

Introduction and Overview

Mid-air haptics is a novel technology that creates tactile sensations via ultrasound on a user's skin in mid-air without direct contact with their body [1]. In recent years this has been adopted in VR/AR [9], simulated driving [2], and contamination-free interactions where physical contact with the device is not desirable under the pandemic [3].

However, the available gestures' visibility and the guidance to users for undergoing such interaction have not yet been adequately emphasised, given that those systems are typically designed for use without prior training [7].

Aims, Objectives and Methodologies

As Vermeulen et al. suggested that feedforward can effectively bridge Norman's Gulf of Execution if properly designed [8, 6], the disambiguation of the term "affordance", as defined earlier by Norman, in the domain of virtual objects constitutes one of this project aims [5]. On the other hand, the essence of investigating the match between the system's provided actions and those intended by users cannot be neglected, either [6].

To respond to those under-explored concepts being synthesised from previous works, a 40-50 minute two parts study has been run repeatedly across 27 participants inside the department's interaction room, with the board and environment setup depicted as follows:

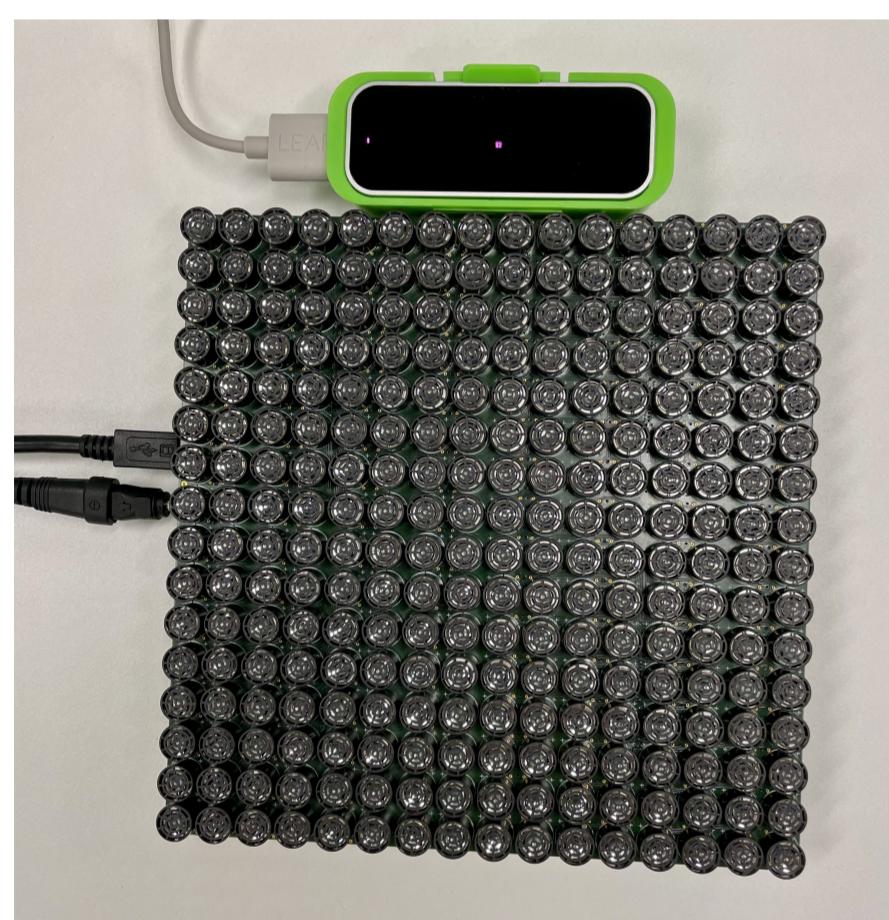


Figure 1. Board setup.

