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HANDS-FREE COMPUTING FOR DISABLED PEOPLE USING COMPUTER VISION

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Abstract

Various hands-free mouse replacement systems have been developed for people having a disability in movement and many improvements have been witnessed during the past three decades. For those with disabilities in the movement who have not yet had a fair chance to use the typical input devices of a personal computer, many authors have put forth replacements for the mouse during the past three decades. The overhead of employing head-mounted devices is decreased in camera-based systems by using the web camera as the mouse. The research problems and opportunities are tracking the user's facial expression of various users with various head poses through the camera and accurately converting into mouse cursor movement and click events. The user's inadvertent head movements cause the present systems to lose the tracked feature, and they are only capable of moving the pointer in a slanting direction. The suggested system employs fuzzy logic in its decision-making to streamline and enhance the effectiveness of managing the cursor and its interactions on Graphical User Interfaces, allowing persons with disabilities to move about and utilise computers with ease. By mapping the mouse cursor movement exclusively with the deliberate head movement and disregarding the natural head motions, the system addresses the issue of feature loss. The technology also accomplishes the cursor's horizontal and vertical movement. The usual GUI interactive features like menus and scroll bars that need horizontal or vertical movement are difficult to operate on the existing systems since they can only move the cursor in a slanting manner. Unintentional head movements by users frequently result in the current system losing track of facial feature tracking. The suggested method uses a standard web camera to capture the three-dimensional head rotation. To shift the mouse pointer vertically, the positions of the nasal bridge and nose tip are collected. The inner corners of the left and right eyes, as well as the tip of the nose, are also used to shift the mouse cursor horizontally. Unintentional head motions are disregarded to prevent the loss of face features, and by using fuzzy logic, the movement of the mouse pointer is only mapped with the intended head movements. The fuzzy control uses the head's rate, direction, and distance as inputs to determine how the mouse pointer will travel. By capturing the stable, purposeful, and sudden movements of the head, respectively, the fuzzy system classifies the movement of the head as weak, fair, or powerful. By removing the weak and strong head motions, the algorithm just maps the fair head movements with cursor movement on the screen. The proposed system has achieved the horizontal and vertical movement of the cursor and the results are significant when compared with the existing system. The system also successfully ignores the slight movement of the head captured by the web camera when the

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user remains the head stable, and the feature loss is completely avoided. The performance metric used here is the accuracy of mouse clicks to evaluate the model.

Keywords: assistive technology; hands-free computing; alternative mouse; camera mouse; face recognition; 3D head movement; disabled users.

1. Introduction

As per the World Report on Disability 2011 by World Health Organization Census, around one billion people are suffering from some type of disability and around 110 million persons have extremely major difficulties in functioning such as quadriplegia [1]. In India, around 2.68 Cr persons are suffering from a disability and around 5.4 million people have a disability in movement [2]. Assistive technology facilitates people with disabilities to enhance productivity and live independently and plays a vital role in accomplishing the equalization of chances for disabled persons [3]. They may utilize hands-free computing significant in their daily lives that can range from using the movement of the head, tongue, lips, or mouth to voice-enabled interfaces utilizing a microphone and speech recognition software or Bluetooth technology [4]. Computer vision can be used in applications that require visual searches by performing detailed image analysis and solving more complex problems such as facial recognition [5]. The method proposed by Paul Viola and Michael Jones [6] is a prevalent approach for real-time face detection that is dependent on Haar features represented by edges and lines that allow capturing important elements in the face such as the mouth or nose. The facial analysis algorithm proposed by Kazemi and Sullivan [7] plays a primary role in the image processing techniques in which the key feature is facial landmarks. Fuzzy logic is a powerful technique that can be implemented in many applications to express values that are uncertain in nature by defining the amount of degree to which an item fits into a particular set [8]. The proposed system enhances the capability of controlling the mouse cursor through the camera-based hands-free computing systems that enable people with disability in the movement to use a standard personal computer by attaining the horizontal and vertical movement of the mouse cursor by capturing the 3D movement of the users' head and mapping the mouse cursor movement only with the intentional head movement of the user by applying fuzzy logic in decision-making.

2. Previous work

Various hands-free mouse replacement systems have been developed and many improvements have been witnessed during the past three decades. Some applications were designed that were used only for limited and specific applications [9]. Few solutions depend on special software and hardware that are specifically designed for people with some form of disability in the movement [10]. Many applications developed for replacing mouse use hardware systems with high-cost [11]. Most of such applications require specially designed hardware to facilitate the motor disabled to use the computer by generally wearing on the head or face [12-26].To condense the burden of using a hardware system with huge cost and holding on to the head, the head motions of the user are captured with a camera for controlling the mouse cursor of the computer [27-41]. Many systems use speech recognition to map the mouse click events as it is a straightforward and user-friendly interface. The current applications facilitate the disabled

