A Nose-Teeth-based system for users with restricted upper limb mobility to interact with computer devices.

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***Abstract*—Multimodal interaction is a recent development in the field of Human-Computer Interaction that offers a variety of ways to interact with devices. The use of this technology allows those who are physically disabled to utilize technology effectively and work alongside physically fit individuals. Due to their physical limitations, people with physical disabilities are always one step behind society as a whole, which causes them to have inferior complexity and prevents them from using their hidden talents. Our research aims to develop a platform for people with physical disabilities so they can use their noses and teeth to interact with their devices. The disabled can use their devices without assistance, and they can play games that will improve their efficiency as they use the system. Additionally, these games will help them improve their verbal, mathematical, and vocabulary skills, which will be extremely beneficial for children with disabilities. Overall, our paper makes a proposal for a nose-teeth interaction system that will greatly help people with physical disabilities contribute to society.**

***Index Terms*—Human-Computer Interaction, physically disabled, nose-teeth interaction**

I. INTRODUCTION

Different ways of interacting with devices have been developed alongside the conventional method of using the touch of hand fingers as the world becomes more modern day by day. Multimodal interaction can take many forms, such as nose-teeth interaction, eye gaze, speech-based interaction, body language and gestures, etc. These interactions have been developed mainly to help those who, like physically fit people, are unable to use their devices conventionally.

Physically unfit individuals can't use their devices independently and require assistance, which makes them reliant on others. The world is gradually evolving, but they are still vulnerable, which prevents them from improving their skills and keeps them behind. Numerous people become underutilized as a result. There may be hidden genius in many of them, but these qualities are hidden from view.

Our research has two main goals. Firstly, we want to create a nose-teeth-based interaction system that physically disabled people can use. People who are physically disabled include those who are mute, deaf, or paralyzed. Secondly, interactive games will be a part of this system, which will enhance the vocabulary, math, and verbal skills of physically disabled people, especially kids.

We chose nose-teeth-based interaction over many other modes of interaction that were available for development for a variety of reasons. For the advancement of disabled people in interacting with devices, eye gaze-based interaction is frequently used. However, because the area of interaction in eye gaze interaction is so small, errors like selecting an unwanted point or performing an unwanted action on the screen can happen with just a small deviation in the gaze. Blinking of the eyes is yet another issue that might arise. Multiple errors can result from blinking. To create a system that can also be used by patients who are mute or speechless, as well as those who have hearing loss, speech-based interaction has also been removed from our research. We discarded interaction through body language and gestures because our user group consists of people with physical disabilities. So, keeping everything in mind, we can rely on nose-teeth-based interaction for the creation of a hand-free interaction system for people with physical disabilities.

Compared to the other modes of interaction, nose-teeth-based interaction is still a very new idea. The user must direct the interaction system by moving their nose in the direction of the point at which they want to act. The user shows or occludes (the position of the teeth and how the upper and lower teeth fit together) their teeth as the point of action is reached, and the action is then carried out. All required actions for using a device are included in the action.

II. LITERATURE REVIEW

There has been a significant amount of research done in this area for disabled people using computer devices to provide an alternative way to interact, so they face fewer obstacles and can have a significant impact on their daily lives.

M. Mangaiyarkarasi and A. Geetha [1] created a system that detects faces using Viola-Jones and Haar-like features to detect eye regions and track eye movements. The SVM method was also employed in the tacking of the eye for cursor control, as seen in [2]. P. Gyawal et al. [3] developed another system that uses eye tracking for face detection and is accompanied by the eye variance feature (EVF) and Gaussian mixture model (GMM) to track the eyes, and then uses the Finite State Machine (FSM) to detect the blinking pattern. Yan Shi et al. [4] used the CNN model for face detection and an end-to-end model for face expression recognition for cursor control in another system. Likewise, Rahib H. Abiyev and Murat Arslan used eye tracking for wheelchair control.

Apart from eye tracking, research on nose tracking for cursor control has also been conducted. Shadman Sakib Khan et al. [5] developed a system that uses the Viola-Jones algorithm to track the mouse using the nose point, and the nose is tracked by calculating the middle point for cursor control and smile detection for click. A similar method was used by Rohit Lal and Shital Chiddarwar [6] for face detection and nose tracking, as well as Haar-like features for eye tracking, with the exception that the smile is used for scrolling and left or right eye blinking is used for clicking. S. Kasun Chathuranga et al. [7] built another system that combined nose tracking with voice commands. Mireya Zapata et al. [8] used OpenCV and dlib to perform nose tracking as well as smile and voice commands.

