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Research Article

Computerised Hand-held Portable Eye Testing Kit

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Abstract: This study describes development for set of stand-alone portable electronics eye testing kit using microprocessor and LCD screen. A brief explanation of the system development and the selection of the hardware are presented and the prototype is successful built with Arduino Uno and Adafruit 1.8 inch diagonal TFT LCD screen. The prototype is working in good condition and the images are displayed according to the own specification.

Keywords: Arduino, amsler grid chart, ishihara colour plates, TFT LCD

INTRODUCTION

Vision, also known as visual perception is one of five of the human senses. It is the ability of the human eye to capture and interpret images of visible light. The photoreceptors on the retina then convert light into electrical nerve impulses to the brain to be interpreted as images. Damage to the eye especially the retina and optic nerve that are connected to the brain or eye disorders may result in visual impairment or total blindness. Retinal degeneration, cataract, glaucoma, extra ocular muscle disorders, corneal disorders, diabetic retinopathy, congenital disorders and ocular infections are common eye disorders that can lead to visual impairment.

Colour blindness, also known as colour deficiency is a condition where a person is unable to distinguish colours of an object. Colour blindness can be categorized into 2 main groups, total colour blindness and partially colour blindness. Another name for total colour blindness is achromatopsia (Kreutzer *et al*., 2011). The incidence is very few with a ratio of 3 in a million (Miller and Friedman, 1996). The colours that affect such people are not truly represented or deficient. Normally, there are three kinds of cone cells, each containing a different pigment, which are activated when the pigments absorb light. When only one type of cone does not function well like the other two, it is called as anomalous trichromatism (Luckiesh, 1922; Kreutzer *et al*., 2011). If one type of cone is impaired or absent, this results in anomalous dichromatism (Luckiesh, 1922; Kreutzer *et al*., 2011). The colour deficiency monochromatism happens when there is only one type of cone receptors functioning (Kreutzer *et al*., 2011).

Shinobu Ishihara, a Professor Emeritus at University of Tokyo in Japan created the Ishihara Colour Vision chart in year 1917 (Wiggins, year) and it is a pigment-based colour vision test that judges on deficiency of colour vision (Brazis *et al*., 1998). The design of the Ishihara Colour Plate is based on the pseudo isochromatic principles that invented by Stilling (Duke-Elder, 1961). The colour plate is composed by using red and green colour spots so that can differentiate in the simulation of the cones at the retina. Consideration of varies of spot size, in both background and pattern and the brightness of the spot is added into design of the colour plate in order to solve the edge artefact problem (De Alwis and Kon, 1992). The Ishihara Colour Plates are very effective in determining the defect of the protan (red photoreceptor) and deutan (green photoreceptor) (Pickford, 1949).

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Fig. 1: Vision for normal person and macular disease patient

It has been widely used to test colour blindness that commonly on congenital red-green color deficiency (Birch, 1997). To maximize the performance and the accuracy of the colour plate test, the arrangement of the colour plate with complete recording chart and scoring strategy must be presented (De Alwis and Kon, 1992). Beside that Ishihara Colour Plates has also been used in other tests like acquired colour blindness associated with multiple sclerosis, digoxin toxicity, diabetes, simultanagnosia, alcohol toxicity and other functions still in research level (McCleary *et al*., 1996). In this testing, the patients are required to differentiate various colours in colour plate and link the dots into a number (Wiggins, year).

People suffering from vision impairment may suffer a lot of inconveniences. Some of them even can't take care themselves, especially the elders. They have to depend on others. Macular disease or generally known as Age-Related Macular Degeneration (AMD) is the common eye disease for older adults. Figure 1 shows the different of view between normal vision and AMD patient. It is caused by the degeneration of the retina. The common symptoms of AMD are blurred vision, trouble in differentiating colour and central scotomas that missing area or shadow of patients' vision.

Early detection of the eye disease may help patients in term of getting treatment in early stage of the disease so that may have chance to recover and avoid from loss vision (Crossland and Rubin, 2007). Eye testing based on the image is the most common and easiest way for the eye testing. It is the first line eye testing procedure to the ophthalmology.

Amsler grid test is one of the common and effective tests for macular disease. It is a tool that consists of intersecting lines and looks like a graph paper that shown in Fig. 2; ophthalmologists may use it to monitor any visual changes at central vision (D'Amico *et al*., 2003; Chang *et al*., 2004; Gragoudas *et al*., 2004). The function of the central black dot is providing a place to let eye focus. Besides that, Amsler grid chart also widely used to diagnose the central serous retinopathy, cystoid macular edema and macular pucker.

