VR-BASED VISUAL ACUITY TESTS WITH REFRACTIVE ERROR DETECTION USING WAVEFRONT SENSOR FOR EARLY DETECTION OF AMBLYOPIA

A Project Study Presented to the Faculty of

Electronics Engineering Department

College of Engineering

Technological University of the Philippines

In Partial Fulfillment of the Course Requirements for the Degree of

Bachelor of Science in Electronics Engineering

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APPROVAL SHEET

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ABSTRACT

Amblyopia is a vision development disorder that starts during early childhood in which the vision of the eyes is reduced because the brain is not functioning well. Early detection can prevent significant loss of vision or even blindness that might be the result if left untreated. Due to the cost of the equipment and tests used for detecting amblyopia, it is commonly left untreated. Over the past years, virtual reality technology has been acknowledged in the field of education and entertainment. It is an experience of the virtual world similar or different from the real environment. In this study, a child-friendly device that will utilize virtual reality to include a visual acuity test and measurement of refractive error of the eyes using Wavefront sensor was developed to diagnose Amblyopia among children ages five to eight. The device is a 3D printed VR goggles intentionally designed to be detachable which is divided into two parts. The first detachable part is designed for the VR simulation while the second part consists of microcontroller and Wavefront sensor for the measurement of refractive error. The VR app has the LEA Symbol Test that is used to test the sharpness of the vision, which will provide a numerical value of the Visual Acuity of each eye. The Shack-Hartmann principle will be used to construct the Wavefront sensor, that will capture the wavefront of light reflected by the eye. It will provide a raw image that will be processed through the program. The code will compute the Fast Fourier Transform (FFT) of the image and will generate the magnitude and phase spectrum from two peaks surrounding the (DC) frequency. These values are correlated and computations using formula for Zernike polynomials are performed. The data will provide the refractive errors of the eye, which are represented in spherical (SPH), cylindrical (CYL), and axial (AX) value. The data

results will be then displayed in (GUI) in the provided tablet or can be also accessed through the website which will be analyzed by the ophthalmologist to determine if there are significant signs of Amblyopia. With this results Amblyopia will be detected at an early age and prevented to cause severe visual disability on the affected eye, or even legal blindness.

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CHAPTER 1

INTRODUCTION

This chapter presents the background of the study, the statement of the problem, the objectives, the significance, and the scope and limitations of the study.

1.1 Background of the Study

Amblyopia is a vision disorder in which the vision of the eyes is reduced because the eye is not functioning well with the brain [1]. It is a very serious condition that starts during early childhood and if left untreated, may cause significant vision loss or even blindness. It needs to be detected earlier so that it could be treated right away [2]. It normally arises before the age of eight. There is also a greater chance of this occurring in children born prematurely or with low birth weight [3]. Amblyopia is often the result of strabismus, in which the eyes are not aligned properly, and anisometropia, in which the two eyes have different refractive power [4]. Amblyopia will not disappear if left untreated, so detection tests should be done on children as soon as they show signs of having it to be treated early and to avoid reduced vision.

Meanwhile, the technology keeps on advancing and has become essential to our daily life. Modern technology has helped us accomplish tasks easier and faster. Unlike in the previous generations, certain tasks take a long time to accomplish and would require a lot of effort to be done. As technology advances, these things can now be done more efficiently than before.

One of the products of modern technology is Virtual Reality (VR). Virtual Reality is a technology that lets people see a computer-simulated environment and then interact with it. People can create their world or reality using VR. With VR, there are a wide variety of things people can do as it is only limited by imagination [5]. VR is used in architecture, medicine, sports, arts, and of course entertainment [6]. It helps us do things virtually, rather than physically which makes certain tasks easier to do.

There are four key elements of a Virtual Reality experience. These are the virtual world, immersion, sensory feedback, and interactivity. With this, creating an enjoyable interactive environment for children where they can immerse themselves into being quite possible. And with Sensory feedback, senses like vision and hearing will be stimulated, making the experience realistic [7]. Integrating the Amblyopia detection tests in the immersive world is desired. Instead of the conventional tests where children would get the feeling of being forced and will just misbehave, it would be beneficial for doctors to conduct detection tests for Amblyopia on children as they will find it entertaining and feel voluntary to do.

1.2 Statement of the Problem

Amblyopia is a vision development disorder that begins during early childhood or infancy. Most of the cases of this pathology affect only one eye, but in some other cases, reduced visual acuity in both eyes can occur. If Amblyopia is left untreated, it can cause severe visual disability in the affected eye or even legal blindness. That is why early diagnosis among the children is crucial to obtain a better response to treatment particularly in the first few years of life [8]. But because the equipment used is so expensive, many parents cannot afford this test, therefore this medical condition is left undetected.

Conducting Amblyopia detection tests on young children could be quite troublesome as they could sometimes be naughty and mischievous. Because of this, doctors could get fairly stressed. Common causes of Amblyopia include misalignment between the two eyes, a large difference in refractive error, media opacity, and strabismus [9]. The cause of Strabismus is due to the abnormal eye movement, the corneal dysfunction mechanisms, and the inappropriately slow development of the brain. If it's not detected as soon as possible, especially in kids, it may cause severe damage to the sight up to blindness when they get old [10]. In view of this, the researchers have decided to develop a device that will aid doctors in detecting Amblyopia on young children. The researchers sought how to make the device more child-friendly and how it will benefit the children and doctors that will use it.

1.3 Objective of the Study

1.3.1 General Objective:

This study is generally aimed to diagnose Amblyopia on children using Virtual Reality Simulation and Wavefront Mapping.

1.3.2 Specific Objectives:

The specific objectives of the study are to:

1. To construct a device that will utilize virtual reality (VR) in the detection of Amblyopia among children ages five to eight through visual acuity tests such as LEA symbol.
2. To measure the refractive error using a Shack-Hartmann wavefront sensor.
3. To test the functionality and accuracy of the device in terms of quantifiable values

1.4 Significance of the Study

Some tests can be done to detect Amblyopia, but the way or the method, it is implemented can't be appealing enough for children. This may cause a problem for a faster detection or diagnosis of the disease. Therefore, the proponents introduce a study that will benefit society as it could aid the doctors in conducting tests on their patients, specifically, children. The earlier Amblyopia is detected and treated, the better the chances of success [11]. Due to subjects being children, conducting detection tests on them will be quite troublesome, as they could be a bit mischievous and stubborn at times. Children are notorious for getting easily preoccupied mostly because of Television (TV), toys, etc. They also have their natural need to move restlessly [12]. Thus, a device that can make them stay still and be obedient will be very helpful.

Virtual Reality is an interactive experience occurring inside a computer-generated environment that people of all ages find entertaining because of the immersion [5]. In this study, a child-friendly program will be created using Virtual Reality that will do detection tests for Amblyopia. Instead of thinking of it as just tests, the children will see it as a game, thus, making the detection tests more enjoyable for the children and easier for the doctors.

As for future researchers, this can be helpful as a based study for the detection and diagnosis of Amblyopia using the proposed parameters.

1.5 Scope and Limitations of the Study

This study aims to create a device that can detect Amblyopia on children using Virtual Reality. It focuses on integrating detection tests like the LEA symbols eye chart into the interactive environment created. The data collection will be conducted solely on young children ages five to eight. This study will only diagnose the Refractive and Strabismic Amblyopia, which are a very common type of Amblyopia among children and will not cover other types of Amblyopia. This study will also not cover the treatment of lazy eye or Amblyopia as it is outside the scope of the study. This study does not intend to replace the experts in this field; instead, it will serve as assistance to them to make their work easier.

1.6 Definition of Terms

- Axis – describes the lens meridian that contains no cylinder power to correct astigmatism that is defined with a number from 1 to 180
- Cylinder (CYL) – indicates the amount of lens power for astigmatism
- LEA Symbol - a chart that can be used for children that contain optotypes (circle, square, house, and heart)
- Refractive Error – occurs when the shape of the eye prevents light from focusing directly on the retina.

- Shack–Hartmann Wavefront Sensor – a wavefront sensor commonly used in adaptive optics systems consists of a lenslet array and a camera
- Sphere (SPH) – indicates the amount of lens power, measured in diopters (D), prescribed to correct nearsightedness or farsightedness.
- Strabismus – is a failure of the two eyes to maintain proper alignment and coordination
- Visual Acuity – refers to acuteness or clarity of vision

CHAPTER 2

REVIEW OF RELATED LITERATURE

This chapter includes principles, theories, and related studies applicable to conceptualizing the project. This includes technical terms from projects developed before and in the present.

1.1 Definition of Amblyopia

Amblyopia, also referred to as the “lazy eye” syndrome, is a visual system disorder that is most frequently diagnosed among children. In most cases, Amblyopia is only available in one eye that has reduced vision than the other, in the absence of any ocular disease. It can’t easily be treated using glasses. This disorder is caused by the disrupted cooperation between the eye and the brain where the brain has its tendency to prefer one eye for visual perception, leaving the other eye to perform fewer movements and activity which further leads to a decrease of vision [13]. Due to reduced vision in the amblyopic eye, the capability of sensing towards three-dimensional objects is insufficient and that leads to defective binocular and three-dimensional visual function. [14].

There are several causes of Amblyopia. The intervention to the clear vision in either of the eye can result in Amblyopia. Constant strabismus (constant eye turn), anisometropia (different prescriptions in each eye), and/or blockage of an eye due to trauma are one of the causes of Amblyopia. If the eye doesn’t have an equal vision, the brain will obstruct the blurry eye and use the good eye. [15]. Having a family history of Strabismus, Amblyopia, or Media opacities (e.g. Down syndrome) could also increase the risk of having Amblyopia. The risk of developing Amblyopia diminishes as the child ages eight to ten years old. Therefore, Amblyopia is less critical the older someone gets at the time of the beginning of the factor in Amblyopia. Monocular vision loss in children is commonly caused by Amblyopia. It is also causing more visual loss in under 40 age group [16]. Hence, early diagnosis is crucial to obtain a better response to treatment. This is because ophthalmologists consider that the approximate visual maturity age is eight to nine years. There is more possibility of success when Amblyopia is treated in the first years of life. [17].

1.2 Types of Amblyopia

Amblyopia can be categorized according to its type or degree of loss. The severity of the Amblyopia is correlated with the degree of imbalance between the two eyes and to the age at which the amblyogenic factor occurred [18]. These types of Amblyopia are classified as Strabismic Amblyopia, Refractive Amblyopia, and Deprivation Amblyopia. This research will focus only on the two types which are Strabismic and Refractive Amblyopia.

1.2.1 Strabismic Amblyopia

Strabismic amblyopia is one of the most usual causes of Amblyopia. It is usually due to the constant non-alternating or unequally alternating misalignment of the eyes. One eye may turn in (Esotropia), out (Exotropia), up (Hypertropia), or down (Hypotropia) [19]. Because of the misalignment of the eyes, the brain disregards the visual input from the misaligned eye, thus, leading to a subsequent drop in the vision of the eye that can result in Amblyopia [8].

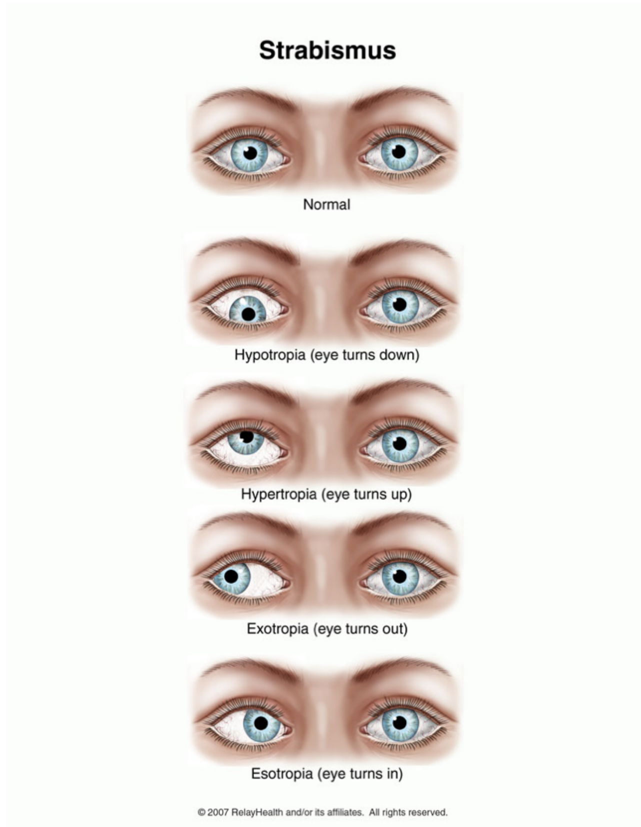


Figure 1. Strabismic Amblyopia [20]

1.2.2 Refractive Amblyopia

Refractive amblyopia is the most usual type of Amblyopia among children. This is developed when there is an unequal refractive error between the two eyes, to be more defocused than the other [19]. For example, only one eye has nearsightedness or farsightedness, or one eye may have astigmatism and the other one does not have. Because of this, the brain depends on the better eye and disregards the other eye with a blurry vision, causing Amblyopia in the other eye [8]. The two main types of refractive Amblyopia are Anisometropic Amblyopia and Isoametropic Amblyopia. Anisometropic Amblyopia refers to the presence of Amblyopia only on one eye which is caused by the difference of refractive error in each eye. Isoametropic amblyopia, on the other hand, involves an almost same refractive error in both eyes. The severity of the refractive error, therefore has a direct relationship with the presence of lazy eye. Anisometropic amblyopia is probably in the occurrence of the following: 1.0–1.5 D or more anisohyperopia, 2.0 D or more anisoastigmatism, and 3.0–4.0 D or more anisomyopia. Bilateral or isoametropic amblyopia, on the other hand, may take place in the occurrence of the following: of 5.0–6.0 D or more of myopia, 4.0–5.0 D or more of hyperopia or 2.0–3.0 D or more of astigmatism. [21].

