Research Project Title : Improving the Web Interface Accessibility for People with Motor Disabilities through Gesture Recognition

Research Question :

How could gesture recognition technology be effectively implemented to improve the accessibility of web interfaces for people with motor disabilities?

Problem Scope :

People with motor disabilities limit themselves to interact with web interfaces using traditional methods such as mouse and keyboard inputs. This will be the barrier for people with motor disabilities to access digital information and services. The challenges faced by these people with motor disabilities in navigating and interacting with web interfaces include :

1. **Accessibility Challenges:** People with motor disabilities will face difficulties in accessing and interacting with web content due to limitations in motor control. The challenges they face are like accurately clicking on small elements to navigate complex interfaces.
2. **Limited Input Methods:** Traditional input methods such as keyboards and mouse may not be comfortable for individuals with motor disabilities. Where we have some alternate input methods like touch and audio inputs but those cannot help every category of people with motor impairment people.
3. **Usability Issues:** Existing web interfaces have accessibility features that address the people facing challenges like the visually impaired, hearing problems but it was not designed with the specific needs of users with motor disabilities which is leading to usability issues and frustrations during interaction.

Motivation:

The motivation behind addressing the problem of improving web interface accessibility for people with motor disabilities through gesture recognition is due to several factors like

1. **Critical Evaluation of Existing Interfaces:** After going through the lot of current web interfaces has revealed that there is limitation in addressing the users with motor disabilities. These problems include operating an application interface without any external help, navigating through the application without using a click or touch. This gap will be addressed with this proposed solution through gesture technology .
2. **Inspiration from HCI:** Engaging in the Human-Computer Interaction class lectures and going through recent HCI conference papers provided inspiration and insights. We identified challenges, and innovative solutions to push the accessibility design even more effectively.
3. **Improving Accessibility:** While addressing the accessibility topic and category of people who can access the web interfaces with disability and gaps. Web interfaces are important for ensuring equal access to information and services for all types of users. Gesture recognition technology offers a solution to empower individuals with motor disabilities, allowing them to navigate and interact with web content more effectively.
4. **Recognition of Gesture Technology Developments:** The recent continuous developments of gesture recognition technologies caught our attention. Recognizing the potential of these developments and the reliability in it, we thought there is a possible way to address the unique challenges faced by individuals with motor disabilities.

Literature Review:

The major research topic of this literature review is the implementation of gesture recognition technology to enhance web interface accessibility for individuals with motor disabilities. This literature review aims to investigate and analyze existing research on enhancing web interface accessibility through gesture recognition technologies for users with motor disabilities and identifies the broad problem area and discusses the importance of this topic within HCI field.

The broad problem area addressed in this literature review is to address the limited accessibility of web interfaces for individuals facing motor disabilities. This challenge requires the development of inclusive and effective interaction methods related to the unique needs of users with motor impairments. The project research holds importance in the field of HCI as it addresses the accessibility challenges faced by individuals with motor disabilities. The significance of this project research extends beyond the user group, emphasizing the need for technologies that serve to diverse abilities of the people which also includes HCI principles of universal design and user-centered interaction in the digital world.

Relevant Research:

[1] Leah Findlater, Karyn Moffatt, Jon E. Froehlich, Meethu Malu, and Joan Zhang. 2017. Comparing Touchscreen and Mouse Input Performance by People With and Without Upper Body Motor Impairments. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17). Association for Computing Machinery, New York, NY, USA, 6056–6061. https://doi.org/10.1145/3025453.3025603

[2] Radu-Daniel Vatavu. 2017 May 6. Fundamentals of Gesture Production, Recognition, and Analysis. doi:https://doi.org/10.1145/3027063.3027106

[3] Ovidiu-Ciprian Ungurean, Radu-Daniel Vatavu, Luis A. Leiva, and Réjean Plamondon. 2018. Gesture Input for Users with Motor Impairments on Touchscreens: Empirical Results based on the Kinematic Theory. In Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems (CHI EA '18). Association for Computing Machinery, New York, NY, USA, Paper LBW537, 1–6. https://doi.org/10.1145/3170427.3188619

[4] Radu-Daniel Vatavu and Ovidiu-Ciprian Ungurean. 2019. Stroke-Gesture Input for People with Motor Impairments: Empirical Results & Research Roadmap. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19). Association for Computing Machinery, New York, NY, USA, Paper 215, 1–14. https://doi.org/10.1145/3290605.3300445

[5] Eliza, Silva L, Pereira R. 2019 Oct 22. Personalized interactive gesture recognition assistive technology. doi:https://doi.org/10.1145/3357155.3358442

[6] Radu-Daniel Vatavu and Ovidiu-Ciprian Ungurean. 2022. Understanding Gesture Input Articulation with Upper-Body Wearables for Users with Upper-Body Motor Impairments. In Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems (CHI '22). Association for Computing Machinery, New York, NY, USA, Article 2, 1–16. https://doi.org/10.1145/3491102.3501964

[7] Zhanna Sarsenbayeva, Niels Van Berkel, Eduardo Velloso, Jorge Goncalves, and Vassilis Kostakos. 2022. Methodological Standards in Accessibility Research on Motor Impairments: A Survey. ACM Comput. Surv. 55, 7, Article 143 (July 2023),35 pages. https://doi.org/10.1145/3543509

[8] Radu-Daniel Vatavu. 2023. IFAD Gestures: Understanding Users' Gesture Input Performance with Index-Finger Augmentation Devices. In Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23). Association for Computing Machinery, New York, NY, USA, Article 576, 1–17. https://doi.org/10.1145/3544548.3580928

Summary of the Research :

The existing research studies have observed and delved into various aspects, including the examination of touchscreen and mid-air motion gestures, application of the Kinematic Theory to stroke gestures, assessment of iFAD gestures, comparison of iFAD gestures with other devices , empirical results on stroke-gesture input, exploration of methodological standards, existing barriers in the accessibility and a comparative study on touchscreen vs. mouse input performance and highlighting differences in performance, error rates and challenges faced by users with motor impairments. The potential of personalized gesture interaction for AAC, and the importance of considering cognitive and physical demands in gesture interface design have also been demonstrated.

