Measuring Visual Acuity using Periscope and Android Application

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***Abstract*— Visual acuity is defined as the clearness of vision. It is usually measured by an eye doctor (ophthalmologists/ optician) using a Snellen's chart, is one of the most commonly applied clinical tests in the world. With the patient's participation, it measures the smallest letters which can be reliably identified at a given distance and thus tests the resolution power of our eyes. The conventional acuity test requires the patient to review and indicate the letters they see. Currently, visual acuity tests are performed in a room having an ample amount of space where the distance between the patient's eye and standard Snellen chart is 6 meters. Also, a proper light ambience is required to perform this test. But in rural areas, these eye check-up camps are organized in small rooms such as in primary schools without proper light ambience available. This lack of space and light ambience not only makes it difficult to perform eye tests but also affects its accuracy. So, to overcome these problems, we have proposed a solution that uses a periscope and an android application together that will solve the problem of space and the external ambience and check the visual acuity of a patient in any available space. The proposed system has the property of portability and gives excellent accuracy at an affordable cost.**

Keywords*— Visual Acuity, Snellen Chart, Periscope, Laws of Reflection, Android, Cataract, Pinhole Occluder, Portable Device.

I. Introduction

Our eyes are one of the most vital parts of our body. All of us rely on our eyes to see and make sense of the environment and world around us. But unfortunately, some eye diseases or defects can also lead to vision loss, hence it becomes very important to identify and treat our eye problems as early as possible. One should get their eyes checked as often as recommended, or if one has any new eye problem. As much as it is important to keep our body healthy, one also needs to keep their eyes healthy. To check for one's eye or vision problems and defects, everyone needs to have their eyesight tested. For example, children usually have eye check-ups at schools or vision screenings at their health care provider's office during routine check-ups. Adults may also have similar check-ups. But for adults, just a normal screening is not enough, they need more than that- that is, a detailed comprehensive eye test [1][2].

Many times, some of the eye diseases may not show any warnings, signs or symptoms, hence such detailed comprehensive eye exams become more and more important. With the help of these exams, it becomes easy to detect these diseases in early stages which makes them eventually easier to treat [1]. This exam includes many tests, for example:

A visual acuity test, where a chart is read from a distance of approximately 20 feet, ensures that it can be seen from a distance. Dilation, it involves putting eye drops that dilate (widen) eyes' pupils, so that more light can enter eyes. And then the doctor examines those eyes using a special magnifying lens. This helps in getting a clear view of important tissues at the back of the eye, including the retina, macula, and optic nerve. Tonometry measures one's eye's interior pressure. Glaucoma is detected with the help of tonometry. A visual field test that measures one's side (peripheral) vision. Peripheral vision loss may be a sign of glaucoma [3].

After these tests/exams, if one is identified with a refractive error and is going to need glasses or contact lenses, then they will have a refraction test also. In this test, the patient looks through a device that has lenses of different powers to help the eye care professional figure out which lenses will give the patient the clearest vision. But in a country like India where the population is one of our major concerns, providing good eye care at the grassroots level with all the limitations is a challenging situation for both the government as well as health/eye care providers. Hence, we aim to solve the very basic problem of unavailability of proper light ambiance and space which hinders the very basic process of measuring visual acuity, which further helps in identifying which eye test one needs to take. This is the biggest problem faced by the majority population in our country which resides in villages and rural areas, where proper eye care clinics or hospitals are not approachable and affordable by the population. Hence, we aim to propose a solution that will be helpful to both medical and non-medical staff/volunteers to carry out tests more conveniently and affordably.

The paper is organized as follows. Section II discusses the literature review of similar existing platforms. Section III explains in detail the actual problem statement and current methods available for use. Section IV shows the design and architecture details of the proposed system. Section V summarizes the actual implementation along with the results. Section VI concludes the paper.

II. Related Work

Stanton Optical [4] website describes that there are many charts available for testing visual acuity, some of them are:

- The Snellen Eye Chart: It is an eye chart named after Herman Snellen. The Dutch Ophthalmologist developed the chart in 1862 and laid the foundation for better visual acuity tests.
- Tumbling E Charts: This eye chart is utilized for children who are not able to read or adults with reading or speaking difficulties. The patient is asked to hoist their hand, down, or to left or right depending

on the image orientation of the letter E, they optically discern on the chart.