Although the testing image for eye is important, but there are no compact hand-held devices that improve the convenient level in using testing image. There are

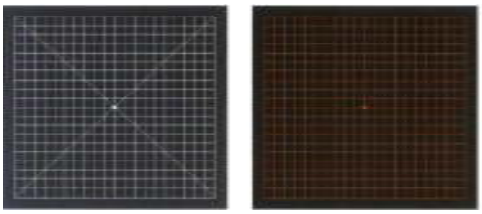

Fig. 2: Example of Amsler grid chart (Franklin, 2003)

certain conditions that need to be fulfilled in order to have a highly accurate testing result such as the testing room must be set in a place with enough light passing through and distance between the chart and the patient must be of specific length. These conditions are not convenient for ophthalmologists or doctors to set up the testing room outside hospital or clinic, especially at rural areas where resources are limited. To overcome this problem, the manufacturer had come out with a solution to develop a simple monocular testing kit, but it is still not user friendly since ophthalmologist needs to bring along the entire testing charts with the testing kit. Therefore, research and development on the computerised eye testing kit is being carried out to have a better solution by using electronics components to build a portable testing kit.

Nowadays, embedded system using microprocessor becomes very familiar to the public. It exists from the simplest structure like mouse and digital watch until complex structure like smart phone. Therefore, the path of using embedded system in hand-held medical device is growing fast in the trend. One of the examples is by using mobile telephone with stand GSM to design telemedicine device by Woodward *et al*. (2001).

Another example using embedded system is related to patient monitor. In the era of on wireless technology implementation, Sichitiu introduced the concept of wireless into the patient monitoring and care device which is able to provide instant response from the monitored patient within the server in year 2000 (Bauer *et al*., 2000).

In year 1998, a research was carried out by applying Ishihara Colour Plates test on PC-based screening system to reduce resources (Hoffmann and Menozzi, 1999). In this research, the Ishihara Colour Plates was presented using CRT monitor and a series of test were conducted to ensure that the performance using CRT

monitor was same as the paper-based test. Nowadays, LCD and microprocessor technology are widely used in medical field like health monitoring device. Therefore, it is a good solution to develop electronics Ishihara Colour Plates and Amsler grid testing kit.

METHODOLOGY

Since the application on this prototype is simple and doesn't require many Input and Output (I/O), therefore PIC and Motorola microprocessor are out from the list of selection. The Arduino Uno is the suitable choice for this project. The reason of choosing Arduino Uno is that it has the enough input output port for this project, its size is suitable for hand-held device, it comes with complete protect shield design and its price is the lowest among the embedded system in the comparison table. Besides that, Arduino Uno need universal power input (USB type B in 5V and 1A). It is easily available for all situations. Although Raspberry Pi is well known as credit card computer and it is able to handle more complex design due to the ARM processor, but its size is not suitable for this project and price is a bit higher compared to Arduino Uno.

On the other hand, this prototype is a hand-held design therefore the overall side must be not too big. The main criterion in choosing the right LCD screen in this project is the size of the screen. Most of the LCD screen in the market is thin-film transistor or TFT LCD screen. This type of LCD screen provides the normal colour vision of the image, which is 16 bits colour. The most suitable size of screen in this project is below 2-inch diagonal. Since Arduino Uno is the microprocessor implied for this application, therefore few small size TFT LCD screens which suit the Arduino Uno are available in market. There are LCD developed by Arduino company themselves and Adafruit Industry. Both are in 1.8-inch diagonal size, 160×128 pixel, 16 bit colour and build-in micro SD for data storage. Adafruit TFT LCD with joystick has the advantage of present of

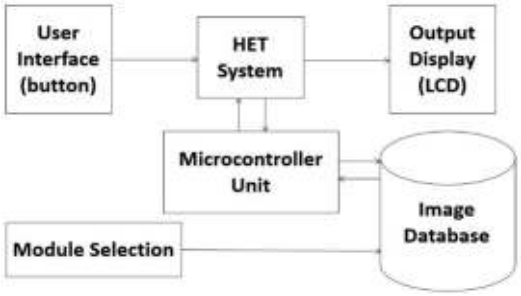

Fig. 3: Block diagram for the project

joystick and shield fitted to Arduino Uno. Therefore, Adafruit TFT LCD with joystick is the final decision for this prototype.

Whole project idea is shown in Fig. 3. In this prototype, the inputs are joystick and micro SD card. Users just control the device by pressing the joystick button and the micro SD card is function as database and storage for image. The TFT LCD screen is the main output of this prototype for image display. Hand-held Eye Test (HET) system is loaded into Arduino Uno for image display function from micro SD card. Different cards store different type of testing image and users just need change the card to the module selection.