1.3 Diagnosis

Amblyopia is an eye disorder that can be treated if detected early that is why early diagnosis is essential to prevent significant loss of vision. Some eye specialists say that children must get an eye check-up at six months, three years, and every year at school [22]. These are the factors that will be checked upon their eye exam [23]: 1.) The eyes are letting the light all the way through, 2.) both eyes can similarly see well, and 3.) eyes are moving properly and are aligned.

If there's a problem seen upon taking the eye exam, further tests by an ophthalmologist should be done. If in case there is a presence of misalignment between the eyes, childhood cataracts, or other eye diseases in their family history, an ophthalmologist must also conduct some tests on the child [24]. There are many ways of detecting Amblyopia among children. This research will only focus on the two which are: 1.) Autorefraction, and 2.) Visual Acuity Test using the Snellen Chart.

1.3.1 Autorefraction

Autorefraction is an automated retinoscopy that calculates the refractive error of each eye. More patient cooperation is needed in this test for it requires the subject to remain fairly still during the examination. It also limits the ability to screen for strabismus for it evaluates each eye independently [25]. Autorefraction has more advantages over the traditionally used vision chart assessment because it provides specific visual information that is beneficial for further detection of some factors that can lead to Amblyopia [26].

1.3.2 Visual Acuity Test – Lea Symbols

The Visual Acuity (VA) test is most often conducted to measure a patient's vision. Some of the factors that can affect the result are the lighting of the room, distance set between the patient and the chart, the test chart to be used, and the type of test to be used in monitoring [27]. The LEA Symbols were developed to provide a chart that follows the standards of the Committee on Vision having children as their primary users for it can be difficult for them to be tested with Sloan letters or Landolt rings [28]. It also shows that LEA symbols presented a high sensitivity for the detection of lazy eye [29]. It uses figures of different sizes such as circle, square, house, and heart that are arranged proportionally in lines wherein each line contains five optotypes having each line a difference of 0.1 log unit steps. The chart (Figure 2) is to be viewed by the patient simultaneously. A lamp or overhead light fixture can be used to produce lighting for the LEA Symbols test. This produces uniform illumination across the chart and minimum luminance of 100 candela/m2 as measured with a light meter [30].

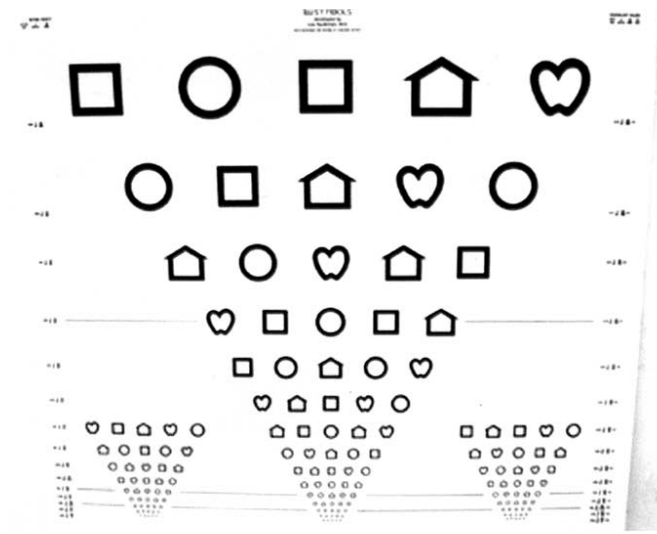


Figure 2. LEA Symbols Distance Visual Acuity Chart [30]

1.4 Related Literature

1.4.1 Virtual Reality

The potential of virtual reality is undeniable in terms of measuring and helping identify many problems with vision. For this reason, Diplopia, a virtual reality game was created using Unity3D. This utilizes the Oculus Rift head-mounted display (HMD) and Leap Motion controller which, helps treat and restore the vision of those who suffers from amblyopia. The game uses the two eyes to work together to win the game. It exercises the muscle in the weak eye more than normal and with sufficient use of the game, they may be able to gain depth in normal seeing conditions. This virtual reality game can aid people who suffer from Amblyopia, treat and restore their vision without them even noticing it. It might take a couple of months, but it can also be of help to treat their eye problem with Amblyopia [31].

Children with congenital ptosis are in danger of having anisometropic and strabismic amblyopia, which may continue to develop during the early stage. Regular intervals of examination and treatment should be done to stop the further complications, Amblyopia was more likely to occur in cases with greater relative eyelid asymmetry and did not develop in children with symmetric ptosis. In few cases, Anisometropia and Amblyopia were not initially apparent but progressively developed during follow-up [32].

A technique that used to treat Strabismus uses the patient's interest in virtual environments. The most essential part of this project is the fact that the patient forces its eyes to cooperate in what he or she is seeing in the environment resulting in the affected eye being exercised. This project is composed of low-cost VR goggles and uses a phone for its display.

A proposed virtual reality application that focused on the treatment for young amblyopic patients used a computer photo hunt game and visual reality headset device which control the visibility of each patient’s eye [33]. The virtual reality photo hunt game runs on an Android device that attaches to the Google VR Cardboard. The reason that it is developed on mobile devices over the Personal Computer (PC) is due to its portability. The treatment must be done regularly four to five times per day. The application only works for mobile devices, therefore, future works include an extension of the system to support photo hunt contents creation that runs on PC [31].

A treatment in which children will play an interactive virtual game to improve their vision. This study used to improve the vision of children with dense Amblyopia. It is also stated that the amblyopic eye can respond in the visual display. This study is limited to children. Future development may include the design of a visual environment for its effectiveness for all ages [34].

1.4.2 Wavefront Sensor

The Wavefront Sensor is widely used in the optical industry in terms of measuring the aberrations of the eye. The Shack-Hartmann wavefront sensor and Fourier transform-based algorithm are used in the fabrication of a new autorefractor to measure refractive error. The Shack-Hartmann-based autorefractor (SHAR) uses Fourier-based data analysis that represents the wavefront irregularity as a consolidation of Astigmatism and defocus only, then conveys the wavefront in the matter of measurable quantities in Fourier-space, finally, relates them to the refraction of the subject. The SHAR has the capability to perform no less than the commercial autorefractor [41].

The measurement of off-axis wavefront aberrations of the eyes is essential. A scanning Shack Hartmann Aberrometer (SSHA) was produced by integrating a double-pass scanning system with a Shack Hartmann Wavefront Sensor (SHWS), in order to attain adequate measurement. The off-axis wavefront aberrations over +/- 15 degree visual field within seven seconds were effectively calculated by the prototype SSHA. It evaluated change in defocus aberration exactly and precisely in two experiments using a wide angle model eye. An experiment with the human eye proposes the viability of the prototype SSHA [42].

A study about measurement of refractive errors in myopes used the COAS Shack-Hartman aberrometer. The refractive errors of 20 subjects were determined using a Complete Ophthalmic Analysis System (COAS), a phoropter, and a Nidek ARK-2000 autorefractor. Both eyes were tested, with or without cyclopegia, small and large pupils. The basis for the true refractive error was the data from the phoropter, it was a comparison between the phoropter refraction and the COAS and autorefractor. The accuracy, repeatability, and instrument myopia of the COAS were akin to the autorefractor when measuring myopic subjects. Both were more accurate than the subjective refraction. The COAS is as dependable as the autorefractor [43].

A study was made to design a handheld wavefront sensor. The purpose of the study was to produce a low cost and accurate autorefractor. The Prototype Autorefractor (QuickSee), Grand Seiko WR-5100K (GS) autorefractor, and Subjective Refraction (SR) were tested on 41 adults. The QS and GS were assessed using a Bland-Altman analysis. The SR was used as the standard for the accuracy of both QS and GS. The prototype autorefractor has the capability to perform no less than the GS autorefractor [44].

CHAPTER 3

METHODOLOGY

This chapter presents the methods and procedures used in the development and implementation of the project. The proponents also included the program algorithms, and the design flow process in making the whole system.

1.5 Theoretical Framework

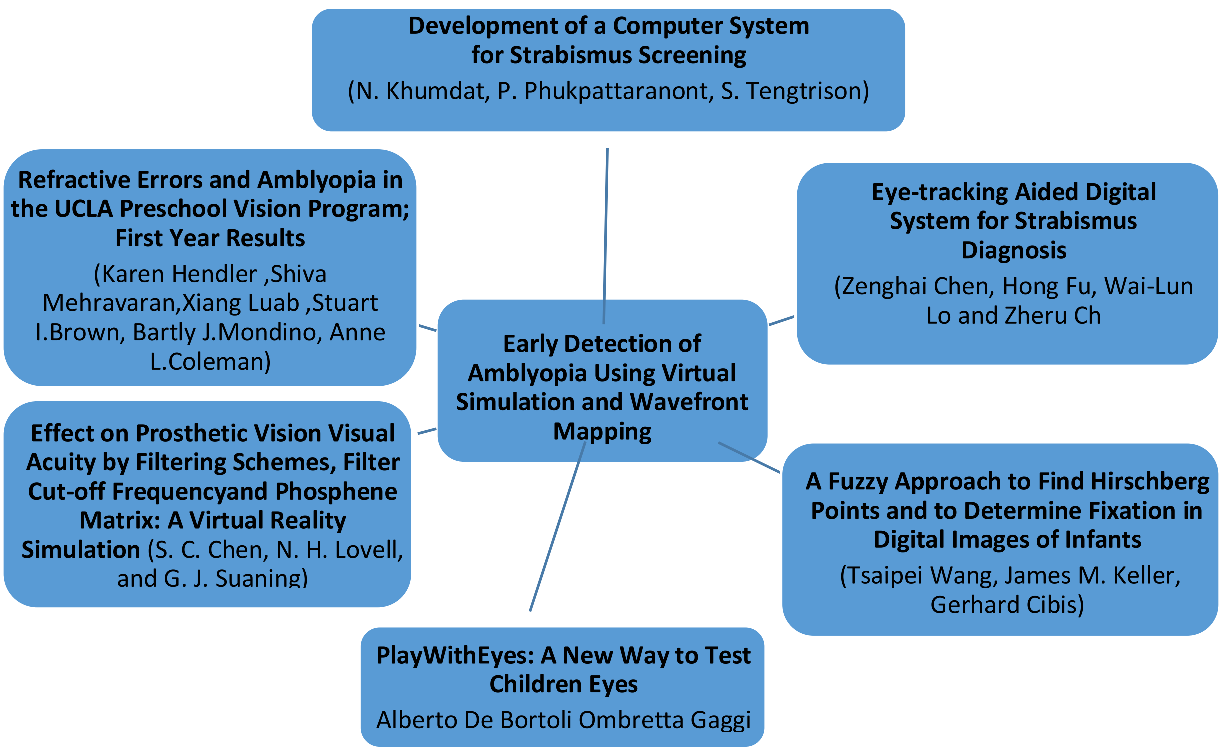
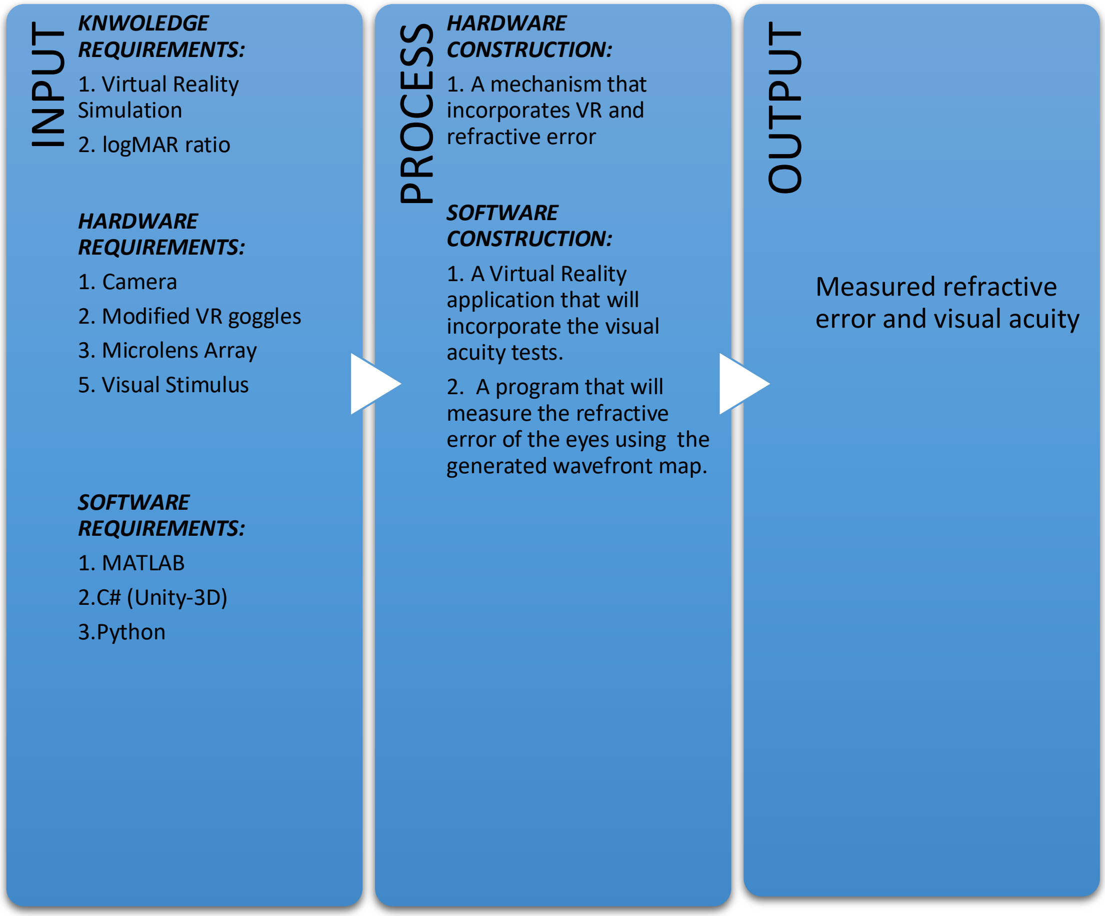


Figure 3. Block diagram of related studies

The figure shows all studies that are relevant in making the project possible. The concept from each study such as getting the refractive error, Hirschberg points, and visual acuity through image processing are also considered.



