A Gaming Approach in Physical Therapy for Facial Nerve Paralysis Patient

Tamanna Tasneem, Atanu Shome, SK Alamgir Hossain
Computer Science and Engineering Discipline, Khulna University
Khulna, Bangladesh
{(tamannacse09, atanu.cse.ku}@gmail.com, alamgir@cseku.ac.bd

***Abstract*—This work is based on developing a system for the Bell's palsy, a type of facial nerve paralysis, patients to help them in passive exercise, which is one of the major ways to recovery. This exercise method will be provided in the form of computer game so the user will be able to perform exercise without the hardship that comes with active exercise. It will also show how much this system helps the patients and how its performance is analyzed by the users' i. e. the patients. We will also show that how passive exercise is preferable to current active one. As per initial experimentation, we found out that the proposed gaming approach for Bell's palsy recovery is useful to the patient.**

***Index Terms*—Bell's palsy, facial nerve paralysis, passive exercise, computer game**

I. Introduction

Computer science is spreading in each and every field that one can think of now-a-days. And now it's bonding with medical field as some robust composition in terms of both detection and cure of diseases. Human Computer Interaction (HCI) made it possible to shorten the gap between human and computer methods by which new possibilities and ways are opening for new treatment methodologies [1] [2] [3]. Dropping of cost, modern technical advancement, powerful tools made it possible to have larger impact on health care field which lead us to think of a way to cure Bell's palsy disease [4] .

Bell's palsy is a form of facial paralysis resulting from a dysfunction of the cranial nerve (the facial nerve) causing an inability to control facial muscles on the affected side [5] [6]. Facial nerve controls the muscles of facial expression, and functions in the conveyance of taste sensations from the anterior two-thirds of the tongue and oral cavity.

When a patient attacked by Bell's palsy disease it damaged the facial nerve [7], and facial nerve generally creates a trauma on one side of the face. Electrochemical signals sent from the brain travel along facial nerve. If the facial nerve is disrupted, no signals can get pass through these muscles, and then half side of the face gets affected by experiencing muscles weakness or paralysis, known as Bell's palsy. Some effects of Bell's palsy causes disruption in eye controlling, smiling, eating, interference in facial expressions, and sometimes speech may also blurred. Tearing of eye, interference in hearing also could be seen in Bell's palsy.

Bell's palsy affected one side of the face and it can cause closing of an eye for a certain period. Exercise is required to save the eye from severe or permanent damage. Most of the cases without any treatment Bell's palsy may recover with exercise. So doctors advise to do eye and mouth exercise to close the eye and move the mouth. But due to muscles weakness patient have trouble to control the eyes and mouth by himself. So passive exercise by the patient is effective than the active exercise. So we propose gaming technique which will help a patient to exercise in a manner that will help to exercise the eye muscles and facial nerves which will result in better retrieval from bad effects. In our proposed method patient concentrate on the game rather than exercise which is less laborious than actively open or close the eye.

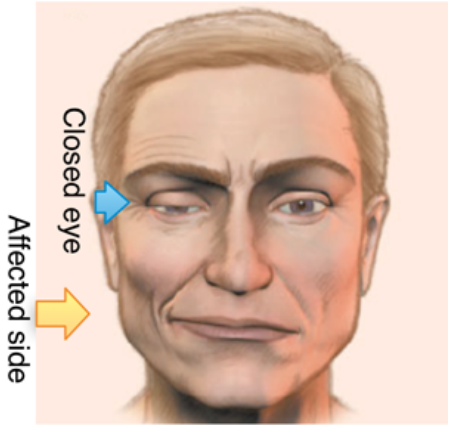


Fig. 1: A human face illustrating Bell's palsy.

Our contribution in this paper is two-fold. First, we present an algorithm by which bell's palsy patient have the opportunity to exercise with less trouble. Second, we presented the experimental result based on our developed prototype system.