- ETDRS: The Early Treatment Diabetic Retinopathy Study availed develop standardization for both visual acuity testing and ocular perceiver chart design. The ETDRS is accepted by The National Eye Institute and the Food and Drug Administration as the mandated standard for clinical eye test trials worldwide.
- Landolt C: Edmund Landolt, a Swiss Ophthalmologist, created this visual acuity chart. This eye chart is similar to the Tumbling E chart and uses Landolt's broken ring symbol in various orientations. hence, it is a very convenient way to check vision for illiterate or mute patients.

Paulo J & Gaspar P. D. et. al provides an overview of the traditional vision test methods that could not meet the needs of the general public. It mentions the advances in technology that led to the tendency that a variety of medical equipment becomes electronic and portable including visual acuity equipment [5].

Chen M & Li J. D. et. al developed an automated test system of visual acuity based on liquid crystal display and software control and used it for clinical application successfully [6].

Shi J & YAO Juncai et. al also achieved good results measuring contrast sensitivity function by monitors. These new test methods formed electronic and automated visual acuity tests, but the measuring equipment and required test site were too large to achieve portability [7][8]. There are many new charts invented which are much better than the older ones. But currently, opticians still use traditional physical standard-sized charts, and upgrading to new charts requires changes in the infrastructure. because of which migrating to new charts is not easy.

Hennelly ML et. al**,** explains the refractive errors in the human eye namely myopia, hypermetropia, and astigmatism, and the concept of pinhole occluder. If a patient has a refractive error it can be solved using corrective lenses. It can be identified that a person has refractive or non-refractive error using a pinhole occluder. Pinhole occluder only allows the light rays to pass through the center of the eye lens and block all other light rays. In this way, we can estimate the maximum improvement in the eyes. So, this can be used to distinguish visual defects caused by refractive error, which improve when the occlude is used, from other problems which do not. In view of the above-mentioned problems, the vision test has been converted into software designed and created based on the characteristics of the widely used tablets to test vision easily and correctly, which has become an important indicator of visual performance. computer. In the application, the software itself has become suitable for home use [9].

Nangia V & Jonas JB et. al have tried to establish a logical association between visual acuity and the level of education in the Indian rural population and also tried to establish their influence on each other. It was concluded that the corrected visual acuity in the rural population of Central India is highly dependent on factors like higher socioeconomic background, body mass index and body stature [1].

III. Problem Description

Through this project, we intend to develop a solution that can be used to conduct eye tests in areas having lack space and light ambiance facilities, especially in rural areas or villages. The major objective is to come up with:

- A visual acuity measurement solution that gives consistent and accurate readings.
- A cost-effective and easy to use solution for rural areas
- A solution that can be easily used by a non-medical field (social) worker/volunteer also.

The currently used traditional test for acuity requires the patient to see and report the letters they can identify easily from the chart. Currently visual acuity tests are performed in a room having an ample amount of space where the distance between the patient and standard Snellen chart should be 6 meters. Also, good light ambience is required to perform this test. But in rural areas these eye check-up camps are organized in small rooms such as in primary schools without proper light ambience available. This lack of space and light ambience possesses various difficulties in performing eye tests. Hence our major focus lies on solving this issue to make this project useful for the targeted users of rural areas.

IV. Proposed Model Design

This section includes the method how we are planning to use to overcome the difficulties of unavailability of proper light and ambience issues. These primarily include use of periscope.

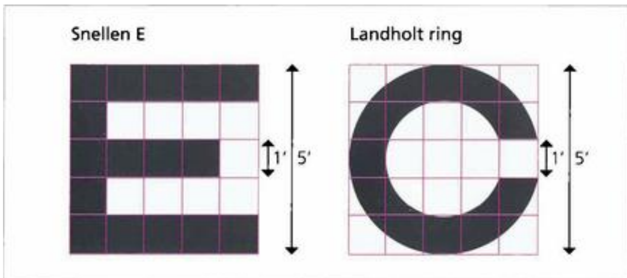

Fig. 1. Optotype subtending an angle of 5'[10].

The most familiar test of visual acuity is the Snellen chart. This has a series of letters of graduated size, each subtending an angle of 5 minutes of arc at a specific distance. The top letter on the chart subtends this angle at 60 metres while the smallest letters subtend the angle at 5 metres. The test is conducted at a distance of 6 metres (20 feet) which is optically equivalent to infinity. A patient who can only see the top letter has a visual acuity of 6/60, while a patient who can read down to those letters subtending an angle of 5 minutes of arc at 12 metres has a visual acuity of 6/12. Visual acuity of 6/6 is the accepted normal (in America, expressed as 20/20).