1.6 Conceptual Framework

Figure 4. IPO of the project

In this project, the general objective is to design and construct a mechanism that incorporates VR, Visual Acuity Test, and Refractive index measurement setup together. Knowledge about Virtual Reality Simulation, logMAR ratio, Zernike polynomials, and Fourier transform are very much needed in this project. The main components of this project are Camera, Microlens Array, Modified VR Goggles, and Visual Stimulus. The device will conduct two different tests and after gathering enough data, it will undergo processing to generate the measured refractive error and visual acuity of the eyes that can be a basis to diagnose if it is false positive or false negative to Amblyopia.

1.7 Research Design

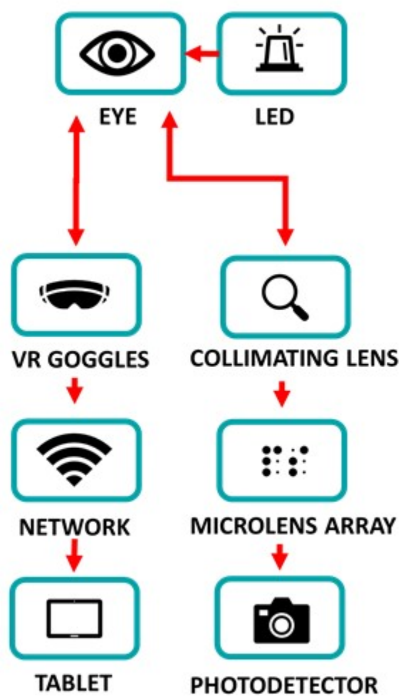


Figure 5. General Flow Chart of the Device

The device is composed of two different tests, naming Refractive index and LEA symbols. The subject will first undergo the refractive error before conducting the test in VR, as this test can be less entertaining for the children. The purpose of this is to make the children anticipate the VR experience. The researchers will obtain the refractive error of the eye based on the raw image coming from the wavefront sensor. In testing the visual acuity of the subjects, the VR goggle that is incorporated with LEA symbols will be used.

1.7.1 Hardware Construction

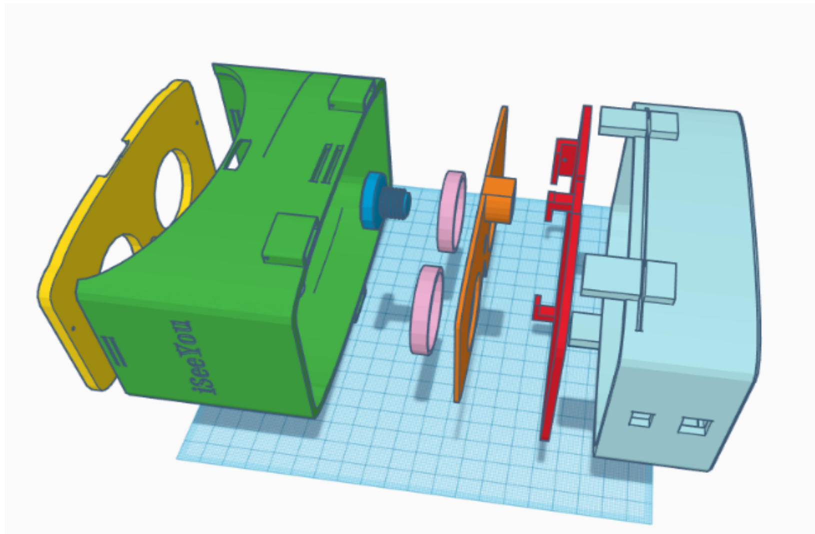


Figure 6. Prototype Design. Perspective view of the VR

Figure 7. Actual design of the device

The first stage is the Virtual Reality Simulation where the patient will wear the VR goggles and will interact with the Virtual Reality World. The Virtual Reality Application will incorporate Lea's Symbol test which will determine the Visual Acuity of the patient.

The second stage is measurement of the refractive error. The visual stimulus will strike a light and when it enters the human eye, it will be reflected and will produce a wavefront. When the wavefront hits the microlens array, the array will split the wavefront into two discrete portions on each lenslet. Each lenslet will then focus its portion of the approaching wavefront to a specific spot on the Charge-Coupled Device (CCD). A plane wavefront will be produced from a perfect eye, therefore, it creates a perfect grid on the CCD camera, but an aberrated eye will create a distorted grid that deviates both on the horizontal and vertical of the optical axis of the lenslet by a value that is relative to the angular ray aberrations of the eye on the matching pupil position. The CCD now takes the image that will undergo a process with the program to have the wavefront map.

1.7.2 Software Development

For the Virtual Reality Application, the proponents decided to use Unity 3D as the cross-platform game engine. The language that's used in Unity is called C# (C-sharp). Unity operates with an object-oriented scripting language [35]. Like any language, scripting languages have syntax or parts of speech, and the primary parts are called variables, functions, and classes. The application includes the visual acuity test which is LEA symbols.

As for the algorithms of each method, Python will be used. For it is a high-level, general-purpose programming language that can be used for advanced purposes like performing calculations and also in some applications such as signal processing. The program will process two sets of data (for refractive error, visual acuity). First, for obtaining the refractive error, the program can process incoming images instantly once the sensor has detected the raw image (coming from the wavefront sensor). This input will be classified by using Zernike Polynomials according to its aberration order. Once its order is determined, its polynomial values will be extracted and will serve as the coordinates in the program to map the wavefront aberrations. In this stage of the program, the aberrations of the eye will be mapped and will provide sufficient data for the program to give accurate results according to the processed wavefront. And for visual acuity from the VR, manual inputting of data will be done and will be analyzed based on what the program will produce.

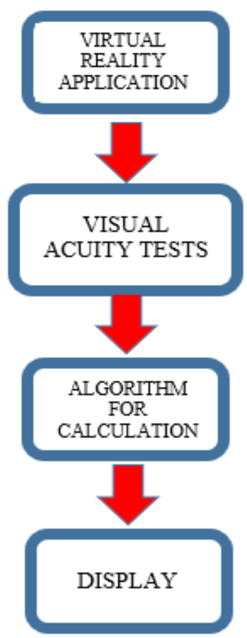


Figure 8. Development of Application and Algorithm of the VR

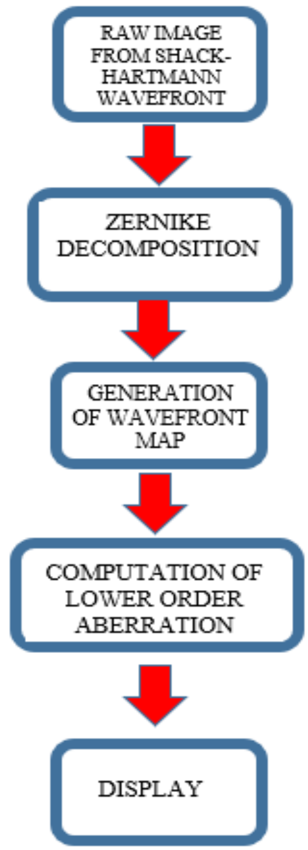


Figure 9. Development of Algorithm for the Refractive error

1.8 Materials and Equipment

Camera - is an optical instrument that will be used to capture still images or to record moving images of the eye to measure its refractive error and CCLRR.

Figure 10. Webcam [36]

Microlens Array – are more efficient in terms of collecting light, providing smaller and brighter spots, which is especially important for low-light applications. The focal length of the microlens array proportionally improves the sensitivity of the Shack – Hartmann wavefront sensor.

Figure 11. Microlens Array [37]

Raspberry Pi–is a low cost, a little device that plugs into a computer monitor or TV, and uses a standard keyboard and mouse that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python [38].

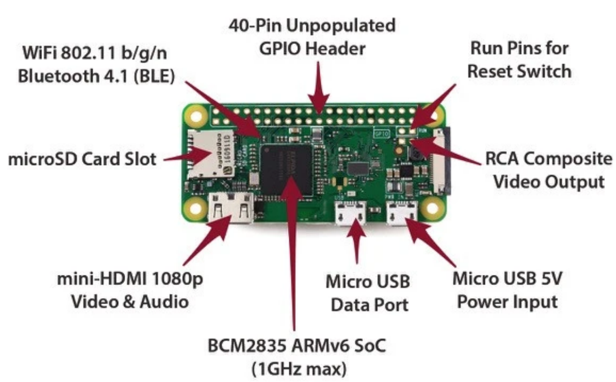


Figure 12. Raspberry Pi [39]

Light – Emitting Diode (LED) – is a semiconductor device that is used as a light source for the Shack – Hartmann wavefront Sensor. Red LED is used since it is the safest light source color to use for it has the longest wavelength.

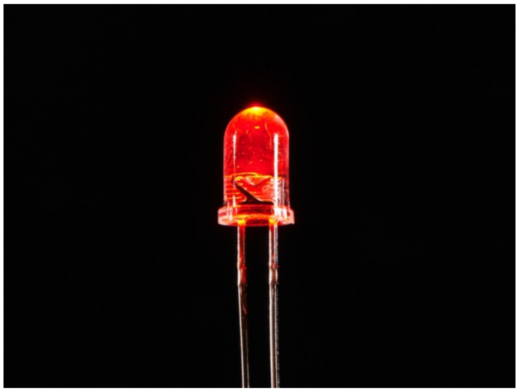


Figure 13. Light - Emitting Diode [40]

1.9 Testing Procedure

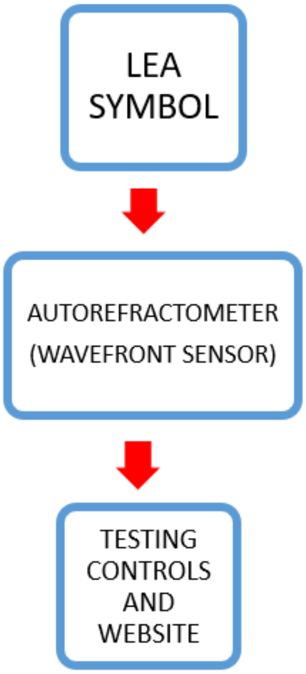


Figure 14. Testing Setup

In testing the device, the subject will undergo the LEA Symbol test and auto refractometer for the refractive error. As for the LEA Symbol test, the doctor will be the one evaluating the result that is based on the patient's capability. For the auto refractometer, the scanned image of its eyes will serve as the input for the processing. As an output, the device should produce a raw image from the Shack-Hartmann wavefront sensor and its numerical result.

1.10 Evaluation Procedure

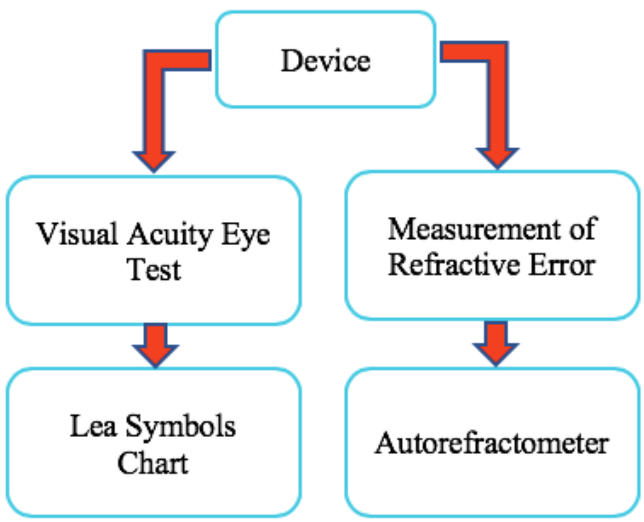


Figure 15. Evaluation Diagram

For evaluation, the proponents will let an ophthalmologist use the modular VR device in conducting eye checkups for children five to eight years of age. The gathered data will be compared to the result using the traditional way of conducting a visual acuity test to know the accuracy of the device.

1.11 Data Analysis

The results obtained in the portable auto refractometer or the Shack-Hartmann wavefront sensor consist of three parameters such as spherical, cylindrical, and axial.

The spherical deals with the degree of nearsightedness or farsightedness of a patient while cylindrical tells the amount of astigmatism, usually it is in the unit of diopters and lastly Axial, for a complete and accurate prescription knowing the orientation of astigmatism is important.

LEA symbol eye test result will be based on the Snellen denotation. The visual acuity in each eye should 6/9.5 or better to be categorized as pass. The two-line difference between the eyes can also be considered.

