Progress on Human Factor and Measurement System for MTP Latency

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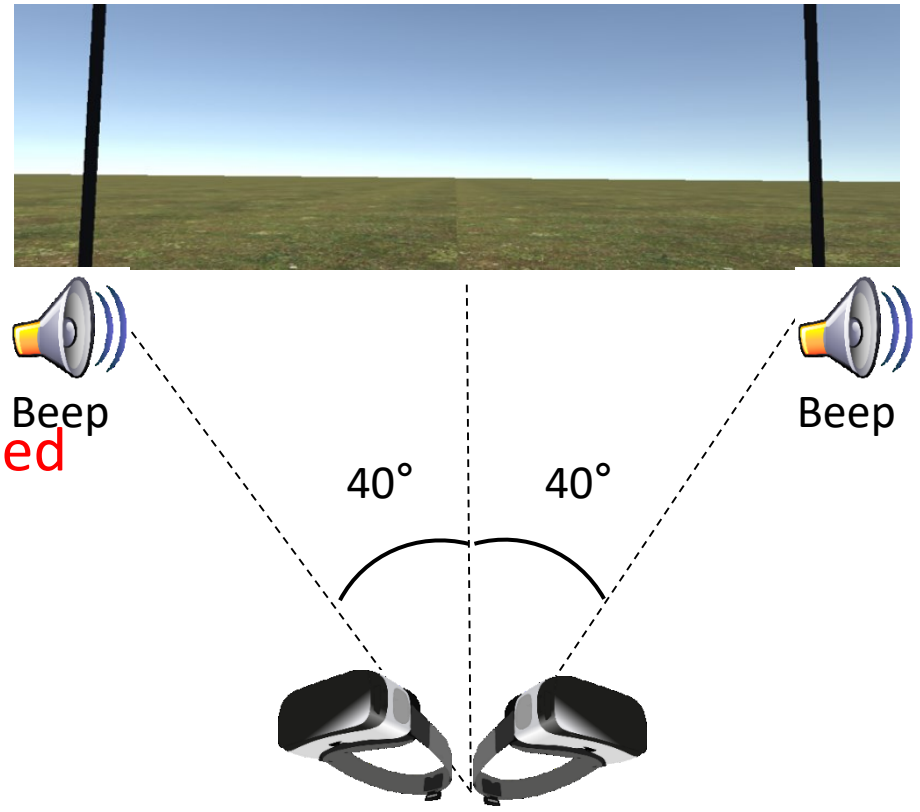
Goal of the Study

- Requirements and test methods for motion to photon (MTP) latency that cause virtual reality (VR) sickness
  - Hardware
  - Software
  - Human factor

- Our study
  - Test method for hardware using head-model based system
  - Requirement based human factor using bio-signal

Experimental Design



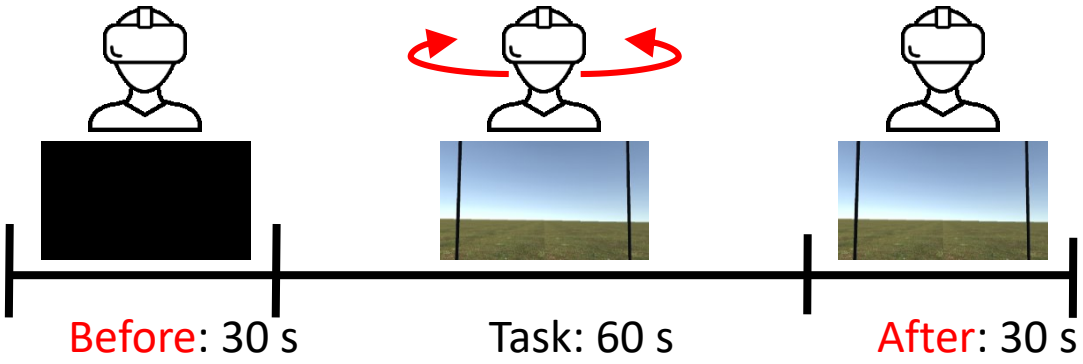
- Neck movement: angular speed
  - 80°/sec
- Beep sound
  - Every seconds
  - To limit speed of neck movement