The remainder of this paper is organized as the following. At first, in Section II we present some recognized work that are related to this paper. Then in Section III we illustrate the various components of our proposed technique. Further, in Section IV we present the implementation details of our prototype. The experimental results and the performance of our system is discussed in Section V. At the end we provide conclusion of the paper in Section VI and state some possible future work directions.

II. Related work

Bell's palsy is not a new disease among the physicians. At first Sir Charles Bell [8], a Scottish surgeon, in 19th century

recognized the disease. From onward various researches try to find out the treatment for this disease. The most commonly used treatment tries to find out from the patient's history and neurological examination. If weakness is central, brain magnetic resonance imaging (MRI) is required to evaluate the patient for ischemia and for infectious and inflammatory diseases. If facial weakness is peripheral, no apparent cause will be found in most instances and no tests are immediately indicated [1].

The Bell's palsy recovery and characteristics are mostly highlighted by Olsen [9]. He presented a statistical result based on 50 Bell's palsy patients. He showed facts about signs, symptoms and causes of Bell's palsy. Bell's palsy may occur one single time or may come every month or year. The Bell's palsy which comes recurrently calls recurrent Bell's palsy. It is still unknown why recurrent Bell's palsy happens in a patient. To identify nature of recurrent Bell's palsy Pitts et. al. [10] presented a statistical report based on 140 real patients. From his study he observed that in 7.1% cases had recurrence in Bell's palsy.

Apart from antiviral treatment, physiotherapy can be beneficial to some individuals with Bell's palsy as it helps to maintain muscle tone of the affected facial muscles and stimulate the facial nerve [6]. It is important that muscle re-education exercises and soft tissue techniques be implemented prior to recovery in order to help prevent permanent contractures of the paralyzed facial muscles [6]. To reduce pain, heat can be applied to the affected side of the face [11]. Physiotherapy may consist of electrical stimulation or facial exercises, or both. The facial exercises can be performed at home whilst the electrical stimulation is done by the physiotherapist at their clinic. The facial exercise involves doing different muscle movements to work each group of the facial muscles.

The computer based physiotherapy is a relatively new idea. In 2010 Alamri et. al. [2] proposes a novel approach based on augmented-reality (AR) technologies that can increase a stroke-patient's involvement in the rehabilitation process. The approach takes advantage of virtual-reality technologies and provides natural-force interaction with the daily environment by adopting a tangible-object concept.

The approach takes advantage of virtual-reality technologies and provides natural-force interaction with the daily environment by adopting a tangible-object concept. Similar work has been done before on rehabilitation of the hand of post-stroke patients in 2006 [12].

III. Proposed Framework

In this section we describe the general architecture of the proposed system. The architecture is depicted in Figure 2 as a block diagram. The Bell's palsy patient face is captured by a video feed or a standalone camera. An IR (Infra-Red) sensor is used to measure the distance between the camera and the patient face. In our system the patient have to sit between 12cm-16cm feet distance. The IR sensor measures the distance and suggests the patient to adjust his/her face in the right distance.