1.12 Financial Plan (Bill of Materials)

MATERIALS	QUANTITY	PRICE	COST
3D Printer Filament	2	₱6,000.00	₱12,000.00
Collimating Lens	1	₱3,000.00	₱3,000.00
LED	1	₱3.00	₱3.00
Microlens Array	1	₱130,000.00	₱130,000.00
Mobile Phone	1	₱11,000.00	₱11,000.00
Power Bank	2	₱400.00	₱800.00
Raspberry Pi Zero	2	₱4,000.00	₱8,000.00
Resistor	1	₱3.00	₱3.00
Screws	8	₱20.00	₱20.00
SD Card	2	₱500.00	₱1,000.00
Tablet (for controls)	1	₱35,000	₱35,000.00
USB Camera	2	₱3,000.00	₱6,000.00
USB Cords	2	₱30.00	₱60.00
Velcro	1	₱50.00	₱50.00
		TOTAL	**₱206,936.00**

Table 1. Bill of materials

CHAPTER 4

RESULTS AND DISCUSSION

2.1 Project Technical Description

The purpose of this study was to develop a modular device that can be used for the early detection of Amblyopia. It is a device that incorporates VR simulation and an auto refractometer. The device is expected to give aid to the doctors in conducting visual acuity tests for children. This project used the concept of VR for the LEA Symbol test and Shack-Hartmann wavefront design for the auto refractometer.

Figure 16. The proper way of using the device

The purpose of having a VR design of the device is to catch the interest of the children while conducting the visual acuity test. The controls and the instructions or the ways on how to use the device will be seen on the tablet provided for the doctor. And because the device is modular, there are different setup for the LEA Symbol and the auto refractometer.

2.2 Project Structural Organization

2.2.1 Device

Figure 17.a Front view

Figure 17.b Side View

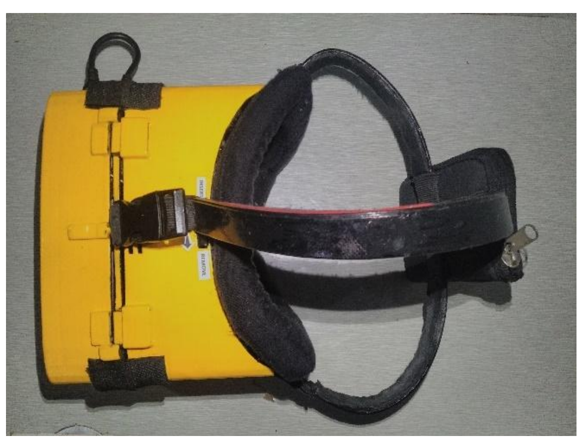


Figure 17.c Top View

The figures above show the final structure of the device having a dimension of (130mm x 75mm x 90mm). The design of the device is based on a VR goggle. The device is modular and has two setups in it that is why the front part is detachable. The power bank which supplies the microcontroller for the autorefractor setup is located at the back part of the strap. There are ports on the side for the connection of the microcontroller.

2.2.2 Step-by-Step Procedure

ISEEYOU MANUAL

A simple guide on using the device safely and efficiently.

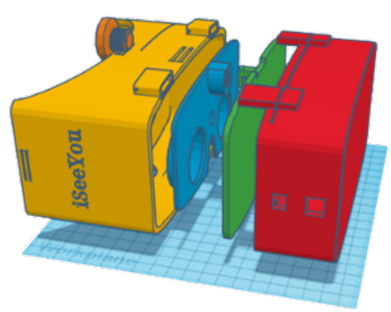


Figure 18. Visual Acuity Set-up

PARTS

- **VR Body/Base –** This part is fixed and placed on the head of the child.
- **Knob –** It is a rotatable knob to adjust and remove the lens holder.
- **Lens Holder** – This part is where the lens is placed to be able to remove it after the test.

■ **Phone Holder**

■ **Phone & Raspi Case**

How to use the Visual Acuity Set-Up?

1. Wear the VR Body/Base in the head of the child, make sure that it is perfectly fitted.
2. Open the app named ISEEYOU on the android phone placed on the Phone and Raspi Case.
3. After opening the app, safely attach the Phone and Raspi Case to the VR Body/Base and lock it with the Velcro.
4. Next, open the Tablet and select the app named CONTROLLER, after opening press the connect button (It must indicate if the device is connected).
5. After connecting, place the eye cover on the right eye to test the left eye, then ask the children to read each line on the LEA SYMBOL (Note: You can use the tablet to indicate which line to read.).
6. After testing the left eye, place the eye cover on the left eye then test the right eye.
7. When done testing both eyes, unlock the Velcro and safely remove the Phone and Raspi-Case from the VR Body/Base.
8. You can now remove the Lens Holder for the next eye test, just simply slide the knob clockwise (when you are facing the child) until it pops out (Do the opposite when putting it back).

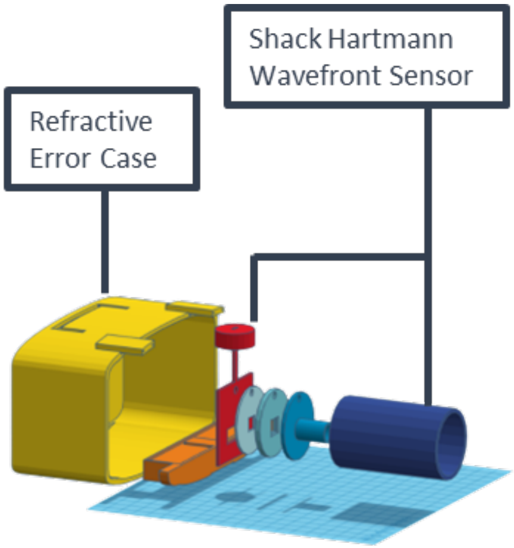


Figure 19. Refractive Error Set-up

Refractive Error Case - 162x99x81mm in size

Shack Hartmann Wavefront Sensor - It contains Collimating Lens, Microlens Array, Red LED Light and Raspberry Pi Zero with 8MP Camera.

How to use the Refractive Error Set-Up?

1. After testing using the Visual Acuity Set-Up, make sure to remove the Lens Holder for this Test.
2. Safely attach the Refractive Error Case on the VR Body/Base and lock it with the Velcro. Connect the wire to the power bank at the back of the head of the child.
3. Wait at least 30 seconds after connecting the wire on the power-bank.
4. Open the app named ‘VNC Server’ on the Tablet, and select ‘Wavefront Sensor’.

5. On the app, select the ISEEYOU folder and select the program named 'ISEEYOU.py' then press Run.
6. After pressing Run, the app will display a GUI and press the screen, then follow the instructions written on the GUI.
7. Well done! You have now obtained the data for the Refractive Error of the Eye which is SPH, CYL and AXL.

Note: When capturing the image, make sure that the dotted lines are inside the circle, unless it will give inaccurate results.

Reminders:

- Always turn off the screen of the phone and tablet after use and charge the phone when the battery is low.
- Always remove the power-bank from the wire after use because the raspberry pi might overheat.
- Change the foam regularly.
- Contact us if there's any problem occurred
- Always put the device in its proper box after use.

2.2.3 Graphical User Interface

Figure 20.a GUI main window

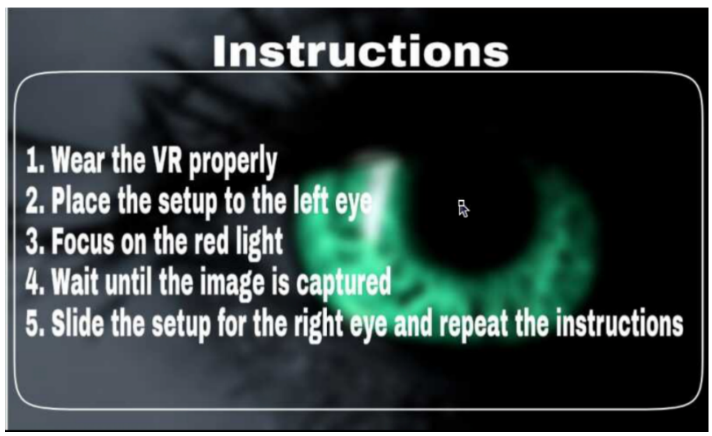


Figure 20.b Display of instructions

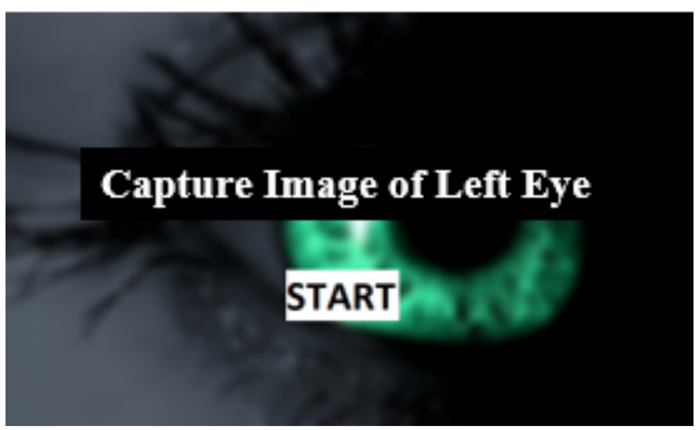


Figure 20.c Left eye start button

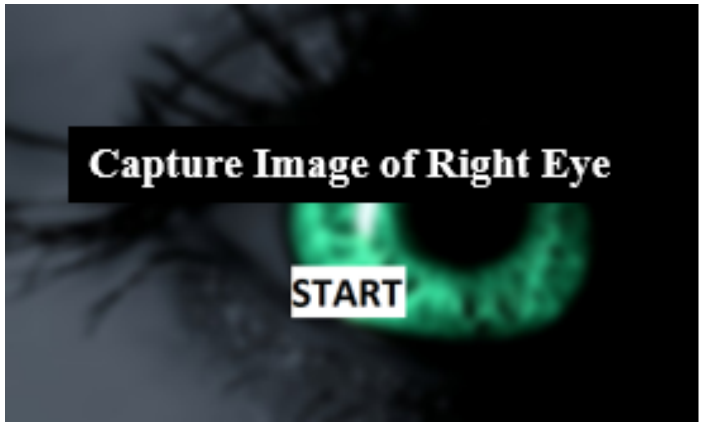


Figure 20.d Right eye start button

Figure 20.a shows the Graphical user Interface main window while figure 20.b shows a list of instructions on how to use the device if it is in the refractive error setup. Figure 20.c and 20.d shows the start button for image capturing in the left and right eye respectively.

2.2.4 Sample Raw Image

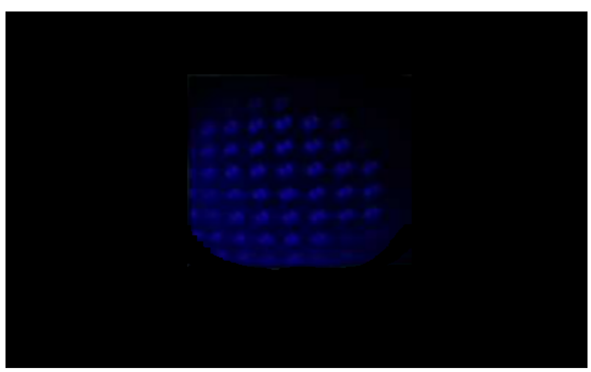


Figure 21.a Raw Image in the Left eye

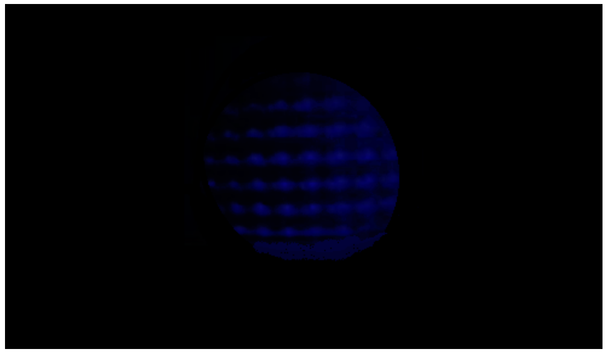


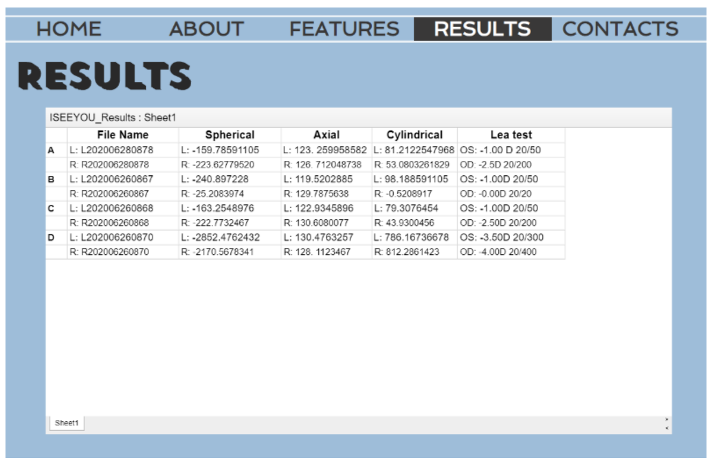
Figure 21.b Raw Image in the Right eye

Figures 21.a and 21.b show the raw image captured on the left and right eye respectively. These raw images will undergo image processing using different algorithms to measure the refractive error. The wavefront creates a perfect grid in an eye without aberrations or a distorted grid in an eye with aberrations. The spots diverge in horizontal and vertical manner from the optical axis of the lenslet.