Experimental Procedure

	Task	Time
1	Resting without HMD (eyes-closed/eyes-open) *	2 min each/total 4 min
2	Resting with HMD (eyes-closed/eyes-open)	2 min each/total 4 min
3	Session 1 (none, 0/30ms/60ms randomly)	2 min each/total 17 min
4	Break	10 min
5	Session 2 (none, 0/30ms/60ms randomly)	2 min each /total 17 min
6	Break	10 min
7	Resting without HMD (eyes-closed/eyes-open)	2 min each /total 4 min

* 3 min break was given to a subject before the next task.

Session 1, 2



Data Collection & Analysis

- Participant
  - Total of 43 healthy males participated (20 – 29 years).
  - High MSSQ group (> 22.00)
    - Average score of 20‘ male: 15.41
    - More than 75% of 20’ male: 21.56
  - Exclusion criteria (Data from 12 subjects were excluded)
    - Ambidextrous (n= 1)
    - Any disabled related motor control (n= 1)
    - Data quality unsatisfied (n= 10)
- Bio-signal
  - EEG (256-channel), ECG (2-channel), and respiration
- Analysis
  - First session was used in this study

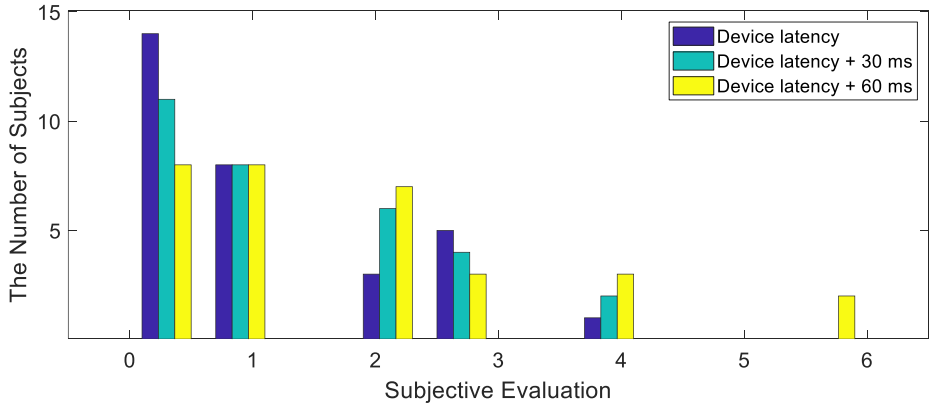
Subjective Evaluation (Misery Scale)

Misery scale (MISC) — Bos et al., 2005

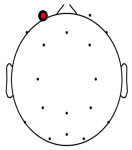
Symptom	MISC
No problems	0
Slight discomfort but no specific symptons	1
Dizziness, warm, headache, stomach awareness, sweating, etc.	
Vague	2
Some	3
Medium	4
Severe	5
Nausea	
Some	6
Medium	7
Severe	8
Retching	9
Vomiting	10

+90 ms or complexity?

	Device latency	Device latency + 30 ms	Device latency + 60 ms
Mean	1.06	1.29	1.77
Std.	1.22	1.25	1.66
Min.	0	0	0
Max.	4	4	6
Median	1	1	1