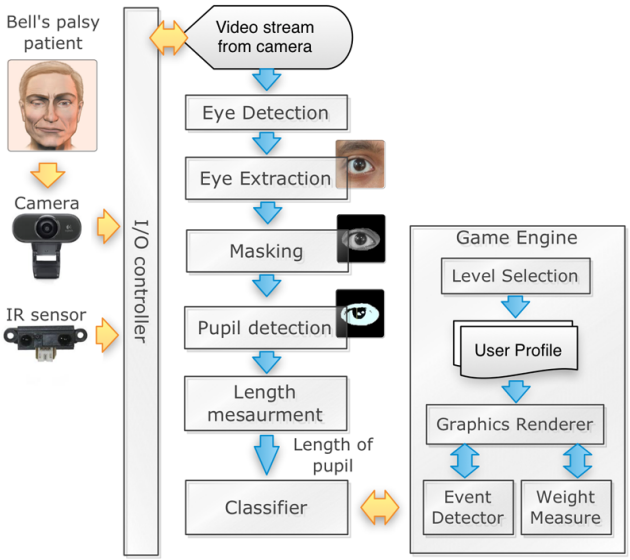


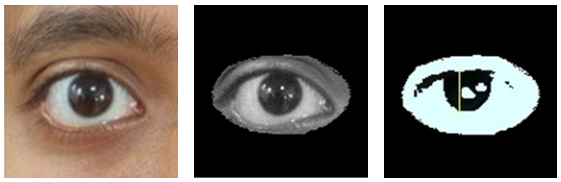
Fig. 2: Proposed gaming architecture for Bell's palsy patient.

A. Eye Extraction Module

Video is captured from the camera and extracted the video frames for eye detection. The eye is detected from the video frame by OpenCV [13] frontal haarcascade classifier. Haarcascade classifiers are XML files that contain information for object detection like face detection, eye detection etc. After the detection the eye is extracted from the face image. Later on the extracted eye image is scaled and cropped to 125*125 pixels image for masking.

B. Eye Image Masking Module

As different people have different skin and eye color so in order to get better result the system mask the cropped eye image. In the masking process the system will remove unnecessary skin parts, eyebrows and the noise. The skin parts will remove by comparing each pixel with human skin color. As human color is different so in our system has the facility to recognize the current user face color during face recognition stage. The system default face color is $RGB(239, 208, 207)$. In the final stage we perform some image processing operations to separate the pupil from the white part of the eye and from the skin. We're converting all the pixel colors that are greater than RGB (55, 55, 55) to the color RGB (224, 255, 255). Rest of the pixel colors is closer to the pupil colors.



(a) Cropped eye (125*125 pixel) (b) Gray scale and masking (c) Length measurement

Fig. 3: Different stages of eye image processing.

C. Pupil Length Measurement Module

After masking the image the system will measure the length of pupil. As in the masking stage most of the skin and noise are removed so the maximum connected colors that are not RGB (224,255,255) indicates the pupil length and this length value can be used to identify how much open the eye in-front the camera.

TABLE I: Properties of the videos that are used in the experiment.

	Interval (In pixel)	Openness (In percentage)
1	0-10	0%
2	11-19	25%
3	20-29	50%
4	30-39	75%
5	40 and above 40	100%

D. Classifier Module

Once the pupil length is measured the system determine the openness of the eye comparing with some predetermined values that are listed in table I. And based on those values, system will categories eye openness into five classes 0, 25, 50, 75 and 100 percent. As human eye is very responsive and the distance between fully close and fully open is very short so we discarded the intermediate classes. Following algorithm 1 is used to calculate the openness value.

Algorithm 1: Eye openness value calculation

```
Output: Eye openness array : g[]
begin
    Initialize window with OpenGL;
    while inside the glutmainloop do
        Draw initial bar for the game using workOnRectangle();
        while face exist in current image frame do
            frame ← Capture video frame using cvCaptureFromCAM();
            eyes[] ← IdentifyEye (frame);
            foreach eye e ∈ eyes do
                m ← maskImage(e);
                m_w ← Identify and transform color of the white portion
                of the eye;
                m_l ← Perform the length measurement of the pupil usign
                m_w;
                c ← classifyOpenness(m_l);
                g[] ← Pass the openness value c into method based on
                openness stages draw rectangle and ball position;
    return g[];
```

E. Game Engine Module

The game engine receives eye openness value from the classifier and makes use of them to control the game elements. The game has two different objects ball and a horizontal bar. Every certain amount of time a ball will fall down from the top to the bottom bar. If patient can open his/her eyes 100 percent the bar will be balanced horizontally and the ball will be in the middle. But if eyes are not open 100 percent then the ball will start to fall on the left or right according to the less openness. And if eyes are closed that means eye's openness is 0 percent the ball will fall off the bar and bar will be horizontally balanced. The game point will calculate based on the number of ball remain in the bar in a certain amount of time. So the patient concentration will be on the game point rather than exercise the eye. He will always try to keep maximum number of ball on the board i.e. keep the board horizontally balance.