2.2.5 Website

Figure 22.a Main Window

Figure 22.b About the device



	File Name	Spherical	Axial	Cylindrical	Lea test
A	L: L202006280878	L: -159.78591105	L: 123. 259958582	L: 81.2122547968	OS: -1.00 D 20/50
	R: R202006280878	R: -223.62779520	R: 126. 712048738	R: 53.0803261829	OD: -2.5D 20/200
B	L: L202006260867	L: -240.897228	L: 119.5202885	L: 98.188591105	OS: -1.00D 20/50
	R: R202006260867	R: -25.2083974	R: 129.7875638	R: -0.5208917	OD: -0.00D 20/20
C	L: L202006260868	L: -163.2548976	L: 122.9345896	L: 79.3076454	OS: -1.00D 20/50
	R: R202006260868	R: -222.7732467	R: 130.6080077	R: 43.9300456	OD: -2.50D 20/200
D	L: L202006260870	L: -2852.4762432	L: 130.4763257	L: 786.16736678	OS: -3.50D 20/300
	R: R202006260870	R: -2170.5678341	R: 128. 1123467	R: 812.2861423	OD: -4.00D 20/400

Figure 22.c Summary of results

The figures above show the interface of the website. (a) The main window, (b) the description of the device, and (c) shows the lists of results from the device.

2.3 Project Limitations and Capabilities

This study focuses on the construction of a modular VR device that incorporates a visual acuity test and a portable auto refractometer that can be used in the early detection of Amblyopia.

This study incorporates the principle of VR simulation for the visual acuity test and the concept of the Shack-Hartmann wavefront sensor in constructing the auto refractometer. The resulting data can be seen in the tablet where the doctors have access and on the website constructed for easy entry of data.

2.4 Project Evaluation

Figure 23. Testing

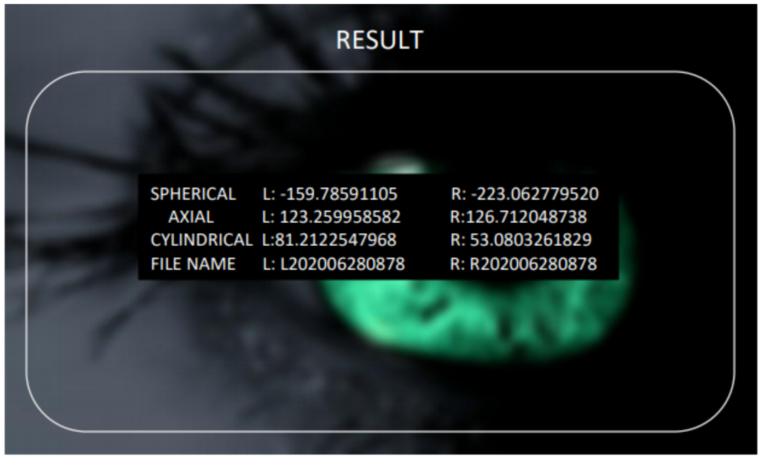


Figure 24. Sample Result

The refractive error was measured using the Shack-Hartmann wavefront sensor in the device. Computation of the visual acuity was obtained from the utilization of Virtual Reality and LEA Symbols. A total of four samples were obtained using the device; both for the refractive error and for the computation of visual acuity. This is due to the cancellation of the deployment of the device because of the global pandemic. Thus, Figures 23 and 24 show the gathering of data and a sample result obtained solely from the device.

2.4.1 Functionality

The proponents conducted a survey among the users of the device to evaluate its functionality with the question of:

- "How would you rate the performance of the device?"

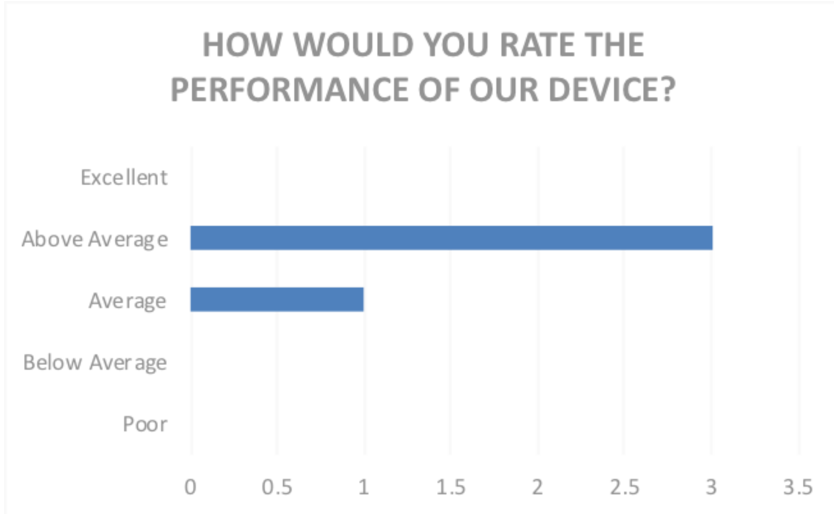


Figure 25. Survey for the Device's Functionality

Figure 25 shows the data gathered from the survey conducted among the users who were tested using the device. 3 of them gave the device an evaluation of "Above Average" while 1 of the users rated its performance as "Average". This serves as the evaluation of the device for its functionality based on its performance in delivering results according to its purpose.

2.4.2 Convenience

A survey was conducted among the users of the device to evaluate its functionality with the question of:

- "Is the device easy to use?"

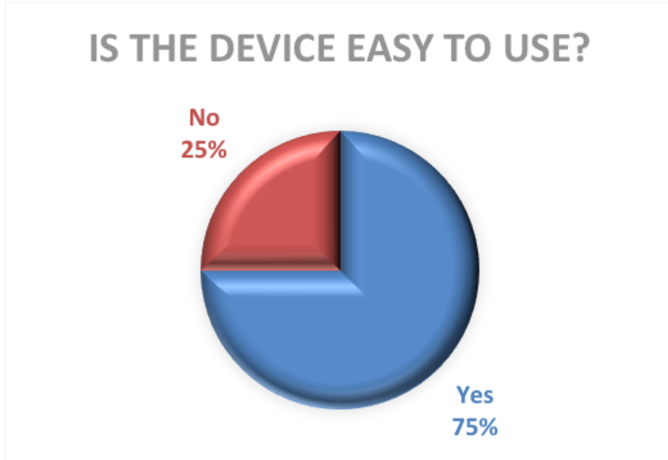


Figure 26. Survey for the Device's Convenience

For the evaluation of the device in terms of convenience, Figure 26 shows the result of the survey conducted among the 4 users who were tested using the device. 75% of the respondents evaluated the device as convenient and easy to use since it is portable and wireless.

2.4.3 Design

The evaluation for the design of the device are the following:

- Interesting
- Child-friendly

The following evaluation was made by Dra. Patricia Cabrera, an Ophthalmologist at Philippine General Hospital, upon the initial evaluation of the device as shown in Figure 27. According to her, the device stirs interest, especially for children since the device uses Virtual Reality.

Figure 27. Initial Evaluation at Philippine General Hospital

2.4.4 Accuracy

The accuracy of the device can be evaluated using the following statements:

1. Are the results from the Virtual LEA symbols chart the same as the results obtained from the physical LEA symbols chart?
2. Does the portable refractometer give accurate result in comparison with the auto refractometer used on eye clinics?

The cancellation of the deployment of the device due to the global pandemic led to insufficiency of data in evaluating the accuracy of the device. This is because there are no data obtained from the clinical auto refractometer and the actual LEA Symbols chart from which the data results will be compared to evaluate the accuracy.

CHAPTER 5

SUMMARY OF FINDINGS, CONCLUSION, AND RECOMMENDATIONS

3.1 Summary of Findings

Since there is no comparison that can be made due to insufficient data, the accuracy of the device cannot be evaluated. However, the functionality of the device was obtained from the feedback of the users through a survey. Figure 24 shows the result of the survey. Based on the results, the users find the device convenient and easy to use considering that there are two tests that can be performed using the device. 75% of the users were satisfied and rated the device as "above average". When asked if the users will recommend the device, all of them answered "Yes" due to the following factors: "The device is compact, accessible, interesting, and child-friendly."

3.2 Conclusion

The following conclusions have been made based on the results and findings obtained:

1. The construction of the device was successful because Virtual Reality and Wavefront technology are incorporated into one modular device that can aid doctors in conducting eye tests.
2. The autorefractometer or the wavefront sensor produces numerical values for the Spherical, Cylindrical, and Axial parameter of the refractive error of the eye.
3. The evaluation of the functionality and convenience of the device was made based on the surveys gathered from the users who were tested using the

device. 75% of the respondents find the device easy and convenient to use and rated it “Above Average” for its performance considering that it is designed for multiple testing to aid ophthalmologists in conducting tests for the detection of Amblyopia among children. The design of the device was evaluated as “Interesting” and “Child-friendly” by Dra. Patricia Cabrera upon checking the device. The accuracy of the device is not proven because there is no data obtained from the clinical eye refractometers and the LEA symbols eye chart from which the data from the device was supposed to be compared to.

3.3 Recommendations

To further improve the study, the researchers recommend the following:

1. As for the composition of the device, the researchers recommend using a high-speed microcontroller with built-in Wireless Fidelity (Wi-Fi) for wireless connectivity. It is also better to use PiJuice HAT to power the microcontroller.
2. Having another setup for the refractive error is recommended for faster and easier testing of both eyes at the same time.
3. Using a higher quality of the LEA symbols chart will also give a more accurate result for the visual acuity.

4. Development of an application that will aid doctors in conducting multiple tests using the device. Additional visual acuity tests can also be included in the system.