We found that there is limited exploration of gesture recognition techniques specifically for users with motor impairments with wide categories like complete body impairment or paralyzed persons. Also there is a need for continuous improvement and iterative refining through the different user input capturing as well as a lack of comprehensive overviews of methodological standards are the identified gaps from the existing research studies.

In the further process we need some advanced gesture recognition techniques that address the challenges for unique characteristics of people with motor impairments. It should also ensure continuous improvement and iterative refinement based on user feedback to enhance the user experience.

Building on these findings in the existing researches, the research question emerges as

How could gesture recognition technology be effectively implemented to inclusive and effective web interfaces for users with motor disabilities to improve the accessibility?

Proposed Methodology :

The proposed methodology involves gesture recognition to enhance web interface accessibility for individuals with motor disabilities. Initially, a comprehensive user survey will be conducted to understand specific challenges and preferences.

Following this survey we will review the existing gesture recognition technologies based on the recent developments in the gesture recognition technologies that suits our project research. Prototypes will be developed and tested for the gesture recognition integrated into web interfaces. The developed solution will be compared against accessibility standards. After obtaining the feedback from the users and the prototype will be refined. The implementation will involve HTML, CSS, and JS for seamless integration with web interfaces.

As a first step we have gathered surveys from the people suffering from the various motor impairments and got to know the challenges they are facing, preferred ways to interact with the interface and their comfort levels.

Dataset Link : **https://sluedu-my.sharepoint.com/:x:/r/personal/akhil_vemulapally_slu_edu/_layouts/15/Doc.aspx?sourcedoc=%7B683354AD-2B9D-4D3B-8635-778A4D287FC2%7D&file=Sprint_2_Motor_Impairment_User_Survey_Dataset.xlsx&action=default&mobileredirect=true&DefaultItemOpen=1&logi**

n_hint=bhanuprasad.kandula%40slu.edu&ct=1714540680857&wdOrigin=OFFICECOM-WEB.START.REC&cid=2c3d970e-c035-4478-9fd4-c369e0b38362&wdPreviousSessionSrc=HarmonyWeb&wdPreviousSession=702932e0-7d06-4229-aad5-fed4828a2a91/

From the above survey collected from the various users we have performed the inductive analysis

Inductive Analysis:

Based on the information collected in the dataset, we have performed inductive analysis can be performed to identify common themes, challenges, and preferred gestures for web interaction among individuals with motor impairments.

Themes:

1. **Types of Motor Impairments:**

The dataset covered a range of motor impairments, including Cerebral Palsy, Spinal Cord Injury, Muscular Dystrophy, Parkinson's, Multiple Sclerosis, Arthritis, Stroke, Hemiplegia, Moto Neurolysis, Upper Body Paralysis, Full Body Paralysis, Lower Body Paralysis, Repetitive Strain Injury (RSI), and Quadriplegia.

2. **Challenges in Accessing Web Interfaces:**

    a) Difficulty in operating input devices like mouse and keyboard due to tremors, weakness, or limited mobility.
    b) Struggling with precise movements required for clicking small buttons, links, or form fields.
    c) Pain and fatigue from prolonged use of input devices.
    d) Difficulty in using touchscreens with limited mobility
    e) Challenges in navigating web pages using keyboard commands alone for long time.
    f) Difficulty in understanding content due to small text or improperly designed components.
    g) Speech and language impairments affecting the use of voice-controlled interfaces.

3. **Preferred Gestures for Web Interaction:**

    a) Swipe, tap, and pinch gestures using the unaffected hand or fingers.
    b) Voice commands for navigation and selection.
    c) Eye-tracking technology for cursor control and interaction.
    d) Head movements for scrolling and selection.
    e) Hand gestures using sensor devices or gloves.
    f) Symbolic representation for navigation shortcuts.
    g) Coordinating voice commands with symbolic representations or gestures.
    h) Lip movement capturing without relying solely on voice.
    i) Brain-Computer Interface (BCI) for direct communication between the brain and computer.

4. **Comfort Levels with Gestures:**

    a) Swipe gestures: Comfort level ranging from 3 to 5 out of 5.
    b) Voice commands: Comfort level ranging from 3 to 4.5 out of 5.
    c) Eye-tracking: Comfort level ranging from 2.5 to 5 out of 5.
    d) Hand gestures: Comfort level ranging from 3 to 5 out of 5.
    e) Keyboard navigation: Comfort level ranging from 4 to 5 out of 5.
    f) Symbolic representation: Comfort level of 4 to 5 out of 5.

5. **Feedback on Gestures:**

    a) Swipe gestures reduce muscle strain and provide a more interactive experience.
    b) Voice commands are helpful but may sometimes be misinterpreted or have limitations.
    c) Eye-tracking allows for hands-free interaction but may cause discomfort.
    d) Hand gestures with sensor devices or gloves can reduce strain on muscles.
    e) Symbolic representation is intuitive and efficient for navigation when accompanied by a reference guide.
    f) Coordinating voice commands with gestures can be challenging and may require practice.

