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Usability of the Fuzzy Logic-based Visual Impairment Level Identification System for Pre-schoolers and Toddlers

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***Abstract*—Nearsightedness, or myopia, and Colorblindness, the two common eye diseases, can affect preschoolers and toddlers. This research is to provide parents with a method for testing the two eye impairments listed above in children who are illiterate in both letters and numbers. Using the knowledge offered by ophthalmologists, comments from parents with young children of survey findings, and pertinent literature, this is to create a mobile gaming application based on Fuzzy Logic, that could evaluate the level of children's Colorblindness and Nearsightedness. The "Ishihara test" and "Hue test," which are still widely used today, can be used to identify color blindness by selecting hues from a color palette that have a similar color intensity, and by allowing children to choose images that range in size from large to small (follow the Snellen Chart), and Preferential Looking Test concept that parents can determine whether their child has nearsightedness based on the child's outward behavior. Also, a usability test has also been done at the current level of development of this app. This mobile gaming application roughly identifies the level of the above two eye defects in young children and refers to medical advice if there is a certain risk level. This research paper mainly considers the current development of this mobile gaming app and its usability.**

Keywords—Fuzzy Logic, Colorblindness, Nearsightedness, Mobile gaming application

I. INTRODUCTION

Children under the age of five frequently experience visual impairments such as nearsightedness (myopia), and color blindness. It is thought that visual abnormalities can be quickly controlled if they are identified and corrected at a young age. This research study intends to provide an idea for a technique for using artificial intelligence technology to discover eye problems.

A. Research Background

1) Color Blindness: After roughly age 4 years, a child with color blindness could have problems distinguishing between reds, greens, browns, and oranges.

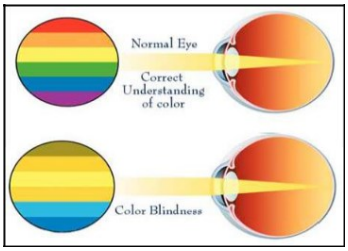

Fig. 1. Difference between Normal and Color Blindness Eye

Source:< https://www.medindia.net/patients/patientinfo/color-blindness.htm>

What are the common tests that might understand that the child has color blindness? - Ishihara tests, Hue tests, Anomaloscope test: Children will be tested by turning a knob to set the lights at the same level in each eye-viewer's eyepiece.

1) Nearsightedness or Myopia:

The typical onset age for this eyesight issue is between the ages of 6 and 14. Around 5% of toddlers, 9% of school-age children, and 30% of teenagers are impacted by it.

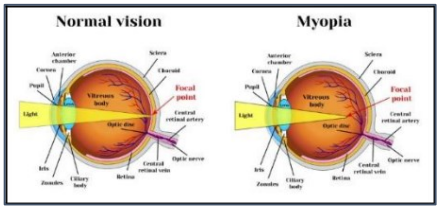

Fig. 2. Difference between Normal Eye and Myopia Eye

Source: <https://www.stahlny.com/myopia-nearsightedness-control/

Among the signs or symptoms of nearsightedness is blurry vision when gazing at distant objects, the need to squint or partially close one's eyelids in order to see clearly, headaches, and eyestrain. Children may also exhibit the following traits that point to vision problems: a tendency to squint constantly,

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an inability to focus on faraway objects, an excessive tendency to blink, a propensity to rub their eyes, and a tendency to watch television up close.

The common test for Myopia - The child must attend an optometrist or ophthalmologist to receive a diagnosis of myopia. The optometrist conducts an eye examination. The toddler will be asked to read letters on a chart or look at a light while having various lenses placed in front of their eyes. Special eye drops may be administered to the youngster to assess the health of their eyes so that the optometrist can more clearly see the rear of the eye.

B. Research Problem Identification, Aim and Objectives

Nearsightedness or Myopia and Color blindness are two of the most common eye disorders in children today. But the toddlers and pre scholars do not have enough understanding to express their visual impairments, and even though the parents recognize that the child has some visual impairment through their child's external behavior, and the child is still unable to recognize and express letters, the children cannot face the eye tests appropriately. There are cases where parents have to wait until the child is older for eye examinations due to the lack of understanding to face it.