users to move the cursor comfortably only in a slanting direction, and so find it difficult to use the common graphical interactive features such as menus and scroll bars that require the cursor to move horizontally or vertically [42-44]. Synchronizing the speed of movement between the mouse cursor and the user's head is very difficult [45-51]. They lose the tracking of facial features when the user unintentionally moves the head [52-53]. They fail to capture the feature due to different illumination [54] [55]. Occlusions, limited head movements, and variant poses are the major problems in tracking facial features [56] [57]. Participants were irritated by slight cursor changes when the cursor entered the target and the participant tried to continue gazing at the target [58]. Several developments need to be made for the head-mounted technology to continue to replace the actual mouse. The eye gaze motions have been monitored through solutions to manipulate the mouse pointer on the screen. To lessen the expense of employing expensive hardware limited options for system and head-mounted gadgets employ web cameras to record user head movements in order to utilize mouse pointer controls like. Naturally, People gaze at the thing they want to do something with. Consequently, little work is done on moving the mouse cursor. Utilizing eye movement to increase effectiveness monitoring the movement of the head and other parts of the head or a situation like [59 - 67].
The research challenges have paved the approach to identify future guidelines for research and development such as moving the cursor horizontally or vertically, synchronizing the mouse cursor with the head movement, avoiding feature loss, and overcoming the limitation of environment control.

3. Methodology

Fuzzy logic is used in the proposed system's decision-making to simplify and increase the effectiveness of controlling the cursor and its interactions on graphical user interfaces, allowing "mobility-impaired" individuals—those who are unable to move the mouse or any pointing device—to use computers conveniently and easily. The head movement takes the place of mouse movements, and the camera records eye blinks. The mouse cursor is moved by head movement, left eye blinks in place of left mouse clicks, and right eye blinks in place of right mouse clicks. The suggested system's initial function is to take a picture of the user's nose. The distance, direction, and rate of head movement all contribute to the fuzzy input variations for head movement detection, whereas period and interval only contribute to the fuzzy input variations for nose direction. The cursor movement and mouse clicks will be affected by the fuzzy logic we employ to integrate the aforementioned input variations. Head and nasal movements can be predictable and unexpected.

3.1 The Region of Interest (ROI)

The proposed system uses a web camera to record the video sequences of the user's head movement. Though the web camera captures the sequence of images in two-dimensional, the proposed system calculates the users' head movement in three-dimensional. To detect the face region, the system uses the algorithm designed by Viola and Jones [6] known as the Haar Cascade object detection algorithm using OpenCV. To estimate the Region of Interest (ROI), the proposed system uses the algorithm designed by Kazemi and Sullivan [7] known as a pretrained facial landmark detector using DLib built-in library. The Inner-left-eye-corner, the Inner-right-eye-corner, the Nose-bridge, and the Nose-tip are the proposed system's ROIs.

3.2 Fuzzy logic for mapping intentional head movement

To avoid the loss of facial features, the proposed system ignores unintentional head movements and maps the movement of the mouse cursor only with the intentional movements of the head by applying fuzzy logic. Tracking the movement of users' heads is an imprecise computational task where the tolerance for imprecision has to be exploited for choosing the best outcomes and making complex decisions by applying soft computing techniques. Head movement is a physiological occurrence of imprecision and so fuzzy logic can be applied to make a computer resolve the direction, the distance, and the rate of movement of the head [68]. The fuzzy control system takes the 'Distance', 'Direction', and 'Rate' of the head movements as inputs for controlling the mouse cursor movement.

3.3 ‘Distance’ of head movement

3.3.1 Capturing the 3D vertical movement of the head

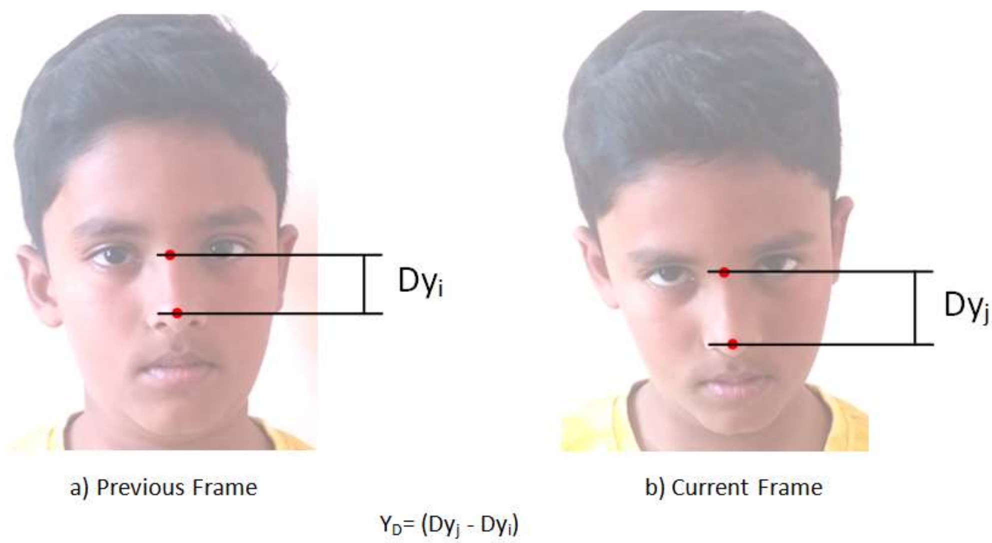


Fig. 1. Capturing the vertical distance of the head movement.

