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DEVELOPMENT OF A THERMO-FEEDBACK VISION ASSISTIVE SYSTEM

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ABSTRACT

Blindness is a problem encountering a large percentage of humanity. Scientists are looking at ways to improve vision or at least help acquire some of its functionality. A fraction of improvement in vision would make a difference. In this paper, we present a new method to reconstruct an image in the brain using thermo-feedback effect through the skin.

KEY WORDS
Thermal vision, Skin, Computer controlled, Blindness, Vision assistive device.

1. INTRODUCTION

What we call here a Thermo-Feedback Vision Assistive System (TFVA) is actually a system that uses thermo-feedback effect. TFVA system composes of a sensor (a camera) and actuators (heaters) as well as a controlled unit including software and hardware. We use the term object in this paper to represent the person who uses the system.

There has been a tremendous improvement and changes in the vision assistive devices throughout the years. In 1995, Giulio and others published their work [1], which compares the effectiveness of the feedback of two systems (acoustic and vibratory). These systems were tested to be used to assist blind people who have mental retardation. One of these systems is acoustic feedback and the other one is vibratory feedback. Ram and Sharf [2] developed an electronic travel aids. This device was designed to transform visual environmental cues into a different sensory modality. It was a very helpful device for the visually impaired people. In 2000, MacNamara and Lacey presented their paper [3], which describes the design of their system. The system provided a useful tool for the visually impaired people and it is based on the concept of a walker and a walking frame with wheels. Another attempt was introduced in 2001 by Ulrich and Borenstein who presented the GuideCane system [4]. This device was designed to help blind people to navigate among obstacles. The user pushes the GuideCane forward, and if the GuideCane detects an obstacle; an embedded controller determines a suitable direction of motion that helps the user to change direction. In 2003, Humayun and his team presented their paper [5] which has a study of implanting a retinal prosthesis into a blind subject to detect light presence or absence. In 2004, Hub and others published their work [6] on the development of a sensor, which is easy to handle like a flashlight and helps blind people to move in the indoor environment. In 2005, Willis and his team introduced their RFID system for blind navigation and way finding [7]. In 2006, André and his team presented a paper [8] focuses on using thermal images for a mobile robot to track people. They introduced a vision-based approach to track people using thermal images. In 2007, Lahav and Mioduser presented a study [7] of blind people using the virtual environment, sing haptic and audio feedback to explore an unknown place. In 2009, Saaid and others presented their work [10] and explain the development of a Radio Frequency Identification Walking Stick (RFIWS) prototype. It is to be used for the visually impaired on a sidewalk. The paper shows that the device was intended to assist the blind who walks on a sidewalk. It might be considered as a replacement of the traditional methods such as dogs and regular walking sticks. In 2010, Rastogi, and his team improved the computer mice to use tactile pin displays on the upper part [11], this was developed as 2-D graphical data for visually impaired users.

TFVA uses a regular imaging camera. The experiments, which we conducted, show a promising and efficient technique for the study of the skin as a sensory input. It is an accurate, quantifiable, non- invasive technique that allows the object to visualize and quantify changes in skin surface temperature using a regular camera to construct an image accurately in the brain.

The construction of the first thermo-vision system is the ground of this paper. This paper gives importance to integrate other sensory systems and sub-systems. The basis of the paper is to use the skin as an input platform to the brain to gradually replace the retina. What we have constructed here is a skin based thermal vision system. In the current study, our objectives are the following points.
1) To design the novel TFVA system capable of converting images into thermo-feedback activity using a

high performance low cost thermo-feedback device (TFD), 2) To design the high performance low cost TFD's.
3) To conduct a usability study to assess the capability of the TFVA system and to investigate how the vision impaired people interact with the system and record their responses in terms of behavioral feedback while practicing a simple activity. Further study will focus on physiological and psychological feedback.

The goal of the developed TFVA is to build an assistive device for vision impaired people. The proposed system should have the following two features:
1) The system helps any person who has total vision loss to see an object with resolution of 3*3 in black and white. Moreover the system serves as a training platform to teach users how to use the TFVA system.
2) The system allows users to conduct very limited activities such as playing table tennis with a regular person and conduct other tasks independently but may not simultaneously.

2. METHOD

TFVA system is based on the fact that the skin can feel a change in temperature δt of an attached device. The object is then exposed to a very low change in temperature δt of an apparatus. This apparatus is so-called thermo-feedback device (TFD). If the temperature of the TFD increases with an amount of (δt), the object can feel this change through his/her skin. The change of temperature δt is constant in our current experiments and it is going to be explored in future research in order to determine the best value of (δt). However the TFD device is changing according to the pixel position as we have nine TFD's each corresponds to a particular pixel.