The optotype is rendered in a 5 x 5 square grid with each unit square subtending an angle of 1 min at the nodal Centre of the eye and the whole letter subtends an angle of 5 minutes of arc at the nodal center of the eye as shown in Fig. 1 and Fig.2 [10].

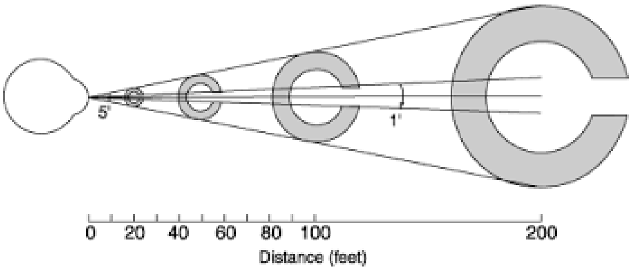

Fig. 2. Optotype Size Calculation [11].

So, angle subtended by the letter,

$$A = 5 \min of\ arc = \frac{5}{60}\ x \frac{\pi}{180}\ radians$$

Let X be the distance between the optotype and the patient then size of the optotype s is

$$s = X\ x\ A$$

Table 1. shows size of the optotypes for different lines of the chart at different distances and the angle subtended by them at the nodal center of the eye.

TABLE I. VISUAL ACUITY AND THE SIZE OF OPTOTYPE

Line	Decimal	LogMAR	Optotype size in cm at a particular distance(m)				
			6 meter	3 meter	2 meter	1 meter	Angle Subtended at Nodal Point
6/60	0.1	1.00	8.726	5.816	2.908	1.454	50'
6/36	0.167	0.80	5.235	3.4896	1.7448	0.8724	30'
6/24	0.25	0.60	3.49	2.3264	1.1632	0.4362	20'
6/12	0.5	0.30	1.745	1.1632	0.5816	0.2908	10'
6/9	0.667	0.20	1.308	0.8724	0.4362	0.2187	7.5'
6/6	1	0.00	0.877	0.5816	0.2908	0.1454	5'

A. Periscope

To overcome the problems of space and light ambience unavailability everywhere, we have proposed a solution which uses a periscope.

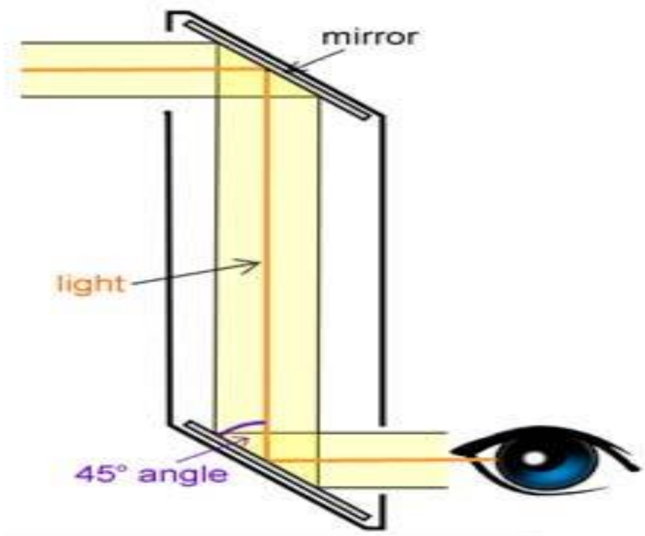

Fig. 3. Wokring of Simple Periscope [12].

A simple periscope is just a long tube with a mirror at each end which works on the Laws of Reflection as shown in Fig. 3. The mirrors are fitted into each end of the tube at an angle of exactly 45 degrees (45°) so that they face each other. In the periscope, light hits the top mirror at 45° and reflects away at the same angle. The light then bounces down to the bottom mirror. When that reflected light hits the second mirror it is reflected again at 45°, right into your eye. Light is reflected from a mirror at the same phase that it strikes the mirror. [12].