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APPENDIX A

Program Codes

```
from guizero import App, Combo, Text, CheckBox, ButtonGroup, Box, Picture, yesno,
Window, PushButton, info, TextBox,ListBox


import RPi.GPIO as GPIO
import datetime
import picamera
import time
import cv2
import numpy as np


def open_instructions():
    instructions.show(wait=True)
    app.hide()


def open_window():
    left.show(wait=True)
    instructions.hide()
```

```
def close_window():
    left.hide()
    right.hide()


'App'
app= App(title="ISEEYOU", width=800, height=480,bg="white")
open_button = Picture(app, image="first.png")
open_button.when_clicked = open_instructions


'Instructions'
instructions= Window(app, title="ISEEYOU", width=800, height=480, layout="grid",
bg="white")
instructions.hide()
instructionbg=Picture(instructions, grid=[0,0],image="instructionss.png")
instructionbg.when_clicked= open_window



def open_right():
```

```
    right.show()
    left.hide()
    d = datetime.datetime.now()
    imgYear = "%04d" % (d.year)
    imgMonth = "%02d" % (d.month)
    imgDate = "%02d" % (d.day)
    imgHour = "%02d" % (d.hour)
    imgMins = "%02d" % (d.minute)
    fileNameL = 'L'+ str(imgYear) + str(imgMonth) + str(imgDate) + str(imgHour) +
str(imgMins)
    fileName = '/home/pi/Desktop/ISEEYOU/images/L' + str(imgYear) + str(imgMonth) +
str(imgDate) + str(imgHour) + str(imgMins) + '.jpg'
    GPIO.setmode(GPIO.BCM)
    GPIO.setup(18, GPIO.OUT)
    GPIO.output(18, GPIO.HIGH)
    time.sleep(7)
    GPIO.output(18, GPIO.LOW)
    GPIO.cleanup()
    camera = picamera.PiCamera()
```

```
camera.start_preview()

time.sleep(5)

camera.capture(fileName)

camera.stop_preview()

camera.close()



# Import necessary packages

import cv2

import numpy as np



# Load image and crop

imageL = cv2.imread(fileName)

y = 200

h = 150

x = 309

w = 150

cimage1 = imageL[y:y+h, x:x+w]
```

```
# Save as PNG

from PIL import Image

im.value = Image.fromarray(cimage1)


# Convert to greyscale and enhance edges

gray1 = cv2.cvtColor(imageL, cv2.COLOR_BGR2GRAY)

gray1 = cv2.GaussianBlur(gray1,(5,5),0);

gray1 = cv2.medianBlur(gray1,5)


# Fourier transform

f1 = np.fft.fft2(gray1)


# Apply shift to place DC component in the center

fshift1 = np.fft.fftshift(f1)


# Power magnitude spectrum of the fft

magspec1 = 20*np.log(np.abs(fshift1))
```

```
# Phase Spectrum of the fft

phase1 = np.angle(fshift1)


# Selecting region for peak values - Magnitude

magL = magspec1

m1= magL[238:243, 471:476]

m2= magL[191:196, 398:403]


# Peak values for each region

pkL1 = np.amax(m1)

pkL2 = np.amax(m2)


# Selecting region for peak values - Phase

phL = phase1

p1 = phL[238:243, 471:476]

p2 = phL[191:196, 398:403]


# Peak values for each region
```

```
pkL3 = np.amax(p1)

pkL4 = np.amax(p2)


# Constants

pupilsize = 6


# Magnitude and Phase

rhoL = np.abs(pkL1-pkL2)

thetaL = np.abs(pkL3-pkL4)


# Zernike Coefficients

z1 = 2*np.square(rhoL)-1

z2 = np.square(rhoL)*np.cos(2*thetaL);

z3 = np.square(rhoL)*np.sin(2*thetaL);


# Convert to meters

z1 = z1/10**6;

z2 = z2/10**6;
```

```
z3 = z3/10**6;


# Computation : Left Eye

if (z3==0):

    alphaL = (-1)*np.sign(z1)*np.pi/4;   #special case when z3 is equal to zero

else:

    alphaL = (-1)*0.5*np.arctan(z1/z3);



if (abs(z3)<abs(z1)):

    AL = z1*2*np.sqrt(6)/np.sin(2*alphaL);

else:

    AL = -z3*2*np.sqrt(6)/np.cos(2*alphaL);



axL = (-1)*180*alphaL/np.pi; # AXIAL



if (AL<=0):

    AL = (-1)*AL;

    axL = axL-90;
```

```
    if (axL<=0):
        axL = axL+180;


    DL = z2*2*np.sqrt(3)-AL/2;
    cylL= -20*DL/((pupilsize/2000)**2); # CYLINDRICAL
    sphL = -20*AL/((pupilsize/2000)**2); # SPHERICAL


    cylLeft.value=str(cylL)
    sphLeft.value=str(sphL)
    axLeft.value=str(axL)
    raw_fileNameL.value=str(fileNameL)


    import gspread
    from oauth2client.service_account import ServiceAccountCredentials
    scope = ['https://spreadsheets.google.com/feeds' ,
'https://www.googleapis.com/auth/drive']
    credentials = ServiceAccountCredentials.from_json_keyfile_name('iseeyoueyetest-
fe1cdb2c9f1f.json', scope)
    gc = gspread.authorize(credentials)
```

```
    wks = gc.open('ISEEYOU_Results').sheet1
    wks.append_row([fileNameL, sphL, cylL, axL])


'LEFT'
left=Window(instructions, title="ISEEYOU", width=800, height=480, layout="grid",
bg="snow")
left.hide()
box = Box(left,layout="grid", grid=[0,0])
hehestry=Box(box, grid=[0,0])
push=PushButton(box,image="left.png", command=open_right, grid=[0,0])
Pictureha=Picture(hehestry, image="Latestbg.png" ,grid=[0,1])



def open_showresults():
    showresults.show()
    right.hide()

    d1 = datetime.datetime.now()
    imgYear1 = "%04d" % (d1.year)
```

```
    imgMonth1 = "%02d" % (d1.month)
    imgDate1 = "%02d" % (d1.day)
    imgHour1 = "%02d" % (d1.hour)
    imgMins1 = "%02d" % (d1.minute)
    fileNameR = 'R'+ str(imgYear1) + str(imgMonth1) + str(imgDate1) + str(imgHour1) +
str(imgMins1)
    fileName1 = '/home/pi/Desktop/ISEEYOU/images/R' + str(imgYear1) +
str(imgMonth1) + str(imgDate1) + str(imgHour1) + str(imgMins1) + '.jpg'
    GPIO.setmode(GPIO.BCM)
    GPIO.setup(18, GPIO.OUT)
    GPIO.output(18, GPIO.HIGH)
    time.sleep(7)
    GPIO.output(18, GPIO.LOW)
    GPIO.cleanup()
    camera = picamera.PiCamera()
    camera.start_preview()
    time.sleep(5)
    camera.capture(fileName1)
    camera.stop_preview()
```

```
camera.close()


# Import necessary packages

import cv2

import numpy as np


# Load image and crop

imageR = cv2.imread(fileName1)

y = 200

h = 150

x = 309

w = 150

cimage2 = imageR[y:y+h, x:x+w]


# Save as PNG

from PIL import Image

im1.value = Image.fromarray(cimage2)
```

```
# Convert to greyscale and enhance edges

gray2 = cv2.cvtColor(imageR, cv2.COLOR_BGR2GRAY)

gray2 = cv2.GaussianBlur(gray2,(5,5),0);

gray2 = cv2.medianBlur(gray2,5)



# Fourier transform

f2 = np.fft.fft2(gray2)



# Apply shift to place DC component in the center

fshift2 = np.fft.fftshift(f2)



# Power magnitude spectrum of the fft

magspec2 = 20*np.log(np.abs(fshift2))



# Phase Spectrum of the fft

phase2 = np.angle(fshift2)



# Selecting region for peak values - Magnitude
```

```
magR = magspec2

m3 = magR[238:243, 471:476]

m4 = magR[191:196, 398:403]


# Peak values for each region

pkR1 = np.amax(m3)

pkR2 = np.amax(m4)


# Selecting region for peak values - Phase

phR = phase2

p3 = phR[238:243, 471:476]

p4 = phR[191:196, 398:403]


# Peak values for each region

pkR3 = np.amax(p3)

pkR4 = np.amax(p4)


# Constants
```

```
pupilsize = 6

# Magnitude and Phase
rhoR = np.abs(pkR1-pkR2)
thetaR = np.abs(pkR3-pkR4)

# Zernike Coefficients
zR1 = 2*np.square(rhoR)-1
zR2 = np.square(rhoR)*np.cos(2*thetaR);
zR3 = np.square(rhoR)*np.sin(2*thetaR);

# Convert to meters
zR1 = zR1/10**6;
zR2 = zR2/10**6;
zR3 = zR3/10**6;

# Computation : Right Eye
if (zR3==0):
```

```
    alphaR = (-1)*np.sign(zR1)*np.pi/4;   #special case when z3 is equal to zero
else:
    alphaR = (-1)*0.5*np.arctan(zR1/zR3);


if (abs(zR3)<abs(zR1)):
    AR = zR1*2*np.sqrt(6)/np.sin(2*alphaR);
else:
    AR = -zR3*2*np.sqrt(6)/np.cos(2*alphaR);


axR = (-1)*180*alphaR/np.pi; #AXIAL


if (AR<=0):
    AR = (-1)*AR;
    axR = axR-90;
if (axR<=0):
    axR = axR+180;


DR = zR2*2*np.sqrt(3)-AR/2;
```

```
cylR = -20*DR/((pupilsize/2000)**2); # CYLINDRICAL

sphR = -20*AR/((pupilsize/2000)**2); # SPHERICAL


raw_fileNameR.value=str(fileNameR)

cylRight.value=str(cylR)

sphRight.value=str(sphR)

axRight.value=str(axR)


import gspread

from oauth2client.service_account import ServiceAccountCredentials

scope = ['https://spreadsheets.google.com/feeds' ,
'https://www.googleapis.com/auth/drive']

credentials = ServiceAccountCredentials.from_json_keyfile_name('iseeyoueyetest-
fe1cdb2c9f1f.json', scope)

gc = gspread.authorize(credentials)

wks = gc.open('ISEEYOU_Results').sheet1

wks.append_row([fileNameR, sphR, cylR, axR])
```

```
'RIGHT'

right=Window(left, title="ISEEYOU", width=800, height=480, layout="auto",
bg="white")

right.hide()

boxr = Box(right,layout="grid", grid=[0,0])

hehestryr=Box(boxr, grid=[0,0])

pushr=PushButton(boxr,image="right.png", command=open_showresults, grid=[0,0])

Picturehar=Picture(hehestryr, image="Latestbg.png" ,grid=[0,1])


def open_results():

    showresults.hide()

    results.show()



'Show Results'

showresults=Window(right, title="Show Results", width=800, height=480,
layout="grid", bg="black")

showresults.hide()
```

```
firstboxpic=Box(showresults, layout="grid", grid=[0,0])

show=Picture(firstboxpic,image="pictureresults.png", grid=[0,0])

show.when_clicked= open_results

secondboxpic=Box(firstboxpic, layout="grid", grid=[0,0])

im=Picture(secondboxpic, grid=[0,0])

im1=Picture(secondboxpic, grid=[1,0])




def new():

    results.hide()

    app.show()



#cv2.imshow("output,np.hstack([image, output])





'Results'

results=Window(showresults, title="ISEEYOU", width=800, height=480, layout="grid",
bg="white")

results.hide()
```

```
firstbox=Box(results, layout="grid", grid=[0,0])

background=Picture(firstbox, image="results.png", grid=[0,0])

secondbox=Box(firstbox, layout="grid", grid=[0,0])

secondbox.bg="black"


spherical=Text(secondbox, text="Spherical", size="15", grid=[0,0], color="white")

sphl=Text(secondbox, text="L:", size="15", grid=[1,0], color="white")

sphr=Text(secondbox, text="R:", size="15", grid=[3,0], color="white")

sphLeft=Text(secondbox, text="-", size="15", grid=[2,0], color="white")

sphRight=Text(secondbox, text="-", size= "15", grid=[4,0], color="white")

sphLeft.width="17"

sphLeft.text_color="white"

sphLeft.text_size=15

sphRight.width="17"

sphRight.text_color="white"

sphRight.text_size=15
```

```
axial=Text(secondbox, text="Axial", size="15", grid=[0,1],color="white")

axl=Text(secondbox, text="L:", size="15", grid=[1,1], color="white")

axr=Text(secondbox, text="R:", size="15", grid=[3,1], color="white")

axLeft=Text(secondbox, text="-", size="15", grid=[2,1], color="white")

axRight=Text(secondbox, text="-", size="15", grid=[4,1], color="white")

axLeft.width="17"

axLeft.text_color="white"

axLeft.text_size=15

axRight.width="17"

axRight.text_color="white"

axRight.text_size=15



cylindrical=Text(secondbox, text="Cylindrical",size="15", grid=[0,2],color="white")

cyll=Text(secondbox, text="L:", size="15", grid=[1,2], color="white")

cylr=Text(secondbox, text="R:", size="15", grid=[3,2], color="white")

cylLeft=Text(secondbox, text="-", size="15", grid=[2,2], color="white")

cylRight=Text(secondbox, text="-", size="15", grid=[4,2], color="white")
```

```
cylLeft.text_color="white"

cylLeft.width="17"

cylLeft.text_size=15

cylRight.text_color="white"

cylRight.width="17"

cylRight.text_size=15


filename=Text(secondbox, text="File Name", size="15", grid=[0,3], color="white")

fileNamel=Text(secondbox, text="L:", size="15", grid=[1,3], color="white")

fileNamer=Text(secondbox, text="R:", size="15", grid=[3,3], color="white")

raw_fileNameL=Text(secondbox, text="-", size="15", grid=[2,3],color="white")

raw_fileNameR=Text(secondbox,text="-", size="15", grid=[4,3],color="white")

#fileNameL=TextBox(secondbox, text="-", grid=[2,3])

#fileNameR=TextBox(secondbox, text="-", grid=[4,3])



#fileNameL.text_color="white"

#fileNameL.width="17"
```

```
#fileNameL.text_size=20

#fileNameR.text_color="white"

#fileNameR.width="17"

#fileNameR.text_size=20

background.when_clicked= new

app.display()
```

APPENDIX B

Bill of Materials

Bill of Materials

MATERIALS	COST
Collimating Lens	₱3,000.00
Microlens Array	₱130,00.00
Raspberry Pi Zero	₱8,000.00
SD Card	₱1,000.00
USB Camera	₱6,000.00
USB Cord	₱60.00
3D Printer Filament	₱12,000.00
Power bank	₱800.00
Resistor, Screw, LED	₱26.00
Phone	₱11,000.00
Tablet (for Control)	₱35,000.00
Velcro	₱50.00
TOTAL	**₱206,936.00**

APPENDIX C

Specifications and Datasheets

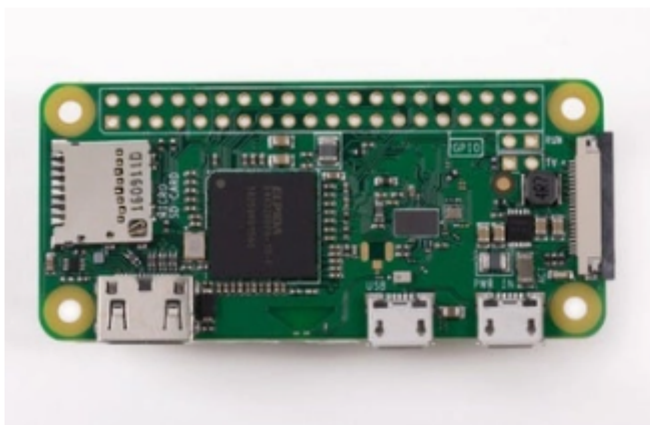
AUTOREFRACTIVE SETUP SPECIIFICATIONS

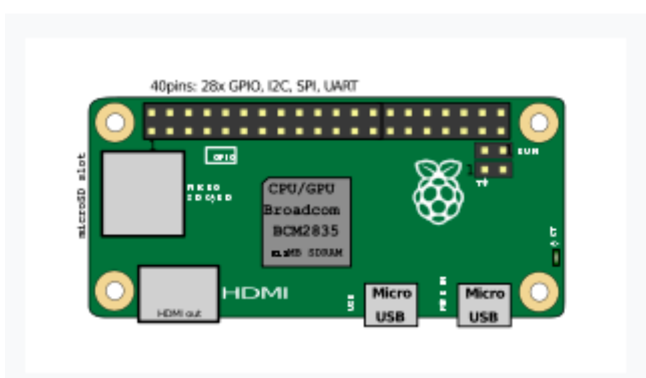
Length	150mm
Width	160mm
Height	90mm
Device weight	504 grams
Array size and type	10x10mm, square grid
Lens pitch	150 µm
Lens diameter	146 µm
Focal length	5.2mm
Camera resolution	8megapixel, 3280x2464pixel
Led wavelength	700nm
Operating hours	24-30 hours
Operating system	Raspberry pi zero

VISUAL ACUITY SETUP SPECIFICATIONS

Length	130mm
Width	160mm
Height	90mm
VR lens size and type	25mm Bi Convex lens
Focal length	45mm