TFVA system is used to convert a low-resolution image in the camera into a change in temperature (δt), which in turn is interpreted by the brain as a black/white pixel.

In this experiment, we use an image with low resolution as of 3*3 pixels in black and white. Once this image is converted into 3*3 B/W format, TFVA is going to switch ON and OFF the TFD’s, which corresponds to the white pixels only. A detailed description about the experiment setup is as follows:
Figure (1) shows the camera is connected to TFVA system. The camera captures an image; the image is then fed into TFVA.

Figure (2) shows the block diagram of TFVA, which receives the image and converts it into 3*3 pixels low resolution B/W image.

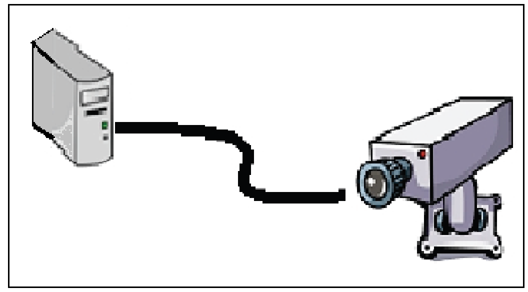
Figure (1): The camera is connected to the TFVA

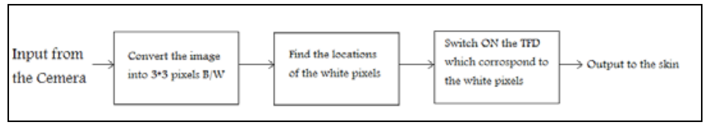

Figure (2): The block diagram of the TFVA system

According to Figure (2), a regular video camera is used to capture an image and feed it into TFVA. TFVA reduces the image resolution to 3*3 pixels, assigns each pixel with its TFD and switch ON the TFD's, which correspond to the white color pixels. We can see how the TFD is switched ON and how it works. Figure (3) shows an example of an image matrix. As we can see, the matrix corresponds to an image which has nine pixels, and only one pixel is ON; this pixel is in the matrix image and in the position (image [1,1]). What we can see in the matrix in Figure (3) is corresponding to an image shown in Figure (4). Figure (5) and (6) show two other examples of the image and the corresponding image matrix.

	1	2	3
1	1	0	0
2	0	0	0
3	0	0	0

Figure (3): An example of an image matrix

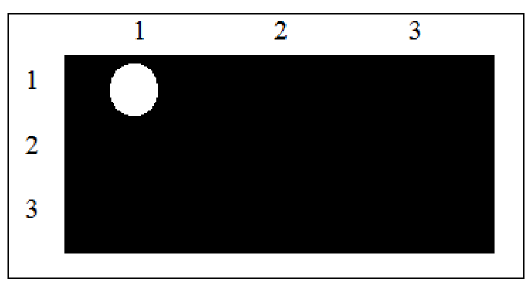

Figure (4): An image of a white ball on a black background

Once the image matrix is constructed, the data of the image matrix is used to control the TFD's through the controller port. In our experiment we use a regular PC to control the TFD's through the parallel port.

D0 through D3 is used in the parallel port; this gives a maximum of 16 TFD’s. In our experiments, we needed only nine TFD's. Figure (7) shows the decoder that decodes the 4 control lines into 9 TFD's. The output line1 controls TFD (1), output line2 controls TFD (2) and so on up to TFD (9). Table (1) shows the image matrix and the corresponding data lines of the parallel port.