Conclusion:

In conclusion, individuals with motor impairments face various challenges when accessing web interfaces, primarily related to the use of input devices, precise movements, and understanding content. They prefer a range of gestures for web interaction, including swipe, voice, eye-tracking, hand gestures, and symbolic representation. The comfort levels with these gestures vary, and user feedback highlights the benefits and limitations of each approach. Designing web interfaces that accommodate hand/finger are the most preferred gestures that will address the identified challenges can significantly improve accessibility and user experience for most of the individuals with various motor impairments. In the Next step we are going to design the Prototypes for the user interface of the tool to users to run on their system where they can customize their gestures for the selection of the movement.

Figma Design Prototype of MIWA (Motor Impairment Web Accessibility) Tool:

Figma Prototype Link – Design 2 for all the design prototypes.

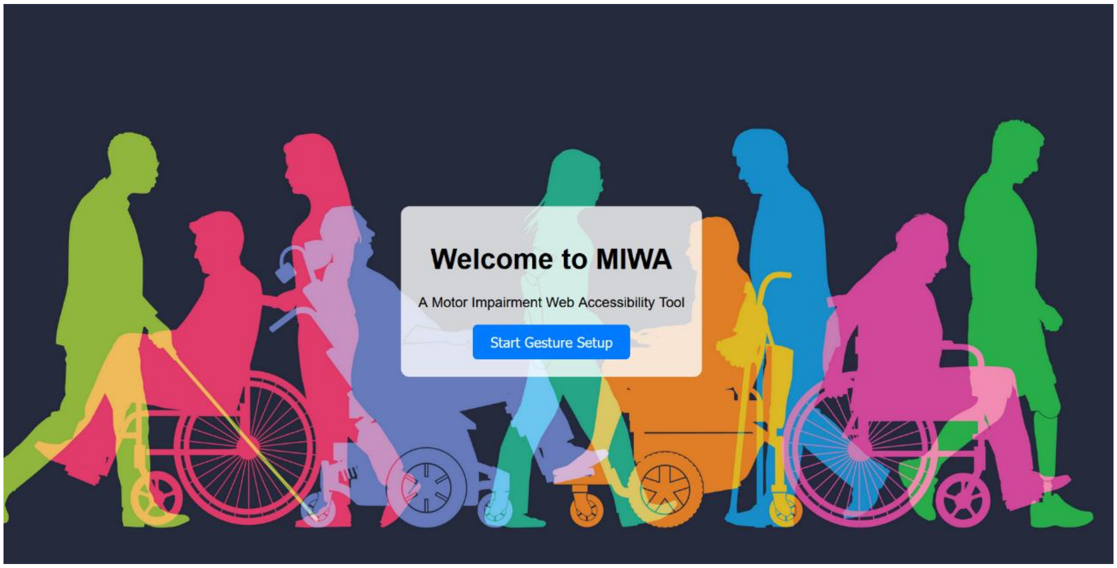
Based on the inductive analysis done in sprint 2, we decided on a design that fits well with the analysis and progressed on it. Below is the preview

Functional Prototype of MIWA (Motor Impairment Web Accessibility) Tool:

After designing the prototype in Figma as per the requirements of Motor Impairment people, we started implementing the design prototype into the functional prototype using HTML, CSS, JavaScript.

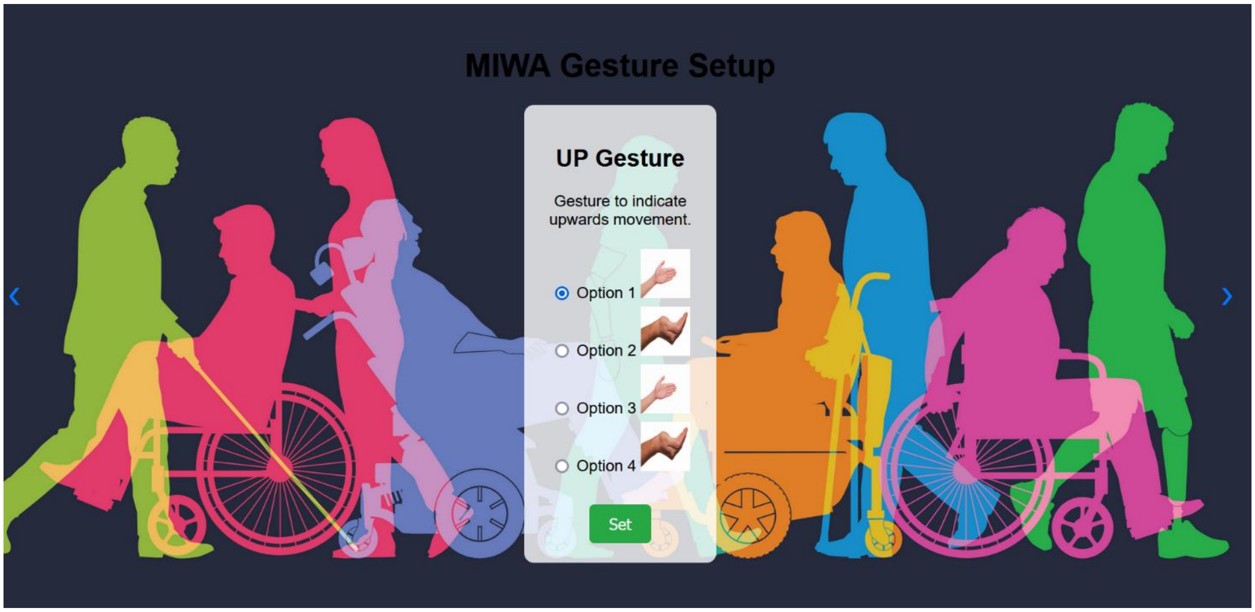
Git link to code repo: https://github.com/BhanuKandula5030/MIWA-Motor-Impairment-Web-Accessibility-Tool/