Capturing the user's head's vertical movement in three-dimensional is achieved by extracting the nose bridge and nose-tip points from the facial landmark. The mouse cursor's movement in the vertical direction is achieved when the user lifts and bends the head in the vertical direction. The distance between the nose-bridge and nose-tip points increases when the user bends the head down. The distance in head movement is captured and that determines the distance of the mouse cursor movement in the vertical direction towards the bottom. Similarly, the distance between the nose-bridge and nose-tip points decreases when the user lifts the head up. The distance in head movement is captured and that determines the distance of the mouse cursor movement in the vertical direction upwards. When the user lifts the head upwards, the distance between the nose bridge and the nose tip will be gradually decreasing when captured by the camera, facing the user. Similarly, when the user bows the head downwards, the distance between the nose bridge and the nose tip will be gradually increasing when captured by the camera. The distance of the head movement in the vertical direction, YD, is the difference in the distance between the nose bridge and the nose tip captured by the previous frame and the current frame as shown in Fig. 1.

3.3.2 Capturing the 3D horizontal movement of the head

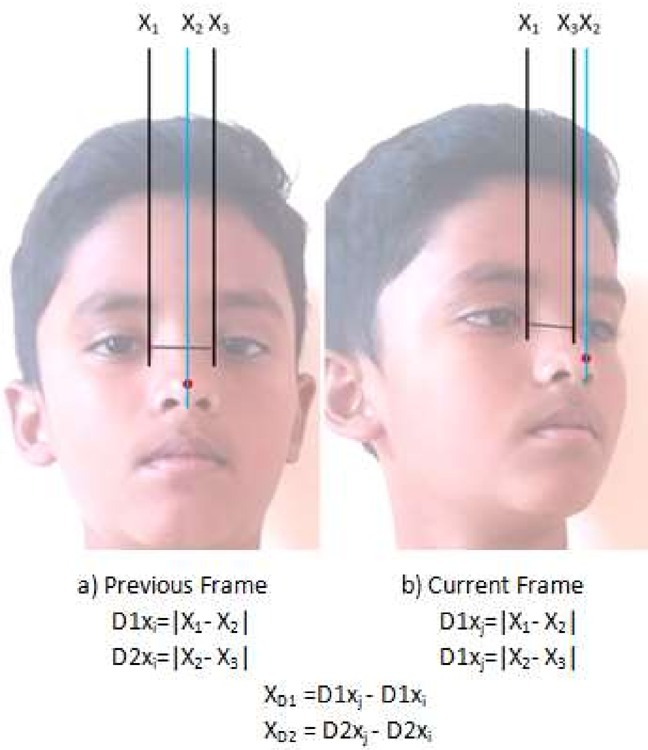


Fig. 2. Capturing the horizontal distance of the head movement.

Capturing the user's head's horizontal movement in three-dimensional is achieved by extracting the inner-left-eye-corner, nose-tip, and inner-right-eye-corner points from the facial landmark. The mouse cursor's movement in the horizontal direction is achieved when the user turns the head left or right in the horizontal direction. The distance between the nose-tip and inner-right-eye-corner point's increases and the distance between the inner-left-eye-corner and nose-tip points decreases when the user turns the head left. The distance in head movement is captured and that determines the distance of the mouse cursor movement in the horizontal direction towards the left. Similarly, the distance between the nose-tip and inner-right-eye-corner points decreases, and the distance between the inner-left-eye-corner and nose-tip points increase when the user turns the head right. The distance in head movement is captured and that determines the distance of the mouse cursor movement in the horizontal direction towards the right. The distance of the head movement in the horizontal direction is (XD1, XD2), where XD1 is the difference in the distance between the inner left eye corner and the nose tip captured by the previous frame and the current frame and XD2 is the difference in the distance between the nose tip and the inner right eye corner captured by the previous frame and the current frame and shown in Fig. 2.

3.4 'Direction' of the head movement

If the value of Y_D is negative, then the direction of the head movement is 'north' and the direction is 'south', if positive. Similarly, if the value of X_{D1} is negative or the value of X_{D2} is positive, then the direction is 'west' and the direction is 'east' for a positive X_{D1} value or negative X_{D2} value.

Table 1: Direction vs Distance of the head movement.

Direction	**Distance**		
	Y_D	**X_{D1}**	**X_{D2}**
Null	Null	null	Null
North	Negative	null	Null
South	Positive	null	Null
West	Null	negative	positive
East	Null	positive	negative
north-east	Negative	positive	negative
north-west	Negative	negative	positive
south-east	Positive	positive	negative
south-west	Negative	negative	positive

The combinations of values of YD and XD1 or XD2 are denoted as any one of the directions: southeast, northeast, southwest, or northwest. Otherwise, the Direction is 'null' as shown in Table 1.

3.5 'Rate' of the head movement

If the value of ($|Y_D|$, $|X_{D1}|$, $|X_{D2}|$) is below the minimum threshold, then the rate of head movement is 'low'. Similarly, the rate is 'high' when the value is above the maximum threshold and otherwise, 'moderate'.

3.6 Fuzzification

The fuzzy system uses the following linguistic variables: *Variation_x, Variation_y, Strength,* and *Output*. These linguistic variables use the following set of decompositions where each member is known as the linguistic term.