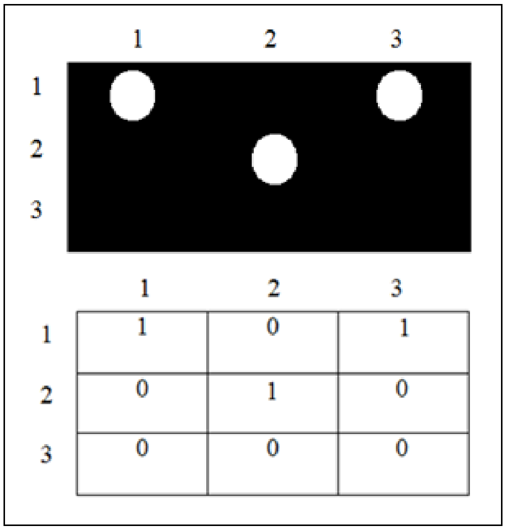

Figure (5): Example 2

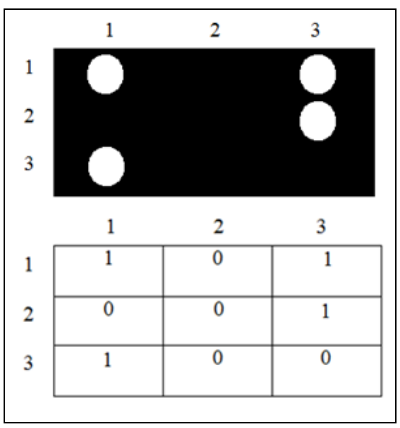

Figure (6): Example 3

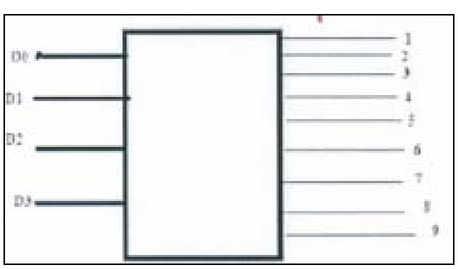

Figure (7): The control decoder

Table 1: Output pins

The image matrix	The output Pins			
	D0	D1	D2	D3
[1,1]	0	0	0	1
[1,2]	0	0	1	0
[1,3]	0	0	1	1
[2,1]	0	1	0	0
[2,2]	0	1	0	1
[2,3]	0	1	1	0
[3,1]	0	1	1	1
[3,2]	1	0	0	0
[3,3]	1	0	0	1

The signal which is received from the decoder is very weak and cannot drive the TFD, so a controlled circuit is used to amplify the current. This control circuit is shown in Figure (8).

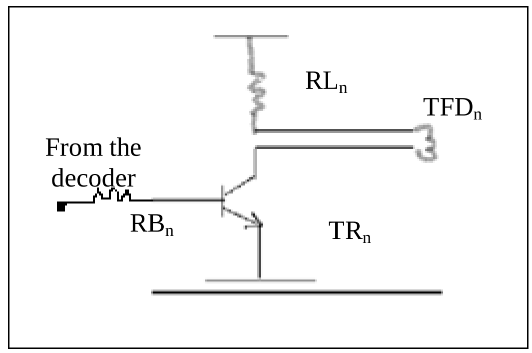

Figure (8): The control circuit

These heaters are designed to produce temperatures of 30oC to 38oC. This temperature is in an experimental phase now and we still working on the optimal temperature. Figure (9) shows the TFD heater.

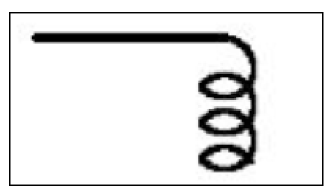
Figure (9): The TFD device

The heaters (TFD's) are distributed on the object chest as shown in Figure (10) and according to the image matrix.

3. RESULTS

We conducted the experiment for more than 100 times, in different setups, and got the following results. The object has to identify the configuration of the matrix. If the object can identify the matrix configuration without errors, it means the object can see the image clearly. Consequently, we managed to send the image to the brain through the skin. This principle has never been explored before, and the empirical finding introduces this contribution to the society. Although there have been many state-of-the-art devices, this experiment introduces the concept of seeing through the skin.

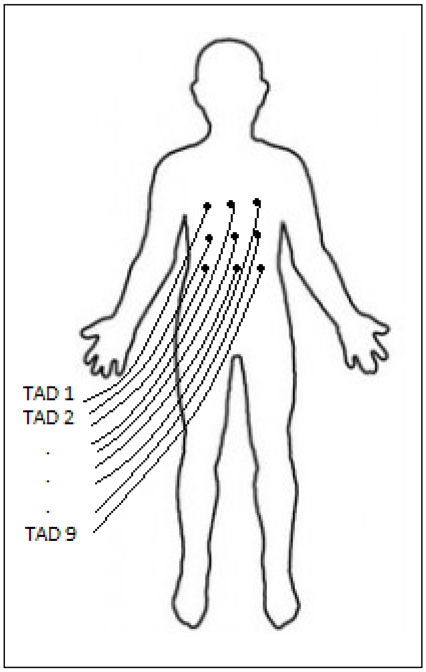

Figure (10): The distribution of the TFD's on the object

3.1 Experiment #1

We use the experiment settings discussed previously, and use only one white pixel in the image. With different positions of the pixel, the object was 100% able to see the pixel position. Then, we used two pixels, and still the object was able to locate the positions of these two pixels, even when we change the pixel positions or replaced the object itself with another one. Then, we switched ON three pixels, but still the object was able to identify the positions. Keeping in mind, the objects were never trained to use the system. Then, we add more pixels and we started to record some errors. The errors were with locating the pixels positions or to identify the number of white pixels. Table (2) shows the result of experiment # 1, and Figure (11) is the representation of this table. Keeping in mind, the image is shown to the object only once. Then, the object has to remove the system. If we want to show the object another image, he or she has to remove the system first and wait for 10 minutes at least.