EEG Analysis



Raw data → Time selection → Channel selection

Channel selection → Bad channel interpolation

Not often

Bad channel interpolation → Re-referencing

Common Average Ref

Re-referencing → Notch filter

60 Hz

Notch filter → Band-pass filter

0.5 – 50 Hz

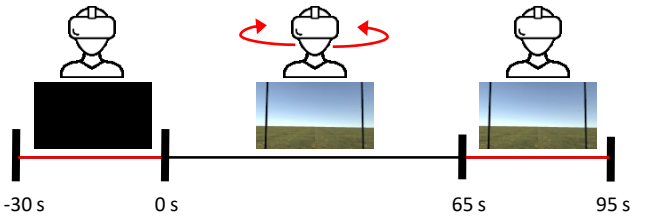
Band-pass filter → Noise removal

EOG, EMG, ECG

Noise removal → Band power

EEG Band Power (Whole Channels)

Power (after) – Power (before)



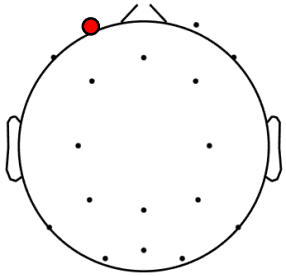
	Delta (1 – 4 Hz)	Theta (4 – 8 Hz)	Alpha (8 – 13 Hz)	Beta (13 – 30 Hz)	Gamma (30 – 50 Hz)
Device latency					
Device latency + 30 ms					
Device latency + 60 ms					

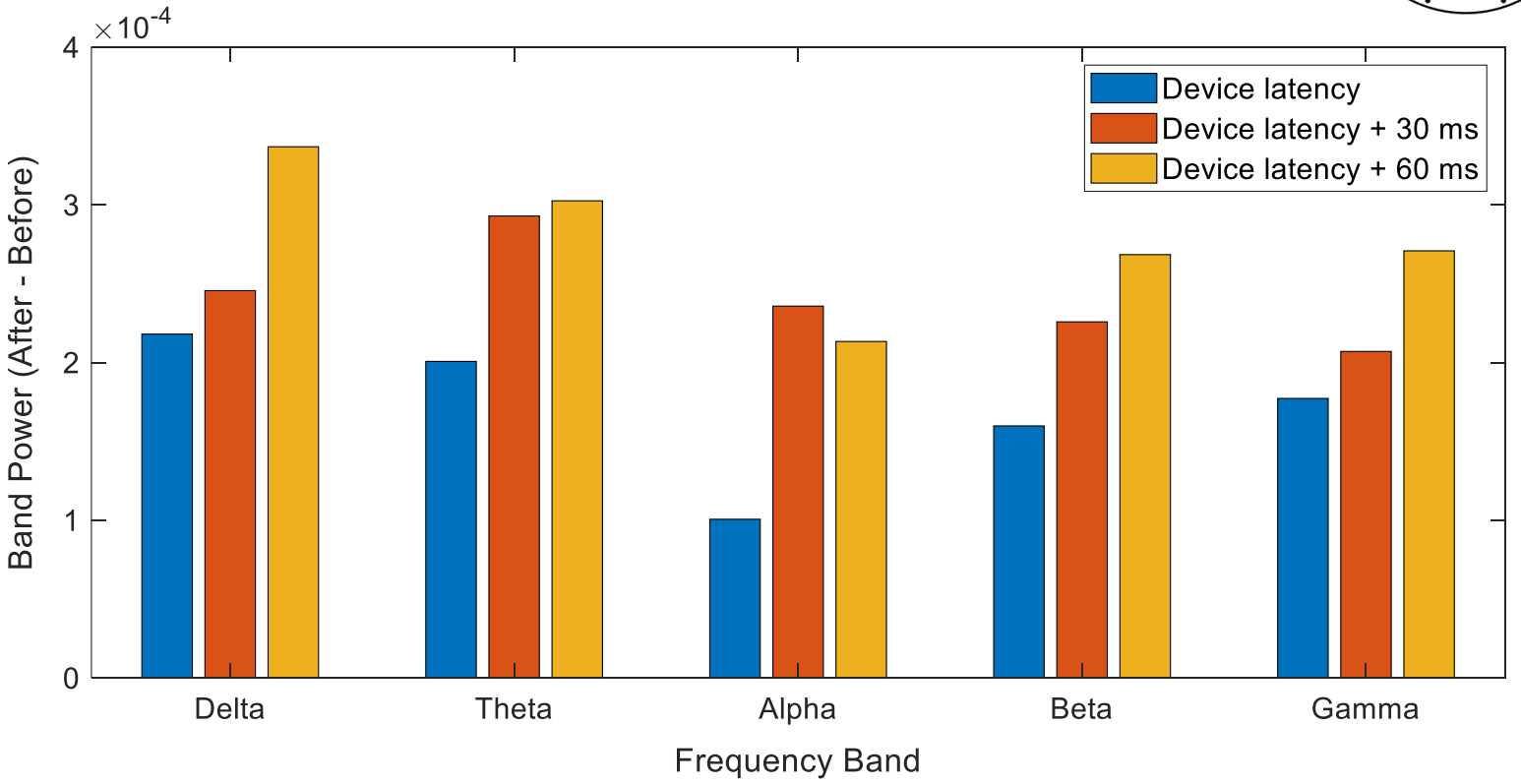
* Statistically different channel ($p < 0.05$)