Variation_x = {Null, Positive, Negative}

Variation_y = {Null, Positive, Negative}

Strength = {Weak, Fair, Strong}

Output = {Null, Fair_N, Fair_S, Fair_W, Fair_E, Fair_NE, Fair_NW, Fair_SE, Fair_SW}

The relationships among *Variation_x, Variation_y* and *Direction* are shown in Table 2, where *Variation_x, Variation_y* are the linguistic variables, and *Direction* is the input generated from the head movement.

Table 2: Variation vs Direction of the head movement in x and y axes.

Variation_x	**Variation_y**	**Direction**
Null	Null	Null
Null	Negative	North
Null	Positive	South
Negative	Null	West
Positive	Null	East
Positive	Negative	north-east
Negative	Negative	north-west
Positive	Positive	south-east
Negative	Positive	south-west

The value of *Strength* is based on *Rate* as shown in Table 3, where *Strength* is the linguistic variable and *Rate* is the input generated from the head movement.

Table 3: Strength vs. Rate of the head movement.

Rate		**Strength**
x-axis	**y-axis**	
low	Weak	low
low	Fair	moderate
low	Strong	high
moderate	Fair	low

moderate	Fair	moderate
moderate	Strong	high
high	Strong	low
high	Strong	moderate
high	Strong	high

The linguistic terms of the linguistic variable ‘Strength’ give the following denotations:

- ‘Weak’: denotes the head is stable, but the camera has captured slight movement.
- ‘Fair’: denotes the intentional head movement; the user has moved the head intentionally to move the cursor in the window screen.
- ‘Strong’: denotes the sudden movement of the head; the user’s casual head movement such as turning back, and bending head to pick something.

The linguistic terms of the linguistic variable ‘Output’ are set as shown in Table 4. The linguistic term ‘Null’ of the linguistic variable ‘Output’ assures that the user’s head movement is not intentional.

Table 4: Output vs. Strength and Direction of the head movement.

Strength	**Direction**	**Output**
Weak	-	Null
Strong	-	Null
Fair	Null	Null
Fair	North	Fair_N
Fair	South	Fair_S
Fair	West	Fair_W
Fair	East	Fair_E
Fair	North-East	Fair_NE
Fair	North-West	Fair_NW
Fair	South-East	Fair_SE
Fair	South-West	Fair_SW

3.7 Defuzzification

Table 5: Output vs Defuzzification variables.

Output	**A**	**B**
Fair_N	0	$-\|Y_D\|$
Fair_S	0	$\|Y_D\|$

Fair_W	-(max(|X_{D1}|, |X_{D2}|))	0
Fair_E	max(|X_{D1}|, |X_{D2}|)	0
Fair_NE	max(|X_{D1}|, |X_{D2}|)	-|Y_D|
Fair_NW	-(max(|X_{D1}|, |X_{D2}|))	-|Y_D|
Fair_SE	max(|X_{D1}|, |X_{D2}|)	|Y_D|
Fair_SW	-(max(|X_{D1}|, |X_{D2}|))	|Y_D|

The defuzzification for *Output*, the linguistic variable is set as below:
IF Output = Null, THEN
Current_Cursor_Position (X_c, Y_c) = *Previous_Cursor_Position* (X_p, Y_p) *;*
ELSE
Current_Cursor_Position (X_c, Y_c) =
Previous_Cursor_Position $(X_p + A*nx, Y_p + B*ny)$ *;*

The values of the variables A and B are shown in Table 5, which are based on the value of the linguistic variable ‘Output’. ‘nx’ and ‘ny’ are the factors that determine the rate of the cursor movement in the window pertaining to the rate of the intentional head movement.

4. Results and Discussion

The laptop computer's configuration for testing the system is as follows:
- 2.10 GHz Intel Pentium CPU B950 with 2 GB of RAM
- 1366 x 768 screen resolution with landscape orientation
- Windows 7 Professional 32-bit operating system
- Logitech C170 webcam
- OpenCV 2.1.0

4.1 Attaining the horizontal movement of the mouse cursor

The horizontal movement of the head, i.e., turning the head left or right, controls the movement of the mouse cursor in the horizontal direction. To attain the horizontal movement of the mouse cursor, the cursor’s vertical movement should be minimum. The attainment of the cursor’s horizontal movement is measured by capturing the variation in the vertical direction in the consecutive frames. The experiment is done with the 10 users intentionally moving the cursor in the horizontal direction from the left end to the right end of the screen. The initial variation is chosen eliminating the negligible variations in the beginning. The vertical variation in the *i*th frame for user *k* is $Y_{ki} – Y_{k0}$, where (X_{k0}, Y_{k0}) is the cursor position in the initial frame for user k and (X_{ki}, Y_{ki}) is the *c*ursor position in the *i*th frame for user *k*.