3.2 Experiment #2

In this experiment, we added the training factor and the object has to go through several images without removing the system. The average switching time between image (n) and image (n+1) was one minute. We hypothesized that if the object was trained to use the system, he or she might be able to see the image better. So, we presented several images to the object in sequence where each image has only one pixel ON. All the images in the sequence have only one pixel ON. We found that the object was able to identify the pixel position. Then, we introduce a sequence of images where each image has two pixels, and the average transition time between frames was 1 minute, and the average time the image is presented was 40 seconds. We found the result of the several training sessions as follow. Training session 1, and 2 without errors, then there was 5% error in the 3rd session, but when we did session 4, there was no error. This unexplained behavior of session 3 was also with the three pixels. However, when we introduced more pixels, the experiment was behaving as expected. Table (3) shows the result of experiment#2, and Figure (12) is a representation of table (3) where series 1 is training session = 1, and series 2 is training sessions = 2, and series 3 is training sessions = 3, and series 4 is training sessions = 4.

Number of pixels	Error rate
1	0%
2	0%
3	0%
4	5%
5	10%
6	20%
7	20%
8	25%
9	25%

Table 2: The error rate when # of patients changes

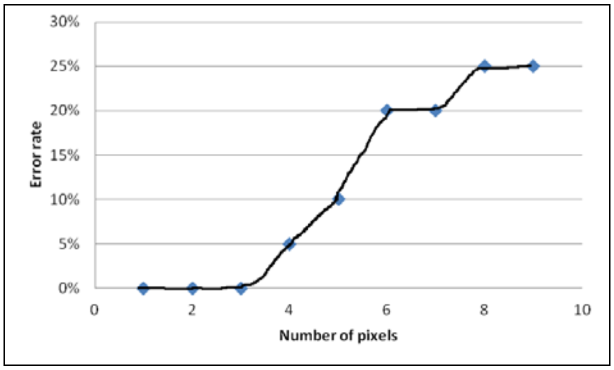

Figure (11): The result of Experiment # 1

Table 3: Experiment 2 training sessions

Pixel	Number of training sessions			
	4	3	2	1
1	0%	0%	0%	0%
2	0%	5%	0%	0%
3	0%	10%	5%	5%
4	0%	10%	15%	20%
5	0%	20%	20%	30%
6	5%	30%	30%	40%
7	10%	30%	40%	45%
8	10%	35%	40%	60%
9	15%	45%	55%	65%

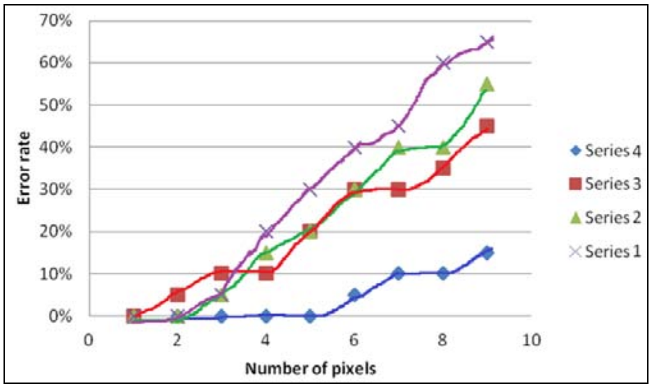

Figure (12): The result of experiment 2

4. CONCLUSION

TFVA system has been developed as a vision assistive device, and it is found that we can train people to use it. Considering the vision and how to transfer an image to the brain, and considering pervious works in this area; we introduced the first thermo-feedback device to be used for an image reconstruction in the brain using the skin. Although the result does not provide high resolution image reconstruction, this is only the first step toward moving into a higher resolution, full color image reconstruction based on the thermo-feedback phenomena using the skin.

TFVA system is a powerful system, and its full potential as a function system with high resolution and full color has not been fully exploited. The major obstacle is the way to transfer an image to the brain using the skin based on the thermo-feedback.

Under the TFVA environment, a beginner user without previous experience can use the system and reconstruct an image into the brain using the skin. Another endeavor in this study is to encourage researchers to explore this phenomenon with more advanced experiments and goals.

TFVA provides a very promising result, which shows that we can identify an image, which was captured by the camera and transfer it to the brain using the skin only.

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