IV. Implementation

For the purpose of checking the validity of our proposed method we have developed a prototype based on the proposed system architecture. We have developed both our module which combined to reflect the whole functionality of the exercise effect. This prototype is based on desktop environment. The environmental setup is illustrated in Figure 4.

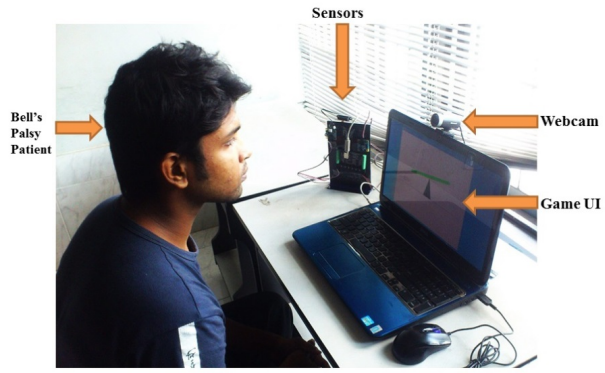
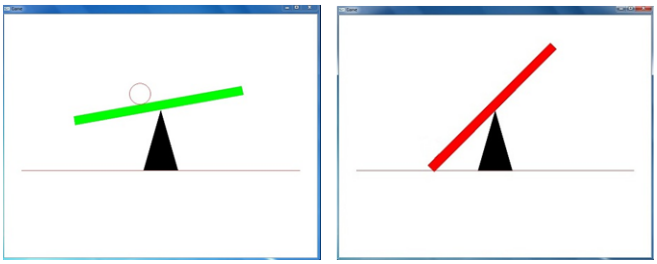


Fig. 4: The environmental setup where a patient is sitting in front of our prototype for exercise.

We developed our prototype system using OpenCV that enable us to interact with the camera. This portion is designed to use the primary camera, also to use the secondary camera if attached. The priority is set to secondary camera as high definition camera can be added on the system. We used a high definition Microsoft LifeCam HD3000 series to produce clearer picture so that noise is reduced in a high factor. Haarcascade that we choose to detect eye is the 'haarcascade_eye.xml', a XML file containing data about eye detection which comes with OpenCV. We used Phidget 1101_0 - IR Distance Adapter & Phidget 3520_0 - Sharp Distance Sensor to measure the distance of the subject. Subjects distance is ensured in between 12-16cm with this sensor. We also measured the environment light to ensure proper light availability with Phidget 1127 - Light Sensor. Light was kept in between 300-400lx for proper video capturing and avoiding shadows on eye portion. We used a Phidget interface kit to connect between sensors and computer. Open Graphics Library (OpenGL) is used to represent the feedback UI which is an interactive game. Besides this we used OpenGL physics engine for collision detection among balls and the board. The game UI is depicted in Figure 5. We used Visual Studio 2010 with .NET Framework 4 to develop our prototype.



(a) Bar position in 75% (b) Bar position in 0%

Fig. 5: Game UI and the bar position.

