A Natural Hand Gesture and EYE Movement System for Intelligent HCI and Medical Assistance

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Abstract: ***This paper intends to explain various gesture recognition methods that are employed in wheelchair used for navigation and that is affordable by the people in developing nations. The need for assistive navigation technologies for elderly has increased due to the modern life style and nuclear family. Moreover navigation using a manually operated wheelchair, which is common in use, is difficult for people with arms or hand impairments. The technology must enable the user to gain a level of independence at least in day to day activities. In this technique we are going to implement the two methods that is hand gesture and improved eyeball control systemcombinally for better implementation.***

Keywords: Hand Gesture, Eye ball movement, HCI

1. Introduction

In this paper, a novel hand gesture system is developed the intelligent wheelchair control. The hand gesture vocabulary consists of five key hand postures and three compound states, and has the advantages of the minimal and motions, users' distraction detection and human-based artery. The rest of the paper is organized as follows. Section 2 presents the designed hand gesture vocabulary employed in the system and its users' reports. Section 3 howls our hand gesture platform. Experimental results are even in section 4.

Hand gesture recognition based man-machine interface is being developed vigorously in recent years. Due to the effect of lighting and complex background, most visual hand gesture recognition systems work only under restricted environment. An adaptive skin color model based on face detection is utilized to detect skin color regions like hands. To classify the dynamic hand gestures, we developed a simple and fast motion history image based method. Four groups of haar-like directional patterns were trained for the up, down, left, and right hand gestures classifiers. Together with fist hand and waving hand gestures, there were totally six hand gestures defined. In general, it is suitable to control most home appliances. Five persons doing 250 hand gestures at near, medium, and far distances in front of the web camera were tested. Experimental results show that the accuracy is 94.1% in average and the processing time is 3.81 ms per frame. These demonstrated the feasibility of the proposed system. In recent years, computer vision based hand gestures recognition as input for man-machine interface is being developed vigorously. The most advantage of these techniques is that user can control devices without touching anything such as panel, keyboard, mouse, or remote controller. User just needs to face the camera and raise his/her hands for operation control. Hand gestures recognition systems make people having high degree of freedom and intuitive feelings. The objective of this paper is to develop a real time hand gesture recognition system based on adaptive skin color model and motion history image (MHI). By adaptive skin color model, the effects from lighting, environment, and camera can be greatly reduced, and the robustness of hand gesture recognition could be greatly improved. We defined six hand gestures which are natural and no training is required before using. By defining four groups of Haar-like patterns, we could distinguish the four directional hand gestures effectively by statistical method. In additional, fist hand and waving hand are detected by checking a region of interest besides face. Fist hand is detected by the other Haar-like feature and waving hand is detected by checking the amount of motion within that specified region. This paper is organized as follows. Section 2 gives some related researches in hand gesture recognition. Section 3 presents the detail of our method which is divided into two parts, one is face based adaptive skin color model and the other is motion history images (MHI) based direction detection of moving hand. Section 4 describes the experimental results. Finally, we make conclusions and give future works in the last section.

2. Common Wheelchair Navigational Methods

2.1 Joystick Based Control Navigation and Acronyms

This method uses joystick as the primary interface between the user and the wheelchair. Using joystick, one can manually control the wheelchair. Here the user has to press and hold the buttons provided on the joystick to move to the desired direction. The movement is achieved by controlling the electric motors attached to the wheel according to the button pressed on the joystick. This technique makes the user more autonomous than wheelchair which uses physical power to move. To be able to use this, the user must have some motor skills to operate the joystick. So this wheelchair can be of great benefit for a paraplegic person i.e., a person with disability only in hind limbs or region lower to hip. This can be implemented as an additional feature like in [7].One of the disadvantages of this method is that the extensive or prolonged use of joystick may cause numbness or soreness in the hands and can make it uncomfortable for the user to use.

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2.2 Touch Screen Based Navigation:

Use of touch screen is very much user friendly and requires very less muscle movement form the user. Touch screen is used as input device and LCD displays the user's gesture correctly when recognized as in [9]. An IR obstacle detection unit can be used which is fixed to the wheelchair to avoid possible collision. A resistive touch screen will be best suited for this application as it is low cost and has greater lifespan compared to other types of touch screens available. From the screen, user can either select a predefined path or can create their path in real-time.

