Eye blink Enabled Nurse Call and Security Alert System for Hospital Patients

Emmanuel Jadesola Adejoke[1] Ibiyemi Tunji Samuel[2] Oladele Tinuke Omolewa[3]
emmanueladejoke@yahoo.co.uk[1] ibiyemits@yahoo.com[2] oladele.to@unilorin.edu.ng

Department of Computer Science, Bingham University, Abuja, Nigeria. [1]

Department of Electrical Engineering, University of Ilorin, Nigeria. [2]

Department of Computer Science, University of Ilorin, Nigeria. [3]

Abstract

Low medical personnel per capital is almost a global issue, this makes nurse call system a necessity in hospitals. Call systems such as pillow speakers and call bells have been used to serve this purpose for patients that can speak and move. This paper presents a computer-aided eye blink triggered nurse call and security alert system for immobile patients. The system pre-processes the face image from a CCTV video stream, and relevant features are extracted. Eye region tracking and blink detection is carried out using the normalised cross correlation algorithm and face of blinker is authenticated by the eigenface algorithm. On detection of coded eye blinks and authentication of face, the system triggers a nurse call or security alert. The system was tested with 90 video stream of human faces and reported a 95% blink detection accuracy and 94% face authentication accuracy to trigger both nurse calls and security alerts.

1.0 Introduction

The low availability of medical personnel per capital in the nation Nigeria has dictated the deployment of automated safety alert systems to call on medical personnel in between scheduled attention period. Previous methods include calling out verbally, making use of pillow speakers, pressing of Nurse call bells or pneumatic press calls, where such is available. The paralysed or physically challenged who cannot move some parts of their bodies may not be able to press bells and the dumb will not be able to call out. The eye blink alert system will be suitable in such extreme cases. The eye being the last part of the body that humans lose control [1], may be a last resort for critically weak patients to raise alerts. The system will also serve as a security alert system for patients who are vulnerable or have intruders come around their bedside. This paper presents a computer-based, human centric communication system for raising safety alerts by eye blink communication.

Patients who need urgent attention raise alerts by making eye blink communications to a CCTV camera which is connected to a computer system. When the blink detection system detects a blink, the face of the blinker is first authenticated by face recognition biometrics before triggering an alert. The alert is triggered to dial the phone number of the assigned nursing or security station with an SMS stating, room and bed number of the patient.

2.0 Related Works

An Eye Blink controlled system for triggering control of home electrical appliance for the use of paralysed persons was developed by [2]. The study utilised

Haar-like features for face and eye detection and a flag mechanism for blink detection. It reported a 95% detection rate under good lighting conditions. Eye blinks were used as a password based liveliness monitor to improve detection of video spoofing using ultrasonic range sensing in [3], eye blinking and chin movement to detect liveliness before a face recognition authentication via a real time web-camera. The system recorded 100% face recognition and liveliness detection accuracy on 100 different users. In this paper ant-spoofing is implied by eye blink communication.

An automatic Human Computer Interface (HCI) System to aid and support people with severe disabilities and have need for interfaces to access the computer was developed in [4]. The system captured the voluntary eye blinks and the blink patterns are decoded to make the interaction possible between the user and computers. The system enabled the communication by making use of the Human Facial features which are tracked and monitored in real-time. The nose tip coordinates in the live video feed were translated to become the coordinates of the mouse pointer on the application. The voluntary right/left eye blinks trigger the right/left mouse clicks. The proposed system in this study is not only useful for the disabled but also for security purposes.

Wireless nurse call systems have been developed which are used to trigger alerts to nurse stations, some are voice and push button based triggers [5], while some are just push button based [6]. A nurse call system for intensive care patients with limited body movement or cannot speak due to tracheal tubes which makes them unable to use bed call or bed button based system, is presented in [7]. This system is a Liquid Crystal Display (LDC) touch screen based system with an ability to rotate 360^{o}. It uses smart pens to touch symbols and write on the screen to trigger alerts to the nurse stations. It was tested and found satisfactory to such patients. The proposed system is suitable for people with limited or no body movement as well as people with inability to speak. This paper presents an innovation to nurse call systems by eye blink triggers.

3.0 Methodology

The system comprises of the Patient enrolment, system training, Eye blink detection and classification, face recognition and trigger alert modules. At the enrolment phase of the system, the patient's record is taken, and the face recognition system is trained. While at the operational phase the system has a CCTV camera fixed at a point where the face of the patient can be easily located without occlusion. The system takes the image of the face and pre-processes it. The blink detection system continually reads the video stream to detect an eye blink from the patient. On detection and decoding of an eye blink, the alert is triggered if and only if the face of the blinker is authenticated by face recognition. Figure 1 presents the pseudocode of the whole system.

```
_ EyeblinkHci
  {
        (          - Define constants;
        -Declare Global Variables;
        -Declare User 's Defined Types;
        -Declare Function Prototypes;
        -import ancillary files;
        -Set  Enrol = .TRUE.
)
Main Moudule
{
-Declare  local variables;
If (enrol) then
{
(* Enrolment/Training Phase*)
        Do i = 1, no-trainset

    *Define faceDetectTrack.h
      (
        -Insert all the necessary include files  ;
        -Define constants ;
        -Declare all function prototypes ;
        -Declare all user defined datatypes, e.g.
structure .
      )

   *Define _main_module( )
    {
Start_EyeBlinkRecognition
        {
                -
Call_DetectndSegmentEyeRegion();
                -Call_TrackEye();
();
                -Call_triggerAction( );
        }end_EyeBlinkRecognition

 }
        Start_FaceDetection_module
        {
        -Call _getRGBimage(   ) ;
              -Call _colorTransform(   ) ;
              -Call _skinProbabilityMap(   ) ;
              -Call _segmentSkinImage(   ) ;
              -Call DisplaySkinImage( ) ;
              -Call_rgb2Grey( );
              -Call _ImageVectorisation(      ) ;
              -Call_PerformSizeNormalisation  ( );
        Call_PerformIluminationNormalisation( );
        } end_FaceDetection
        Start_eigenFaceAlgorithm_Module
        {
                -Call__ZeroMean(       ) ;
                -Call_ Covariance(      ) ;
                 -Call_Householder_QLi(      ) ;
                -Call_weight_TrainingData(   ) ;
                -Call_weight_QueryImage(   ) ;
                -Call_Classify(     ) ;
        }end_eigen_Face_Module
}
}end_EyeBlinkHci
```