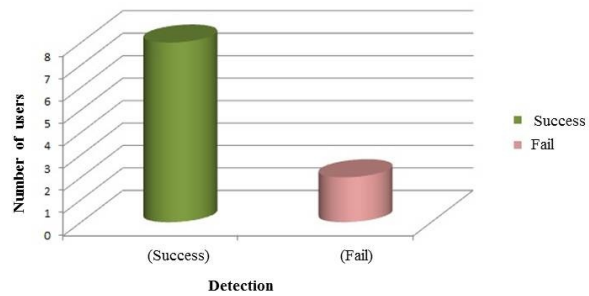


Fig. 6: Pupil's length measurement performance

V. Evaluation and Result

The goal of our evaluations is to determine the performance of our technique. For this reason, we have invited 18 healthy male subjects (including 10 real Bell's palsy patients), age 25-38, to participate in our experiments. These patients were found through local hospitals and known people. Every subject completed each of the exercises three times over 3 days. In the experiment each person invited to sit in front of the computer and keeping their face 12-16 cm away from the camera. Then we take their eye measurements through different shape. We asked them to open their eye naturally or using their hand and then gradually closing them. We took 5 stage images by which we defined pixel intervals for which openness percentage is defined. The environment was proper lighting condition that required for smoothening the video capturing for OpenCV and also with plain background to remove initial noise from the image. This plain background helps to avoid false positive eye detection. High definition cameras will give more accurate result in eye detection than general web-cams.

We have performed 2 types of measurement to evaluate the performance and the suitability of the proposed approach. In the first phase we recorded and demonstrated the success and failure for the pupil's length measurement which is a vital feature of our proposed architecture. And in the second phase we have shown the qualitative analysis by studying different aspects of prototype's feature. These are described in the following section:

A. Pupil's length measurement performance

In figure 6, we have shown the pupil's length measurement performance based on testing the prototype to 10 users. We have chosen 10 users at random and tested the eye detection and length measurement feature with them. We have seen if the system can measure the pupil correctly or the line that we draw to measure the length gone in wrong direction which is interpreted as failure. 2 different colors are used to visualize the success and failure. On the left the numbers represent the number of users.

Based on this performance we calculated the percentage of success, η by equation.

$$\eta = \frac{Number\ of\ successful\ measure}{Total\ number\ of\ users} = \frac{7}{10} = 0.7 \quad (1)$$

According to the graph our system successfully measure 70% user's pupil successfully.

B. Qualitative Measurements

To evaluate the user's quality of experience with the prototype and to justify the suitability of our proposed approach we have performed few qualitative measurement studies. The qualitative analysis is performed by studying different usability aspects of the proposed system. We have incorporated the usability evaluation guidelines [14] to qualitatively measure our proposed system and designed our tests accordingly. Before performing the usability test we designed a test plan where we defined our evaluation objectives, developed questions for the participants, identified the measurement criterion and decided upon the target users of the system.

The test took place at our university laboratory with ten (10) participants comprising of different age groups. Four (4) of the participants are in age group 25-30, five (5) of them are in age group 31-35 and the rest one (1) is in age group 36+. At a time, the selected volunteers were told to play the game and perform the exercise. After each session we have asked them to answer the following questions. The answers to the questions are in the range of 1-5 (the higher the rating, the greater the satisfaction) on a Likert scale [15].

TABLE II: Usability test questions.

#	Question
Q1	Is the system easy to understand than procedural system?
Q2	Is the system easy to learn and adapt?
Q3	The user is more at ease using this system?
Q4	The user do not need to actively use other body parts like traditional physiotherapy.
Q5	It is easy to measure the users progress using this method than the active physiotherapy system.

Figure 7 shows the user's responses for each given assertions. It is worth mentioning that more than 70% of the users would like to use the enhanced system. Overall the 75% users were also satisfied with the gaming approach based physical exercise. 70% patient expressed their willingness to exercise with this passive mode which increased their urge to exercise more and more than conventional method.

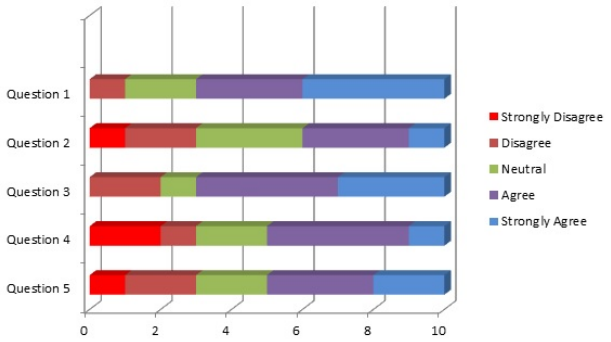


Fig. 7: User response for the usability test questions that are listed in Table II.