B. Features

Firstly, a variety of charts are provided in the application such as Landolt C, Standard Snellen Chart, Tumbling E, Colored chart etc. So, this solution is applicable to all age groups, all types of patients whether literate or illiterate. Secondly, the solution is simple to use by any non-medical worker or volunteer. Also, random letter generation is used so that if the patient has memorized the chart then it would not affect the results. The system works in two modes:

1. *With Periscope –*

This mode uses a periscope so that the effect of external light ambience is eliminated. In this mode, the distance between the chart and the patient is fixed.

2. *Without Periscope –*

It is used where ambience is not an issue. Here chart size is dynamically decided based on the input distance.

C. Design and Working –

At one end of the periscope a Snellen chart is displayed on a digital display. The chart on this display is controlled by the volunteer by using our remote android application. Patient will view the chart from the other end and will speak what they read. Based on the response by the patient the volunteer will give the input in the application.

Fig. 4. Patient using periscope model.

To solve the problem of space instead of increasing the distance between the chart and patient, we have made the light travel a fixed amount of distance greater than 25 cm to avoid strain in the eye, which is the length of the periscope. At both the ends of the periscope there is a thin mirror placed at an angle of 45 degrees to reflect the light from the chart to the patient's eye. As we are using the periscope, there will be no effect of external light ambience on the test. This solution can be used to conduct eye tests anywhere especially in rural areas where there are very small rooms and ambience issues. Fig. 4 clearly shows how patients can easily use this proposed solution, and Fig. 5 depicts the use case diagram that is, the complete working mechanism of the solution we propose.

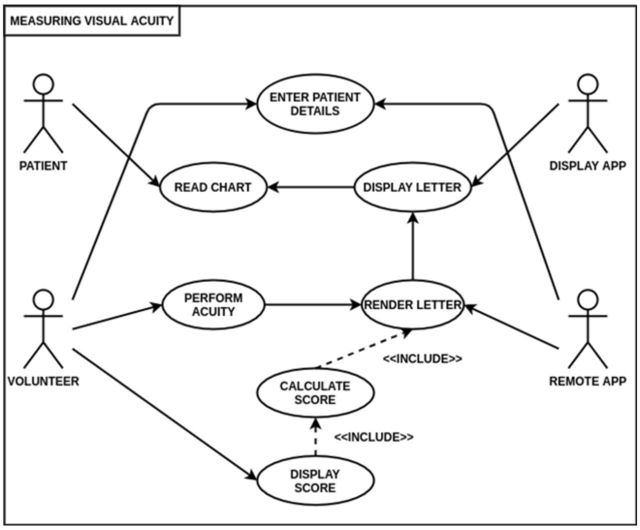

Fig. 5. Use Case Diagram for Opti Mystic.

As shown in Fig. 6., our system consists of two android devices. One device act as a display device on which the optotypes are rendered. Another Android device acts as a remote application that controls the display device using the flask API server. The display device is connected to the flask API server using a socket connection.

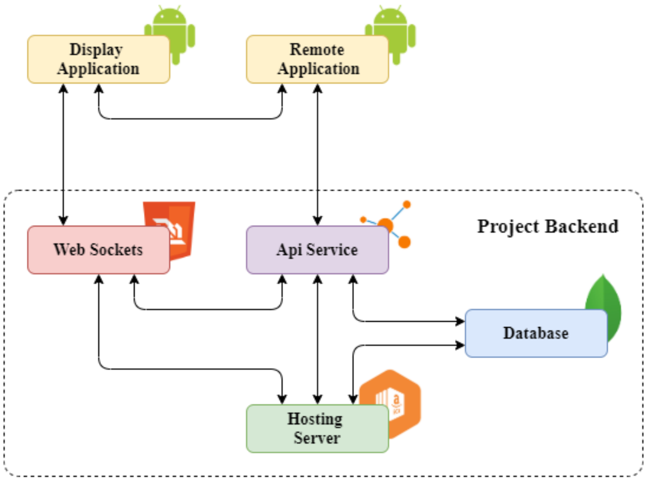

Fig. 6. System Architecture for Opti Mystic.

First, the display device is connected to the API server via a socket connection. The patient registers his/her information from the remote application and the data is stored on MongoDB. The remote application makes an API request to the API server with an appropriate optotype of the specific size to be rendered the server generates the image of a specific size and sends it to the display device using the socket. The patient's response is fed to the remote application by the volunteer and accordingly, the visual acuity is calculated. The test results are sent to the patient on the registered email id using the SMTP protocol.