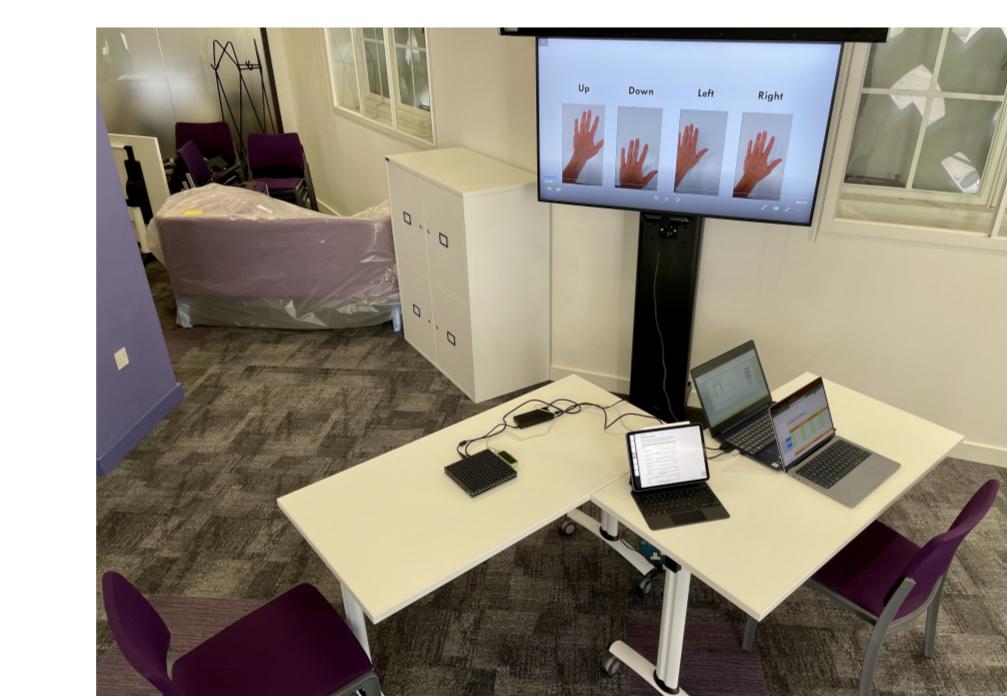


Figure 2. Study setup.

The study revolves around the feasibility of prompting specific physical actions to users via generating mid-air haptics stimuli from the board. All participants were located such that they had visual access to only the large television rather than the coordinator's display, with approximately 20cm from their right hands vertically down to the board being placed in front of them. Two types of data have been collected throughout the experiment. One corresponds to the user's response gathered via several Excel spreadsheets, and the other refers to quantitative data captured by a tablet for the sake of avoiding generating paper copies, which are all accessible here:

Author



- Zihao You
- MSci Computer Science at King's College London
- In collaboration with Ultraleap
- Department of Informatics, Strand Campus, Bush House, London WC2B 4BG
- Supervised by Dr. Timothy Neate
- Other co-authors: Dr. Sergio Alvares R. de S. Maffra, Dr. William Frier

zihao.you@kcl.ac.uk

Part 1: Direction Detection

This part of the study focuses on a set of 4 cardinal directions (i.e. up, down, left and right) followed by a set of 4 common gestures (i.e. swipe left, swipe right, tap and pinch). Participants have been instructed to watch a short video representing those 4 directions/gestures as hand movements (displayed as two screenshots below) at the beginning of each sub-part, plus a familiarisation stage experiencing all 4 directions/gestures at once in random order and being informed the "correct" correspondence between the system's generated stimuli and their announced response.

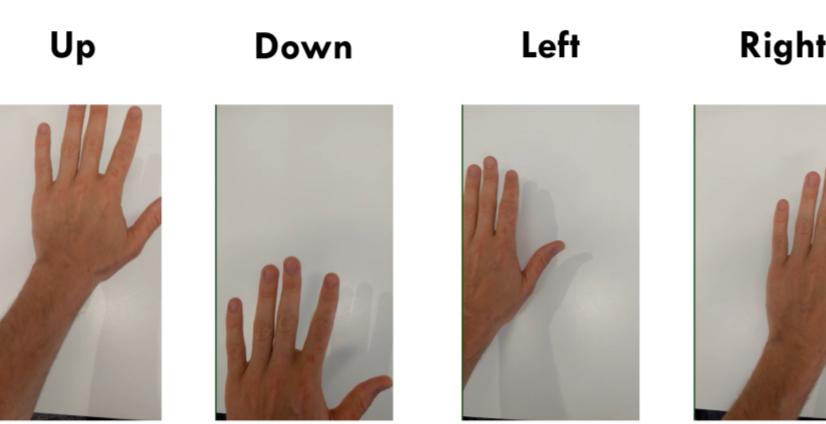


Figure 3. Part 1.1 gestures.

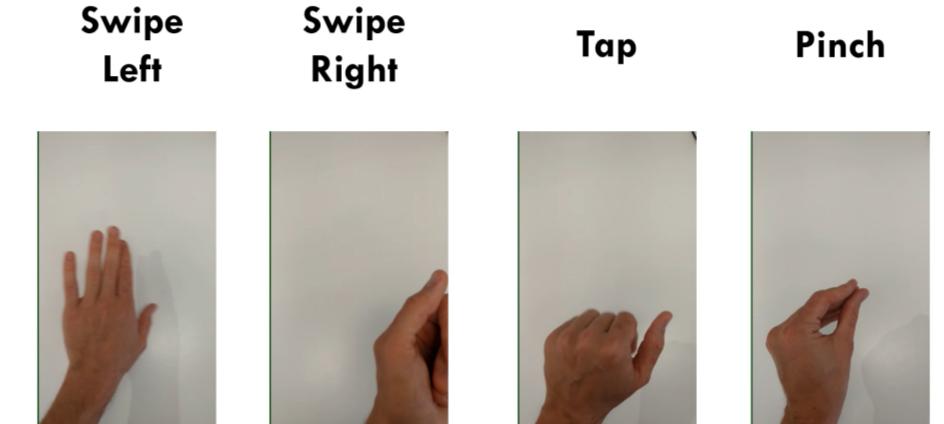


Figure 4. Part 1.2 gestures.