RASPBERRY PI ZERO W





Technical Specifications

The Raspberry Pi Zero W extends the Pi Zero family. Launched at the end of February 2017, the Pi Zero W has all the functionality of the original Pi Zero, but comes with with added connectivity, consisting of:

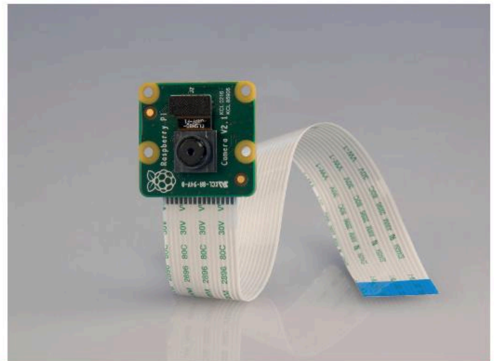
- 802.11 b/g/n wireless LAN
- Bluetooth 4.1
- Bluetooth Low Energy (BLE)

Like the Pi Zero, it also has:

- 1GHz, single-core CPU
- 512MB RAM
- Mini HDMI and USB On-The-Go ports
- Micro USB power
- HAT-compatible 40-pin header
- Composite video and reset headers
- CSI camera connector

RASPBERRY PI CAMERA MODULE

Raspberry Pi



Camera Module

Product Name	**Raspberry Pi Camera Module**
Product Description	High Definition camera module compatible with all Raspberry Pi models. Provides high sensitivity, low crosstalk and low noise image capture in an ultra small and lightweight design. The camera module connects to the Raspberry Pi board via the CSI connector designed specifically for interfacing to cameras. The CSI bus is capable of extremely high data rates, and it exclusively carries pixel data to the processor.
RS Part Numer	**913-2664**

Specifications

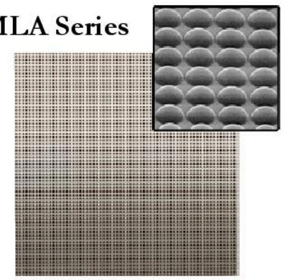
Image Sensor	Sony IMX 219 PQ CMOS image sensor in a fixed-focus module.
Resolution	8-megapixel
Still picture resolution	3280 x 2464
Max image transfer rate	1080p: 30fps (encode and decode) 720p: 60fps
Connection to Raspberry Pi	15-pin ribbon cable, to the dedicated 15-pin MIPI Camera Serial Interface (CSI-2).
Image control functions	Automatic exposure control Automatic white balance Automatic band filter Automatic 50/60 Hz luminance detection Automatic black level calibration
Temp range	Operating: -20° to 60° Stable image: -20° to 60°
Lens size	1/4"
Dimensions	23.86 x 25 x 9mm
Weight	3g

www.rs-online.com/raspberrypi

Product Specification Sheet

Microlens Arrays

MLA Series



Description

Thorlabs Microlens Arrays are best suited for Shack-Hartmann sensor applications. Both lenslets are made from fused silica for excellent transmission characteristics from the deep UV to IR and have a plano-convex shape that allows nearly refraction limited spots.

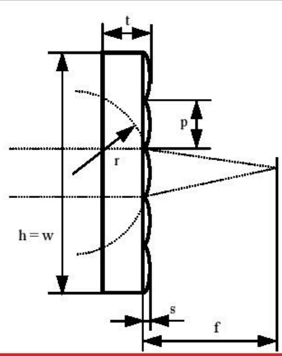
The lenses are formed using photolithographic techniques based on semiconductor processing technology, which allows for excellent uniformity in the shape and position of each microlens, unlike some microlens arrays produced from molded epoxy.

The MLA150-5C has a chrome mask that blocks light from being transmitted unless it goes through a microlens and therefore increases image contrast. The MLA150-7AR and MLA300-14AR have a broadband AR coating to reduce surface reflections in the 400-900nm spectral region to below 1%.

Specifications

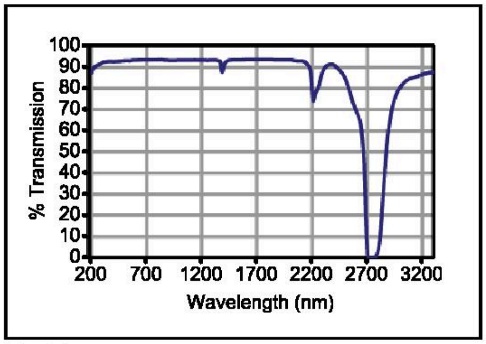
Parameters	MLA150-5C	MLA150-7AR	MLA300-14AR
Substrate Material	Fused Silica (Quartz)		
Wavelength Range	From DUV to IR		
Array Size and Type	10 x 10 mm, Square Grid		
Lens Type	Round, Refractive, Plano-Convex		Square, Refractive, Plano-Convex
Lens Pitch / Diameter	150 µm / 146 µm		300 µm square
Focal Length	5.2 mm	6.7 mm	18.6 mm
AR-Coating	no	Yes, Reflectivity < 1% Within 400 … 900 nm	
Chrome Apertures	Yes, Around Microlenses	no	
Geometric Parameters			
h, w	10 mm	10 mm	10 mm
t	1.24 mm	1.19 mm	1.20 mm
p	150 µm	150 µm	300 µm
s	1.12 µm	0.87 µm	1.31 µm
r	2.380 mm	3.063 mm	8.6 mm
f	5.2 mm	6.7 mm	18.6 mm

Drawings

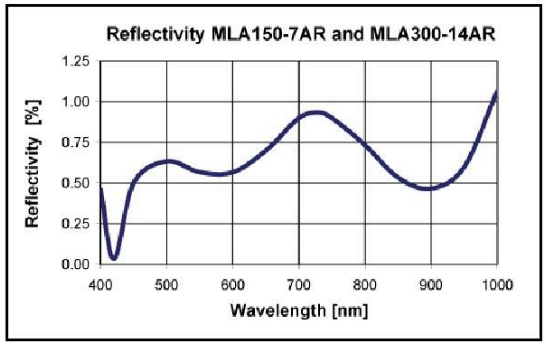


16537– 02/03/2010
Specifications subject to change without notice.

Wavelength Characteristics

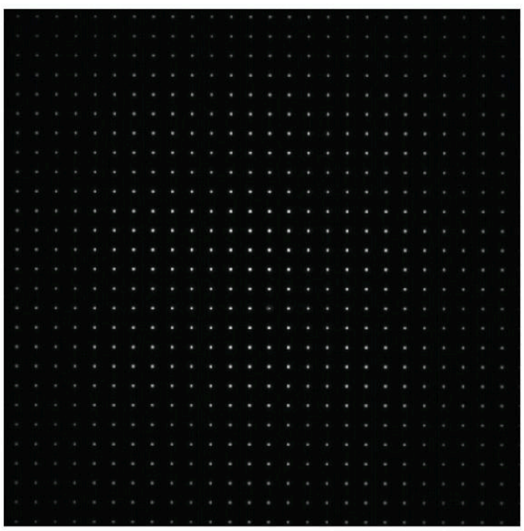


Typ. Transmission of Fused Silica Material



Reflectivity including AR - Coating

Spotfield derived with the MLA150-5C Microlens Array



WEEE

As required by the WEEE (Waste Electrical and Electronic Equipment Directive) of the European Community and the corresponding national laws, Thorlabs offers all end users in the EC the possibility to return "end of life" units without incurring disposal charges.

This offer is valid for Thorlabs electrical and electronic equipment

- sold after August 13th 2005
- marked correspondingly with the crossed out "wheelie bin" logo (see fig. 1)
- sold to a company or institute within the EC
- currently owned by a company or institute within the EC
- still complete, not disassembled and not contaminated

As the WEEE directive applies to self contained operational electrical and electronic products, this "end of life" take back service does not refer to other Thorlabs products, such as

- pure OEM products, that means assemblies to be built into a unit by the user (e. g. OEM laser driver cards)
- components
- mechanics and optics
- left over parts of units disassembled by the user (PCB's, housings etc.).

If you wish to return a Thorlabs unit for waste recovery, please contact Thorlabs or your nearest dealer for further information.

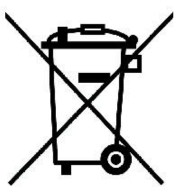
Waste Treatment on Your Own Responsibility

If you do not return an "end of life" unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

Ecological Background

It is well known that WEEE pollutes the environment by releasing toxic products during decomposition. The aim of the European RoHS directive is to reduce the content of toxic substances in electronic products in the future.

The intent of the WEEE directive is to enforce the recycling of WEEE. A controlled recycling of end of live products will thereby avoid negative impacts on the environment.



[redacted] Crossed out "wheelie bin" symbol

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Email:sales@thorlabs.jp

APPENDIX D

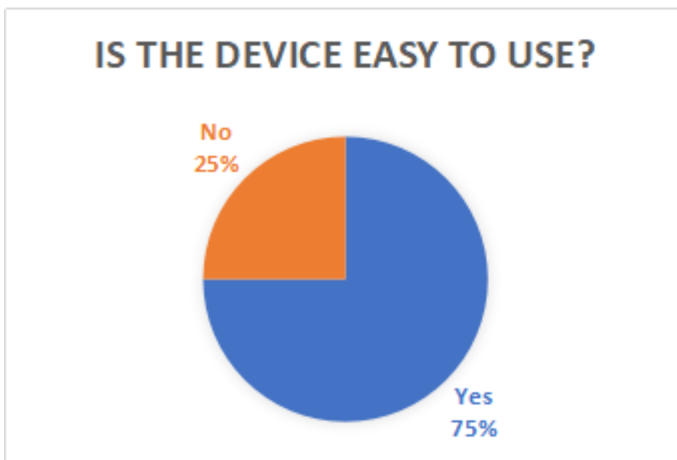
Data Gathered

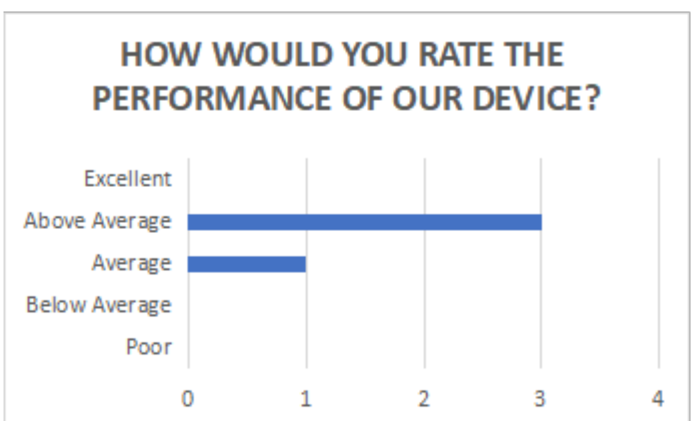
The following table shows the summary of result from the two setups.

ISEEYOU_Results : Sheet1

	File Name	Spherical	Axial	Cylindrical	Lea test
A	L: L202006280878	L: -159.78591105	L: 123. 259958582	L: 81.2122547968	OS: -1.00 D 20/50
	R: R202006280878	R: -223.62779520	R: 126. 712048738	R: 53.0803261829	OD: -2.5D 20/200
B	L: L202006260867	L: -240.897228	L: 119.5202885	L: 98.188591105	OS: -1.00D 20/50
	R: R202006260867	R: -25.2083974	R: 129.7875638	R: -0.5208917	OD: -0.00D 20/20
C	L: L202006260868	L: -163.2548976	L: 122.9345896	L: 79.3076454	OS: -1.00D 20/50
	R: R202006260868	R: -222.7732467	R: 130.6080077	R: 43.9300456	OD: -2.50D 20/200
D	L: L202006260870	L: -2852.4762432	L: 130.4763257	L: 786.16736678	OS: -3.50D 20/300
	R: R202006260870	R: -2170.5678341	R: 128. 1123467	R: 812.2861423	OD: -4.00D 20/400

The following charts show the results obtained during the survey with regard to the patients' evaluation of the prototype.





APPENDIX E

Project Manual

Contact us:

iseeyoueyetest@gmail.com

+(639)29-530-6625

Technological University of the Philippines
Manila
College of Engineering – Electronics Department

ISEE YOU MANUAL

A simple guide on using the device safely and efficiently

Lazaro, Luis Felipe
Escobar, Zeth Justine
Albania, Joanna Marie
Bugarin, Ma. Luisa Katrina
Climacosa, Rica Andrea

How to use the Refractive Error Set-Up?

1. After testing using the Visual Acuity Set-Up, make sure to remove the Lens Holder for this Test.

2. Safely attach the Refractive Error Case on the VR Body/Base and lock it with the Velcro. Connect the wire on the power bank at the back of the head of the child.

3. Wait at least 30 seconds after connecting the wire on the power-bank.

4. Open the app named 'VNC Server' on the Tablet, and select 'Wavefront Sensor'

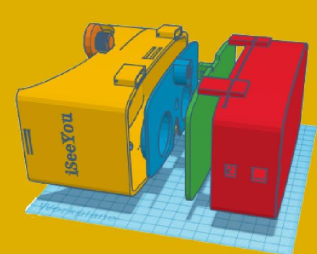
5. On the app, select the ISEEYOU folder and select the program named 'ISEEYOU.py' then press Run.

6. After pressing Run, the app will display a GUI and press the screen, then follow the instructions written on the GUI.

7. Well done! You have know obtained the data for the Refractive Error of the Eye which is SPH, CYL and AXL.

Note: When capturing the image make sure that the dotted lines are inside the circle, unless it will give inaccurate results.