2.3 Human Eye Controlled Navigation

In this technique, webcams are used to read the human eye, to detect its movements and to control the wheelchair as in [8]. This can be either designed in the form of a wearable device or can be attached to the wheelchair, where the user has to adjust him while sitting so that the device can detect the eye movement properly. Another webcam can be fixed to the same structure facing away from the user towards the forward direction for obstacle detection. One of the major disadvantages of this system is that it cannot be used by a person with squinted eyes. Another disadvantage would be that the user must continuously look into the unit and cannot concentrate on other works which can make the user feel uncomfortable. Detection of eye movement is based on the method of electrooculography. Electrooculography is the method of measuring the resting potential of retina. The eye gaze is the factor that is used for controlling the wheelchair. When the user looks upon the system, it is recognized and sends back to the system. An advantage of this system is that a dedicated stop key is not required because the wheelchair automatically stops when the gaze of the user deviates from the system.

2.4 Touchpad Based Navigation

Touchpad based navigation system can be another simple system where in the user has to just move their hands over the touchpad whereby navigating the wheelchair to the desired direction. This system, once designed will be very much compact and simple on look and hence the user will find no confusion in operating it.

2.5 Non-invasive Brain Signal Interface Control (I)

In this technique, two electrodes are placed non-invasively on the scalp and signals are collected as in [4]. A P300 signal and a reference signal is detected and processed for navigation. P300 is an event related potential signal which is any measured brain response that has direct relation with the thought processing part of the brain. This technique has great practical application, at the same time, it is quiet risky as the user has to continuously sit and monitor the wheelchair for its navigation and can be considered as a disadvantage. Here, the brain signals are used to select the pre-defined destination point in the menu and then the wheelchair moves in the selected path. One of the major advantages is that no beforehand training is needed for using this system.

2.6. Non-invasive Brain Signal Interface Control Navigation (II)

In this method, the user faces a screen and concentrates on the area of the space to reach. A visual stimulation process elicits the neurological phenomenon and the EEG signal processing detects the target areas as in [5]. This target area represents a location that is given to the autonomous navigation system, which drives the wheelchair to the desired place while avoiding collisions with the obstacles detected by the laser scanner. This technique allows the user to navigate the wheelchair without serious training for a long term. This method gives great accuracy in the interaction and flexibility to the user, since the wheelchair can autonomously navigate in unknown and evolving scenarios using the on-board sensors shortcoming of this system is that with the synchronous operation, the user has to continuously concentrate on the task. BMI is still in the stage of development as the number of symbols decoded by it is very less. Thus, the control of a wheelchair must rely on a navigation system that receives sparse commands from the user. This method requires complex processing of EEG signals and requires one or more microprocessors dedicated for controlling the chair. The cost of this method is high as a result.

2.7 Voice Based Control Navigation

A voice operated system for wheelchair navigation as in [7] would be very much user friendly and comfortable for elders with limbs impairments. This method can be of much benefit to people who are unable to perform simple movements with their hands. This technique is language unbiased and hence can be considered universal. A voice recognition IC can be used, which is interfaced with a microcontroller. This IC accepts the input from the user as voice commands which are then converted to signals that a microcontroller can process. The microcontroller then produces the desired output which controls the wheelchair.

3. System Design / Layout

The design principles of the hand gesture vocabulary cover the minimal hand motion, attention detection, andhuman-based priority. The hand gesture vocabulary in thesystem has five static hand gestures and three dynamic ones,as shown in Fig. 1.The hand motion in the vocabulary is limited to meta carp phalangeal joint (MCP) abduction and adduction of theindex finger, ring finger and little finger, and the thumb basaljoint (TBJ) radial abduction and adduction of the thumb. Thenormal motion range of the fingers is given in Table 1.

A. Users' Reports

To assess the validity of the proposed hand gesture vocabulary, 14 volunteers (4 female; all right-handed) ranging in age from 24 to 30 years (Mean = 25 years) are recruited to test its performance. Subjects are comfortably seated in an electric wheelchair with right hands executing gestures. The testing results are shown in Table 2.