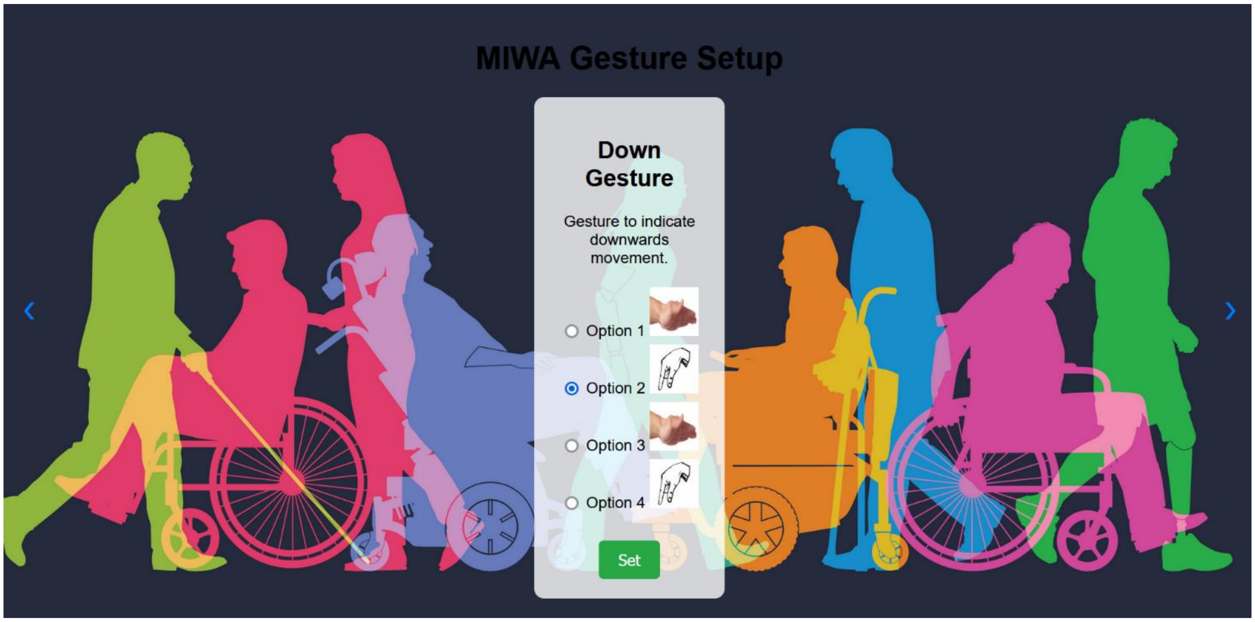
1.Opening Screen: The MIWA tool interface greets the user upon opening.



2.Gesture Setup:

- To initiate gesture setup, the user clicks on the "Start Gesture Setup" button.
- This action directs them to a screen displaying a gesture alongside four options.
- The user selects an option and clicks on "Set," followed by the forward arrow to proceed to the next gesture.
- There are six gestures: Up, Down, Left, Right, Click, and Select.
- To navigate forward and backward, users can utilize the forward arrow and back arrow.

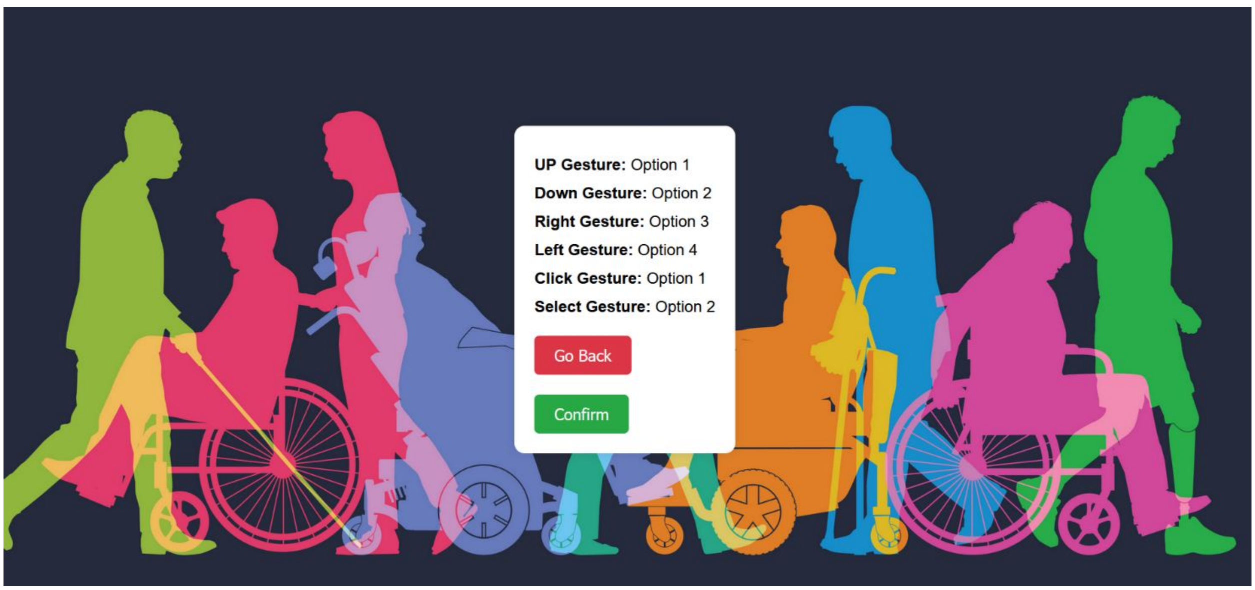




We have similar screens for all the gestures as well.