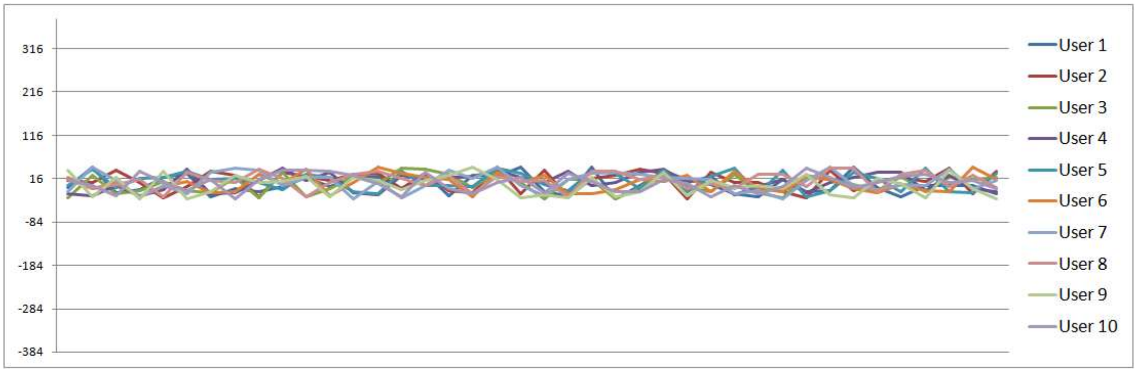


Fig. 3. Vertical variations of the cursor during horizontal move in the proposed 3D method.

Fig. 3 shows the graph of the variation in pixels in the vertical direction in the successive frames when the experiment is done with the proposed method of capturing the head rotation in three-dimensional for mouse cursor movement. For n users and m frames, the lower limit is calculated as $\min_{\substack{1\le k\le n\\1\le i\le m}}(Y_{ki}-Y_{k0})$ and the upper limit as $\max_{\substack{1\le k\le n\\1\le i\le m}}(Y_{ki}-Y_{k0})$.The upper and lower limit of the variations in pixels is found as 42 and -31 pixels on average with the 3D method. When the experiment is done with the existing method of capturing the two-dimensional head rotation, the upper and lower limit of the variations in pixels is found as 87 and -76 pixels on average as shown in Fig. 4.

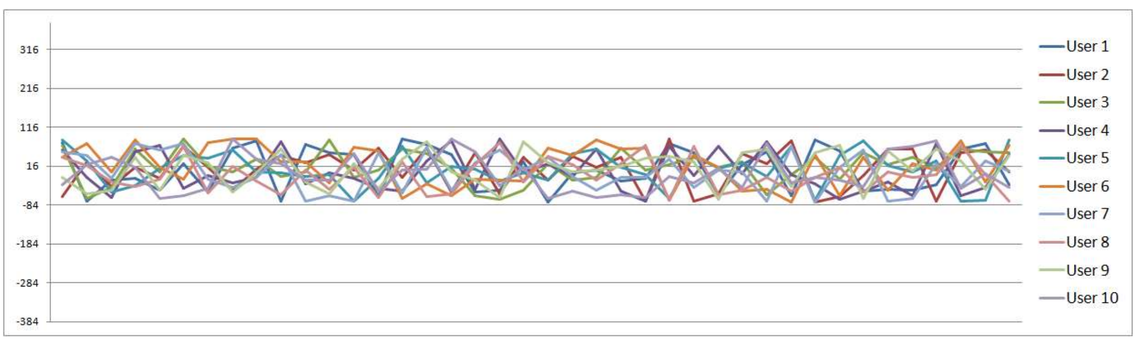


Fig. 4. Vertical variations of the cursor during horizontal move in the existing 2D method.

With the tolerance of T_p pixels of variation, the success rate of moving the mouse cursor in the horizontal direction is calculated as

$$SR=\frac{SC}{m.n}$$

where, SC is the success count that is calculated as

$$SC=\sum_{j=1}^{m.n}\left(1_{[S_j=1]}\right)$$

where S_j is the success array that takes the following values.

$$S_j=\begin{cases}1, & if\ (Y_{ki}-Y_{k0})\le T_p\\0, & Otherwise\end{cases},1\le j\le m.n,1\le k\le n,1\le i\le m$$

Table 6: Attainment of horizontal cursor movement

Variations in pixels				Tolerance	Success rate		
Lower limit		Upper limit					
Existing system	Proposed system	Existing system	Proposed system	±30 pixels of variation	Existing system	Proposed system	Improvement
-76	-31	87	42		37%	82%	71.4%

Table 6 shows the attainment of horizontal movement where the data captured in the proposed 3D method is compared with the existing 2D method. With the tolerance of ±30 pixels of variation, the achieved success rate of moving the mouse cursor is 82% in the horizontal direction when capturing the head in three dimensional, comparing to 37% in the horizontal direction when capturing the head in two dimensional. The improvement in the success rate of moving the mouse cursor in the horizontal direction is calculated as $\frac{(SR_P - SR_E)}{1 - SR_E} \times 100$, where $SR_P$and $SR_E$are the success rates of the proposed and existing system. In the above scenario, the improvement in the success rate of moving the mouse cursor in the horizontal direction is *71.4%*.