VISUAL ACUITY SET-UP



PARTS

- **VR Body/Base** – This part is fixed and placed on the head of the child.
- **Knob** – It is a rotatable knob to adjust and remove the lens holder.
- **Lens Holder** – This part is where the lens is placed to be able to remove it after the test.
- **Phone Holder**
- **Phone & Raspi Case**

Reminders:

- Always turn off the screen of the phone and tablet after use and charge the phone when the battery is low.
- Always remove the power-bank from the wire after use because the raspberry pi might overheat.
- Change the foam regularly.
- Contact us if there's any problem occurred
- Always put the device on it's proper box after use.

How to use the Visual Acuity Set-Up?

1. Wear the VR Body/Base in the head of the child, make sure that it is perfectly fitted.

2. Open the app named ISEEYOU on the android phone placed on the Phone and Raspi Case.

3. After opening the app, safely attach the Phone and Raspi Case to the VR Body/Base and lock it with the Velcro.

4. Next, open the Tablet and select the app named CONTROLLER, after opening press the connect button (It must indicate if the device is connected).

5. After connecting, place the eye cover on the right eye to test the left eye, then ask the children to read each lines on the LEA SYMBOL (Note: You can use the tablet to indicate which line to read.).

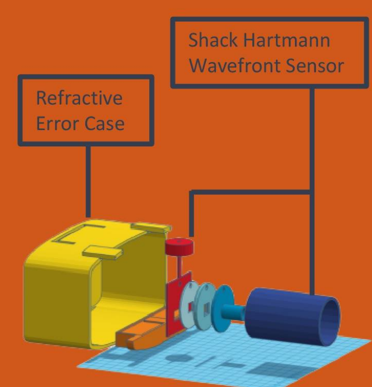
6. After testing the left eye, place the eye cover on the left eye then test the right eye.

7. When done testing both eyes, unlock the Velcro and safely remove the Phone and Raspi Case from the VR Body/Base.

8. You can now remove the Lens Holder for the next eye test, just simply slide the knob clockwise (when you are facing the child) until it pops out (Do the opposite when putting it back)

2

REFRACTIVE ERROR SET-UP



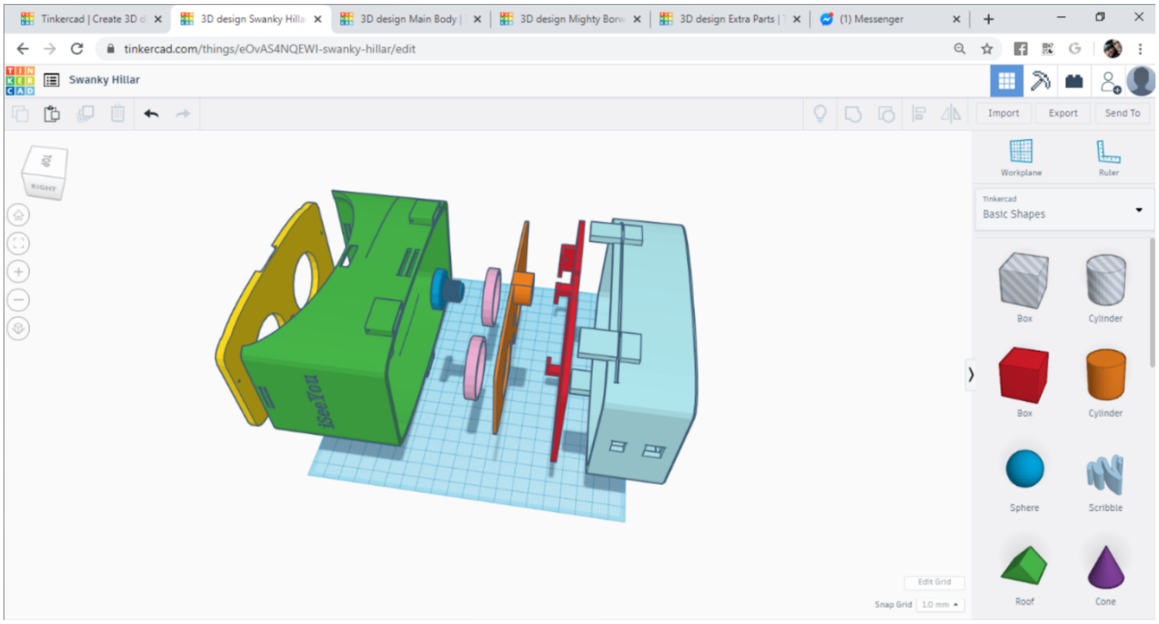
Refractive Error Case — 162x99x81mm in size

Shack Hartmann Wavefront Sensor — It contains Collimating Lens, Microlens Array, Red LED Light and Raspberry Pi Zero with 8MP Camera

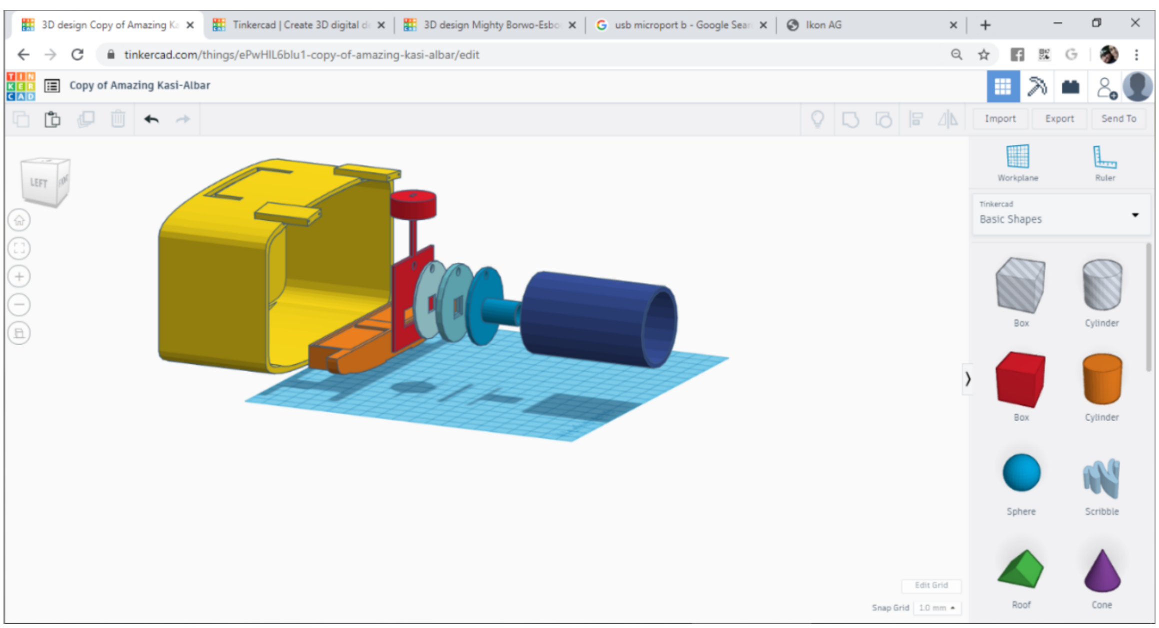
3

APPENDIX F

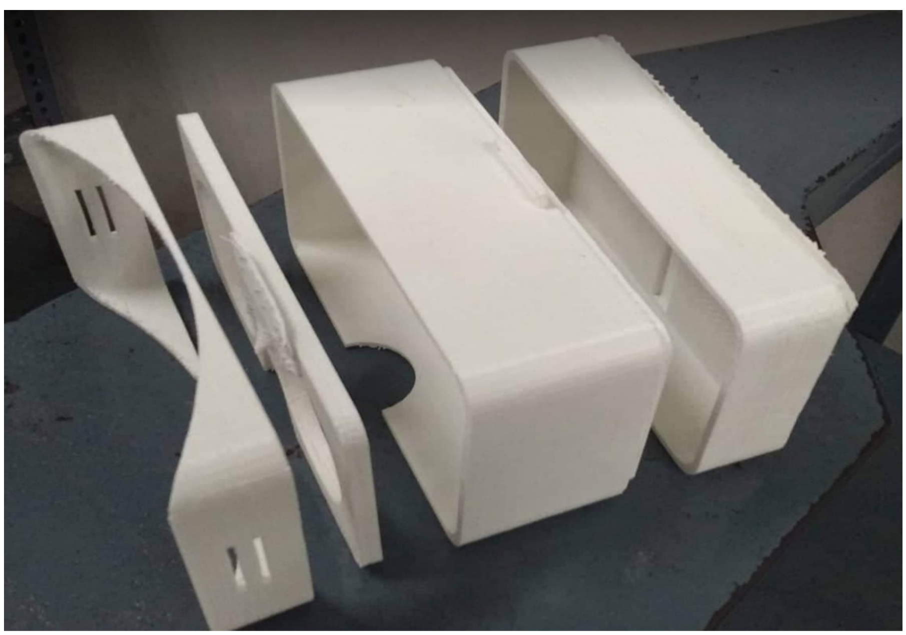
Project Documentation



Design of the VR setup using Tinkercad

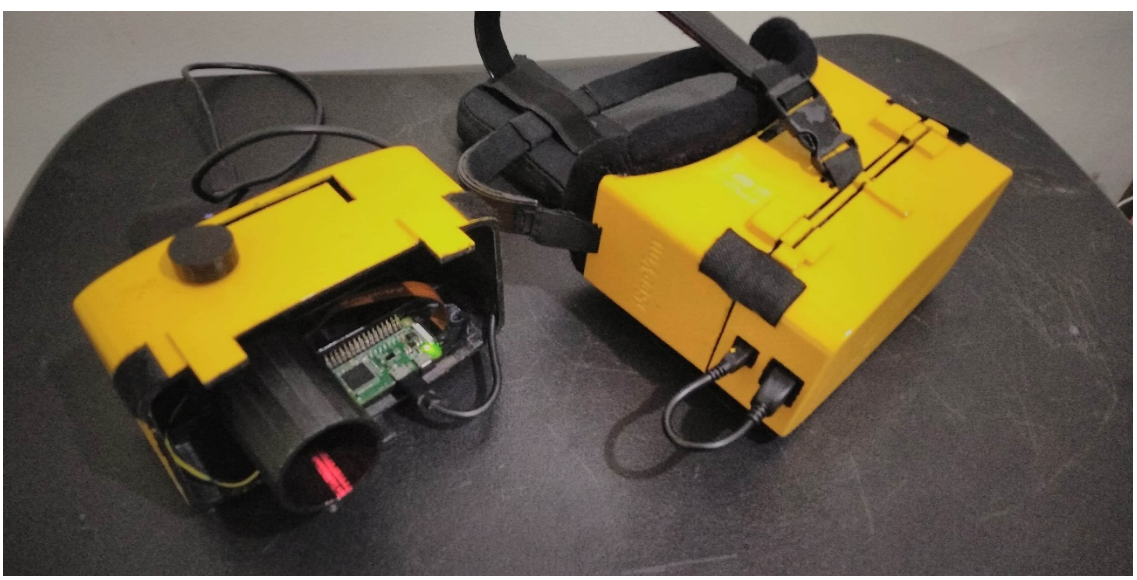


Design of the autorefractor using Tinkercad



Initial design (printed)

Final Structure of the Device

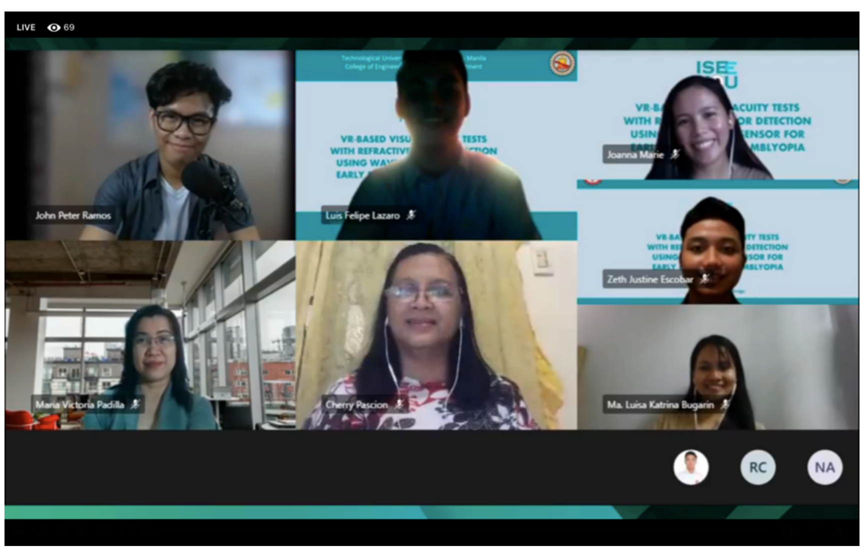


Autorefractor and Visual Acuity Setup

Initial Evaluation of the Device at Philippine General Hospital

Progress Presentation


Project Presentation



Online Symposium 2020

APPENDIX G

Researchers' Profile

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  Technological University of the Philippines-Manila, February 23, 2019
- **APPRECIATE: Annual Presentation of Project Research in Electromechanical, Civil, Information and Telecommunications Engineering 2018- “Strengthening the Engineering Research for a Developing World”**

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  Technological University of the Philippines- Manila, February 23, 2018
- **IECEP – MSC General Assembly 2017: "Hola! Excelentes y Compasivos Ingenieros"**

  San Andres Sports Complex, Malate, Metro Manila, August 13, 2017
- **JOB FAIR 2018/2019**

  Technological University of the Philippines – Manila, March 2018
  Technological University of the Philippines – Manila, March 2019