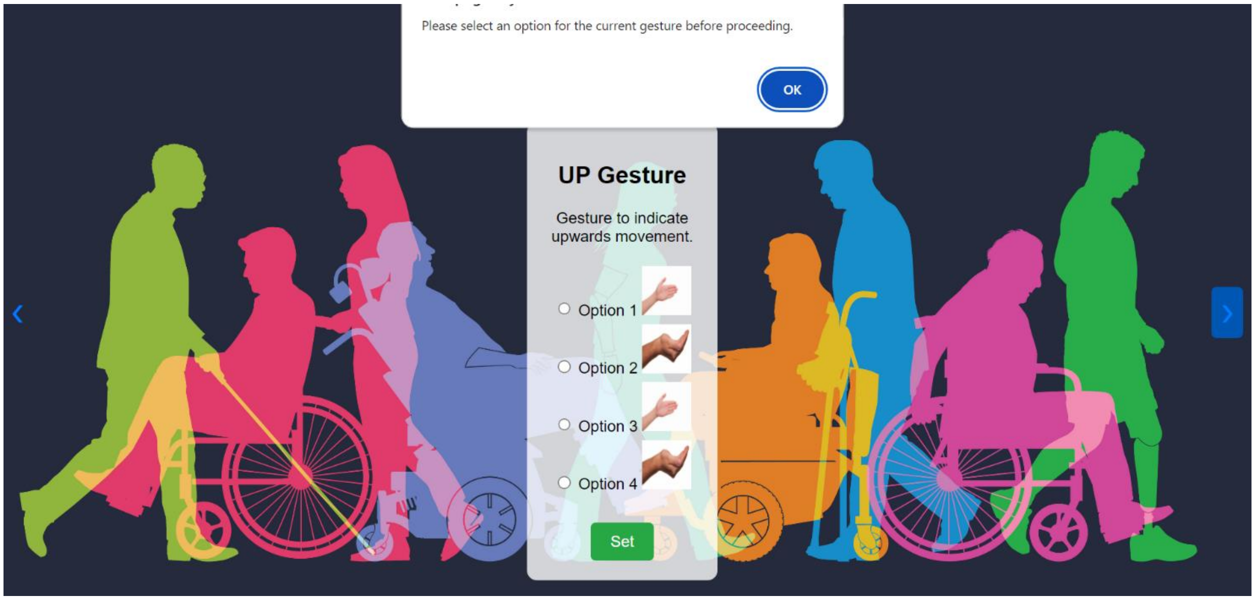
3.Completed Gesture Setup:

- Once all gestures are configured, the user clicks on the "Finish" button.
- This transitions them to a screen presenting the selected options for each gesture.
- Below the displayed options, there are "Confirm" and "Go Back" buttons.
- Selecting "Confirm" triggers a Thanks alert, while choosing "Go Back" returns the user to the gesture selection.



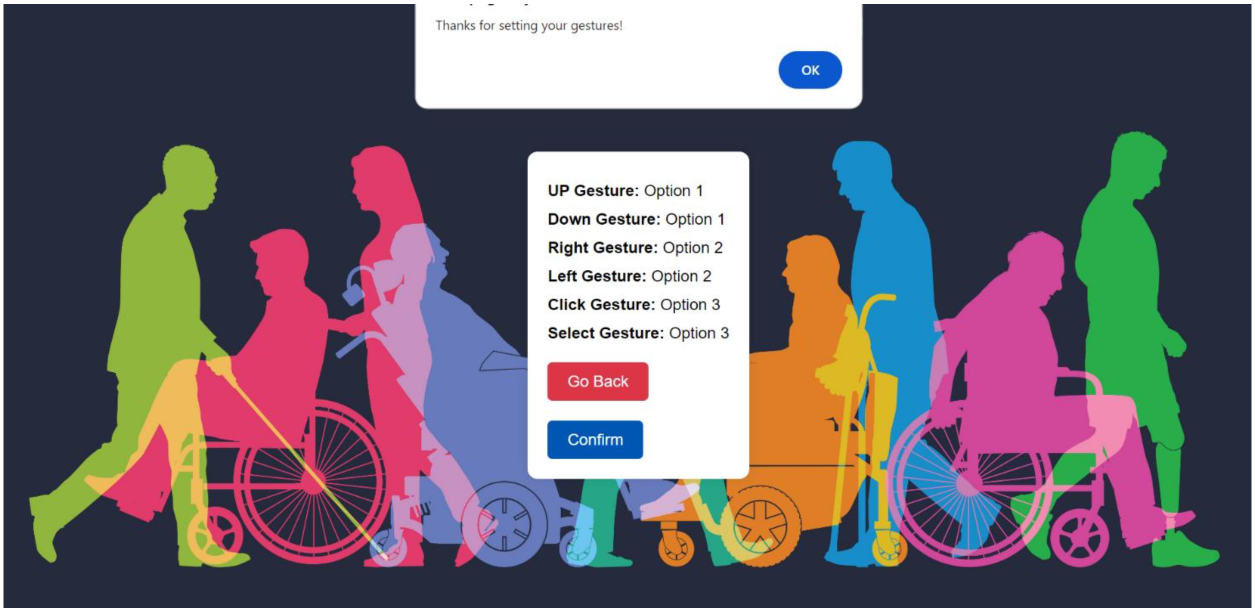
4.Feedback Alert Notifications:

- Attempting to proceed without selecting any option prompts an alert indicating the necessity to select an option to proceed as feedback.



- If a user selects an option and clicks on "Set," an alert confirms the selection for the corresponding gesture as a feedback .

- After displaying the selected options on screen and click on the confirm button will generate a Thanks alert indicating the Thanks for setting up all the gestures and clicking ok will complete the gesture setup process in the MIWA Tool.



In the next step we have performed the Quantitative Analysis by collecting the End user review with a Questionnaire to analyze the metrics like Ease of using the MIWA Tool and few tasks like

Task 1: Navigate to a specific webpage

Task 2: Click on a specific button/link on the webpage.