V. IMPLEMENTATION

It is specified that a volunteer is required who will be using the proposed application- Opti Mystic. The basic requirements of our proposed solution are as follows:

- Two Devices (A mobile and tablet/laptop/mobile).
- Measuring Tape.
- Periscope (optional).
- Pinhole Occluder (To check for refractive and non-refractive error).

The work flow of the proposed solution system goes as follows as shown in Fig. 8:

1. Firstly, the volunteer will register the patient on the application through the registration form by filling required details.
2. Then the field settings will be checked by the volunteers on duty. In case there is no proper space or light ambience available in the surrounding, then the digital chart will be mounted on the periscope, otherwise the device can be mounted between 0.5 to 6 meters and the distance will be then entered in the application with other details.
3. Then the Snellen chart will be read by the patient and accordingly the volunteer will enter the response of the patient in the remote application.
4. Then the visual acuity will be calculated by the application on the basis of all the inputs. If the visual acuity turns out to be less than 6/6, then a pinhole Occluder as shown in Fig. 7 is used and the same test will be performed again. If the vision is improved by using the pinhole Occluder, then the patient may have a refractive error in the eyes which can be solved by using corrective lenses. If not, then the patient has an eye disease and must consult an ophthalmologist for further treatment.

Fig. 7. Pinhole Occluder [13]

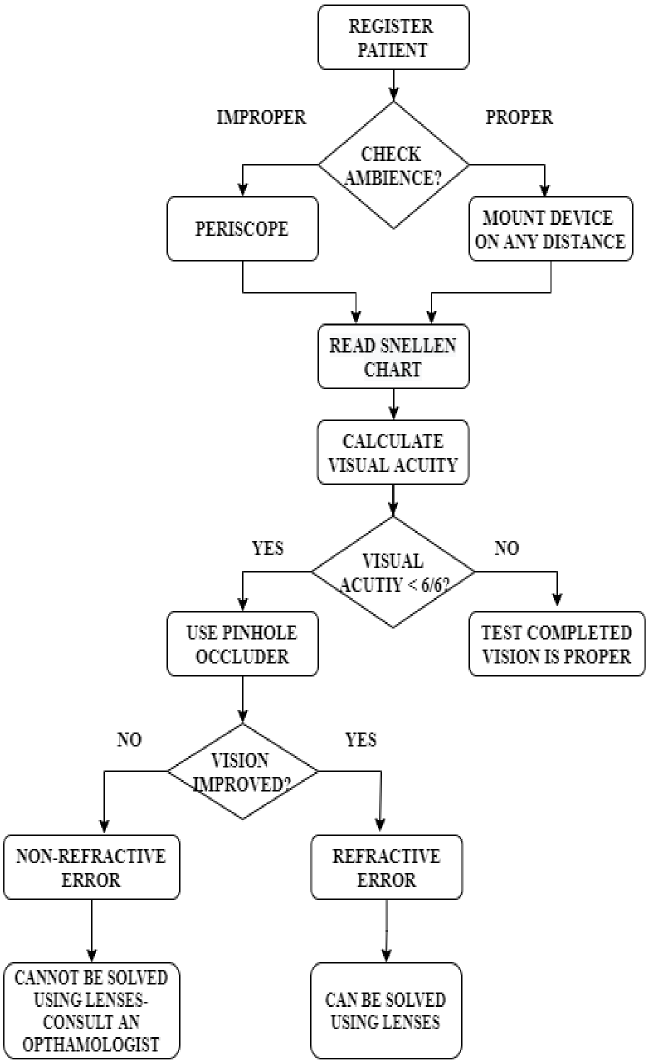

Fig. 8. Flowchart for Opti Mystic.

Fig. 9. Result analysis verified by professional opthalmologists.

Fig. 9 shows a member of our team getting the results and working of our solution verified by Professional Ophthalmologist.

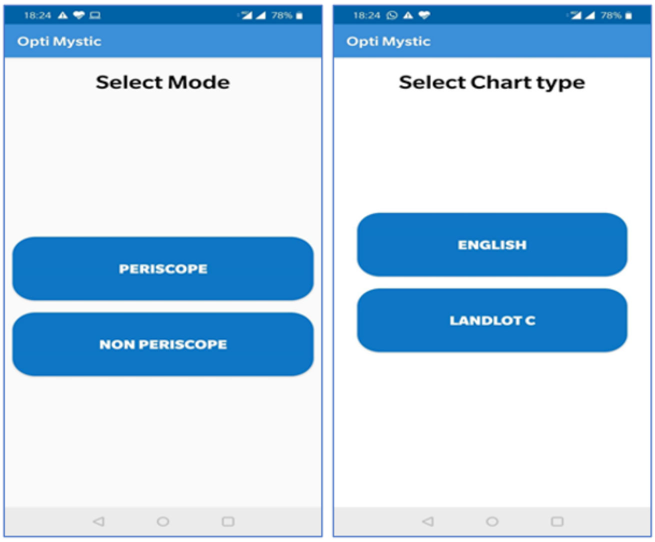

Fig. 10. Mode and Chart Type Selection Page.