4.2 Attaining the vertical movement of the mouse cursor

The vertical movement of the head, i.e., lifting up or bending down the head, controls the movement of the mouse cursor in the vertical direction. To attain the vertical movement of the mouse cursor, the cursor's horizontal movement should be minimum. The attainment of the cursor's vertical movement is measured by capturing the variation in the horizontal direction in the consecutive frames. The experiment is done with the same 10 users intentionally moving the cursor in the vertical direction from the top to the bottom end of the screen by choosing the initial variation eliminating the negligible variations in the beginning. The horizontal variation in the *i*th frame for user *k* is $X_{ki} - X_{k0}$.

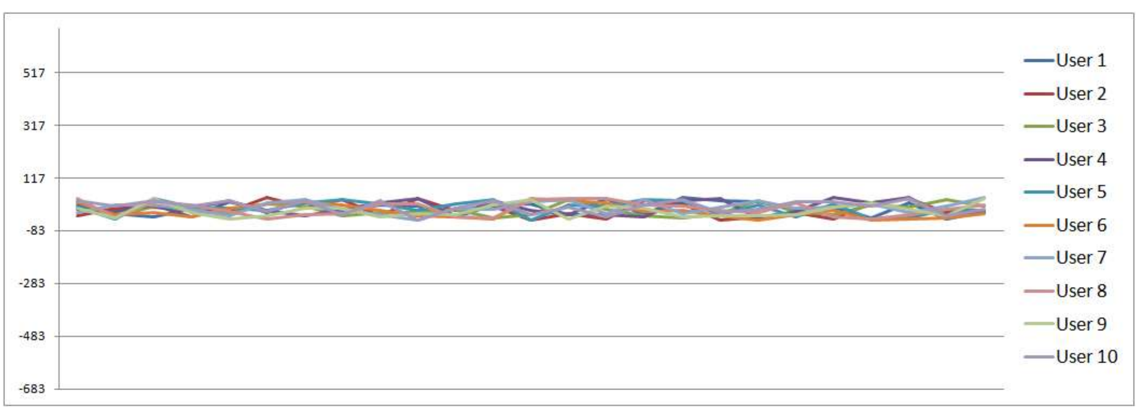


Fig. 5. Horizontal variations of the cursor during vertical move in the proposed 3D method.

Fig. 5. shows the graph of the variation in pixels in the horizontal direction in the successive

frames when the experiment is done with the proposed 3D method. For n users and m frames, the lower limit is calculated as $\min_{\substack{1\le k\le n \\ 1\le i\le m}} (X_{ki} - X_{k0})$ and the upper limit as $\max_{\substack{1\le k\le n \\ 1\le i\le m}} (X_{ki} - X_{k0})$.The upper and lower limit of the variations in pixels is found as 41 and -43 pixels on average with the 3D method. When the experiment is done with the existing 2D method, the upper and lower limit of the variations in pixels is found as 101 and -92 pixels on average as shown in Fig. 6.

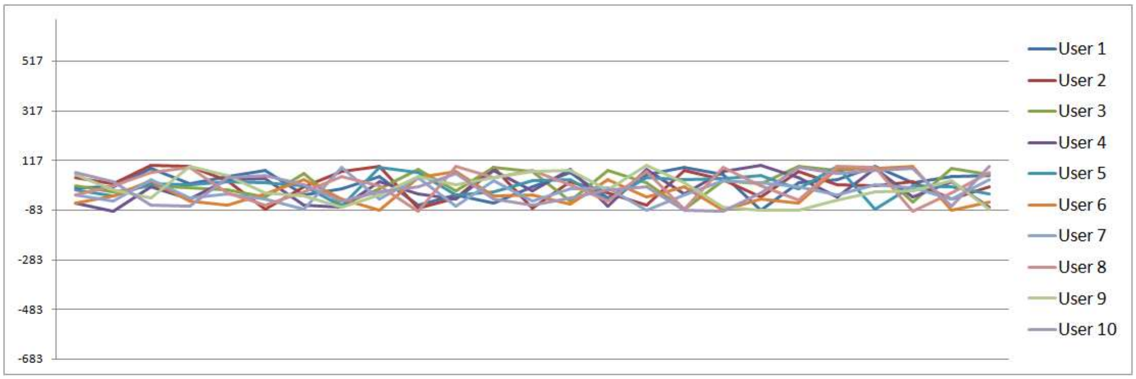


Fig. 6. Horizontal variations of the cursor during vertical move in the existing 2D method.

The success rate of moving the mouse cursor in the vertical direction is calculated based on the following success array.

$$S_j = \begin{cases} 1, & if\ (X_{ki} - X_{k0}) \le T_p \\ 0, & Otherwise \end{cases}, 1 \le j \le m.n, 1 \le k \le n, 1 \le i \le m$$

