Automatic Color detection: A camera-based glass

Glen A. Wilson High School

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Introduction

The goal of Automatic Color Detection: A Camera-Based Glasses is to create a commercial pair of glasses that may effectively help individuals who are suffering from colorblindness, affecting their everyday tasks. This goal is achieved through automatic execution of the scripts, with the Raspberry Pi 4 Model B, and a Camera module, Arducam IMX219. The combined components will be infused with a 3D printed glass replica, and integrated together in a system, allowing the camera to tell the user what color is being detected, using a low-force laser and a pair of earbuds. A battery pack is required, but will meet the user's needs.

Project Goals

Problem Statement:
According to a study conducted in 2017 by Dr. John Barry, about 300 million people are colorblind in the world. 66%-90% of colorblind people have trouble performing common daily activities such as driving, navigating the internet, and identifying people from their faces. This can cause inconvenience and even lead to the lack of job opportunities for jobs that require color perception.

Constraints:
The product must be affordable, and work for all individuals, regardless of what type of colorblindness they may have. Additionally, the product must be small enough, where the product will not be interfering with the daily lives of the person that may be using it. The product must also be accurate, so users may rely on the script that the team will create.

Solution:
Using publicly available libraries, the team took advantage of some, such as espeak and OpenCV, to create a script that will allow colors to be detected. The team will also be careful of integrating multiple key functions, such as the 3D printed glasses and the electrical components.

Overview of the Electrical Components

- **Raspberry Pi 4 Model B With Cooling Case:** Stores and executes a python script successfully and automatically. The Cooling Case serves to prevent the CPU (Computer Processing Unit) from overheating, which may damage the board.
- **Arducam IMX219:** A camera, which the Raspberry Pi 4 Model B can read off of. Utilizing OpenCV, the Arducam can provide data to the python script, which will analyze the colors, and read it to the user
- **Commercial Laser**: This tool will allow the user to control which object the camera should read off of. The laser will only have 3.3 Volts, making it weaker than a typical laser, purchased in store.
- **Commercial Earbuds**: Works by sending information to the user using TTS (Text to speak). This allows the user to understand what color they are looking at, after the final integration of all the other components.

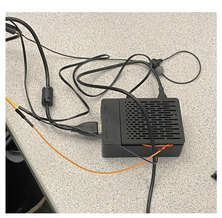

Figure 1a: *The Raspberry Pi, integrated with the commercial earbuds*

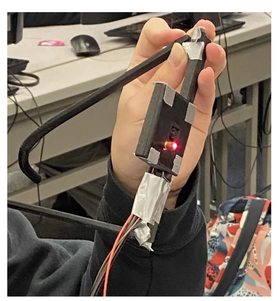

Figure 1b: *The final product, demonstrated with the laser, Arducam, and the 3D printed classes the person will wear (Nose ridge not shown).*

Glasses Design

The glasses component itself was much more complex, requiring the use of external software due to its shape that optimizes comfort for the user. With the use of lightweight PLA from 3D printing, this component can make our product much more convenient and portable. Using mesh modeling, it was possible to easily produce a 3D curve (curved on two different axes) which glasses are typically shaped for comfort around the ears and to secure on the head. The top is flat to allow the Raspberry Pi setup to sit comfortably on top of it. At the end, there is a bulge with a circular hole that allows the connection with the next part while being rotatable. The pieces were later glued due to a lack of strength from the PLA plastic even at 100% infill and the unavailability of small screws.

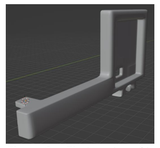

Figure 2a: *First sector of the glasses*

Figure 2b: *Nose pad and pad arms of the glass design*

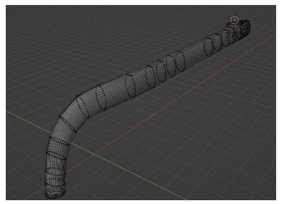

Figure 2d: *Temples part of the glasses in Blender*

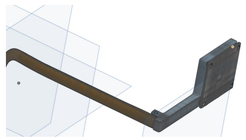

Figure 2c: *Merged design of the glasses*

Figure 2e: *Glasses merged with the Raspberry Pi*

Constraints and Revision

The team has four major tests, to validate the prototype.