The goal is to develop a mobile gaming application which suitable for children mindset and that for parents to diagnose toddlers' and preschoolers' vision problems at home using artificial intelligence technology, based on the wishes of ophthalmologists and parents of young children.

Through the use of this research, a simple Android game will eventually be developed to help young children at home diagnose both vision problems such as color blindness and nearsightedness level in the same app. Also, the objectives of this research are to create simple games to be used for this app in consultation with ophthalmologists, and after creating the games, check the user experience of this app to children of the respective age and their parents and fix the deficiencies related to their feedback. After completing the app, conduct an accuracy test under the supervision of ophthalmologists in eye clinics to confirm the accuracy.

II. LITERATURE REVIEW

This litreture review makes an analysis of the methods that can identify Color Blindness and Nearsightedness by using diffrenet technologies led by Artificial Inteligence. In addition, this also explains which device is most suitable for parents to test tha above two eye defects of toddlers at home.

A. Identify Color Blindness

According to Shahira K.C. and Lijiya A, text-to-speech software solutions allow the blind to access documents thanks to technical improvements. They examine the body of research on comprehending graphs and obtaining visual encoding from them in this work. In order to enable researchers in human computer interaction to attain machine perception of visual data on a human level, this study examines current efforts in the extraction of chart data. In this era of visual data summarization, AI techniques can automate the underlying data extraction and generate natural language descriptions to assist users who are blind or visually impaired. Reviewing this study, one can gain an understanding of HCI (Human Computer Interaction) and how research is combined to identify children who are color blind. [10]

Dey S., Roy S., and Roy K. claim to offer a fully automated system that interacts with the patient and doesn't require outside assistance. According to the study described, the Waggoner model, a color blindness test that is now in use, is made for preschoolers and uses shapes rather than numbers. Therefore, there is evidence that children are colorblind if they are unable to recognize shapes. Which is based on the assumption that a colorblind person won't be able to distinguish between colors that are equivalent. They gave digital eight some thought. It has seven lines, and depending on whether one or more of those lines are missing, it is translated into a variety of digits. The backgrounds of these lines as well as the lines themselves were meticulously crafted. The different buttons are also made with a colorblind person's potential perception of numbers and shapes in mind. To account for every conceivable type of colorblindness, they have taken considerable care. It has been transformed into a complete program for simple installation and use on the Windows platform. That method can be added to this research as needed. [15]

In their study, Moudgil T, Arora R, and Kaur K. indicated that they used the Ishihara's Type Test to diagnose color vision deficiencies. The test was conducted in a well-lit space that simulated daytime sunlight. Students were instructed to read the numbers on the test plates, and their responses were recorded. Less than 5 seconds were allotted for telling the number on a plate. The type of color blindness and the normality or deficiency of color vision are assessed based on the reading of the plate. To determine the prevalence of color blindness, gender distribution, and different types of color blindness, the data was compiled and examined. It will be done using SPSS version 20 and Microsoft Excel to assemble the data and perform the necessary statistical analysis. The chi square test was used to determine the p-value. This study might also incorporate that technique if a color blindness test was required. [17]

Fliotsos MJ, Zhao J, Pradeep T, Ighani M, Eghrari AO. (2020), the goal of the study was to contrast the Ishihara pseudoisochromatic color vision test with a color vision test available through a smartphone app (EyeHandBook). The study concluded that the two tests were not equivalent and recommended using the same modality consistently in clinical situations requiring recurrent testing of color vision.

