Augmentative and Alternative Communication Device Based on Head Movement to Aid Paralyzed Victims with Speech Disabilities

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Abstract

Augmentative and Alternative Communication (AAC) devices have been proven to be as an alternative to help people, who are having communication difficulties. In this paper, high tech AAC device focusing on paralyzed victims or other motor disabilities which allow them to control with their head gestures is proposed. The proposed system consists of a mobile app, a controller and a head tracker. Easy to familiar with and less material cost are some of the key advantages of this device.

Keywords: Augmentative and Alternative Communication, AAC Device, Head Gestures, Speech Disabled

1. Introduction

Technological breakthrough improves day-to-day life, and it gives new opportunities to people with special needs. Augmentative and Alternative Communication (AAC) device is the best example which enhances the quality of life of people who are unable to use verbal speech to communicate. Communication methods used in AAC devices vary from paper and pencil boards to digital speech-generating devices. Eye gaze technology which enables the use of eye movements to operate a device and head pointing/tracking technology which is used to operate a device and does a major role in high tech AAC devices. However, such eye gaze and head pointing communication devices which are available today are not convenient enough to afford by the majority. This paper suggests an AAC device, operated using patient's head gestures and further prioritizing its cost factor for increased affordability.

2. Literature Review

2.1 AAC devices related work

There are a significant amount of researches have been done on AAC devices considering different interaction techniques between patient and the device. Those include mainly, designs based on eye blink detection [1], lip contour detection [2], Brain-Computer Interface (BCI) and EEG based approaches [3] and research based on breathing signal patterns as the main communication medium between the user and the device [4]. The Eye blink detection method uses an IR sensor to detect blinks. However, directing IR to an opened eye for long run may lead to cause health issues [5] and further such systems have been identified as less reliable on different environmental conditions where the IR in outdoor [6] and image recognition for identifying lip movements in dark environments. Some mobility-related issues have been identified under the implementation of BCI and EEG signal based AAC devices as it is more often composed of a separate computer apart from simple Single Board Computers (SBC), in order to carry out complex computations. Since the breathing pattern changes, based on different factors such as emotions, body temperature, diseases suffering from [7], there is a possibility to have unpredictable outputs by adopting breathing signal-based approaches for patient-device interaction.

In order to use most of the above products, the user has to convert his/her message to Morse code using the interaction technique. Then the device captures the Morse code, decrypt and convert it to voice output. So in order to use those devices, knowledge on Morse code is essential.

2.2 Research and commercial products based on head trackers

Many head trackers in the market are allowed the user to move the cursor via head movements. Most of them are not cost effective and such systems more often incorporated with optical sensors or IR cameras to detect head movements. While many systems have extra buttons to get user inputs, most of them have Dwell selection software which in most cases sold separately. Difficulties on the initial adaptation of very young age children and people with cognitive impairment on such systems as well as immediate recognition of the cursor process generally tend to dissatisfactions [8]. Further, it may cause pain with extended use. Several types of research have been carried out on developing systems based on capturing head movements using an accelerometer sensor. The accelerometer sensor which is integrated with such systems detects the head movements of the user reliably and further it is used to control a wheelchair as per the user preferences [9]. Rushikesh T. Bankar has developed a Head Gesture Recognition System using Field-Programmable Gate Array (FPGA) based on a Smart Camera. It is a vision-based gesture recognition system [10].

3. Methodology

The proposed AAC system composed of a Bluetooth enabled controller, head tracker and mobile app.

3.1 Mobile app

The app is an AAC app which can be controlled using head gestures. In order to be controlled via head gestures, the phone needs to connect with the controller through Bluetooth. The app provides 3 screens,

About Screen – This is the screen where Bluetooth settings appear.

Command Screen – Set of core vocabularies, which contain some verbs, pronouns and adjectives. There are 24 words act as touchable buttons and the words are highlight one by one. User has to perform a particular head gesture when the word that user expected to express is highlighted. Then it generates a voice output for the selected items respectively.

Type Screen – This screen allows the user to type sentences/phrases. It contains numbers from 0-9 and the English alphabet, including Space and Delete button as touchable buttons. As same as the Command Screen, the buttons will highlight, one by one and user should perform a particular head gesture when the button that user expected to express is highlighted. Then it will display on the screen.

Initially, the phone's Bluetooth needs to be turned on, then the user has to open the app and click "Connect the Controller" button. After the controller connected successfully with the phone, the app informs the user via a voice message that the phone is connected to the controller successfully. Then the calibration process starts. In the calibration process the application finds the easiest and most suitable two head gestures for the user according to each user's motor ability.

One gesture for selecting the button which is highlighted and another gesture for moving within the screens (About/Command/Type). Then the variation in the angle of inclination in x, y and z in each defined head gesture is analyzed. When a user does a head gesture, the controller compares the head gesture's angles of inclination in x, y and z variation with predefined head gestures' variations and proceed according to matched predefined head gestures.

Fig 1. Selecting loop in Command Screen

3.1.1 Limiting head movements

In order to reduce head movements, the following features were introduced in the app.

