Analysis and Visualization of Passenger Comfort During Low-Speed Mobility Rides in Outdoor Environments Using Heart Rate Variability Index

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Background

- Increased of elderly population and disabled person
  - ➔ Use electric wheelchair as transportation option
- However, some factors might affect passenger comfort (e.g., vibration)
  - ➔ Discomfort may cause a bad riding quality

Previous Study

Detect hazard locations for personal mobility passenger and visualize it into a discomfort-ride map [1]
- ➔ Improve riding quality by giving early hazard information

However, they only focus on detecting hazard
- ➔ Cannot identify discomfort at areas with no hazard

Sawabe et. al. proposed map[1]

Purpose・Proposal

Purpose

- Assist passenger on a better riding quality by evaluating areas that might affect passenger comfort

Proposal

- Methods of **evaluating** comfort using Heart Rate Variability (HRV) and **visualizing** it onto a map

Experiment・Analysis

Overview

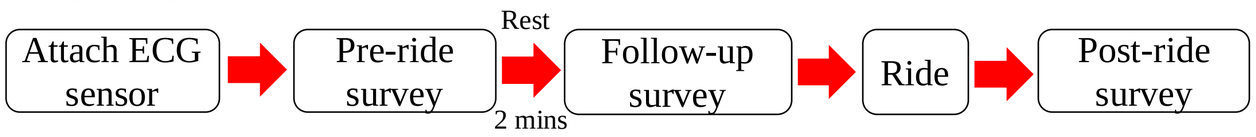
Participants ride WHILL electric wheelchair around Toyosu sidewalk for 2.11 kilometers
- Four participants (3 males, 1 female) aged between 21–33 years old

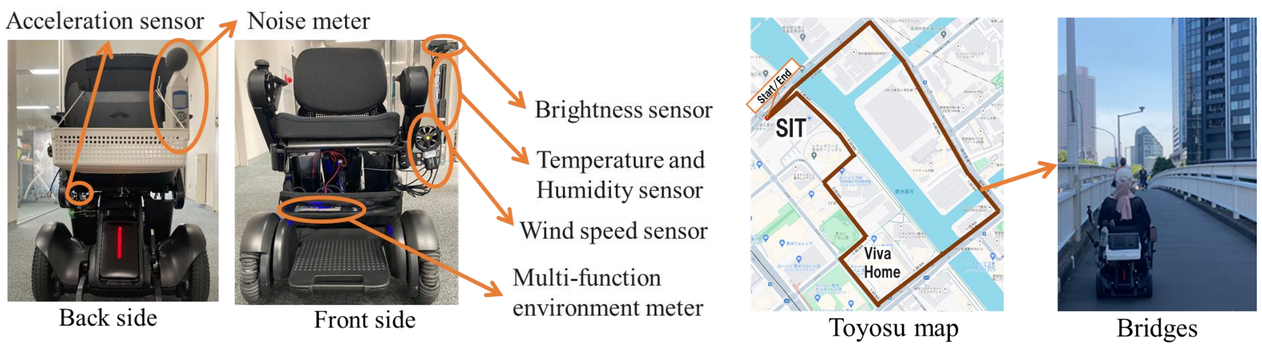
Data collection

- Using ECG sensor to collect HRV
- HRV index used is pNN20;
  - Calculates percentage of consecutive heartbeats differing by more than 20 milliseconds [2]
  - Higher pNN20 suggests higher level of comfort [3]

ECG sensor (myBeat)

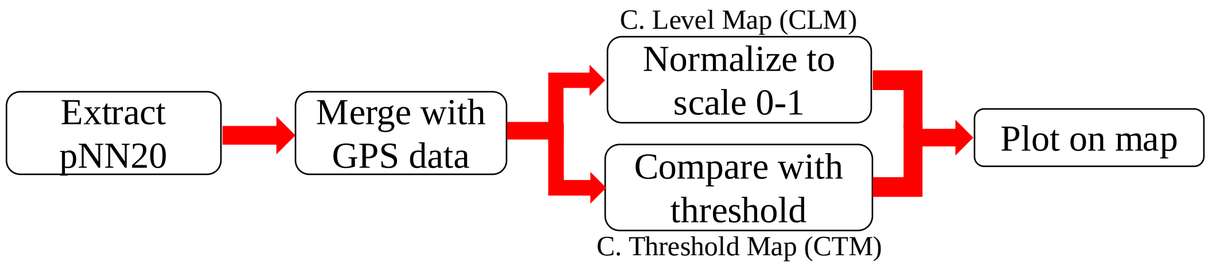
Procedure





Back side | Front side | Toyosu map | Bridges

Comfort Evaluation Method



Comfort Visualization Method

Method

1) Comfort Threshold Map (CTM)