Task 3: Fill out a form with predefined information on the webpage.

Task 4: Scroll through a long webpage.

We have collected the End user review using the google form. Analyzed these tasks by asking them to fill the google form and tasks above

Google Form Link:

https://docs.google.com/forms/d/e/1FAIpQLSdgWJqWuGkx78nJNa9RDWHEG3JjIsc05WaiI_xoAHMBkB8Wcg/viewform/

Demo Video Link (End user demo):

Without MIWA Tool:
https://drive.google.com/file/d/1idschsxW5qy9ifZumNiVIlcWcGqVaUZK/view?usp=drivesdk/

With MIWA Tool:
https://drive.google.com/file/d/1imCZbM3xnCHGuy1nvrtPhp22UIpkqE24/view?usp=drivesdk/

Demo Video Link (As per the guidelines of ACM):
https://drive.google.com/file/d/1ib9-DHS7qsr8JLgvIV5prAGJfMEM9O9w/view?usp=drivesdk/

Quantitative Analysis:

Introduction:

The Motor Impairment Web Accessibility (MIWA) tool aims to enhance web accessibility for people with motor impairments by providing alternative methods of interaction with web interfaces. This report contains the quantitative analysis based on the feedback and task performance of 19 participants with various types of motor impairments.

End user survey report: MIWA End user Review Report.xlsx

Participant Demographics:

- Total Participants: 19
- Age Range: 21 to 66 years
- Gender Distribution: 15 Male, 4 Female
- Location: Participants from various locations including the USA and India
- Types of Motor Impairments: Cerebral Palsy, Spinal Cord Injury, Muscular Dystrophy, Parkinson's, Multiple Sclerosis, Arthritis, Stroke, Repetitive Strain Injury (RSI), Quadriplegia, Hemiplegia, Moto Neurolysis, Upper Body Paralysis, Full Body Paralysis, Lower Body Paralysis
- Challenges: Participants faced difficulties such as tremors, limited hand/finger movement, pain, fatigue, and difficulty with traditional interaction methods.

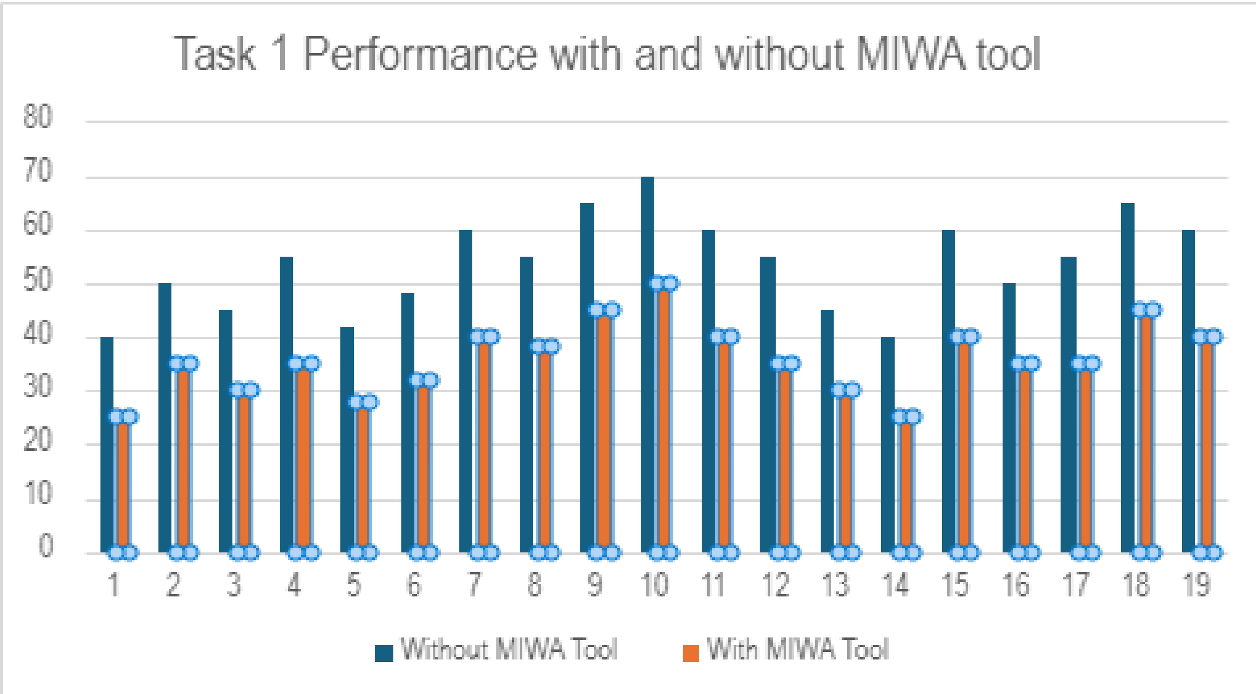
MIWA Tool Usage :