VI. Conclusion

In this paper we presented a system for the Bell's palsy patients to help them in passive exercise. The exercise method will be provided in the form of computer game so the user will be able to perform exercise without the hardship that comes with active exercise. We presented the implementation details of a preliminary prototype and performed usability studies on real patients. While we tried to address as many issues as possible related to the design of a prototype for passive exercise for Bell's palsy patient, there are still some topics that we did not treat or that could be treated in more detail. There are some limitations in our prototype tool. One of the biggest limitations of our system was currently the eye detection which we have done using OpenCV and which is not so much intelligent that it can recognize all types of eyes correctly and sometimes miscalculates other things as eyes. Another limitation is the synchronization time between the game board movements with the quick eye movement. If user open or close the eye very quickly then the system fails to recognize the correct openness of the eye. Besides this limitation, we believe that our proposed techniques for passive exercise for Bell's palsy patient will remain as our motivation for further research in this area.

References

[1] D. H. Gilden, "Bells palsy," in *New England Journal of Medicine*, vol. 351, 2004, pp. 1323–1331.

[2] A. Alamri, J. Cha, and A. El Saddik, "Ar-rehab: An augmented reality framework for poststroke-patient rehabilitation," in *IEEE Transactions on Instrumentation and Measurement*, vol. 59, October 2010.

[3] F. Anderson, M. Annett, and W. F. Bischof, "Lean on wii: Physical rehabilitation with virtual reality and wii peripherals," in *Stud Health Technol Inform*, vol. 154, 2010, pp. 229–234.

[4] C. Balance and A. Duel, "The operative treatment of facial palsy," *Arch Otolaryngol*, vol. 15, p. 170., 1932.

[5] B. palsy, "http://en.wikipedia.org/wiki/bell's_palsy."

[6] B. P. F. Sheet, "National institute of neurological disorders and stroke," in *Archived from the original on 8 April 2011*, 2003-04.

[7] K. Adour, F. Byl, R. J. Hilsinger, Z. Kahn, and M. Sheldon., "The true nature of bells palsy: analysis of 1,000 consecutive patients," in *Laryngoscope*, vol. 88, 1978, pp. 787–801.

[8] M. Sajadi and S. Tabatabaie, "The history of facial palsy and spasm: Hippocrates to razi," *Neurology*, vol. 77, p. 174182., July 2011.

[9] P. Z. OLSEN, "Prediction in recovery in bells palsy," in *Acta Neurologica Scandinavica*, vol. 52. Blackwell Publishing Ltd, 1975, pp. 1–119.

[10] D. Pitts, K. K. Adour, and R. L. Hilsinger, "Recurrent bell's palsy: Analysis of 140 patients," in *The Laryngoscope, John Wiley & Sons, Inc*, vol. 98, pp. 535–540.

[11] T. Shafshak, "The treatment of facial palsy from the point of view of physical and rehabilitation medicine," *Europa Medicophysica*, vol. 42, pp. 41–48, 2006.

[12] M. J. A. Jannink, G. J. V. D. Wilden, D. W. Navis, G. Visser, J. Gussinklo, and M. Ijzerman, "A low-cost video game applied for training of upper extremity function in children with cerebral palsy: a pilot study," in *CyberPsychology & Behavior*, vol. 11, no. 1, 2008, pp. 27–32.

[13] OpenCV, "http://en.wikipedia.org/wiki/opencv," Tech. Rep.

[14] D. Chisnell, "Usability testing: Taking the experience into account." in *IEEE Instrumentation Measurement Magazine*, vol. 13(2), 2010, pp. 13–15.

[15] wikipedia, "Likert scale, , http://en.wikipedia.org/wiki/likert," Tech. Rep.