We need to verify them again whether they are purely EEG or not.

EEG Band Power (Prefrontal Channel)

Power (after) – Power (before) on Fp1 channel



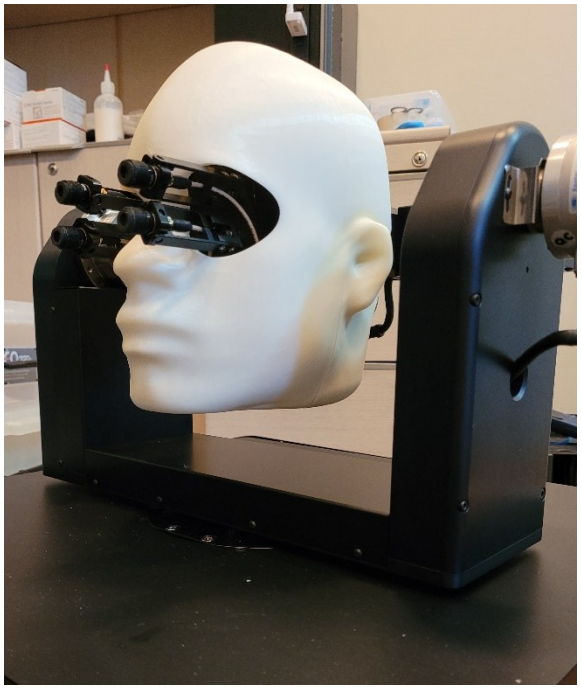


Some are significantly different but need to verify them later.

Tentative Conclusion and Future Study for Human Factor

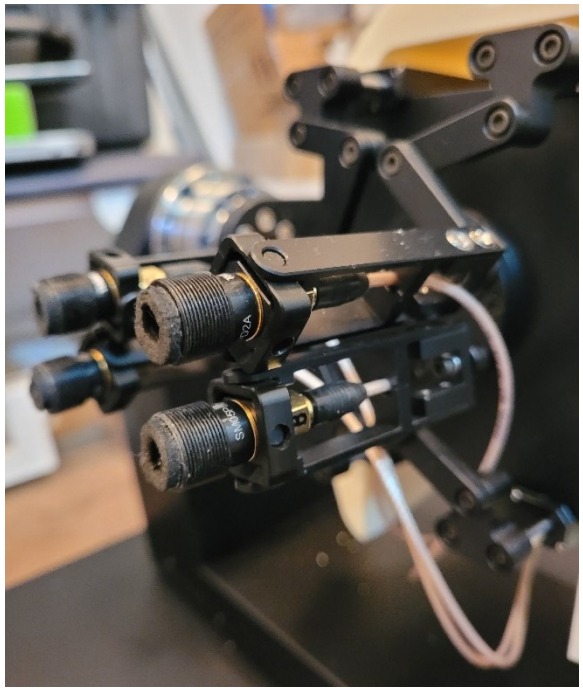
- Tentative conclusion and discussion
  - Prefrontal and frontal EEG data may be VR sickness indicator for MTP latency.
  - Additional 60 ms delay yielded mild VR sickness
    - Less than 30 ms additional delay may have similar symptoms to only device latency from subjective and objective measures
- Future study
  - Propose objective indicator of VR sickness by MTP latency based on bio-signal
  - Suggest requirement of HMD device and VR contents for MTP latency