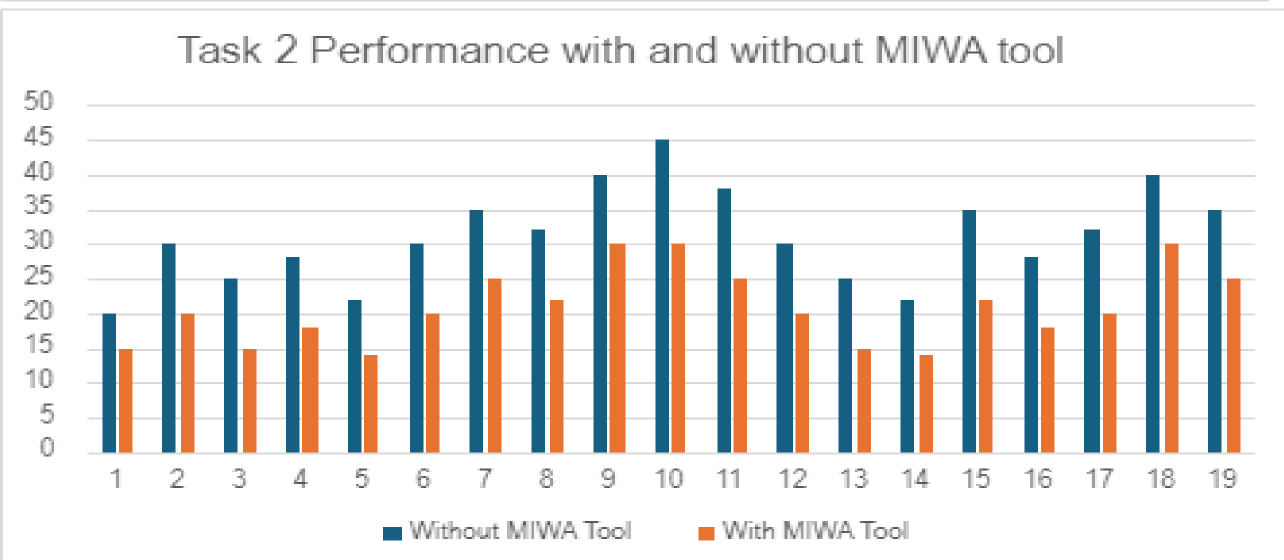
- **Ease of Use of MIWA Tool Rating**: Average rating of 3.92 out of 5 indicates moderate ease of use.
- **Preferred Gesture for Web Interaction**: Various gestures including hand gestures, eye-tracking, swipe gestures, voice commands, finger gestures, palm gestures, wrist gestures, and customized keyboard navigation were preferred based on individual comfort and efficiency.

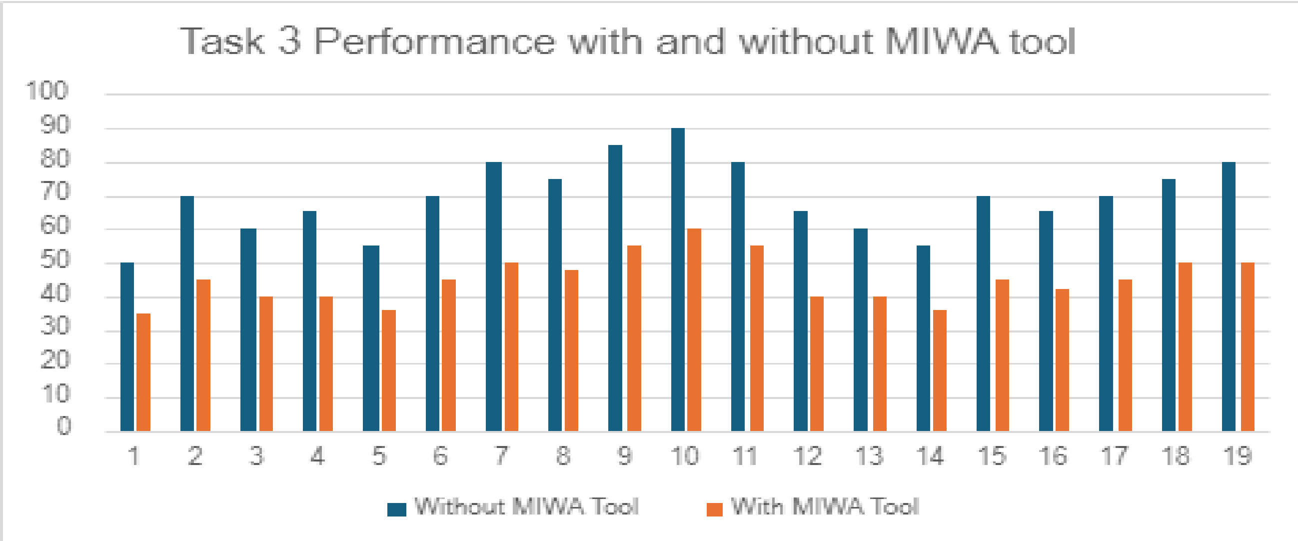
Task Performance Comparision:

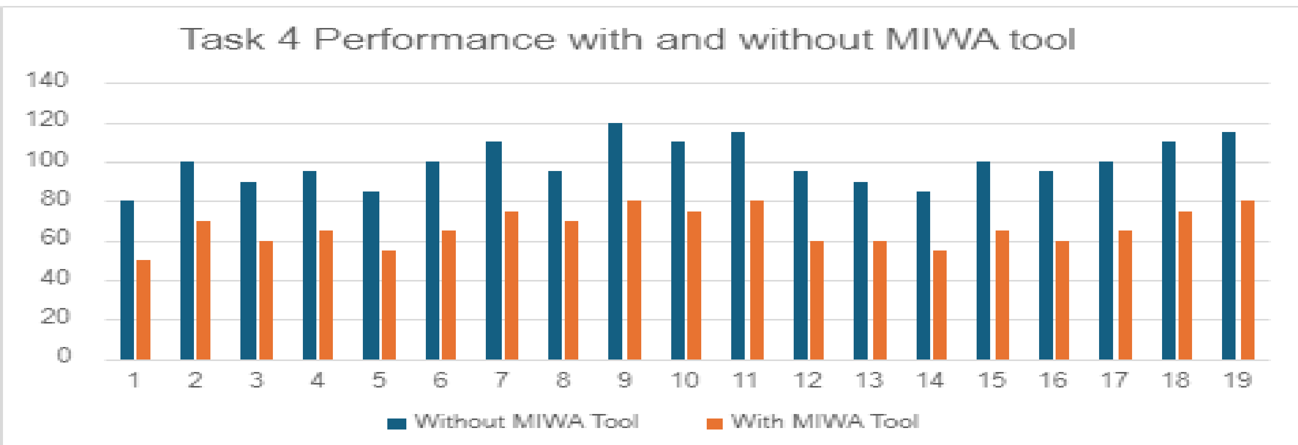
- **Task 1: Navigate to a specific webpage**
  a) Without MIWA Tool: Average time taken = 53.68 seconds
  b) With MIWA Tool: Average time taken = 35.94 seconds
- **Task 2: Click on a specific button/link on the webpage**
  a) Without MIWA Tool: Average time taken = 31.15 seconds
  b) With MIWA Tool: Average time taken = 20.94 seconds
- **Task 3: Fill out a form with predefined information on the webpage**
  a) Without MIWA Tool: Average time taken =69.47 seconds
  b) With MIWA Tool: Average time taken = 45.10 seconds
- **Task 4: Scroll through a long webpage**
  a) Without MIWA Tool: Average time taken = 99.47 seconds
  b) With MIWA Tool: Average time taken = 66.57 seconds