The purpose of the joystick is navigating the images inside the database. When the button is pressed, the system will receive the signal and ask the microprocessor to change the image to the output display and this case is the TFT LCD screen. Inside the program of Arduino Uno (HET System), the counter number will represent the image displayed and joystick button is used to control the counter number. If user presses the UP button, the counter number will increase by 1 and next image will be display on screen. The counter number will decrease by 1 and previous image will be display on screen. The module selection is based on the micro SD memory card. Users can change the module or SD memory card according to their needs. The flow of button usage is shown in Fig. 4.

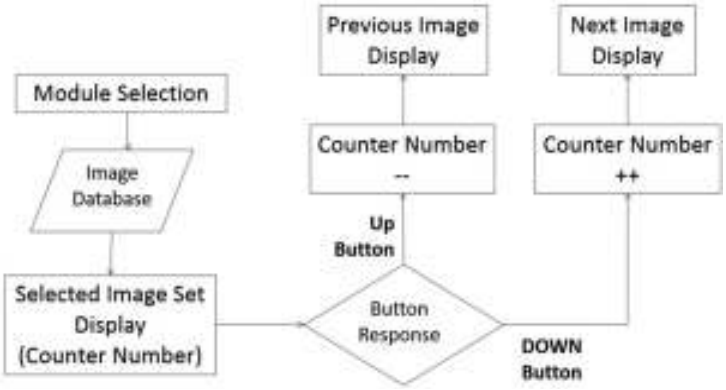

Fig. 4: Flow chart for the button usage

RESULTS AND DISCUSSION

Figure 5 displays the example of vision test image that suit in the system. The whole prototype is started with building of the Ishihara Colour Plate and Amsler Grid Chart image database. Arduino Uno is the selected microprocessor which will use in the prototype. Therefore, the format and the size of the image must be suitable to be display using Arduino Uno. The maximum pixel can support for the TFT LCD screen is 168×120 and colour is in 16 bit. The format which can support by Arduino Uno is bitmap file (.bmp). The images in database are built according to the characteristics above using Adobe Photoshop software.

After finish building database for image, the next step is test the performance of the screen display. The Arduino Uno is programmed according idea of HET system. The image displayed on screen is shown in Fig. 6.

The prototype is completed when the design of the outer shell for holding all unit of Arduino Uno and screen. The purpose of the outer shell is stimulating the proper distance during the test. The Amsler grid chart test should be carry out in the distance of 14 cm between the patients' eye and the grid chart. The design of outer shell is involved of Solid works software and shown in Fig. 7.

The performance of the prototype is within the expectation. The Ishihara Colour Plate and Amsler Grid Chart are displayed in the correct specification. The Ishihara Colour Plate is displayed in perfect circle shape and the colour is acceptable by using 16 bit colour TFT LCD. The square boxes of Amsler Grid Chart are clearly visible. The concept of button control for HET System is polled operation by using IF and SWITCH case. The disadvantage of polled operation is slow response when button pressed. Users need press the button until the next command is executed. Due to the analog input type of the joystick button, the interrupt method can't direct apply on the coding. This problem can be solve in the future by applying joystick into digital input and fabricate own TFT LCD module instead of using ready-make TFT LCD screen.

The idea for designing for hand-held portable eye testing kit is concept proofing for ophthalmology department. In the future, the ophthalmologists can perform the eye test without considering the limitation of the resources. What the ophthalmologists bring for the test is the portable eye testing kit and modules need, not setting the testing room and brings the full scale of the testing device. The concept of portable eye testing kit can be improved in the future due to the limitation of the size of the microprocessor and the technology of the LCD screen nowadays. For example, the resolution of the screen used in this prototype is can't support for the test image which consist of small alphabet like modified Snellen chart. Besides that, the 32 bit colour (true colour) will give the better result of showing the colour test image.

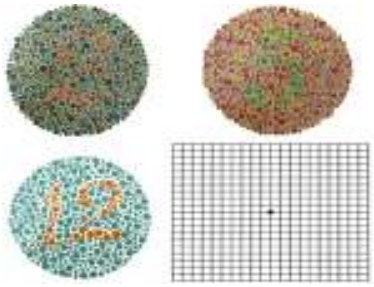

Fig. 5: Image for the database/module inside testing kit

Fig. 6: Performance of the TCT LCD

Fig. 7: Outer shell design in solidworks

CONCLUSION

As the conclusion, the hand-held portable eye testing kit is successful developed into prototype model. The prototype testing kit can be the concept proofing of overcome the problems facing by ophthalmologists like limited resources for carry out eye test outside hospital. However, the performance of the prototype is limited due to the technology of the microprocessor and LCD screen. In the future, the concept of portable eye testing kit can be improved to fit more modules for eye testing.

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