Overall, several issues with the existing research were discovered. For instance, much research has been conducted on eye-gaze-based tracking, which requires a high level of precision that may be difficult for disabled people to achieve. Furthermore, eye detection is easily influenced by lighting conditions, eye shapes, eye sizes, and eye fatigue, making it difficult to use. Second, while the number of studies using the nose for cursor control is limited, it does necessitate the use of additional hardware devices. In some cases, the nose is assumed to be in the center and is not properly detected because it might vary. To address the research gaps and problems, we set the goal of developing a nose-teeth-based interaction system for computers, that does not require any hardware devices and detects the nose point accurately.

III. METHODOLOGY

The following subsections provide a description of our system's development process.

A. Nose Tracking Cursor Control

We have used MediaPipe's FaceMesh for robust face detection and key facial landmark extraction on the live webcam input. Then we detected five nose points, including the nose tip, and the other points around the nose. We have calculated the distances and directions of the points around the nose from the nose tip and mapped them for cursor control as described in Fig.1

B. Lips detection with different operations

The MediaPipe's FaceMesh model was also used to detect the middle lowest point of the upper lip and the middle highest point of the lower lip, which are generally in the

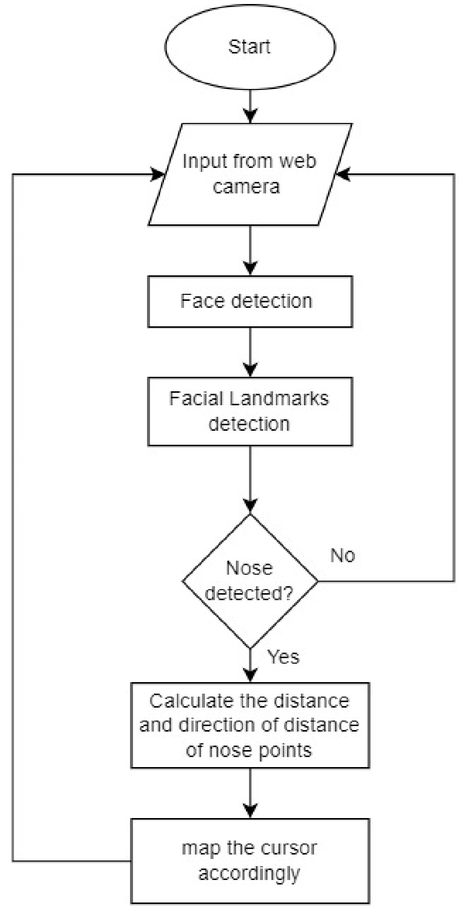

Fig. 1. Cursor Control Using Nose Tracking.

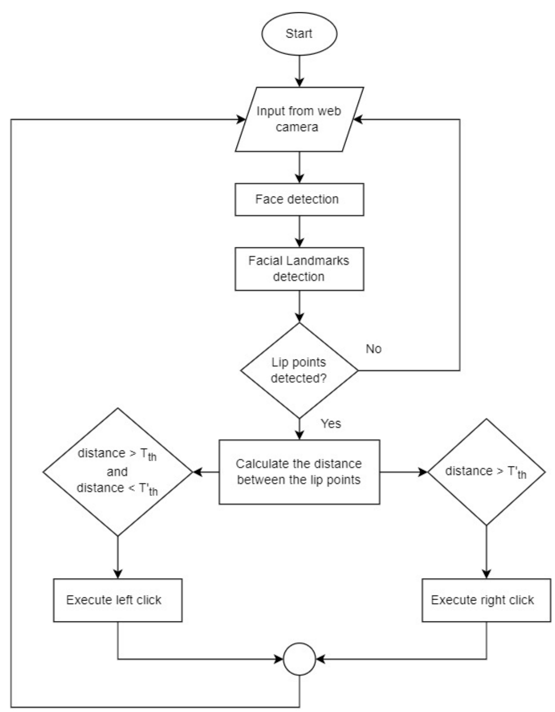

Fig. 2. Lip detection for clicking.

same place, and if the lips are unsealed, the difference between them increases, which is calculated for the click operation as mentioned in fig. 2. For opening the mouth, the click operation is done, and for opening the mouth wider, a right-click operation is executed. Two threshold values are considered for this T_{th}, T'_{th} for left click and right click, respectively, and they denote the distance between the lip points where $T_{\text{th}} < T'_{\text{th}}$. For operations like scrolling, double-clicking, and drag and drop, the respective mode has to be activated based on the mouse position on the screen, as mentioned in table I

TABLE I
DIFFERENT OPERATIONS AND THEIR ACTIVATING CONDITIONS

Conditions	Mode or Operation	Operation Description
Cursor is in the first half of the left corner of the display	Scroll	Scroll to the extreme up.
Cursor is in the second half of the left corner of the display	Scroll	Scroll to the extreme down.
Cursor is in the first half of the top corner of the display	Mode 0	Double clicks are executed.
Cursor is in the second half of the top corner of the display	Mode 1	Drag and drop operation is executed.