Graphical Analysis of the Performance:









Analysis:

- The MIWA Tool showed the significant improvements in task performance across all tasks with average time reductions ranging from 20% to 30%.
- Participants confirmed varying levels of ease and comfort with different interaction gestures provided by the MIWA Tool.
- Finger gestures are the most preferred methods for web interaction without physical movement.
- Participants with lower body paralysis found palm gestures and wrist gestures particularly helpful in reducing tremors and pain during interaction.
- A part from the overall positive feedback some participants experienced challenges such as difficulties with accuracy.

- The MIWA Tool addresses specific challenges faced by people with motor impairments making web interfaces more accessible and user-friendly.

Discussion on our project contribution in HCI Community:

The results of our research and the implementation of the Motor Impairment Web Accessibility (MIWA) tool offer significant insights and implications for the Human-Computer Interaction (HCI) community.

1.Impact on HCI Research: Our study contributes to the HCI field by addressing a gap in web interface accessibility. Our approach to improving accessibility is very unique style as we use gesture recognition technology to address the needs of people with motor disabilities. By highlighting the including the design principles and gesture recognition technologies that meet a range of user needs this study particularly broadens the focus of HCI research.

2.Advancements in Gesture Recognition: The implementation of the MIWA tool demonstrates the potential of gesture recognition technology in improving accessibility feature. Gesture-based interaction provides some of the advanced features for users with motor impairments to navigate web interfaces reducing dependance on traditional input devices like mouse and keyboards. This highlights can be seen in the graphical analysis and reduction in the average time taken to complete the task and importance of our research and development in gesture recognition techniques for many users in HCI Community.

3.User-Centered Design Approach: Our study using the MIWA tool will highlight the significance of user-centered design approach in developing accessibility related solutions. By conducting user surveys, analyzing user preferred gestures and challenges, and incorporating end user feedback into MIWA tool's design and implementation.

Conclusion:

The Motor Impairment Web Accessibility (MIWA) tool demonstrates its necessity and usefulness in improving web accessibility for people with motor impairments. By offering alternative interaction methods tailored to individual needs and preferences the MIWA Tool increases the user experience and reduction in the average time taken to complete the task .Although further refinement and customization may be needed to address specific challenges faced by users, overall feedback indicates its effectiveness in facilitating easier and more inclusive web interaction experiences than before . Further development and adoption of MIWA-like tools are essential in promoting digital interaction for individuals with motor impairments.

Reflection :

In our project we have 3 contributors

Bhanu Prasad Kandula – I have contributed to the Idea innovation, Literature review, User survey, Code for the Prototype, Quantitative analysis, Demo Video

Akhil Vemulapally – I have contributed to the Proposed Methodology, User survey ,Figma Prototype, Inductive analysis (Qualitative analysis), End user review report, Presentation

Sandeep Sutharapu – I have contributed to the Idea innovation ,literature review , user survey ,Figma Prototype, Inductive analysis (Qualitative analysis),End user review report, Discussion on HCI

Our project MIWA is to address the accessibility challenges faced by people with motor disabilities through the implementation of gesture recognition technology in web interfaces. Reflecting on our project, there are several things we would consider doing differently or expanding upon if we had more time:

1.User Engagement: While we conducted user surveys to understand the challenges and gesture preferences of people with motor disabilities involving more active participation from end-users could have provided deeper insights and have more support towards the MIWA tool truly meets their needs.
2.Evaluation Methodology: Although we have conducted quantitative analysis and collected End user feedback through questionnaires, incorporating qualitative methods such as surveys have impacted our understanding of user experiences and preferences. Additionally tracking user interactions with the MIWA tool over time would give more insights about the usability.

3.Further Exploration of Gesture Recognition Techniques: Our project mainly focusing on implementing basic gesture recognition for web interaction by exploring the more advanced gesture recognition techniques such as machine learning-based approaches and integration with advanced wearable devices to operate using gestures could enhance the accuracy and uniqueness of the MIWA tool.

4.Customization and Personalization: In our project we are providing users with fixed options of gesture selection for the users and if we have more time we want to provide the users with greater flexibility to customize gestures and adapt the MIWA tool to their specific needs and preferences would further improve its usability and effectiveness.

Publishing the Work:

Regarding the publication of our work, our team would be happy about the sharing our findings and contributions with the HCI community. Publishing our research in peer-reviewed conferences or ACM journals would not only validate the importance of our work but also facilitate knowledge on this innovative idea in the field of accessibility and HCI.