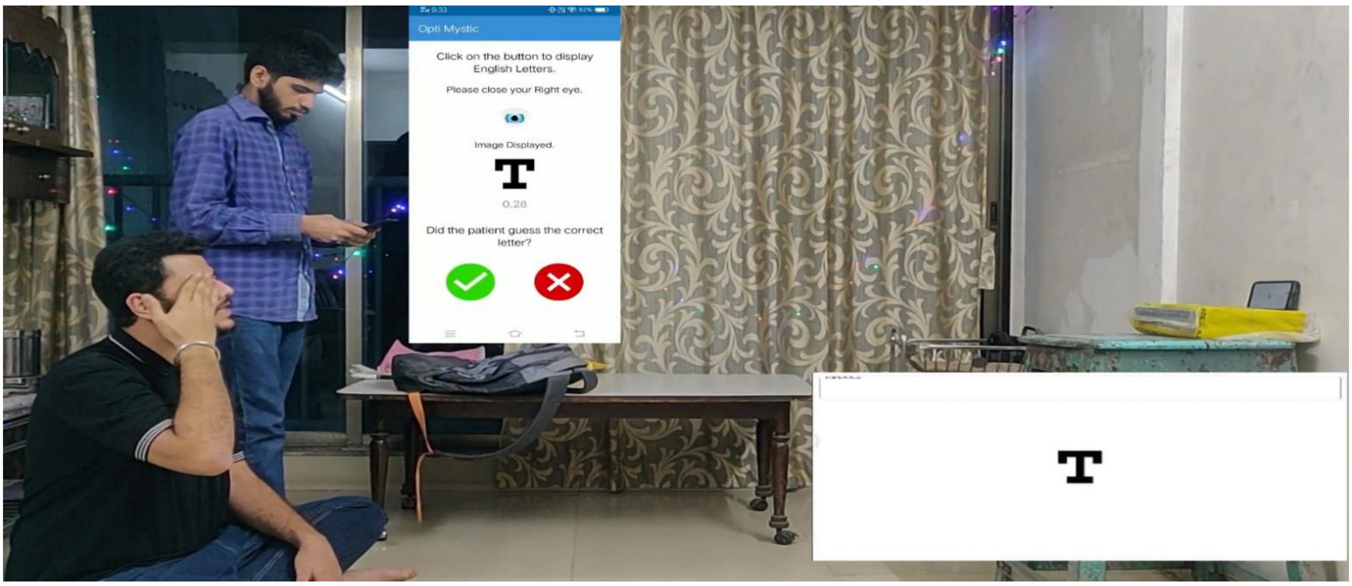

Fig. 11. Patient using the Non Periscope Mode.