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Table 2: USER's Experiment Report of the Designed Hand Gesture Vocabulary

Level \ Item	Low	Moderate	High
Learnability	0	0	14
Mental load	14	0	0
Intuitiveness	0	0	14
Comfort	0	2	12

The results demonstrate that the designed hand gesture vocabulary is intuitive and comfortable to implement with the low mental load and the high learnability. Two participants report the inflexibility of performing radial abduction of the little fingers, but they believe it can be handled with slight effort. Another accounted factor in the vocabulary design is the users' attention detection. In order to successfully perform the controlling gestures except for "Stop", users must keep moderate attention to their hand postures to keep primary driving tasks of wheelchairs from users' distraction.

3.1 Hand Gesture Platform Design

The hand gesture platform consists of a fixed set-top webcamera and a fixed background, which simplify the problemof the hand segmentation and are robust to lighting change.

A. Background Color Selection and Segmentation
In order to rapidly segment hands from the backgrounds, we test the background colors with pure black, white, red, blue, green, and purple colors respectively, and select hands using the simple threshold segmentation method.

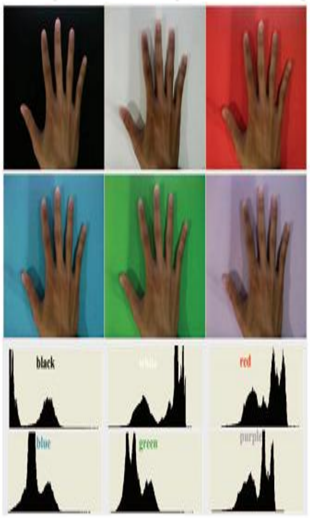

Figure 2. Background color selection. The top two rows are the images of the "Stop" gesture under different colors. The last two rows are the corresponding histograms of the red channel.

We useonly the red channel of the captured images due to itsmaximal similarity to the hand skin color. The results areshown in Fig. 2. The results show that the background color of pure black acquires the best performance, because it has the most distinct "buffer zone" between two peaks, and the main noises,i.e., shadows, is close to black color. The segmentation threshold is set to 55 (Image intensity is from 0 to 255).To avoid the effect of reflection, we use the coarse black cotton cloth as the background material. The prototype of the system is shown in Fig. 3.

B. Illumination Change Test
To assess the validity of the proposed hand gesture platform, we test the system in both of the indoor and outdoor environments, as shown in Fig. 4. Experimental results demonstrate that the system is robust to strong illumination change, and can efficiently and accurately select hands from backgrounds.

3.2 Head Gesture Recognition Using Camera

To overcome the various above discussed problem faced by the quadriplegics and paraplegics, a system is designed which uses an IR sensitive camera to identify the gesture shown by the user. The capture images of the gesture are given to the microprocessor which does further processing. It has got four different modules.

3.3 Gesture Capture Module

This module uses an IR sensitive camera to capture the images of the gesture shown by the user. A simple webcam can be made IR sensitive by removing the IR filter. An array of IR led is placed above which the user shows the gesture. The camera then captures the image and stores it in the database.

3.4 Gesture Capture Module

The database consists of default images which are taken beforehand and assigned to each gesture. This module compares the image taken with the default images and then using the correlation factor decides which gesture is shown and gives the required instruction to the motor controlling unit discussed in the next section which controls the wheelchair.

Figure 3: The prototype of designed system

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3.5 Motor Controlling Module

This module works based on the input received from the gesture recognition module which drives the wheelchair in the desired direction. The input from the gesture capture module is the images taken by the camera.

3.6 Obstacle Avoidance Module

This module can be considered as a safety module which is designed using ultrasonic sensors fixed on all sides of the wheelchair. This helps in stopping the wheelchair when it comes in front of any obstacle. The sensors are interfaced along with the main modules with the microcontroller. Hand Gesture Recognition Using Photodiode Array This novel method of the gesture recognition uses an array of photodiodes (phototransistors can replace them) as the main component in the module to detect the gesture and control the wheelchair. The benefit of using this system is that it recognizes simple gestures accurately cutting down the cost of implementation. By this way a better technique of gesture identification is designed which can be easily operated by the user himself.