The study also suggested that to accurately simulate color vision loss, digital color editing methods need to be improved. A color vision test modeled after conventional Ishihara pseudoisochromatic color vision plates is one of many screening tests available in the Eye Handbook app. In tests of color vision, differences between the physical and digital Ishihara replications were found. Because the two devices' screens, light levels, and image scale differ, the study's conclusions could have been biased. The ability of these image processing methods to accurately imitate patients with and without color vision problems must be determined. In order to design the color blindness test application for this study, the device's size and image color quality must be taken into account. According to this study, the Ishihara test concept is best for determining color blindness. Therefore, the "Ishihara Test" concept will be employed in the project.[11]

Lee, Jinmi & Dos Santos, Wellington. (2010), Three computational methods designed to help people who are colorblind are presented in this research. The initial instrument assesses color blindness and rates how severe it is. Based on fuzzy logic, the second tool enhances the visual quality of digital images. The final tool imitates color blindness to red and green. The study also created the DaltonTest, a diagnostic tool that classifies color blindness, illustrates its severity, and explores its different presentational forms. The DaltonTest result is used by the rectification tool to generate a fuzzy character for the application. The DaltonCor correction tool employs digital image processing to enhance colorblind people's visual capabilities. The study used 10 bitmap-32-bit images and several correction versions, including RGB, LMS, and with and without histogram equalization, to examine the effects of the correction tool.[8]

B. Identify Nearsightedness

The authors, Lavric A., Popa V., Takahashi H., and Yousefi S., report that they used a variety of machine learning algorithms to identify keratoconus and then tested the algorithms using real-world medical data, such as corneal topography, elevation, and pachymetry parameters gathered from OCT-based topography instruments from several corneal clinics in Japan. The suggested model might help doctors identify keratoconus earlier on in the disease's course when it is still preclinical, which is difficult to do with subjective evaluations. For corneal assessment and early-stage keratoconus detection, the method can be applied to stand-alone software or integrated into corneal imaging devices. Adding that method to this research is challenging because it concerns a straightforward Android development, yet it can provide some useful insights. [2]

According to Yang Y., Li R., and others, describe a deep learning system (DLS) that can identify myopia using pictures of the ocular surface. This DLS demonstrated great diagnosis accuracy and was able to learn the ocular appearance characteristics of myopia using a dataset collected from the Myopia AI Program. Therefore, it might be applied to routine myopia evaluation. This review could aid in identifying nearsightedness and in properly analyzing the survey results for this study. [20]

C. Suitability of testing these Eye Defects using mobile phone

This review, conducted by Senjam S.S, Manna S. and Bascaran C. (2021) aims to highlight accessible functions, uses, and benefits, such as those for education and the use of smartphones as assistive technology for the blind and visually impaired. It also discusses user advantages and challenges as well as usability testing conducted by app developers. Innovative assistive gadgets have been created as a result of advancements in "human-computer-interaction" research, with novel interface designs that make them more accessible and user-friendly for those with visual impairment. Touch displays offer completely hands-free human-smartphone interaction by moving the need for visual function to alternative bodily senses through haptic or sonic gestures. A person with vision impairment can interact with the contents of a smartphone by using a range of accessibility features. Youngsters are more familiar with smart phones today because of their complexity and inclination for utilizing them for the majority of chores. As a result, mobile applications are more suited for screening youngsters for color blindness and myopia.[16]

This literature review implies that although there are separate specialized methods for color blind testing currently in use, besides the traditional snellen chart method to test nearsightedness, there are scientific methods that are limited and difficult to use in general and simple as above. Therefore, the technologies that can be used to solve the problem presented above have been presented in detail through this literature review.

Accordingly, the Fuzzy Logic concept of Artificial Intelligence technology, Image processing and HCI techniques, and machine learning models can be used to test these 2 eye defects. Also, this implies that the mobile phone is the most suitable device for this test.

III. METHODOLOGY

After identifying the scope of this research by reviewing past research papers and discussing it with the supervisor and making the decision to create this app based on the technology called fuzzy Logic

The areas to be tested by the app were discussed with the ophthalmologists. Then the games to be made for the app and how to test the visual impairment level were discussed.