1. **Seeing colors:** Can different tones of colors be read. To prepare for this test, the team manually inputted approximately 50 different types of colors, all in Red-Green-Blue form. Additionally, the team will not only gather random colors from a random color generator online, but will test with real-life objects users may face everyday.
2. **Works for Everyone**: Making sure regardless of what colorblindness an individual may have, they are able to use the product without problems. To prepare, the team did gather five people, all with different colorblindness types.
3. **Comfortableness**: Are users happy with the product. In order for users to use the product, users must be satisfied, or else they may not use it.
4. **Duration and Timings**: Tests how fast each colors are read. In order to check, the test will be going through a live linear regression, to not only test how accurate the colors are being read, but how fast the computer takes to recognize the colors, and save the information on the terminal, or the y-axis.

Despite the major tests, the team needs to make a major revision to the glasses, in order to make sure it's comfortable and the weight distribution on both ears are equal. This can have a big influence on how comfortable it may be.

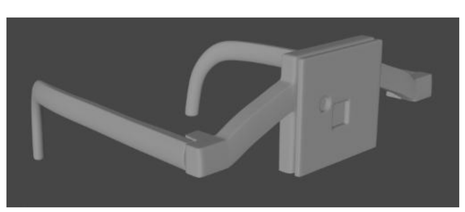

Figure 3: *The modifications made, showing the temple on both sides instead of one. Raspberry Pi will be in the user's pocket instead of on the glasses*

Testing Phase

Each test was conducted in a controlled environment, and with appropriate supervision from members of the project. With instructions given to each volunteer, the team was able to collect data from the four tests that's conducted. Due to the limited volunteers, three out of four tests are not statistically significant, violating the Central Limits Theorem. Additionally, there is a test, which was later determined irrelevant and will be discussed later.

Trial Number	How many correct colors	Pass/Fail?
1	0	Fail
2	7	Pass
3	8	Pass
4	10	Pass
5	10	Pass
6	8	Pass
7	3	Fail
8	8	Pass
9	2	Fail
10	7	Pass

Figure 4a: *Seeing Colors test results.*

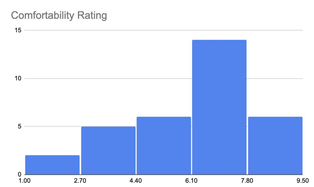

Figure 4b: *Comfortability bar graph results*

Trial Number	Type of Colorblindness	Notes on Severity	Pass//Fail?
1	red-green	Cant see red and green	Pass

Figure 4c: *Works for Everyone test, only one person able to test. Will be elaborated later.*

Trials	Average times to identify each color (s)
1-10	<1 sec

Figure 4d: *Duration to identify each colors.*

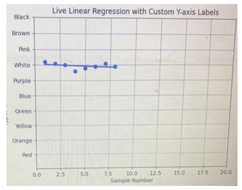

Figure 4e: *Linear Regression graph to assist with duration to identify colors*

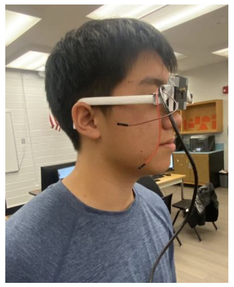

Figure 4f: *A volunteer testing the comfortability of the glasses*

Difficulties Faced During Testing

Throughout the testing phrase, there has been difficulties the team has faced. Some of the difficulties were unexpected, resulting in some data not being statistically accurate. The three main points are:

- **Volunteer's availability:** As the team approached April, multiple colorblind people were busy, due to business trips, university finals, and internal problems. As a result, making sure it works for everyone only has one user testing it. However, this would be combated with an expert review.
- **3D print glasses breaking:** Because of the glasses breaking, the team had to remove the component and rebuild the glasses. As a result, the time to test the product significantly decreased. The team did combat this issue by printing with a greater infill, and making sure there would be a temple on both sides (See Figure 3).
- **Bugs:** During the testing phrase, the team has noticed some bugs that requires attention. As a result, multiple weeks were reserved to fix the code, while researching through websites on how to handle the task.