Threshold: Average pNN20 during resting for Participant 1 = 0.61

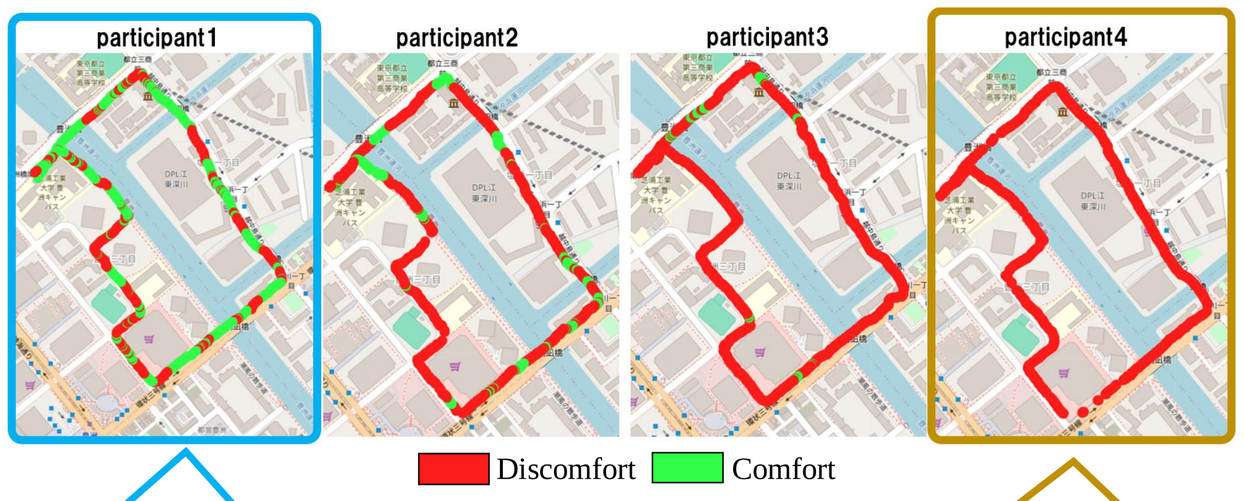
Comparing comfort between **resting and riding**

2) Comfort Level Map (CLM)

Comparing comfort between **riding area**

Results・Discussion

Method 1: Comfort Threshold Map (CTM)

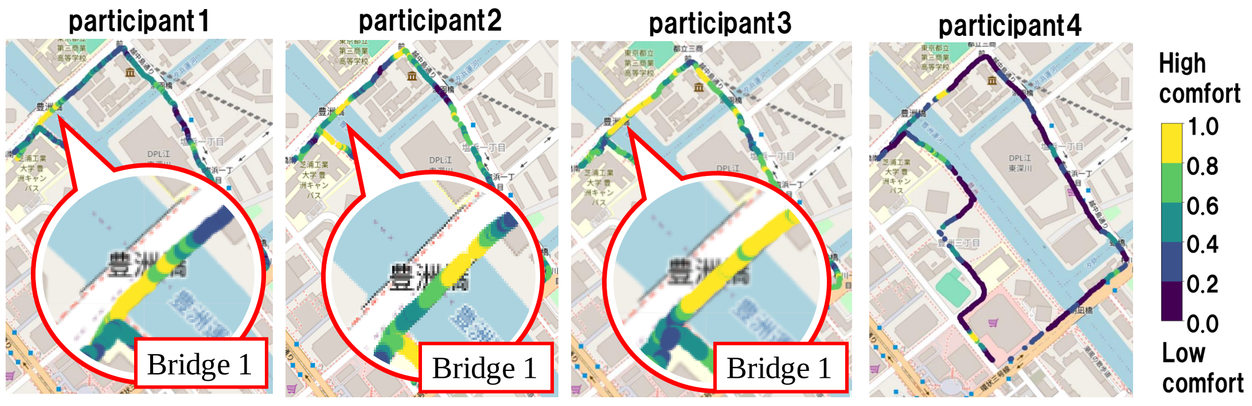


Participant 1 data shows more green areas
➔ more comfort during riding

Participant 4 data shows all red
➔ discomfort in entire ride

- **3 out of 4 participants feel more discomfort during riding (more red areas), compared to during resting.**

Method 2: Comfort Level Map (CLM)



- **Each participant feels different level of comfort in different areas**
- **3 out of 4 participants experience the highest level of comfort (yellow) in the same location (Bridge 1)**

Discussion:

- Analysis from video footage reveals that:
  - Bridge 1 has a wide width with separate lanes for cyclists and pedestrians
- Kang et. al. [4] indicated that narrow sidewalk and higher bicycle flow rates are associated with reduced comfort, which aligns with our findings

Bridge 1

Conclusion

This study analyzed and visualized passenger comfort into two maps;
- Comfort Threshold Map (CTM) and Comfort Level Map (CLM)

The finding suggests that participants feel:
- More discomfort during riding compared to during resting
- Highest comfort in locations with low collision risk

Future Work

- Investigate comfort factor in other areas of the map:
  - Identify common comfort/discomfort area between participants
  - Identify which factors affecting the comfort based on that area
- Conduct more experiment to get more data and increase accuracy

Reference

[1] T. Sawabe, N. Naoki, M. Kanbara, U. Norimichi and N. Hagita, "Discomfort-ride map for personal mobility passengers on sidewalks area," 2017 IEEE International Conference on Systems, Man, and Cybernetics (SMC), Banff, AB, Canada, 2017, pp. 1185-1190
[2] Immanuel S, Teferra MN, Baumert M, Bidargaddi N, “Heart Rate Variability for Evaluating Psychological Stress Changes in Healthy Adults: A Scoping Review,” Neuropsychobiology, 2023, 82(4):187-202
[3] Bregant L, Lorenzino M, Agostin FD (2021) The Importance of Psychophysiological Factors in Comfort Studies. J Ergonomics.S1:001.
[4] Lei Kang, Yingge Xiong, Fred L. Mannering, “Statistical analysis of pedestrian perceptions of sidewalk level of service in the presence of bicycles, Transportation Research Part A: Policy and Practice,” 2013, Vol 53, pp. 10-21