Development of a Low-cost Video-based Diagnostic System for Early Detection and Monitoring of Movement Disorders

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Introduction:

The majority of examinations evaluating tremor and other upper body neurological motor deficits are currently performed by an examiner or researcher[1]. This method has several drawbacks, including lack of quantitative measurements, lack of video conformation, as well as inter-rater reliability problems. The goal of this project is to further develop a Hand-Arm Movement Monitoring System (HAMMS) capable of measuring tremor, velocity, acceleration, and accuracy in addition to several other factors. Although there was a heavy focus on the analysis algorithms, there was also much consideration on improving patient interactions, finding new applications for the device, maximizing the ease of use and in designing new tasks and layouts for the system.

Design Challenges & Requirements

- Tracking circle in different lighting conditions
- Software/Hardware limitations
- Clear and informative interface
- Maintain a low cost
- Lack of literature for reference
- Encourage patient engagement
- Minimize fatigue

Summary of the Task:

The system consists of three devices:
1. Camera
2. Laptop with LabVIEW
3. Custom Mount

There are two different tasks used in the HAMMS system, Stationary and Moving. A flowchart showing how to perform each task is shown in Figure 2.

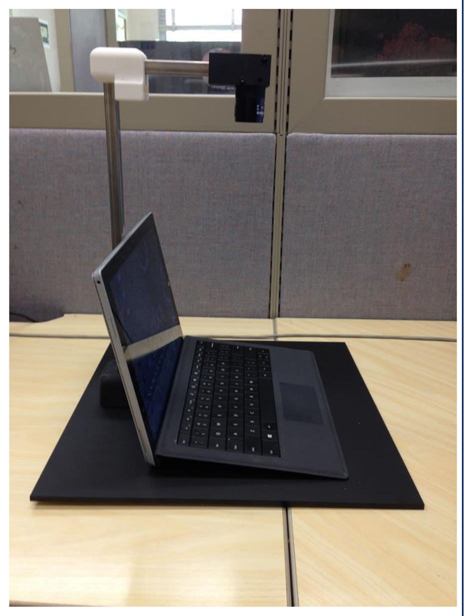

Figure 1: The HAMMS System showing the Camera, Mount and Laptop (Surface 3 Tablet)

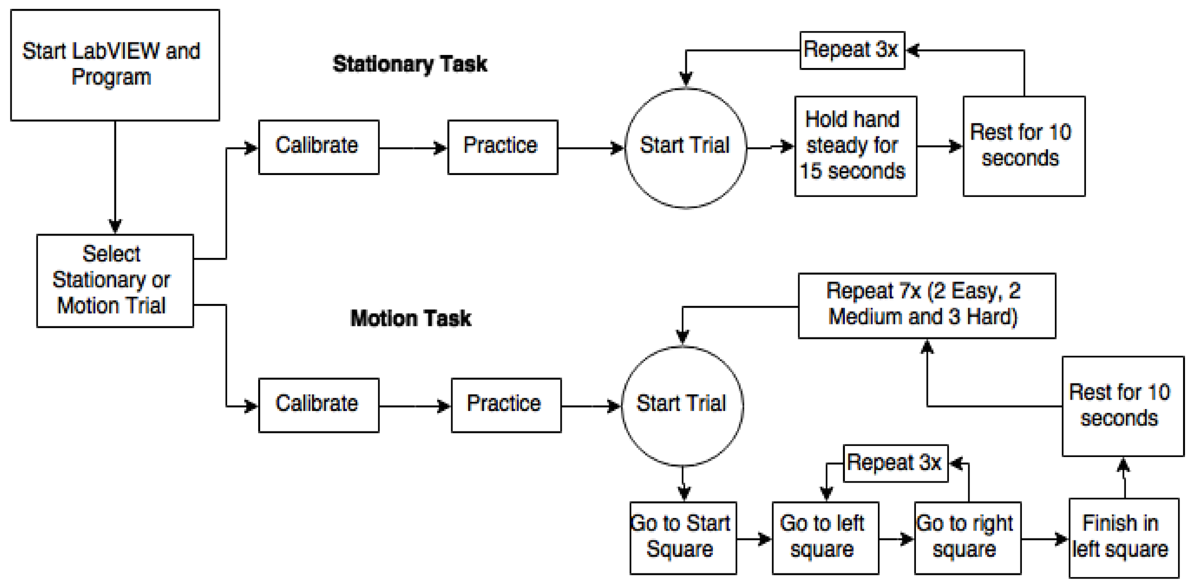

Figure 2: A flowchart detailing how to perform the task. The two major branches represent the options to start either the Stationary Task or the Motor Task. Both tasks are repeated several times and recorded using LabVIEW.