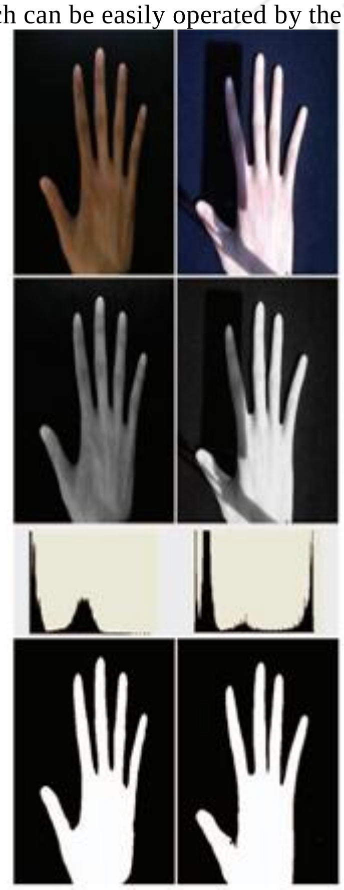

Figure 4. Illumination change test. The first row shows the the "Stop" gestures under the weak and strong lights in the left and right columns respectively. The following rows are their corresponding red channel images, histograms, and final segmentation results.

Figure 5: Camera-Gesture Capture Modules

Block Diagram

The Gesture recognition system consists of a sensor array made up of sixty four photodiodes as shown in Fig. 2. The array is organized as an eight by eight array. The array outputs digital signals ideally but due to the external light interference, the result is not as expected. A sixty four channel analog output is obtained from the array. Each of these channels is given to a comparator array where output values are compared to a reference value and then converted to digital accordingly. These outputs form the input to the eight bit parallel in serial out digital to analog converter. The output from the comparator array is bunched into eight groups (One group has signals coming from one row of the sensor array) each having eight channels, refer Fig 2.

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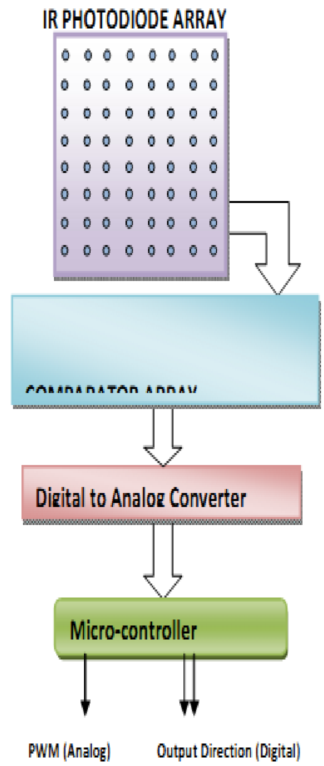

These channels are given to eight digital to analog converter. Hence we obtain eight channel analog outputs containing all the necessary information. These eight channels are given to a microcontroller and processed to find out the gesture made.

3.7 Gesture Capture Module

This module uses an IR sensitive camera to capture the images of the gesture shown by the user. A simple webcam can be made IR sensitive by removing the IR filter. An array of IR led is placed above which the user shows the gesture. The camera then captures the image and stores it in the database.

3.8 Gesture Sensing Module

When the hand is placed above the photodiode array, the IR light falling on the photodiodes placed directly below the hand gets blocked whereas the uncovered region receives light. This Idea is utilized to design a gesture recognition system. The circuit in Fig. 3 is the simplest sensing unit in the system. An 8 X 8 array is created using this unit. The V-out shown in figure is ideally zero volts Gesture templates are shown in Fig. 4. Reference gesture shown in the Fig. 4 is the initializing gesture. The user has to make such a gesture first in order to initialize the gesture recognition system properly. Based on this reference gesture, other gestures made are processed. The V-out shown in Fig. 3 is ideally zero volts when light falls on it and Vcc Volts when no lights falls on it. This acts like a switch.

3.9 Gesture Templates

Gesture templates are shown in Fig. 4. Reference gesture shown in the Fig. 4 is the initializing gesture. The user has to make such a gesture first in order to initialize the gesture recognition system properly. Based on this reference gesture, other gestures made are processed

3.10 Gesture Identification Algorithm

The 8 channel output of the digital to analog converter array is given to a microcontroller. An algorithm is designed which effectively decodes the signals from the DAC. The eight analog values are converted to binary. Then the binary numbers are stored in an eight by eight array. The significance of the array so obtained is that this array is exactly representing the ON-OFF states of photodiodes used in the sensing unit. ON state indicates that there is light falling on photodiode or in other words the hand is not placed on the photodiode and OFF state indicates the reverse. This array hence has all the information regarding the present location of the hand above the sensor array.