C. Automatic extended battery life

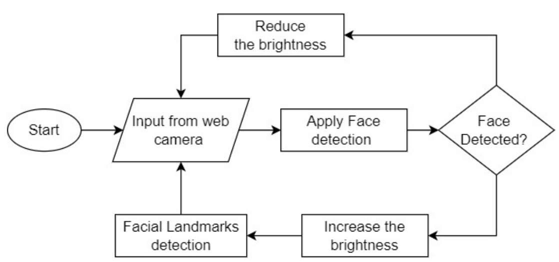

Fig. 3. Brightness Control for Extended Battery Life.

For extended battery life and controlled power consumption, the screen brightness is lessened whenever the face is not detected for some time, and upon detecting the face again, the brightness is set back to default as described in Fig. 3

IV. EVALUATION

A. Initial Setup

To assess computer accessibility, usability testing was conducted with individuals with clinical disabilities. We used five different desktop devices and selected three tasks that represent common desktop activities. The following tasks were selected:

- Task 1: Open a PDF file and navigate it using extreme up-and-down scrolling.
- Task 2: Create a new folder.
- Task 3: Organize 3 files on a desktop (alphabetically).

These task scenarios were chosen to reflect common user challenges.

B. Participants Profile and Study Procedure

A total of 15 participants were invited to conduct the test. None of them were involved in the development process, and each of them was familiar with using computers. To explore the effectiveness of our developed system, three trials were conducted for each task, and a within-group study was conducted. For each of these tasks, three different metrics are recorded. The matrices are as follows:

- Efficiency.
- Effectiveness.
- Satisfiability.

For each of the metrics, several parameters were considered. For efficiency, the following parameters were calculated:

1) **Standard Task Completion Time(A):** The time taken for the user to complete the task.
2) **Task Completion Time By The Evaluator(B):** The time taken by the evaluator or researcher to complete the same task as the user this Helps assess the task complexity and difficulty level from the evaluator's perspective.
3) **Time Deviation (B-A):** The difference between the task completion time by the evaluator (B) and the standard task completion time (A). This indicates the degree of deviation or discrepancy in task performance between users and evaluators and provides insights into user efficiency and potential areas for improvement.
4) **Number of clicks:**The number of clicks performed by the user to complete the task.
5) **Optimal click:**The minimum number of clicks required to accomplish a task efficiently this represents the ideal interaction scenario where users can achieve task objectives with minimal effort.

For effectiveness, the following parameters were calculated:

1) **Number of times asked for help:** Indicates how frequently users need assistance or guidance to complete tasks. A higher number of help requests may indicate difficulty understanding or navigating the interface. This identifies areas of the interface or tasks that users may find unclear or difficult to understand.
2) **Number of attempts/mistakes:** Each attempt or mistake made by the user is recorded to determine the task's difficulty or complexity.
3) **Success rate:** The percentage of successful task completions compared to the total number of attempts. Calculated as the inverse of the number of attempts, it provides a percentage of successful task completions and insight into users' overall effectiveness in completing tasks within the interface or application.

Lastly, for satisfiability post questionnaire was used.

V. RESULT ANALYSIS

The summary table of the evaluation is provided here for each of the parameters.

A. Efficiency

Each of the parameters is discussed below:

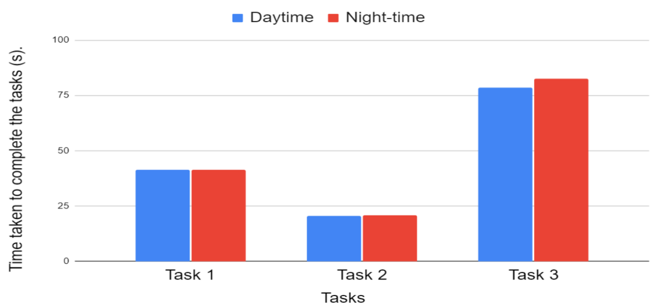

Fig. 4. Time taken (avg) for each of the tasks

1) Time taken to complete the task: : Here in Fig. 4 task 3 takes the most time followed by task 1 then task 2.

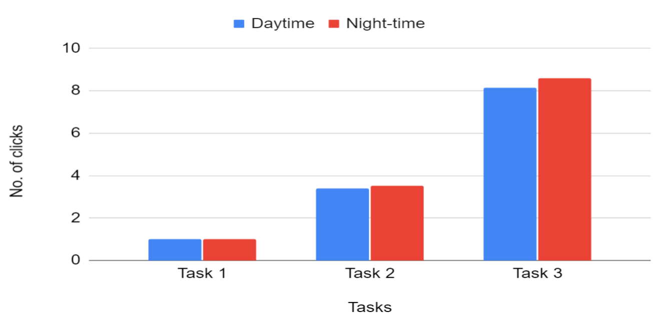

Fig. 5. No. of clicks (avg) for each of the tasks

2) No. of clicks:: Here in Fig. 5 task 3 requires the most number of clicks followed by task 2 and task 1. It can be seen that the number of clicks for the first and the second tasks is the same compared to the usual case.