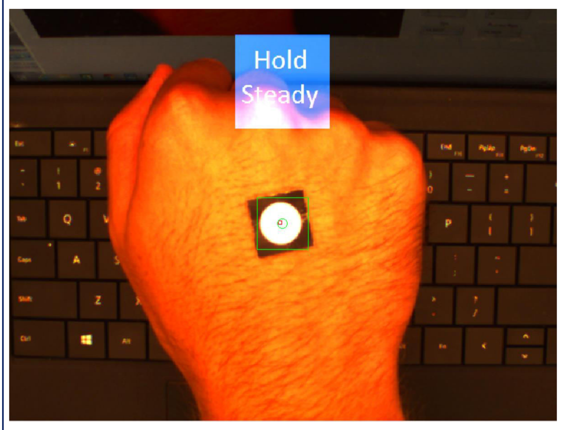

Figure 3: The Hold Steady Cue displayed during the Stationary Task

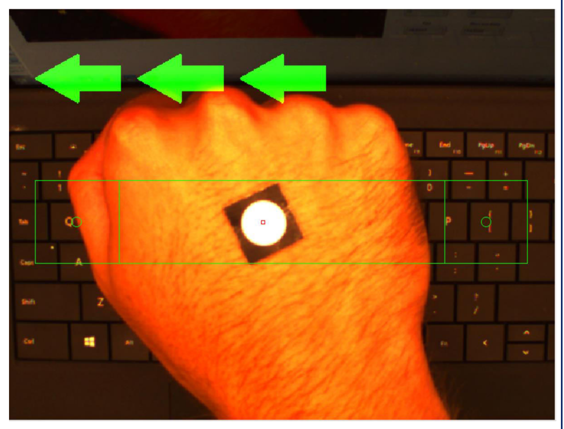

Figure 4: Arrows indicate the direction of travel during the Moving task with the Easy mask

Figure 5: The three different masks used for the motion task. Images show size relative to one another

Results:

To analyze the data, several methods were used to evaluate different parameters in the motion and velocity of the movement. For this project, the differences between the dominant hand and non-dominant hand were evaluated. The parameters measured include:

- Number and Duration of Error (Amount and duration of time path is outside of mask) to measure accuracy
- Path Length (Total distance traveled and total excess from ideal path) to measure deviation from ideal path
- Curvature (Average radius of circle drawn through three consecutive points) to measure sharpness of the line
- Frequency Analysis (Tremor, Average Amplitude) to measure tremor or other repetitive movements
- Overshoots on end (Distance overshot or undershot) to measure accuracy
- Velocity (Average and Number of Peaks) to evaluate velocity/accuracy relationship
- Acceleration (Average and Number of Peaks)
- The Best Fit Line (Linear, Quadratic, Cubic, etc…) to classify type of path
- Percentage of time in the edges vs. time inside the rectangle to determine velocity/accuracy relationship

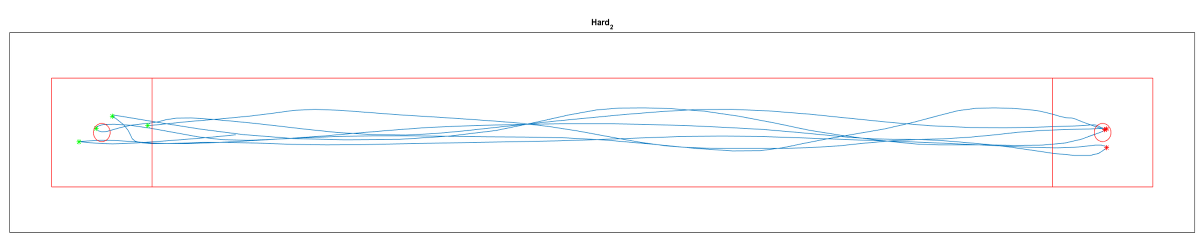

Figure 6: A path with no errors for a trial with a Hard Mask

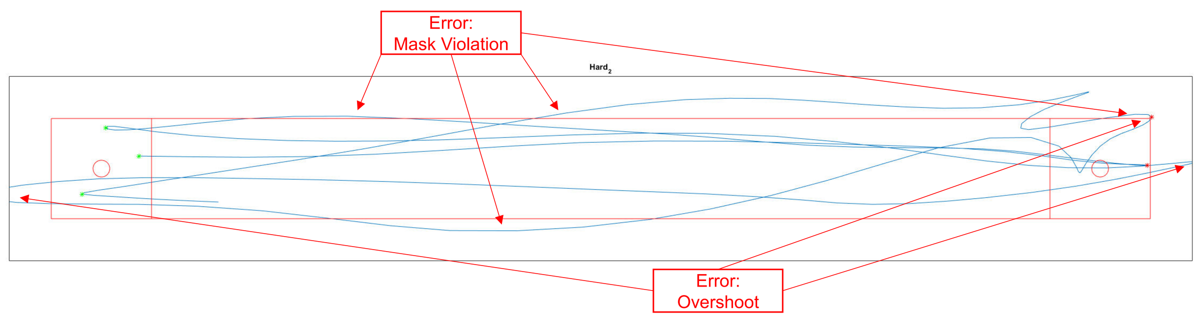

Figure 7: A path with a Hard Mask and multiple errors marked in red. The endpoints are automatically marked.