MTP Measurement System



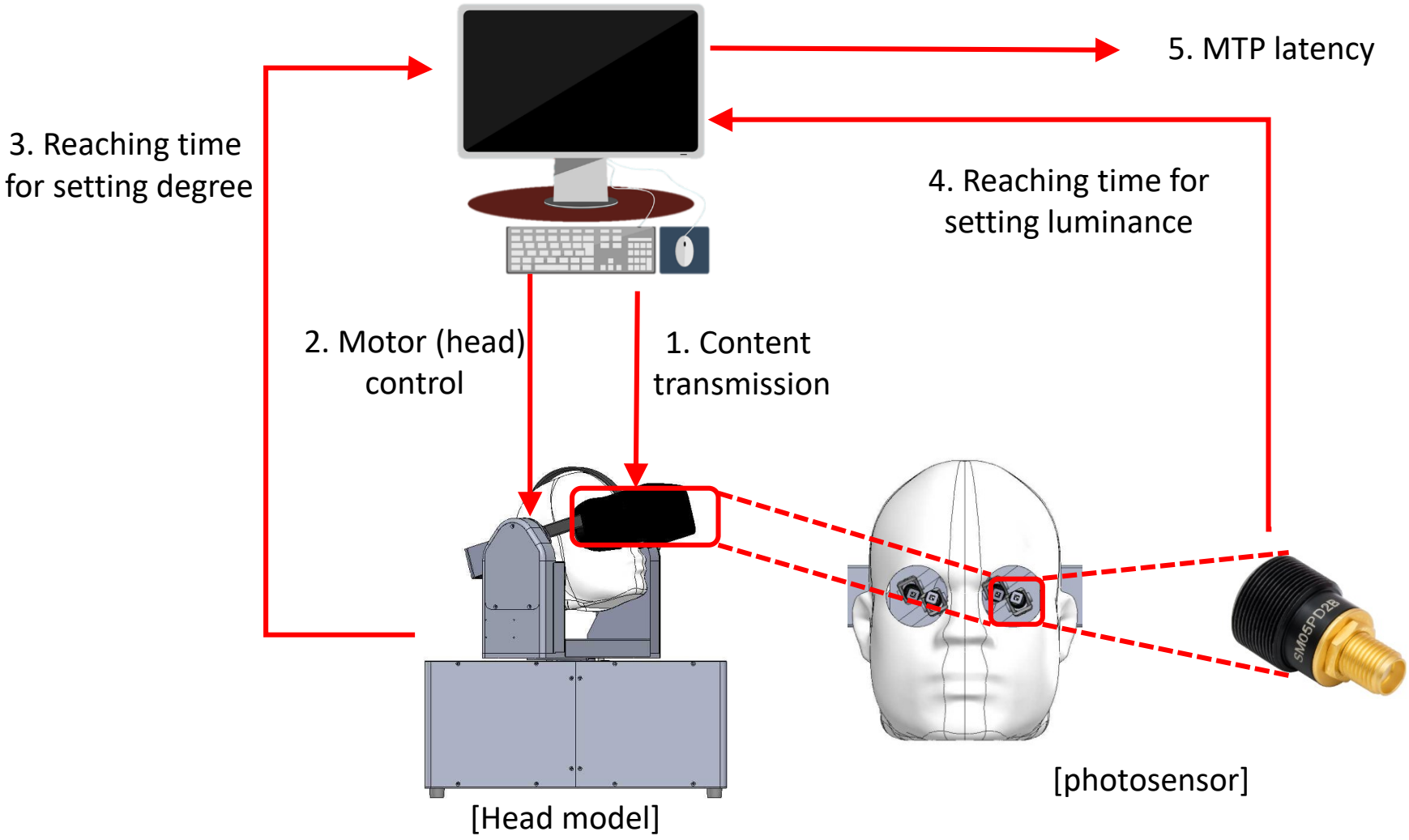
[Front]

