AN INTEGRABLE TECHNOLOGY ON A SMART CHAIR USING FACIAL EXPRESSIONS

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Abstract- Smart chairs can be designed to aid paraplegics and quadriplegics with higher degree of impairment, such as Quadriplegia with paralysis, Traumatic Brain Injury or Multiple Sclerosis. They are unable to move any part of the body, except the head or slight movement of their facial muscles. Devices designed to help them communicate their needs are very complicated, rare and expensive. In this paper, an intelligent system able to detect facial gestures thereby, enabling the patient to convey a fixed set of information is presented. A novel facial gesture/ muscle movement recognition technique based on principal component method in Image data processing is proposed. This system can be used with different types of standard electric wheelchairs. The system is tested successfully for its performance through simulations.

Index Terms- Image Processing, Smart Wheel Chair, Paraplegia, Quadriplegia, Traumatic Brain Injury, Paralysis, Principal Component Analysis, Lighting Compensation, Image Segmentation, Image Tracking, Image Database Learning, Image Testing, Eigen Vectors, Eigen values, Mean, Co-variance, Noise Cancellation, Edge detection.

I. INTRODUCTION

Independent mobility is critical to quality of life for people of all ages and impaired mobility leaves one with both physical and mental frustration. Assistive technologies are dedicated to providing additional accessibility to individuals who have physical impairments and disabilities that limit their capabilities to operate an electric wheelchair. Elderly and other users with disability also have restricted limb and muscle movements caused by Parkinson's disease or Traumatic Brain Injury.

The prime objective of this paper is to present what is possible in the form of an aid to the patient's communication of his wants to the people around him.

A smart wheelchair is a motorized platform with a chair designed to assist a user with a physical disability, where an artificial control system augments or replaces user control. Its purpose is to reduce or eliminate the user's task of driving a motorized wheelchair. Usually, a smart wheelchair is controlled by a computer, has a suite of sensors and applies techniques in mobile robotics. These chairs are designed for a variety of user types.

The role of the smart wheelchair is to interpret small muscular activations as high-level commands and execute them. Thus, smart wheelchairs play an important role in helping the handicapped and the elderly people to live more independently at home and have a low cost on their healthcare.

In this paper, an idea has been proposed for the wheelchair users in whom, voluntary control of muscle movement maybe substantially limited or highly inhibited.

For such patients who cannot talk, it becomes very difficult to convey their thoughts and emotions, or even their everyday needs to their caretaker or any person around. Hence, this work is mainly aimed at helping these patients convey their basic needs to the person in the immediate surroundings with the help of facial gestures or muscle movement.

An intelligent system recognizes the facial expression and alerts the caretaker accordingly.

II. STAGES INVOLVED IN IMPLEMENTATION OF THE INTERFACE

After ascertaining the requirements of the patients for whom this module has been designed, the following are the stages involved in developing the multimedia interface as shown in Fig.1.

- Data acquisition: the process of capturing the image with a digital camera and pre-processing at the camera's embedded level.
- Pre-Processing: after acquiring the digital picture, useful information is extracted from the picture.
- Identification: as soon as the feature information is gathered, an intelligent algorithm does the facial expression deduction.
- Interface: the command language is implemented on this level and it is conveyed to the outside world.

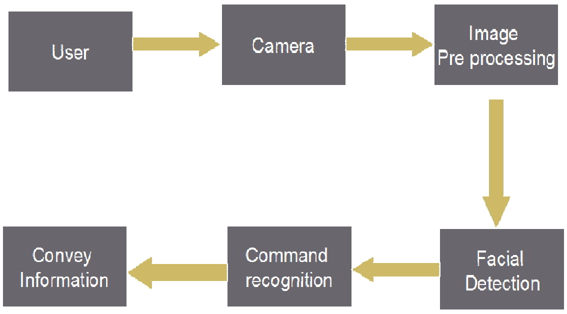

Fig.1. Block diagram representation of the stages involved in the multimedia interface.

III. FACIAL EXPRESSION RECOGNITION

Once the captured image has been pre-processed, an intelligent algorithm has to detect the expression based on an existing image database.

The various algorithms that can be used for facial expression are:

- Principal Component Analysis using Eigenvectors
- Linear Discriminant Analysis
- Elastic Bunch Graph Matching using Fisherface Algorithm
- Hidden Markov Model

All the above methods are statistical methods used in pattern recognition and machine learning techniques. The focus of this work is on Principal Component Analysis using Eigen Vectors which is used for the purpose of intelligent expression detection.

IV. ADVANTAGES OF PRINCIPAL COMPONENT ANALYSIS

1. The basic Benefit in PCA is to reduce the dimension of the data.
2. No data redundancy as components is Orthogonal.
3. With help of PCA, complexity of grouping the images can be reduced.
4. Smaller representation of database because we only store the training images in the form of their projections on the reduced basis.
5. Noise is reduced because we choose the maximum variation basis and hence features like background with small variation are automatically ignored.

V. PRINCIPAL COMPONENT ANALYSIS

Principal Components Analysis (PCA) is a way of identifying patterns in data, and expressing the data in such a way as to highlight their similarities and differences. PCA is a powerful tool for analysing data. If there are a lot of images that are close to each other in the PCA space, it means that the images differ slightly from each other. The direction of these variations is important because it distinguishes what the images differs in. A "cloud" of these images could therefore be spanned by the directions of the variations, which are called the Principal Components. To characterize the trends exhibited by this data, PCA extracts directions where the cloud is more extended. Using PCA we find a subset of principal directions (principal components) in a set of training faces. Then we project faces into this principal components space and get feature vectors.