The process of the project is as below;

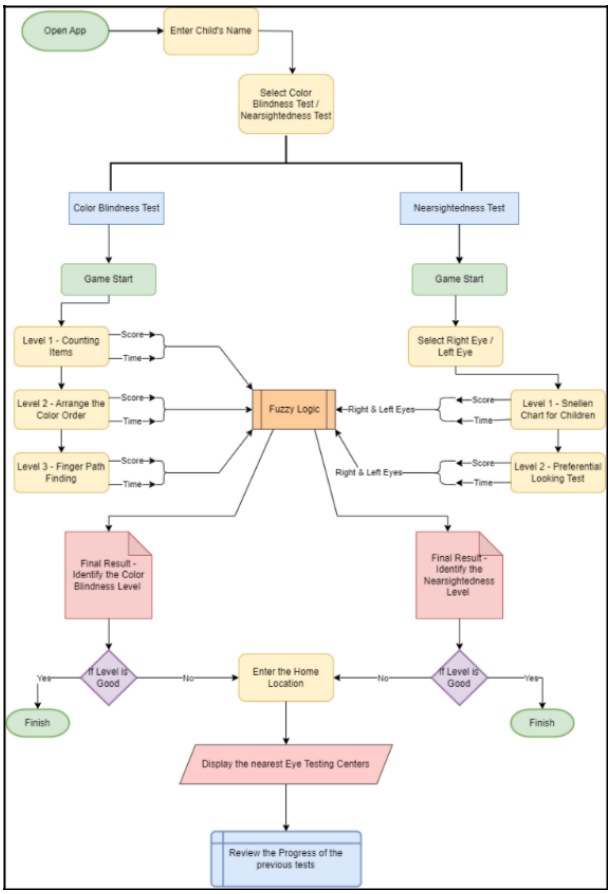

Fig. 3. Project Process Diagram

Source: Author

The colorblindness and Nearsightedness tests have separate levels, each providing a score. That scoring system developing on MATLAB. MATLAB rule base structure is as follows:

Input 1: Correctness of a level (High, Medium, Low).

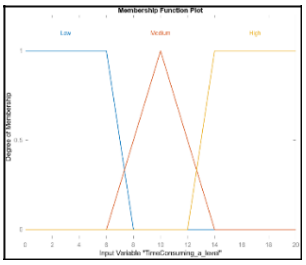

Fig. 4. Membership Function Plot – Input variable: Correctness_a_Level

Source: MATLAB

Input 2: Time-consuming of a level (High, Medium, Low).

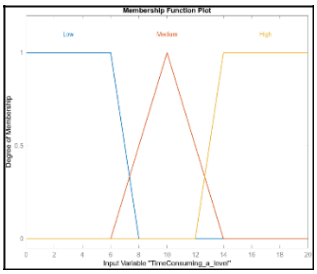

Fig. 5. Membership Function Plot – Input variable: TimeConsuming_a_Level

Source: MATLAB

Output: Threat_Level (hasThreat, noThreat)

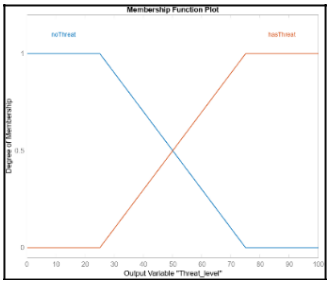

Fig. 6. Membership Function Plot – Out variable: Threat_Level

Source: MATLAB

The fuzzy Logic rule base is as follows:

- Rule1:If Correctness_a_level is Low and TimeConsuming_a_level is Low then Threat_level is hasThreat
- Rule 2: If Correctness_a_level is Medium and TimeConsuming_a_level is Low then Threat_level is hasThreat
- Rule 3: If Correctness_a_level is High and TimeConsuming_a_level is Low then Threat_level is noThreat
- Rule 4: If Correctness_a_level is Low and TimeConsuming_a_level is Medium then Threat_level is noThreat
- Rule 5: If Correctness_a_level is Medium and TimeConsuming_a_level is Medium then Threat_level is hasThreat
- Rule 6: If Correctness_a_level is High and TimeConsuming_a_level is Medium then Threat_level is noThreat
- Rule 7: If Correctness_a_level is Low and TimeConsuming_a_level is High then Threat_level is hasThreat
- Rule 8: If Correctness_a_level is Medium and TimeConsuming_a_level is High then Threat_level is hasThreat
- Rule 9: If Correctness_a_level is High and TimeConsuming_a_level is High then Threat_level is hasThreat