[Side]



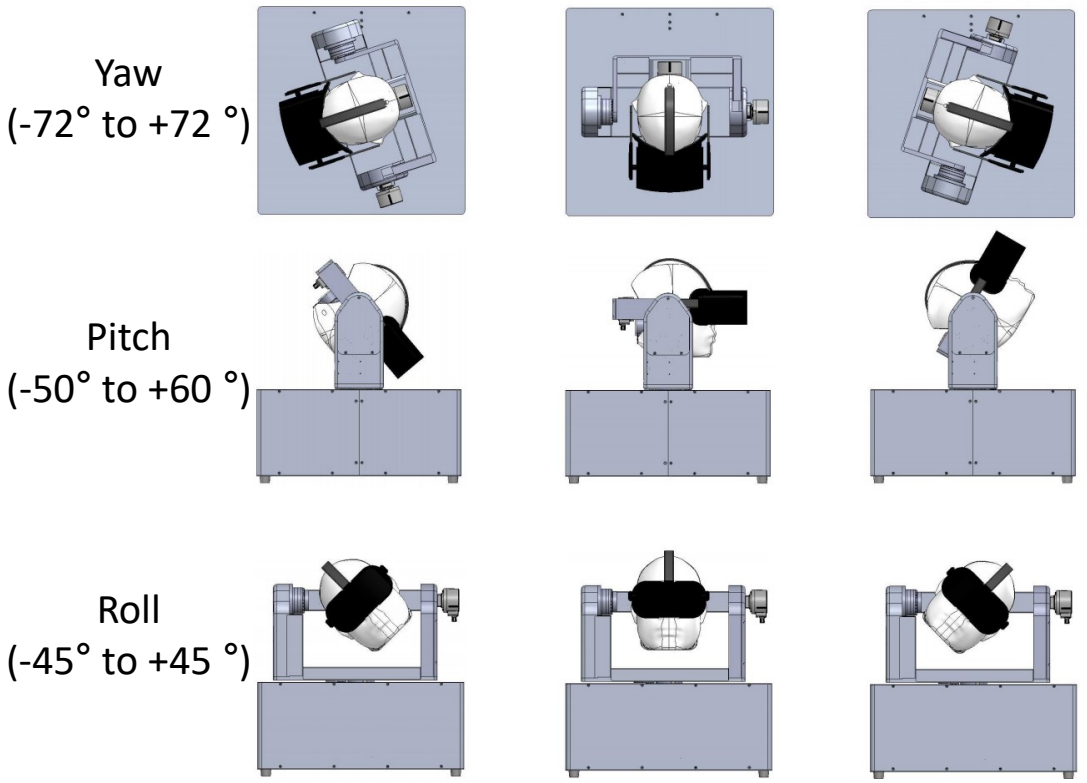
[photodetector]