Steps involved in PCA

1. Get some data
2. Subtract the mean
3. Calculating the covariance matrix
4. Calculate the eigenvectors and Eigen values of the covariance matrix
5. Choosing components and formatting a feature vector
6. Deriving the new data set

Equations

Let's suppose we have M vectors of the image of size N (= rows of image * columns of image) representing a set of sampled images. Let P_j's represent the pixel values.

$$x_i=[p_1\ldots\ldots p_N]^T \qquad i = 1,\ldots\ldots,M \qquad (1)$$

The images are mean centered by subtracting the mean image from each image vector. Let m represent the mean image.

$$m=1/M \sum x_i \quad i=1,\ldots\ldots,M \qquad (2)$$

And let w_i be defined as mean centered image

$$w_i = x_i - m \qquad (3)$$

Now, we have to find a set of M orthonormal vectors e_i for which the quantity

$$\lambda_i = 1/M \sum (e_i^T w_n)^2 \quad n=1\ldots\ldots M \qquad (4)$$

is maximized with the orthonormality constraint given by

$$e_l^T e_k=\delta_{lk} \qquad (5)$$

It has been shown that the e_i's and λ_i's are given by the eigenvectors and eigenvalues of the covariance matrix

$$C=WW^T \qquad (6)$$

where W is a matrix composed of the column vectors w_i placed side by side. A common theorem in linear algebra states that the vectors e_i and scalars λ_i can be obtained by solving for the eigenvectors and eigenvalues of the M * M matrix W^TW[11]. Let d_i

and μ_i be the eigenvectors and eigenvalues of W^TW, respectively.

$W^TWd_i = \lambda_i d_i$ (7)
Pre-multiplying both sides by W
$WW^T(Wd_i)=\lambda_i(Wd_i)$ (8)

which means that the first M - 1 eigenvectors e_i and eigenvalues λ_i of WW^T are given by Wd_i and μ_i, respectively. Wd_i needs to be normalized in order to be equal to e_i.

A facial image can be projected onto M' (<< M) dimensions by computing
$\Omega = [v_1\ v_2 \ldots\ldots v_{M'}]^T$ (9)

where $v_i = e_i^T w_i$. vi is the i^{th} coordinate of the facial image in the new space, which came to be the principal component. The vectors e_i are also images, called eigen images or eigen faces. The simplest method for determining which face class provides the best description of an input facial image is to find the face class k that minimizes the Euclidean distance

$\varepsilon_k=\|(\Omega - \Omega_k)\|$ (10)

where Ω_k is a vector describing the k^{th} face class. If ε_k is less than some predefined threshold μ^2, a face is classified as belonging to the class k.

VI. IMPLEMENTATION

A. Image Acquisition:

For the simulation, an image could be taken from a test folder or captured in real time from the video camera. In a real time situation, a simple slight nod can actuate the image capture. For simulation purposes, an enter key is used in the program to acquire the dynamic image from the camera. An accelerometer can be used to detect the nod in real cases, in which it detects a slight tilt of the head and gives command to the microcontroller to capture the image through the camera.

B. Image Pre-Processing:

The Processing done on the image captured through simulation are:

- Noise Cancellation
- Lighting Compensation
- Segmentation
- Tracking
- Standard Sizing
- Edge Finding

C. Feature Extraction:

PCA is performed using built-in function princomp()
[Coeff, Score, latent] = princomp (X)
X is n by p data matrix. Rows of X correspond to observations and columns to variables.

Coeff: Coeff is a p-by-p matrix, each column containing coefficients for one principal component. The columns are in order of decreasing component variance.

Score: Representation of X is principal comp. Space rows of score correspond to observation, columns to components.

Latent: Eigen values of the covariance matrix of X. It is the variance of Score.

C. Classification:

- Expression categorisation.
- Assign a result file with the corresponding expression.
- Display the output corresponding to the expression (Either through pre-recorded voice or through a display device or both).

The above steps are implemented as a MATLAB code with the result shown in the next section.

VII. INPUT AND OUTPUT FILES

Train images: Each expression has 3 to 4 images with slight variations as shown in Fig.2.The database is loaded onto the system to "train" the system with the images. This is a one-time process in the real system. The images are to be taken according to the patient's convenience and can be custom-made according to the patient's ability or the extent up to which he can move his facial muscles. The more the number of training images, the accurate is the expression detection. These were few of the images used for the training images[14]

Fig. 2. Training Images

Test Images: The test images folder contains 4 test images as shown in Fig.3, for simulation purpose. If the test image is taken dynamically, then the test image is captured and stored in this folder. For analysis purpose, 4 test images are fed into the folder for simulation. The corresponding Label File containing the image names and the expression is also fed into the system database. The test images are shown below [14]

Fig.3. Test Images

VIII. RESULTS

The simulation was carried out and the results were obtained as follows:
Test Image1-matched with Expression2
Test Image2-matched with Expression3

Test Image1-matched with Expression4
Test Image1-matched with Expression5

The corresponding .wav files were played on the audio
Device.
Expression2- I am hungry!
Expression3- I need water!
Expression4- I need to use the washroom!
Expression5- I need medication!
And the corresponding output was displayed on the MATLAB command window.

CONCLUSION

A novel assistive technique using facial expression recognition that uses features derived from Principal Component Analysis algorithm was successfully implemented. The system was evaluated in MATLAB using an image database of fixed face images of the individual using the Wheel Chair, containing various recognizable expressions. Thus Facial expression recognition has been done using PCA and this simulation can be extended on the hardware level for an effective speaking unit of the wheelchair. Further improvements to the same concept can be done as follows:

- Extensive experiments and evaluation in both indoor and outdoor environments
- Cluttered backgrounds, changing lighting conditions, sunshine and shadows.
- EEG simulated speaking unit for Wheelchairs.
- The facial recognition software can also be programmed for other daily tasks like writing emails or watching films, hearing music etc.

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