3) Time Deviation:: This is the difference between the task completion time by the evaluator (B) and the standard task completion time (A). This indicates the degree of deviation or discrepancy in task performance between users and evaluators. Here in Fig. 6 task 3 has the most time deviation followed by

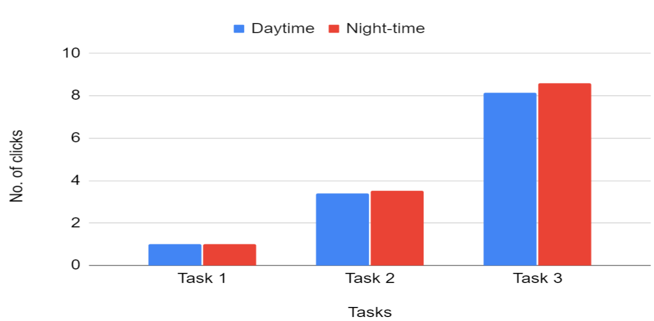

Fig. 6. Time Deviation (avg) for each of the tasks

task 2 and task 1. It can be seen that the number of clicks for the first and the second tasks is the same compared to the usual case.

B. Effectiveness

Additionally, each of the parameters is discussed below:

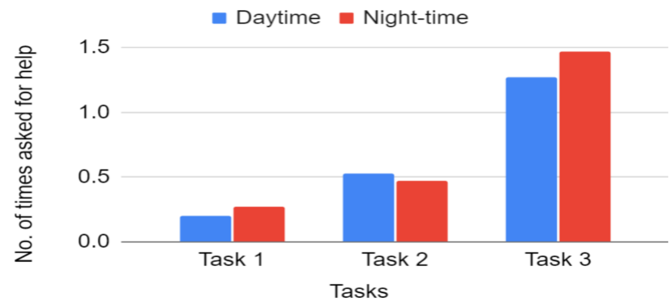

Fig. 7. No. of times asked for help (avg) for each of the tasks

1) No. of times asked for help: : Here in Fig. 7 task 3 requires most help followed by task 2 and task 1.

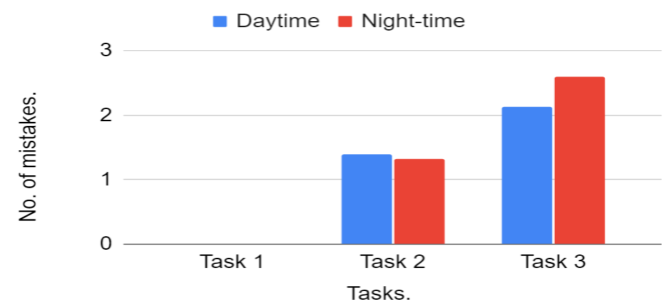

Fig. 8. No. of mistakes (avg) for each of the tasks

2) No. of mistakes: : Here in Fig. 8 task 1 includes no error and task 3 has the most error followed by task2.

Fig. 9. Success Rate (avg) for each of the tasks

3) Success Rate: : Here in Fig. 9 task 1 includes a 100% success rate while task 2 includes the lowest rate of success followed by task 3.

Overall we can see that for each of the parameters, the values for daytime and nighttime are very similar as for most of the other cases they do not work well at nighttime with only screen light and the values for the first two tasks are also adequate.

C. Satisfaction

A post-satisfaction questionnaire was used to measure the efficiency. The outcome of the questionnaire is given below:

1) For a rating out of 5, the average rating is 4 in terms of whether the system enhances comfort, satisfaction, and preference.
2) Around 87% of people feel comfortable with our system.
3) 93% of them state it increases their independence in terms of using the computer.

VI. Future works and conclusion

Future works may include mobile device compatibility, and increasing user accessibility across various platforms. Furthermore, addressing the impact of continuous camera usage on battery life is a top priority for future development. Improvements in click detection accuracy, particularly under varying conditions, are essential for improving user experience. Future research efforts may also concentrate on improving the system for more complex operations and investigating ways to integrate the technology into smartphones to increase user independence and comfort.

Overall, the nose-teeth interaction system has the potential to improve the quality of life for individuals with hand disabilities. It enables them to use digital devices more effortlessly, eliminating all barriers and allowing them to be more independent. With further testing and refinement, this system could become a valuable tool for enhancing the accessibility and inclusivity of digital devices for individuals with disabilities.

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