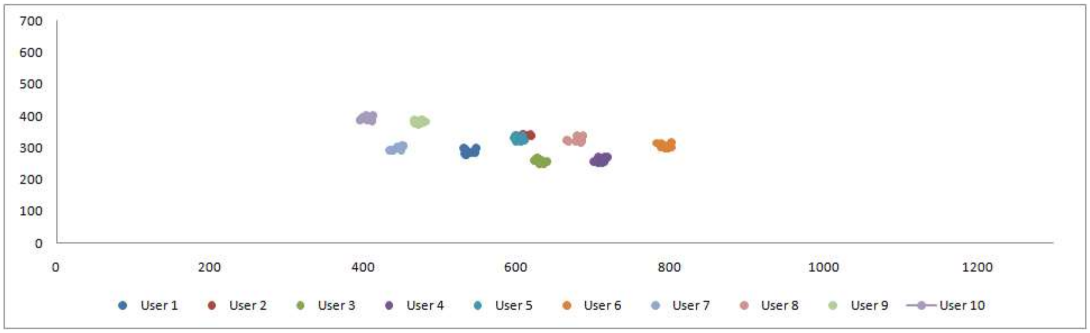
Table 7: Attainment of vertical cursor movement

Variations in pixels				Tolerance	Success rate		
Lower limit		Upper limit					
Existing system	Proposed system	Existing system	Proposed system	±30 pixels of variation	Existing system	Proposed system	Improvement
-92	-43	101	41		31%	71%	58%

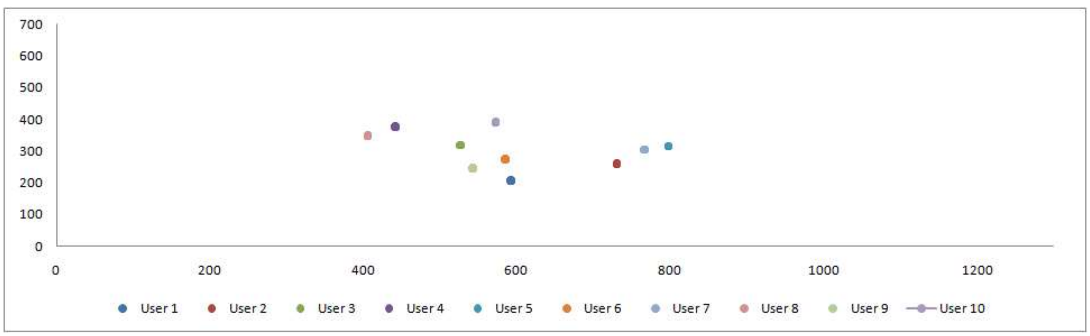
Table 7 shows the attainment of vertical movement where the data captured in the proposed 3D method is compared with the existing 2D method. With the tolerance of ±30 pixels of variation, the achieved success rate of moving the mouse cursor is 71% in the vertical direction when capturing the head in three dimensional, compared to 37% in the vertical direction when capturing the head in two dimensional. The improvement in the rate of success of moving the mouse cursor in the vertical direction is 58%.

4.1 Ignoring tiny variations captured while holding the head stable

The web camera captures the slight movement of the user's head even though the user remains his head stable. The system ignores the slight movement by fixing the minimum threshold when the user remains his head stable. The system is tested before and after applying fuzzy logic with 10 users by asking them to face the web camera by holding their heads stable without moving.



(a)



(b)

Fig. 7. Cursor movement when the head remains stable (a) before and (b) after applying 3D head capturing and fuzzy logic.

Fig. 7(a) shows the result before applying the 3D head capture and fuzzy logic where the system captures the slight movement of the head even though the user remains his head stable and the same is reflected in the cursor movement in the computer window screen. Whereas, the Fig. 7(b) shows the result after applying the 3D head capture and fuzzy logic where the system ignores the slight movement of the head captured by the web camera when the user remains his head stable; the mouse cursor movement retains the position with no change in the screen.

4.2 Addressing feature loss

Unintentional head moves of the users often lead the current system to lose the tracking of facial features. The system ignores the sudden unintentional head movement of the user such as turning back and bending the head to pick something, by fixing the maximum threshold. The system is tested before and after applying fuzzy logic with 10 users by asking them to move the head to and fro all four directions as shown in Fig. 8 within 5 seconds. The user has to move the head fast to complete this task within 5 seconds.