Autocomplete in Type screen - When the user starts typing a word, word suggestions are appearing on the top of the screen. Maximum 3 words are set to appear on the screen. Suggested words are stored in the app.

Dynamic Reordering in Command Screen – All the commands in the command screen are dynamically reordered by their usage. (most clicked commands appear on the top left side)

Text Predicting in Type Screen – When the user starts typing, a suggested sentence is displaying on the screen. The sentence is suggested by a machine learning model which is developed using LSTM recurrent neural network. All the sentences typed by the user are stored in a database and they are used to train the machine learning model.

3.2 Bluetooth enabled controller

The controller composed of a microcontroller (Arduino UNO), a Bluetooth module (HC-05) and a 16*2 LCD Display (LCM1602 IIC V1). The LCD display provides instructions to the user about the calibration instructions.

3.3 Head tracker

The head tracker consists of an accelerometer and gyroscope sensor module (MPU6050) which contains both 3-Axis accelerometer and 3-Axis gyroscope and it acquires the inclination of the current position of the head tracker unit based on its reference X, Y and Z axes. In order to get more accurate values, the acquisition process followed by complementary filtering is used.

3.4 Process

User can give 4 types of commands using predefined head gestures.

Table 1. Commands sent by the controller according to user behaviour

User's Expectations	Command send by Controller to the phone
Go to about Screen	1
Go to Command Screen	2
Go to Type Screen	3
Select a Command/Letter	4

When the user needs to select a Command/Button he/she needs to do a particular head movement defined in the calibration process. Then the controller sends "4" to the phone via Bluetooth. After the app read the value "4", it outputs the respective text assigned selected button.

When the user does the head movement for navigating which is defined in the calibration process the controller send "1" to the phone via Bluetooth. When the user again does the above movement, the controller sends "2", "3" respectively.

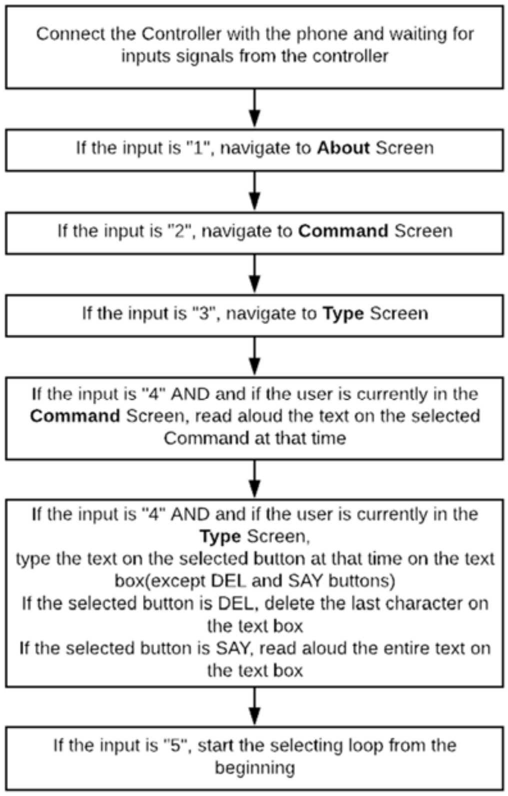

Fig 2. Entire flow in a Flow Diagram

4. Experiment and Results

The objective of the experiment is to determine the accuracy of the proposed system. Hence the test was made for healthy individuals. 8 healthy subjects were volunteered for the test including 6 male subjects and 2 female subjects.

Initially, test subjects were instructed to proceed with some random commands based on their preference and after that they were directed with 15 pre-selected commands using head gestures. Results based such commands mentioned earlier were evaluated based on its accuracy of achieving the exact output.

Table 2. Scores and Success rate for each individual who participated in the experiment

Subject	Score	Success Rate (%)
A	15	100
B	14	93.33
C	13	86.67
D	14	93.33
E	15	100
F	15	100
G	13	86.67
H	14	93.33
Avg. Success Rate		**94.16**

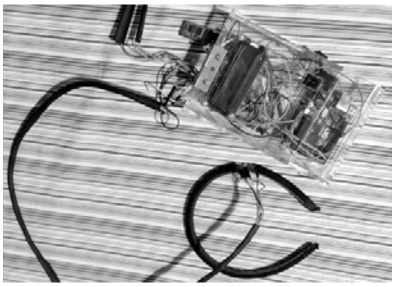

Fig. 3. Image of Controller and Head Tracker

5. Discussion

The proposed system was able to achieve average 94.14% success rate in the testing. Compare to other devices, this system gets a lower time for calibration and understanding the system. It took an average less than 15 minutes for each test user to familiarize with the system inclusive with the initial calibration process. With the high success rate of 94.16% the system can be applied to paralyzed individuals.

6. Conclusion

In this paper, the authors proposed an AAC system which cost less material cost and can be controlled using head gestures. During the testing process it was identified that, compared to many other devices, it takes considerably less time period for the user to become familiarized with the proposed head tracking system. All people selected bowing their heads as one of the gestures. In the experiment, the combination of multiple sensory outputs was suggested in order to get more accurate result. Future research will be focused on integrating other aid devices such as wheelchair controllers with the controller and working on the above-suggested idea.

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