Figure 1: The Main Program Pseudocode

3.1 Patient Enrolment

The objective of the module is to capture the relevant bio-data of the patient and assign him a unique identification number with which the system recognises him and tags the face to an ID. Part of the data collected in this module include frontal face images of the patient taken at a reasonable standoff distance with a white back ground for good contrast, which is required for the face recognition and skin database trainings. The system crops out skin patches from the face image to add to the skin database for training.

3.2 Training Module

Two forms of training are carried at in this module. The skin database training module where skin samples are used to train the skin detection system which is used for the face detection, and the face recognition system training where faces are assigned to particular identity numbers and name for use in the face recognition phase. Training takes place on daily basis to make sure the system is up to date.

3.3 Blink Detection and Classification

Video streams are being captured by the CCTV camera and being read by the blink detection system. Face images from the first slide is used to pre-process the face image, detect face and crop region of interest [in press 8]. Normalised Cross Correlation algorithm is used to track the eye-region and detect blinks. The blink classification system classifies detected blinks, matching them to appropriate alerts. Figure 2 presents the pseudocode of the blink detection and classification system.

```
Step 0: compute for each frame normalised cross correlation
Step1: store cross correlation data in a file
Step2: Read cross correlation data while not end of file
Step3: Read data while cross correlation data < 0.87
        if data< 0.83 &&> 0.55 within 6 frames report blink detected
Step 4: if blink detected 2 times between 12 to 18 frames
            Report double blink detected
  Else
        If blink occurs once and has at lest 6 frames after without a blink
            Report single blink detected
Go to step 1
```

Figure 2: Blink Detection and Classification Pseudocode

3.4 Face Recognition Authentication

The face recognition module is where the face of the blinker is authenticated. The eigenface algorithm is being used here. Query faces are compared to faces in the database and if the face is recognised the appropriate alert is triggered.

3.5 Trigger Alert

Trigger alert module is concerned with the machine autonomously taking action as a result of detection of valid eye blinks made by an authorised person. There are two possible actions; nurse call or security alert. For safety application, the machine on detection of valid coded eye-blink by an authorised person will autodial nurse station telephone numbers, and playback pre-recorded voice messages on those dialled phones vis-à-vis sending a Short Message Service (SMS) containing information on date, time, and location of the call to each of the dialled phone numbers. In the case of intruder alert the action taken is similar to that of the nurse call but it is both the nurse station and hospital security station that will be sent the alert. Figure 3 presents the trigger alert system pseudocode.

```
**********
Input: Face detected =T , Blink Detetion = T, Code of detected blink
Output: Call phone number, Sms of callers data
**********
    Define k=1  (* security alert *)
    Define k=2  (* safety alarm *)
    If  (k=1) do
    {
      Do i= 1 to n
        -Autodial sos phone number(i) ;
        -Read gps data (date, time, location (latitude, longitude, altitude)) ;
        -Translate gps location to gislocation ;
        -Send as sms text message (date, time, location gis) data to dialedphone ;
          -Playback pre-recorded audio message ;
        -Reset
    }
    If  (k=2) do
    {
         -Autodial sos phone number ;
        -Read gps data (date, time, location (latitude, longitude, altitude)) ;
        -Translate gps location to gislocation ;
        -Send as sms text message (date, time, location gis) data to dialedphone ;
          -Playback pre-recorded audio message ;
        -Reset
}
```

Figure 3: Trigger Alert Pseudocode

4.0 Results

The system was implemented in MATLAB and tested with video streams of 90 human faces. The detailed process and results of face pre-processing is published in [8].

4.1 Blink Detection Results

The single blink detection gave 100% detection accuracy, 10% false positives, 100% True positives, 0% false negatives and 90% success rate. The double eye blink detection also gave a 100% detection rate, 5% false positives, 0% false negatives and 95% success rate. On detection of a coded eye blink, the face is sent to the eigen face module for authentication. Table 1shows the results of the eye blink detection stage.

Table 1: Blink Detection Evaluation

Blink Type	Detection Accuracy	False Positives	False Negatives	Success Rate
Single blinks	100%	10%	0	90%
Double blinks	100%	5%	0	95%

The performance evaluation metrics used for the coded eye blink detection stage are as follows:

Detection Accuracy (DA), $DA = \frac{TP}{TP+FN}$

False Alarm Rate (FAR),$FAR = \frac{FP}{TP+FP}$

Success Rate (SR), $SR = \frac{DA}{DA+FAR}$ (All in percentage)

where

TP: Number of correctly detected blinks

FP: Number of false detection of blinks

FN= Number of undetected blinks

The face recognition module recorded 94% accuracy in detection rate. If a face is recognised, a signal is sent to trigger an appropriate action, otherwise the detected blink is ignored.

5.0 Conclusion

A computer-aided, eye blink triggered, face recognition authenticated nurse call and security alert system was developed in this paper with a success rate of 94%. It is recommended for use for patients in hospitals.

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