A subsequent randomly generated 10 trials have been carried out, in which they have been prompted to speak out the stimuli each time. All users' intended responses have been recorded into Excel spreadsheets that would be used to perform the Chi-Square test analysis, their subjective experience has also been captured using metrics such as NASA TLX and 5-point Likert scale.

Part 2: Path Tracing

This part of the study guides each user's hand through 5 randomly generated paths from the start to the destination, with the grid (figure below) inspired by the Android device's unlock screen.

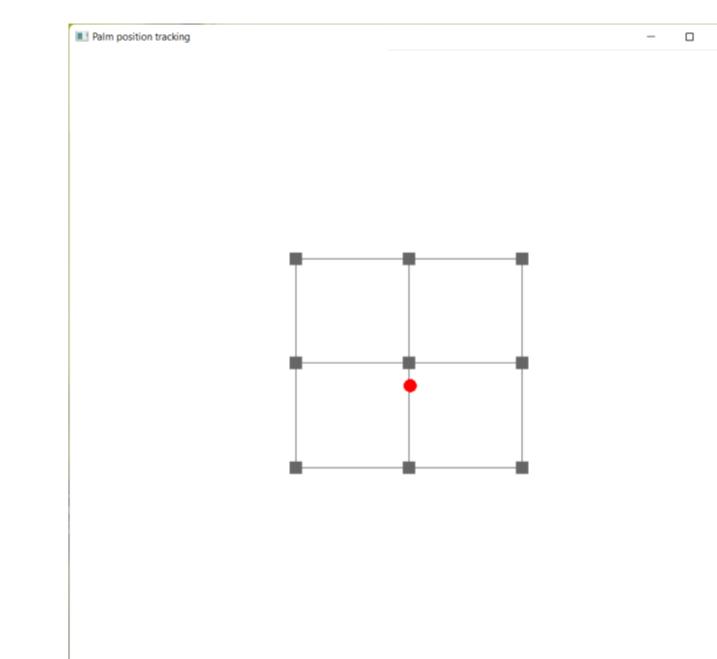


Figure 5. User Interface for hand tracking.

Participants have been told to localise their hands where the red dot lies precisely in the start coordinate. Four directional sensations are then played using the laptop's arrow keys, with the stopwatch recording time throughout each keypress period. The data includes 5 trajectory plots and corresponding completion times for each user, leading to a follow-up analysis creating the correlation and regression plot of the average completion time against the path length, plus their subjective experience being captured in the same format as Part 1.

Results and Discussion

Direction Detection

A 5% Significance Chi-Square Test applied to both subparts reveals no association between the generated tactile stimuli and the users' performance, as the test statistic in both cases, is strictly less than the defined critical value. On the other hand, the increasing challenge of participants determining the "Tap" and "Pinch" sensations potentially causes the up-scaling effect on Mental Demand, Effort and Frustration as determined by NASA TLX.

Path Tracing

Apart from getting similar scores on users' subjective experience as in Part 1, the coefficient value and the below scatter plot with a line of best fit that touches 3 out of 5 points deduces a very strong correlation between the average completion time and trajectory length.

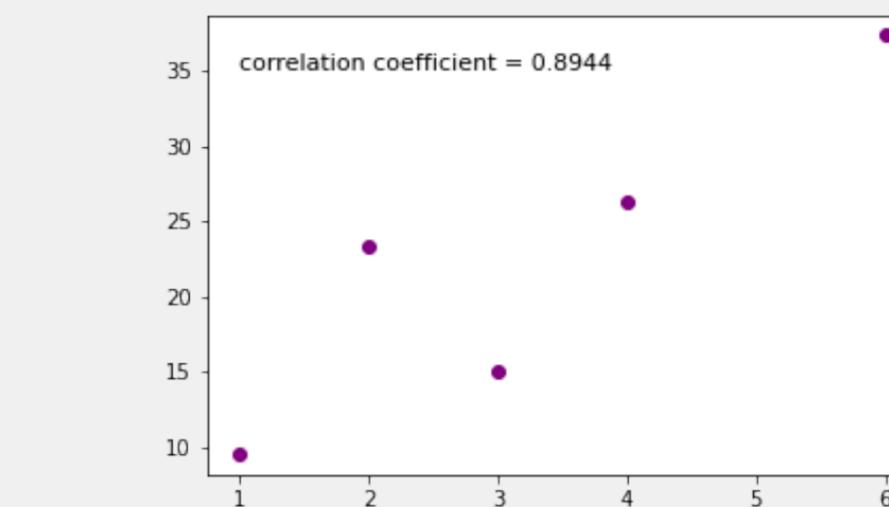


Figure 6. Correlation of average time taken against path length.