MTP Measurement System

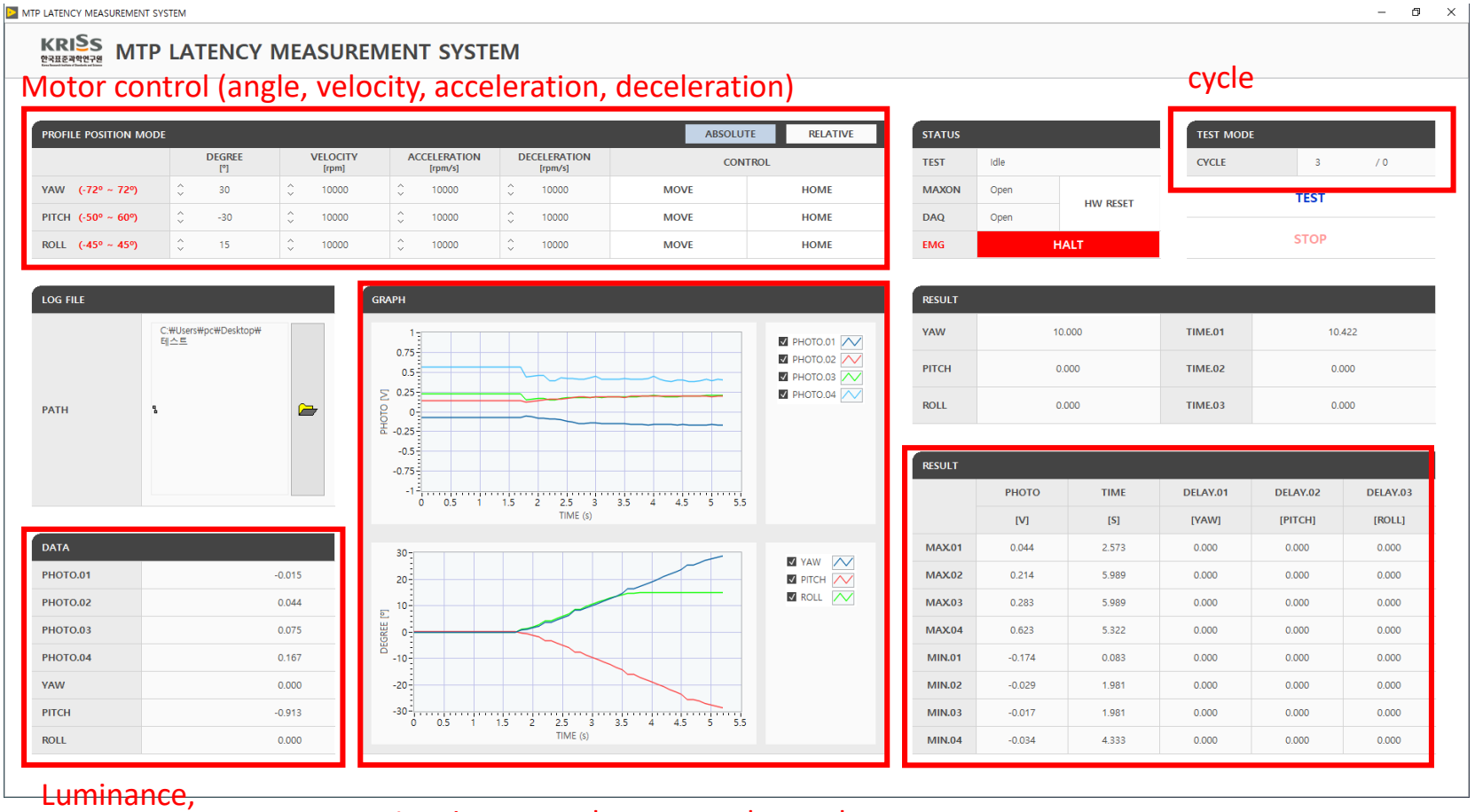


Motor Control

- Axis movement
  - Yaw, pitch, roll
  - Single/multi-axis
- Parameter setting
  - Angle, velocity, acceleration, deceleration, cycle



User Interface (UI)