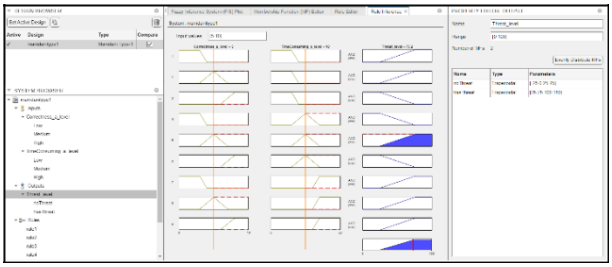

Fig. 7. Rule Inference

Source: MATLAB

Ps: In above mentioned all the values are rough values that are only used to test the structure of the Fuzzy Logic rule base creation.

Under the guidance of the supervisor and the ophthalmologists, the creation of the Android mobile gaming app was started, and at the level that has been created, around 10 children of the relevant age were gathered and their parents were explained about this, and they were allowed to use this app and conducted a usability test. User experience was checked by using that test.

IV. ANALYSIS

A. *Ophthalmologist's suggestions:*

Suggest to the most appropriate method is developing a mobile gaming application suitable for children's usage, under the guidance of the parent.

For Colorblindness:- Suggest following the "Ishihara Test" concept; to instruct the child to drag the finger around the viewable Ishihara test image. And suggest following the "Hue Test" concept to arrange the different shades of colors into the closest color order.

For Nearsightedness:- Suggest following the "Snellen Chart" concept and "Preferential looking test" concept which are suitable for children's mindset. And parents must consider the child's external behaviors. Ex: should consider the child's arm and eye actions.

Suggest instructing the parents to consider the hand/ arm behaviors in the child. As an example; keep the phone 30 cm away from the eye of the child and keep the phone in an arm angle of 60^0 from the child's eye. So, if the child gets the phone closer to the eye that child has some Myopia symptoms.

B. *Supervisor's suggestions:*

It is best to develop a "Fuzzy Logic" for both Color blindness and nearsightedness for this game. Because the level of visual impairment can get using the scoring system by following the Fuzzy Logic concept.

C. *Past Research papers:*

For Colorblindness:- Enable to use of HCI, to attain machine perception of visual data on a human level and can follow the Waggoner model. It would be based on Ishihara Test and Hue Test concepts. Must consider the devices' screens, light levels, and image scales differ, the study's conclusions could have been biased. Can use Image processing techniques, Can follow DaltonTest concept.

For Nearsightedness:- Mostly using Machine learning algorithms. Example: Multi-layer perception models. Can follow Deep Learning Systems.

D. *Survey results from parents;*

More than 65% of parents are willing to develop a mobile gaming app for the abovementioned problem. More than 55% of the parents from the sample are liked to detect and check their child's eyes at an early age and at home.

31.1% of the parents have checked the eyes of their children and 68.8% have not checked yet. The reason for that cannot identify the problems of a child's external behaviors, are unable to identify the letters and numbers correctly, etc. Also 21.9% of the parents from the sample, they do not like to create a mobile gaming app, because some of them mentioned must monitor what kids are doing with their mobile, and some mentioned children do have not enough knowledge about how to use the mobile phone.

E. *Usability Testing*

Ten children of pre-school age between four and six years were used to check the user experience of the app at the current level. Apart from one child, all the other 9 children played games very well and one child was as young as 3 years old, so he did not understand much.

The parents of those children also expressed their desire to let their children play games through this app and confirm whether these 2 eye defects exist in their children.

V. RESULTS AND DISCUSSION

The findings and results of this research can be summarized as follows in perspective of the aim of the research and the analysis performed on the data gathered from outside sources.

A. *Findings*

This solution is a way to detect Nearsightedness and Color blindness in children under five years of age. The most appropriate method is to identify whether or not the child has visual defects by playing the game under the guidance of the parents.

Pictures and colors are more suitable because this game was made for kids who have trouble reading letters and numbers.