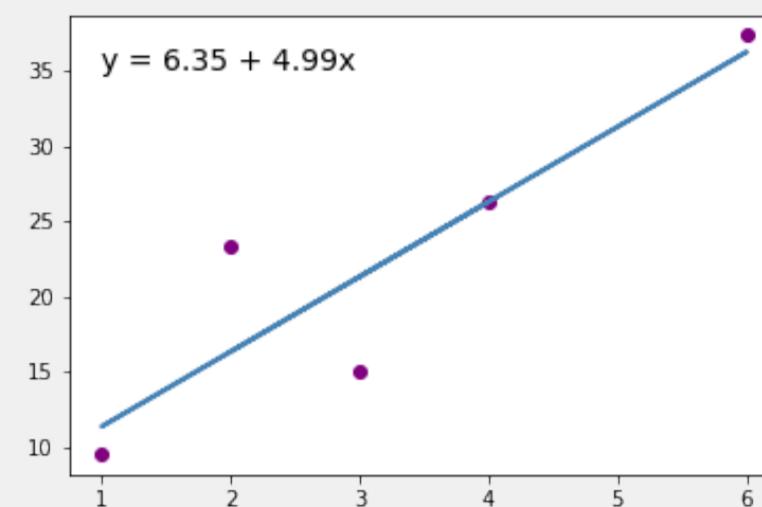


Figure 7. Regression of average time taken against path length.

However, letting participants perform the task straightaway without familiarisation with their relative hand position on the grid and the path generated as continuous stimuli has potentially become a confounding factor, leading to slightly poorer performance on the first trajectory.

Conclusions and Future Work

The study systematically explores the possibility of feedforward interactions via playing various sensations to provide some result indications to users before their response is uttered, in both discrete (Part 1) and continuous (Part 2) fashions, with the outcome as expected except for some training effects appeared in Part 2.

To tackle this, minor study plan modifications may be applied in future project iterations, plus the participants' pool can possibly be extended to a broader age range and discipline to minimise the uncontrolled variation that forms part of Threats to Reliability [4].

References

- [1] Daniel Hajas, Damien Ablart, Oliver Schneider, and Marianna Obrist. I can feel it moving: science communicators talking about the potential of mid-air haptics. *Frontiers in Computer Science*, 2:2, 2020.
- [2] Kyle Harrington, David R Large, Gary Burnett, and Orestis Georgiou. Exploring the use of mid-air ultrasonic feedback to enhance automotive user interfaces. In *Proceedings of the 10th international conference on automotive user interfaces and interactive vehicular applications*, page 13, 2018.
- [3] Shaoyan Huang, Sakthi PB Ranganathan, and Isaac Parsons. To touch or not to touch? comparing touch, mid-air gesture, mid-air haptics for public display in post covid-19 society. In *SIGGRAPH Asia 2020 Posters*, page 1. 2020.
- [4] Piotr Krawczyk, Ilia Maslov, Marcin Topolewski, Marc Pallot, Henri Lehtosaari, and Jouni Huotari. Threats to reliability and validity of mixed methods research in user experience. In *2019 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)*, page 5. IEEE, 2019.
- [5] Pedro Lopes, Patrik Jonell, and Patrick Baudisch. Affordance++ allowing objects to communicate dynamic use. In *Proceedings of the 33rd annual acm conference on human factors in computing systems*, page 2523, 2015.
- [6] Donald A Norman. *The psychology of everyday things*. Basic books, 1988.
- [7] Gustavo Rovelo, Donald Degraen, Davy Vanacken, Kris Luyten, and Karin Coninx. Gestu-wan-an intelligible mid-air gesture guidance system for walk-up-and-use displays. In *IFIP Conference on Human-Computer Interaction*, page 368. Springer, 2015.
- [8] Jo Vermeulen, Kris Luyten, Elise van den Hoven, and Karin Coninx. Crossing the bridge over norman's gulf of execution: revealing feedforward's true identity. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, page 1931, 2013.
- [9] Adam S Williams and Francisco R Ortega. Understanding gesture and speech multimodal interactions for manipulation tasks in augmented reality using unconstrained elicitation. *Proceedings of the ACM on Human-Computer Interaction*, 4(ISS):6, 2020.