Using digital technologies and computer vision for designing and implementing smart-home programs for post-stroke rehabilitation

Sutanuka Bhattacharjya*, Ashwin Ashok**, Peter Presti***,
Sarah Curtis*, Anna Calaicone*, Tessa Chung*, Sophia Delise*

*Department of Occupational Therapy, Byrdine F. Lewis School of Nursing and Health Professions, Georgia State University, Atlanta, GA;
**Department of Computer Science, Georgia State University, Atlanta, GA; Georgia Institute of Technology, Atlanta, GA

INTRODUCTION

Globally, stroke is the leading cause of acquired injuries for adults and one of the most common causes of mortality in adults world wide[1]. There are many barriers to having access to stroke rehabilitation including transportation, economic status, and caregiver support[3]. Telerehabilitation is becoming a more viable and efficient option for rehabilitation[2]. It is important that stroke survivors receive a high dose of therapy, which could be made possible through telerehabilitation[2]. The DigiHand system is a portable digital rehabilitation system which is able to capture the user's movement data and show performance-based feedback.

AIMS

1. Effectiveness at the DigiHand system detecting movement.
2. Identifying factors that influence adherence to using DigiHand.



Figure 1: mHandRehab light and phone holder



Figure 2: mHand Rehab system attachment.

METHODOLOGY

- *Study setting:* private lab room on Georgia State University's Atlanta campus
- *Research Design:* concurrent mixed methods design combining single-subject design and cross-sectional phenomenological designs
- *Participants: 5 healthy adults and 2* community dwelling adults with stroke that had typical mental capacity, were 4+ months post-stroke, and able to open and close hand in order to grasp a mug handle
- *Procedures*
  - 5 activities with 10 repetitions of each using everyday common items
  - Semi-structured usability interview following completion of the tasks
  - XYZ files for data collection decoded for "jerk" scores
- *Instrument: Data from DigiHand system and semi-structured Interview*



0. WRIST
1. THUMB_CMC
2. THUMB_MCP
3. THUMB_IP
4. THUMB_TIP
5. INDEX_FINGER_MCP
6. INDEX_FINGER_PIP
7. INDEX_FINGER_DIP
8. INDEX_FINGER_TIP
9. MIDDLE_FINGER_MCP
10. MIDDLE_FINGER_PIP
11. MIDDLE_FINGER_DIP
12. MIDDLE_FINGER_TIP
13. RING_FINGER_MCP
14. RING_FINGER_PIP
15. RING_FINGER_DIP
16. RING_FINGER_TIP
17. PINKY_MCP
18. PINKY_PIP
19. PINKY_DIP
20. PINKY_TIP

Figure 4: Mediapipe hand tracking

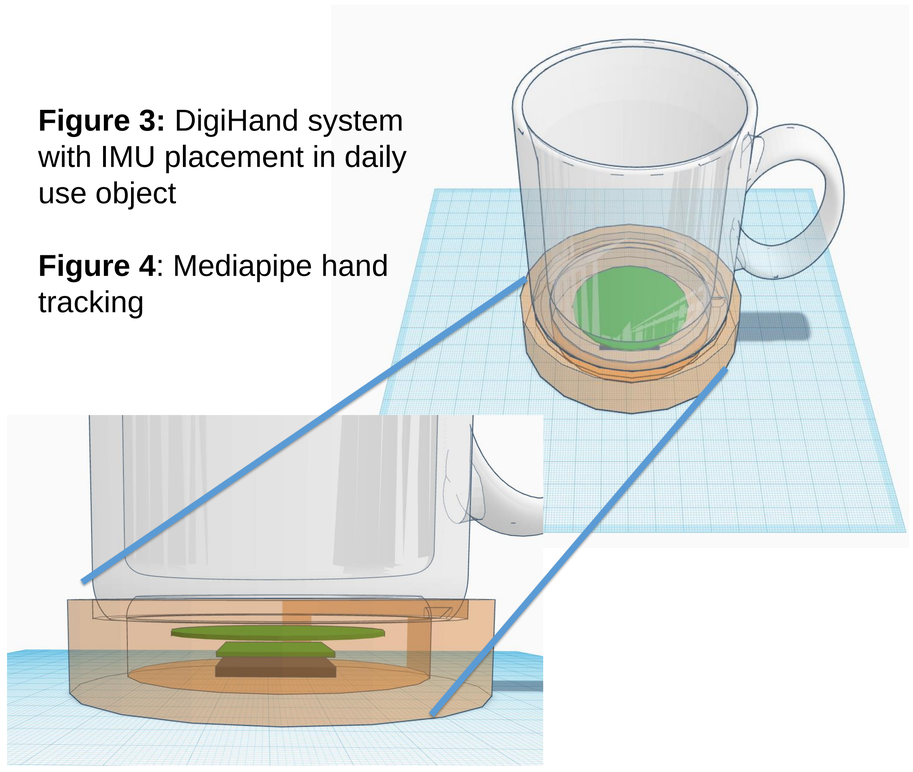


Figure 3: DigiHand system with IMU placement in daily use object

QUANTITATIVE RESULTS

- Compared 24 + 2 healthy participants' hand function for each video trial for the respective activities
  - Each video trial for a given activity is now represented by the 21 x 18 feature matrix
  - Comparison separate for:
    - Each activity
    - Each dimension (x,y,z)
- Comparison models:
  - Correlation
  - Cosine similarity