3.11 Identifying Left and Right Gestures

Algorithm starts searching for bits that are high from top left to bottom right. The co-ordinates of the first bit that is high in top rows and also the first bit that is high in the last row is stored. The co-ordinates of first point are characterized by largest y-coordinate value having largest x-coordinate among the bits having value one. This point is the top right point with value one. The co-ordinates of second point are characterized by smallest y-coordinate value having smallest x-coordinate among the bits having value one. This point is the bottom left point with value one. These coordinates are then used to find the slope of the line joining the first and second points. In this manner, the orientation angle of the hand is found. The algorithm is repeated for the changes in the angle and depending on the angle, the system decides whether the wheelchair must move right or left. Identifying Forward and Backward Gestures The movement of hand in forward and backward direction is tracked by noting the changes in the y coordinate of a specific point. After the test for left or right direction is done and indicates no gesture, the algorithm notes the value of y co-ordinate of the "point one" mentioned in the previous sub-section. Indicate forward hand movement and hence indicate of forward Increase in the noted y coordinate without detecting left or right gestures Gesture. Similarly a decrease in the y co-ordinate indicates reverse hand movement and hence indicates backward gesture.

3.12 Stop Gesture Identification

The whole system does not require a dedicated stop gesture because the unit will automatically stop when it detects no hand over the sensor array. This is an added advantage of the system as it can be used in an emergency condition also.

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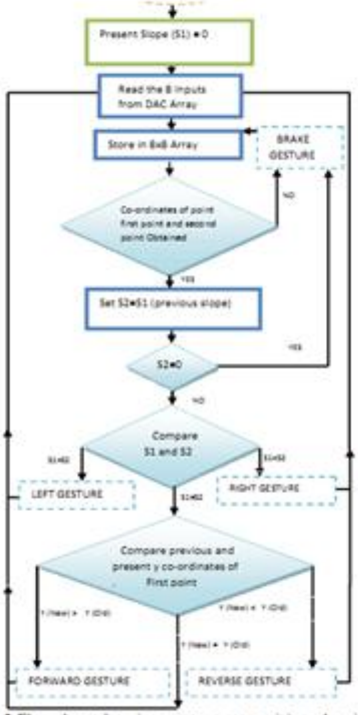

Fig. 5 Flowchart showing gesture recognition algorithm

Features

The various features of MATLAB are as following

- High-level language for technical computing.
- Development environment for managing code, files and data.
- Interactive tools for iterative exploration, design and problem solving.
- Mathematical functions for linear algebra, statistics, Fourier analysis, filtering, optimization and numerical integration.
- 2-D and 3-D graphics functions for visualizing data.
- Tools for building custom graphical user interfaces.
- Functions for integrating MATLAB based algorithms with external applications and languages, such as C, C++, FORTRAN, Java, COM and Microsoft Excel.
- Packages MATLAB applications as executable and shared libraries.
- Allows distribution of standalone executable and software components royalty-free.
- Allows incorporation MATLAB based algorithms into applications developed using other languages and technologies.
- Encrypts MATLAB code so that it cannot be viewed or modified.

4. Conclusions

Depending on the needs and specifications required by the user, any of the above mentioned methods can be used to design the wheelchair making sure that it guarantees safe and comfortable experience to the user. The newly proposed methods are ideal for application in developing countries as there is high need for low cost navigation system for people with health issues affecting walking. In this paper, a natural and ergonomic hand gesture systemis developed for the intelligent HCI and medical assistance. The system is robust to strong illumination change and canrun in real-time for practical purposes. The lexicon sizein the designed vocabulary is 8 which cover the comprehensive manipulating commands for intelligent wheelchaircontrol. The hand gesture vocabulary in the system hasmany characteristics including high learnability, low mentalload, high comfort, and intuitiveness. Experimental resultshave demonstrated the efficiency and accuracy of the systemwhich offers a available and convenient interface for thedisabled and has widely applications in medical assistance.

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