

Introduction: Independent movement is one of the most highly requested Brain-Computer Interface (BCI) applications by families of children with complex physical needs. Key to supporting these children are Power Mobility Training Devices (PMTDs), which allow children to become comfortable using mobility devices. However, to advance PMTDs by implementing autonomous and long distance driving, a sensor system is needed. NeuroMove is a framework designed to allow PMTDs to implement autonomous and long distance driving via mixed-range sensors.

Material, Methods and Results: To perform the spatial mapping and collision avoidance critical to the PMTD's ability to navigate semi-autonomously, a multilevel sensor array was created. It includes a 3-dimensional LiDAR, ultrasonic sensors and force sensing resistors (FSRs). A Unitree 4D LiDAR RM sensor is mounted inverted above the head of the user [1]. It performs spatial mapping, capturing the layout of an area within a 30m radius of the LiDAR. An array of eight MaxBotix LV-MaxSonar-EZ MB1000 ultrasonic sensors are placed around the NeuroMove PMTD for local object detection. Three of the ultrasonic sensors are arranged across the front to completely cover an area in front of the trainer with a working range of 0.2m-6m. The other five sensors cover the sides and back of NeuroMove to detect objects while turning or reversing. The combination of LiDAR and ultrasonic sensors ensure that the system can detect objects that are near infrared absorbing, transparent, or sound absorbing that would be missed by a single sensor type. The Interlink Electronics FSR 408-500 is secured to a flexible "bumper" at the front of the trainer as a safety feature to detect if a collision occurs.

The ultrasonic sensors and FSRs are connected to an Arduino Uno to process and synthesize sensor data before sending it to the Raspberry Pi 5 (RPi). The RPi functions as NeuroMove's controller and is directly connected to the LiDAR for maximum data baud rate. The Unitree 4D LiDAR outputs a series of 4-dimensional tensors to the RPi, where each tensor contains the x, y, z, and sample time of a point in space. The RPi will convert these tensors into a 2-dimensional occupancy grid specifying where the PMTD is and isn't able to navigate to via a subtractive algorithm and downsampling. When a user desires to autonomously navigate to a destination, a modified jump point search algorithm is run on the occupancy grid to find the optimal path to said desired destination. While in motion, a software interrupt from the Arduino Uno due to the FSRs or ultrasonic sensors detecting a close object can halt NeuroMove. The RPi will utilize shared memory for all data transfer and low computational complexity algorithms where possible for maximum software efficiency.

Conclusion: The NeuroMove framework will allow for greater freedom of mobility for children with complex mobility needs by introducing more advanced driving operations. Combining different sensor types allows for full spatial visualization, and pathfinding gives users the option for easier navigation. By putting the NeuroMove framework on top of existing PMTDs, pediatric patients with complex physical needs will have an easier journey towards improved independent movement.

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