Represents Cosine similarity between every participant's every trial (228 videos) compared along x axis for mug activity the subset of 9 selected features (21 x 9)

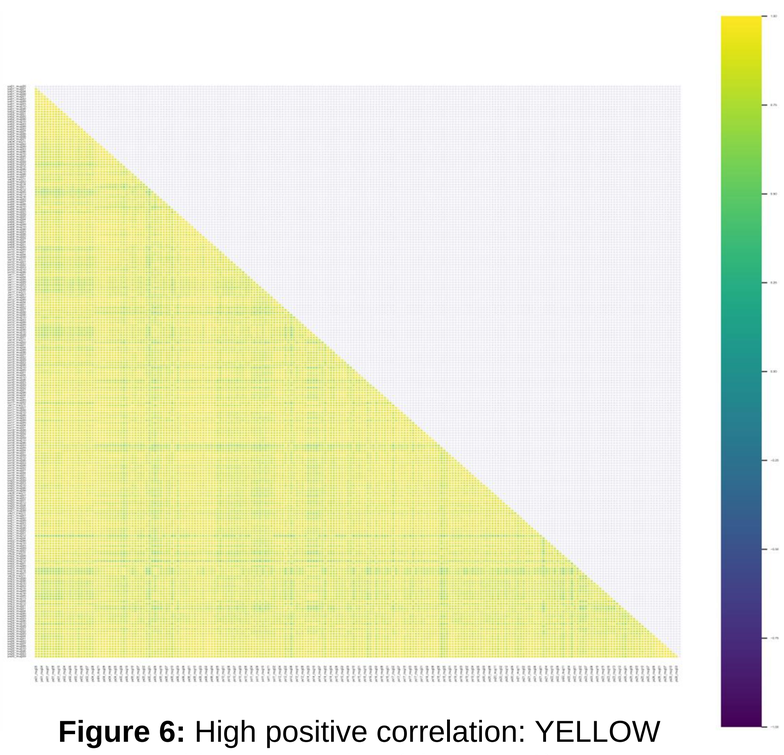


Figure 6: High positive correlation: YELLOW
Less Positive correlation (closer to 0) : BLUE
Negative correlation: PURPLE

QUALITATIVE RESULTS

- **Theme 1:** *For the stroke population to successfully engage with DigiHand, the tasks, order, and set up of the activities must be adaptable and personalized to the client's needs and preferences.*
  - *Feedback about the system: "I thought I did well, but I can see it said 'jerkiness detected' every time so, I guess I'm not as cool as I thought I was."* - WB
  - *User confidence:* Even though *DigiHand* has challenges in its setup, there were some participants that felt confident about doing the setup by themselves and doing the exercises by themselves.

- **Theme 2:** *In order for DigiHand to be successful, personal factors of the client and the characteristics of the system must be adequately compatible.*
  - *Factors that Affect Rehabilitation Growth:* "*I've been able to do it* [shoulder movement] *for so long in my life….but then it all got deleted from my arm so I can't do it anymore*."
  - *Perceived Future Goals:* One of the participants had a very clear goal of being, "*a fully functioning grandma*," and participating in the IADL of caretaking of her grandchild

CONCLUSION

The *DigiHand* system has potential to be a successful home based asynchronous rehabilitative technology for stroke survivors. The DigiHand system successfully gathered data in the form of jerk scores to provide feedback on the quality of movement to stroke survivors. The mHandRehab system can be improved by adapting the system so that it is compatible with the client's personal factors, and to ensure that the tasks, order, and set-up of the activities are both meaningful, personalized, and individualized to the client's needs and preferences.

REFERENCES

1. Appleby E, Gill ST, Hayes LK, Walker TL, Walsh M, Kumar S. Effectiveness of telerehabilitation in the management of adults with stroke: A systematic review. *PloS one.* 2019;14(11):e0225150.
2. Ashok, A., & Bhattacharjya, S. Virtual Hand Rehabilitation using a Mobile Camera. Poster presentation at 2020 IEEE/ACM International Conference on Connected Health: Applications, Systems and Engineering Technologies (CHASE). Published in IEEE Xplore, doi: 10.1145/3384420.3431771.
3. Chen Y, Chen Y, Zheng K, et al. A qualitative study on user acceptance of a home-based stroke telerehabilitation system. *Topics in stroke rehabilitation.* 2020;27(2):81-92.
4. Podury A, Raefsky SM, Dodakian L, et al. Social network structure is related to functional improvement from home-based telerehabilitation after stroke. *Frontiers in neurology.* 2021:41.