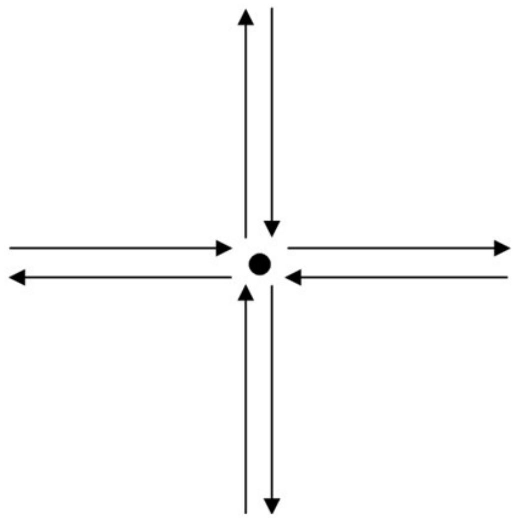
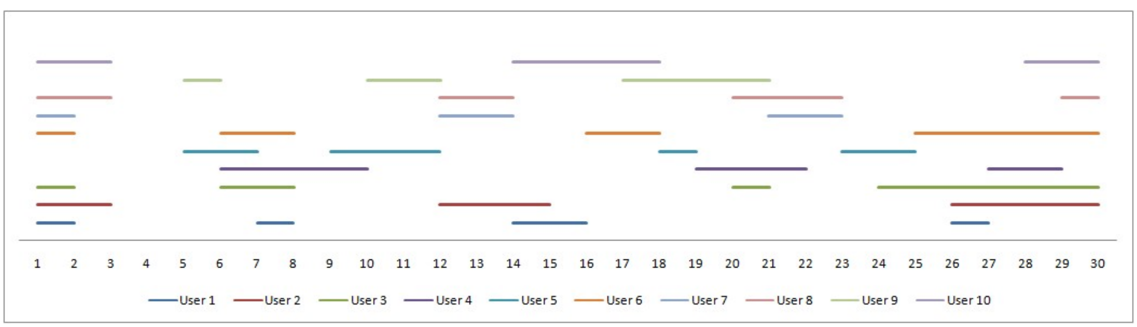
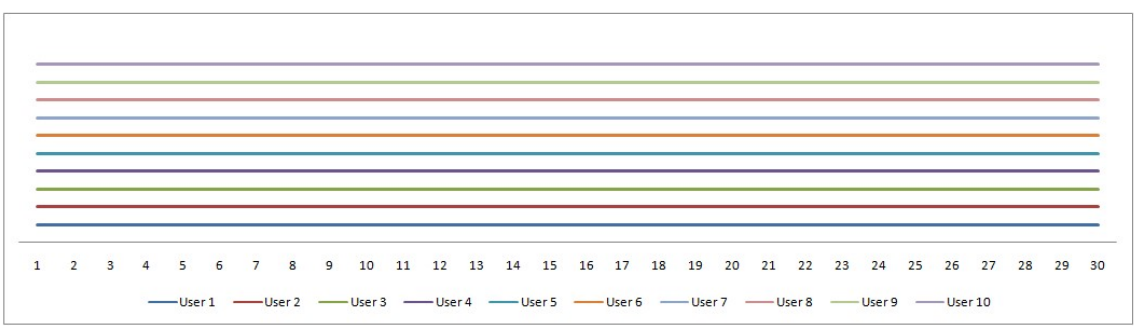


Fig. 8. The direction of the head movement to test feature loss.

The success rate of attainment of avoiding feature loss is 37.7% as shown in Fig. 9(a) which shows the result before applying the 3D head capture and fuzzy logic where the system often fails to capture the head of the user moves fast or the head moves out of the window frame. The lines in the figure show the capturing of the head by the camera while the blank area denotes the missing head in the respective frames shown on the horizontal axis.



(a)



(b)

Fig. 9. Result of testing feature loss (a) before and (b) after applying 3D head capturing and fuzzy logic.

The success rate of attainment of avoiding feature loss after applying the 3D head capture and fuzzy logic is 100% as shown in Fig. 9(b) where the system ignores the sudden unintentional movement of the head. The rate of the head movement captured by the web camera during the sudden unintentional movement of the user falls beyond the maximum threshold. The system retains the mouse cursor position on the screen ignoring the sudden unintentional movement of the head; hence no feature loss.

The success rate of tracking the facial feature in various researches is compared and shown in Table 8.

Table 8: Comparison of the success rate of tracking the facial feature

Kim et al. [69]		Silwal et al. [70]	Wang et al. [71]	Rahib et al. [72]		Proposed Fuzzy-3D Method
Slow films	Fast videos			Head	Eye blink	
97.98%	91.58%	94.37%	>90%	98.12%	93.48%	100%

Kim et al. [69] used KLT and SegNet landmark detectors to obtain 97.98 % for slow films and 91.58 %for fast videos in tracking face landmarks. Silwal et al. [70] used a Convolutional Neural Network with a Softmax classifier to improve the accuracy of facial recognition by 94.37 %. When the moving speed is no more than 20 pixels per action, Wang et al. [71] found that the accuracy of controlling the mouse cursor is greater than 90 %. For the head and eye blink classifications, Rahib et al. [72] attained accuracies of 98.12 %and 93.48 %, respectively.

5. Conclusion

The advantage of mouse GUI operations for people with movement disabilities is the main topic of this article. The use of web cameras is recommended as an alternative to expensive head-mounted devices and expensive hardware systems. The head movement is a biological phenomenon of fuzziness, thus the system used fuzzy logic in its decision-making to identify the distance, direction, and rate of head movement. This increased the efficiency of operating the mouse. The suitable criteria were established to reject both predicted and unexpected head motions. To use the standard GUI interactive capabilities, the mouse pointer must be able to travel both horizontally and vertically.

This research has focused on enhancing the efficiency of controlling the mouse cursor in the hands-free computing system. Though the web camera captures the sequence of images in two-dimensional, the proposed system calculates the users' head movement in three-dimensional to achieve the horizontal and vertical movement of the cursor. To avoid the loss of facial features, the unintentional head movements are ignored and the movement of the mouse cursor is mapped only with the intentional movements of the head by applying fuzzy logic. The results of achieving the horizontal and vertical movement of the cursor are significant when compared with the existing system. The system successfully ignores the slight movement of the head captured by the web camera when the user remains the head stable, and the feature loss is completely avoided. However, the system can be improved in terms of accuracy and speed by detecting the face by using deep learning-based approaches.

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