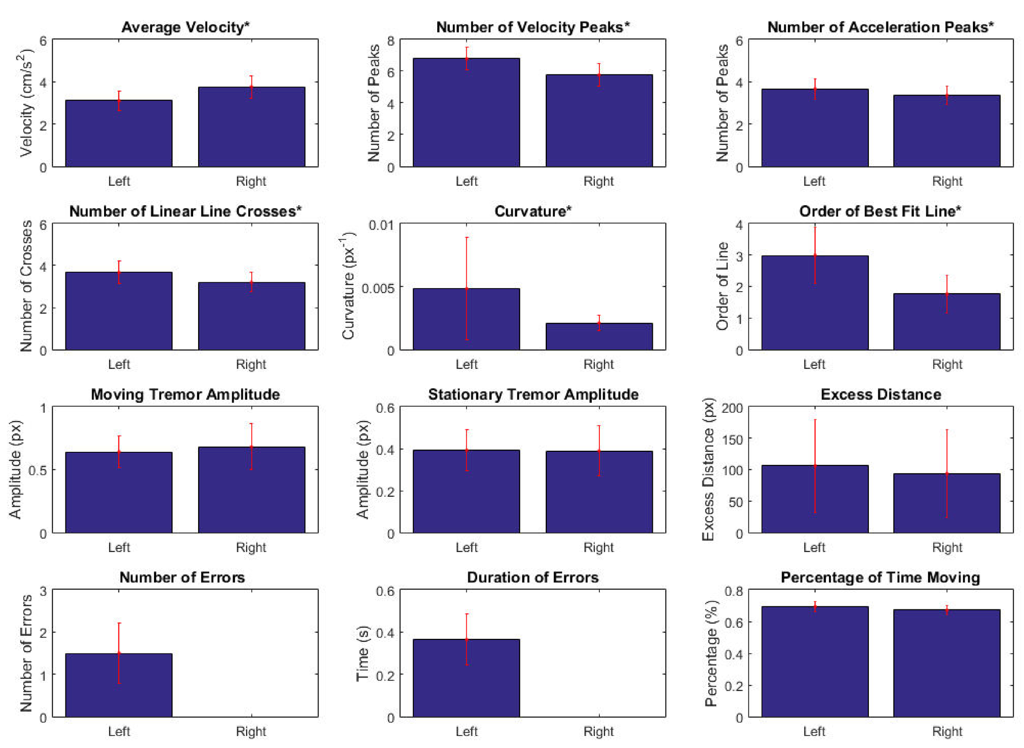

Figure 8: The results of the analysis for one subject for 12 different parameters comparing the differences between the right hand and the left hand for hard and medium difficulty trials. " * " Indicates statistical significance

Conclusions:

There are many things that have to be considered when designing and testing device that works with both patients and researchers:

- Ease of use
- Clarity of Instructions
- Presentation and Design of Hardware and Software
- Cost
- Participant and Patient Interaction
- Hardware and Software strengths and limitations.

Within the subjects analyzed, there were clear trends between the dominant hand and the non-dominant hand. The following variables showed statistical significance ($p<0.05$) for at least one of the participants. The dominant hand typically exhibited:

- Higher Mean Velocity
- More Tremor
- Less Curvature
- Fewer Velocity/Acceleration Peaks
- Less Crossings
- Lower average order of best fit

Future Improvements/Projects:

- Increase the frame-rate for improved physiological tremor detection
- Add arm rests to reduce fatigue
- Generate more data using the device (Baltimore Longitudinal Study of Aging)
- Evaluate similar systems (LEAP Motion)
- Evaluate new parameters such as Jerk or the "Smoothness of Velocity"
- Find a way to compare between subjects, rather than within subject
- Evaluate possible applications include: Parkinson's, Ataxia, Aging, Multiple Sclerosis, Amyotrophic Lateral Sclerosis, Traumatic Brain Injury, Addiction, etc.

References:

1. Reeves, A., & Swenson, R. (1981). *Disorders of the Nervous System: A Primer*. Chicago, Ill.: Year Book Medical.

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