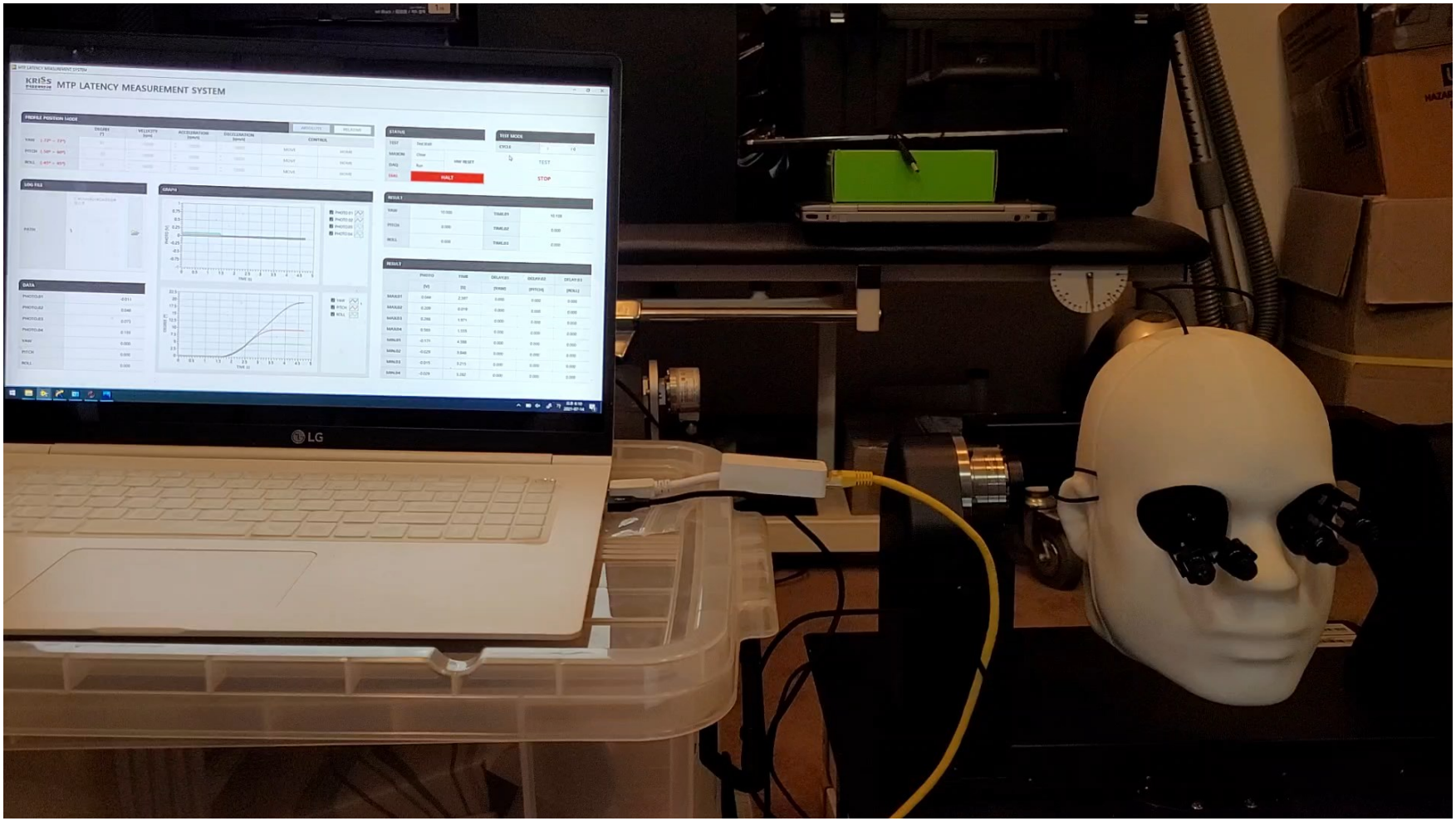


~~Luminance,~~
motor angle value

Luminance and motor angle graph

MTP latency

Video – Motor Control



Future Study for Hardware

- Contents
  - Create grey scale patterns
- Photodetector measurement
  - Conduct tests to understand the characteristics of photodetector
- MTP latency
  - Synchronize between motor movement and photodetector