Virtual Reality Power Chair Simulator for Human Operator Modeling and Tremor Filtering
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Abstract
Approximately 180,000 persons who have a need for a powered wheelchair (PWC) suffer from Parkinson’s’ hand tremor that makes it difficult, even potentially dangerous, for them to operate it. Persons with hand tremor that attempt to operate a PWC have to try to compensate for their tremor, which may not be realistically possible if the tremor is severe enough. Hand tremor can lead to sudden changes in PWC joystick commands that could result in unsafe PWC movements and collisions resulting in injury and/or property damage. These tremor sufferers are candidates for an assistive PWC. As a step toward assistive PWC, the tremor is measured in two axes using a joystick and data collection system. The peak tremor power frequency is used as the basis for a notch filter to mitigate the effect of the tremor on joystick commands to the PWC. To safely test the effectiveness of the tremor notch filter, a virtual reality system is developed that allows for physical PWC operation without actual movement. Hardware was successfully developed and tests conducted with non-tremor and tremor subjects to demonstrate the data collection gathering capabilities and tremor filter effectiveness. Further, the joystick and movement data from the PWC operation are used in the assessment of a human operator model for future PWC developments without human testing. The model is based on a predictive controller that considers the human planning horizon and muscular delay.

Statement of Problem
- Need for 2-axis joystick data collection at frequencies greater than 20 Hz and extraction of peak tremor frequency
- Lack of a safe-no physical harm-powered wheelchair testing environment
- Unknown effectiveness of proposed tremor notch filter
- Absence of proposed powered wheelchair-human operator model validation testing

2-Axis Joystick Data Collection
- Previous Parkinson’s data has only been collected along 1-axis
- Powered wheelchair joysticks have two axes of inputs
- Collecting data in 2-axes is used to investigate axis independence of tremor frequency

Tremor Frequency Detection
- The Parkinson's subject requires a notch filter on both the x and y axes with a notch frequency of 3.6 Hz
- Each axis notch filter has a chosen bandwidth of 0.2 Hz
- Velocity tracking improvement seen when a notch filter is applied

2-Axis Joystick Data Collection
- Each subject asked to hold the joystick in nine positions for 5 seconds: center, directly ahead (north), directly backward (south), directly right (east), directly left (west), northeast, southeast, southwest, northwest
- Fast Fourier Transform applied to data to create power spectral density to find the tremor frequency with peak power
- Tremor motion and peak tremor power frequency were successfully measured and identified for a Parkinson’s tremor subject. Both the x and y axis showed the same tremor frequency. The peak tremor power frequency was used to design a notch filter that was applied in the semi-virtual reality powered wheelchair simulator. The designed simulator provided the illusion of motion using 3-D vision and physical wheelchair movement sounds and vibration. Results for a Parkinson’s subject showed the notch filter had more effect on the desired velocity tracking than on following the desired path. Further, a proposed human operator model was fit to non-tremor subject driving data and the model output showed less severe actions than from the actual operator. More Parkinson’s subjects will be recruited.

Human Operator Model Fit
- Fitting the human operator model revealed a neuromuscular delay of 0.3 s and look ahead planning time of 2 s

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Human Subjects in Research
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Figure: Stationary drive frame.
Figure: Semi-virtual reality powered wheelchair setup.
Figure: Semi-virtual reality powered wheelchair data diagram.
Figure: Joystick and axis definitions [Drive Medical, “Image EC Power Chair Owner’s Manual”, 2017].
Figure: Overhead view of powered wheelchair driving task.

Conclusions and Status
Tremor motion and peak tremor frequency were successfully measured and identified for a Parkinson’s tremor subject. Both the x and y axis showed the same tremor frequency. The peak tremor power frequency was used to design a notch filter that was applied in the semi-virtual reality powered wheelchair simulator. The designed simulator provided the illusion of motion using 3-D vision and physical wheelchair movement sounds and vibration. Results for a Parkinson’s subject showed the notch filter had more effect on the desired velocity tracking than on following the desired path. Further, a proposed human operator model was fit to non-tremor subject driving data and the model output showed less severe actions than from the actual operator. More Parkinson’s subjects will be recruited.