TABLE II. READING AND OBSERVATIONS FROM OPTI MYSTIC

Age	Gender	Ground Truth		Experiment													
				With Periscope				Without Periscope									
				With Ambience		Without Ambience		6 meter		4 meter		2 meter		1 meter			
		OS	OD	OS	OD	OS	OD	OS	OD	OS	OD	OS	OD	OS	OD		
26	Male	20/25	20/20	20/25	20/20	20/25 - 1	20/20 -2	20/25	20/20	20/25	20/20	20/25	20/20	20/25	20/20		
48	Female	20/32	20/40	20/32	20/40	20/32 -1	20/40 -1	20/32	20/40	20/32	20/40	20/32	20/40	20/32	20/40		
17	Male	20/16	20/25	20/16 - 2	20/25	20/16	20/25	20/16	20/25	20/16	20/25	20/16	20/25	20/16	20/25		
53	Female	20/50	20/60	20/50	20/60 -2	20/50	20/50	20/50	20/60	20/50	20/60	20/50	20/60	20/50	20/60		
19	Male	20/32	20/25	20/32	20/25	20/32	20/25	20/32	20/25	20/32	20/25	20/32	20/25	20/32	20/25		
34	Male	20/125	20/100	20/125	20/100	20/125	20/100	20/125	20/100	20/125	20/100	20/125	20/100	20/125	20/100		
52	Female	20/200	20/200	20/200	20/200	20/200	20/200	20/200	20/200	20/200	20/200	20/200	20/200	20/200	20/200		
22	Male	20/50	20/40	20/50	20/40	20/50	20/40	20/50	20/40	20/50	20/40	20/50	20/40	20/50	20/40		
21	Male	20/20	20/20	20/20 - 1	20/20	20/20 -2	20/20	20/20	20/20	20/20	20/20	20/20	20/20	20/20	20/20		
22	Male	20/25	20/20	20/25	20/20 - 2	20/25	20/20	20/25	20/20	20/25	20/20	20/25	20/20	20/25	20/20		
38	Female	20/32	20/40	20/32	20/40 -1	20/32	20/50	20/32	20/40	20/32	20/40	20/32	20/40	20/32	20/40		
71	Male	20/80	20/50	20/80	20/50	20/80	20/50	20/80	20/50	20/80	20/50	20/80	20/50	20/80	20/50		
36	Male	20/32	20/50	20/32 -1	20/50 -1	20/32	20/50	20/32	20/50	20/32	20/50	20/32	20/50	20/32	20/50		
17	Female	20/20	20/20	20/20	20/20	20/25 -1	20/20	20/20	20/20	20/20	20/20	20/20	20/20	20/20	20/20		
22	Male	20/25	20/25	20/25	20/25	20/25	20/25 -1	20/25	20/25	20/25	20/25	20/25	20/25	20/25	20/25		
23	Female	20/80	20/100	20/80	20/100	20/80	20/100	20/80	20/100	20/80	20/100	20/80	20/100	20/80	20/100		
16	Female	20/20	20/20	20/20	20/20	20/20 -1	20/20 -1	20/20	20/20	20/20	20/20	20/20	20/20	20/20	20/20		
32	Male	20/32	20/50	20/32 -2	20/50 -1	20/32	20/50	20/32	20/50	20/32	20/50	20/32	20/50	20/32	20/50		

Oculus sinister (OS) means left eye and Oculus Dexter (OD) means right eye.

Fig. 10. and Fig. 11. show pictures of working of our application, mode and chart selection and chart display after which according to the patient's response, visual acuity will be calculated.

Table. 2 clearly shows the comparison between ground truth values of a normal eye and values of visual acuity after using our proposed software-hardware solution: Opti Mystic. Visual acuity is expressed in fractional terms. Our testing was performed on 18 volunteers between the age of 16-80 years. The volunteers had the proper eye wares if required. The room luminance varied between 30 lux to 1000 lux and the viewing distance was varied between 1 meter to 6 meters. From all the observations, we inferred that:

1. Without the use of periscope (hardware component of proposed solution), the accuracy given by Opti Mystic is almost 100%, as it correctly gives the same values of visual acuity as the ground values even after varying the distance of the chart from the user.
2. Periscope, in the presence of enough luminance (800-900 lux), the accuracy is again almost 100%. In case when ambiance is around 20-50 lux (dark room), the accuracy of the solution drops to approximately 98%.

VI. CONCLUSION

The current method of measurement involves the use of Snellen's chart and the involvement of skilled technicians for measuring visual acuity. We have proposed a solution which eliminates the need of a skilled technician and can be used by the naive users. Hence, this research paper aims to provide a solution: Opti Mystic for convenient, accurate and portable visual acuity tests. The key problem of limited measurement accuracy and range was solved by the size design of the visual optotype based on the number of pixels. The display device renders the optotypes based on the defined criteria by the user.

The complete implementation of the system with its robust and secure backend architecture and mobile application demonstrates how the proposed system solves not only the problem of unavailability of space and light ambience issues faced while measuring visual acuity, but also provides a easy-to-use-and-move, very convenient and portable solution at a very affordable cost for all areas ranging from a well-established hospital in a metropolitan city to any health camp organised in the classroom of a primary school at a village.

A. Future Scope

The visual acuity of a person is automatically related to the physical eye health of the person. In future, we aim to create a handheld mobile-based auto-refractor which will measure the sphere, cylinder, axis and pupillary distance for making the corrective lenses.

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