In the team's high school community, it was hard identifying colorblind people. As a result, only one person was able to test, who are attending the team's high school, while there were four colorblind people the team knew through friends, parents workers, and local universities. Unfortunately, everyone that is not affiliated with the team's high school were busy during the testing phrase.

Expert Reviews and User Feedback

Prior to the construction of the glasses, the team asked someone that is colorblind about their opinions, and an industry expert.

- "I only really need to see color when doing projects that require color, so I kinda want both my hands for working. It's just convenient. I really don't wanna carry a whole box just to see color." -Monica Vagas
- [he] agreed that our design should be small enough to accommodate people's storage so they can carry them everywhere. -Amir Kosari, CEO of Colorwill

Before implementing an automatic script, the team wants to know how the glasses will be able to efficient and have the ability to reach out to customers. As a result, the team asks Shawn Chen, experienced with online business, for the past X years.

- "Despite existing products on the market, capturing niche areas of individuals with color deficiencies that require machine-assisted real time color recognition are essential to avoid competition with established firms that produce color assistance products" -Shawn Chen

Lastly, after the team went through the testing phrase, there was a problem with making sure it works for everyone. As a result, the team asked a student from the University of Southern California, to analyze the test and validate it's irrelevance.

- "The test really only has significance, if the color recognition software is for different types of color blindness. Otherwise, there's no reason to have this test." -Aaron Yang

Bill of Materials

Automatic Color detection - Bill Of Materials					
Part Name	**Part Description**	**Parts Per Order**	**Price Per Order**	**Quantity**	**Net Cost**
Arducam USB Module IMX219	Camera module, for the Raspberry Pi to read	1	$30.00	1	$30.00
Raspberry Pi 4 Model B	One-board computer, automatically running scripts	1	$71.95	1	$71.95
Raspberry Pi 4 Cooling Case	Prevent the Raspberry Pi from overheating	1	$11.99	1	$11.99
Commercial Laser	Allow the user to control which color to see	10	$6.79	1	$0.68
Commercial Earbuds	Allow the user to listen to what color is being read	1	$4.88	1	$4.88
Wires	Allowing information to transfer, and/or power	120	$6.98	8	$0.47
3D Printed Glasses	Connecting all the components, so the user can wear	1	$1.50	1	$1.50
M3 Screws	Securing the components that requires a screw	100	$7.66	4	$0.31
Anker PowerCore Select 20k mAh Power Bank	Allowing the system to power on	1	$29.99	1	$29.99
Subtotal					$151.76
Tax + Shipping (~15%)					15.00%
Grand Total					$174.52

Figure 5a: *Table containing Bill of Materials and Total Budget for the prototype.*

Conclusion and Future Works

Despite the system working properly, there is room for improvements. Such improvements may include the automatic function, having colors be more accurate, and adjusting the design of the glasses, in order for users to feel more comfortable with the design. This project also does add risk towards minors, or individuals who may mess up electrical components, in which it may add to serious injury. To prevent this, there could be more ways to protect critical components, and simpler manual guides. Additionally, the whole system can become smaller, and weigh less, so users will feel comfortable carrying a small sized battery and processor, instead of a one-board computer and a power bank.

The overall design was influenced by an internship a team member recently completed in Summer 2023. Additionally, reading Stanford students who founded TranscribeGlass, allowed the team to be influenced heavily. With the technology TranscribeGlass is using, future works can include the feature of seeing words and using the lens to point at the object, instead of using a commercial laser and a pair of earbuds. With one of the team member's prior experience of Open Computer Vision, the team decided to investigate more with how it may connect with colors and RGB. Not only was the team able to learn, but deliver a prototype that is successful at detecting colors despite needing more work to achieve a 100% accuracy.

Acknowledgments

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Video presentation: https://youtu.be/rk9O7RobkyI