Colour Detection using Matlab and Python

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*Abstract*— Colour detection plays a pivotal role in our daily lives. This research study explains how colour in perceived by the rods and cones in both human as well as animal eyes and transferred to the brain to create images. We make use of two models, namely a Matlab model which extracts specific colours from an image using the pixel values chosen by the user. The second model is a python model which focuses on allowing the user to identify a colour in any image and correctly predict the name of that colour along with its hex values. The research study then elaborates on the different applications of colour detection. We concluded that the easiest colours to extract are red, green and yellow. The most difficult colours to extract is purple. Colour has the ability to evoke emotion, affect purchases in stores, affect mood and alter how one perceives food based on colour. One of the most effective uses of colour is in marketing. Further advancements include the application of colour detection in technology such as x-ray machines, night vision goggles and infrared technology.

Keywords— colour detection, Matlab, python, infrared, electromagnetic spectrum, eye, visible light, ultraviolet light, x-rays, night vision, camouflage, reproduction, evolution

# Introduction (What is colour detection)

According to the *Medium* website, colour detection can be defined as the process of detecting the name of a colour. The brain and eyes of a human work simultaneously to take in light, interpret it and translate it into colour. The light receptors in our eyes such as our cones and rods are used to transmit these signals to our brains. The brain is the organ that recognises the colour. Colour detection can be relevant for both humans and animals alike, however some animals can see more colours than we do from other spectrums while others only see a few colours (1).

Humans can only see colour that is within the visible light spectrum. These colours are indigo, purple, blue, green, yellow, orange, red and every shade thereof.

Colour detection can be manipulated in computers as well as is our aim for this project. We decided on two models for this colour detection project. The first being a Matlab model which focuses on extracting specific colours from an image using the pixel values chosen by the user. The second model is a python model which focuses on allowing the user to identify a colour in any image and correctly predict the name of that colour along with its hex values.

There are many applications for colour detection as well. In nature, colour detection is used by animals to spot their prey such as snakes or eagles who use ultra-violet detection to spot a prey’s heat signature. It is also used by animals to discern whether prey is poisonous or not. In humans we use colour detection to find our way around places and people. Humans have implemented colour detection in technology such as night vision goggles which are used to spot objects at night when our natural vision is not able to as well as heat signature detectors which are used by the fire brigade during fire emergencies.

# BACKGROUND

## The Human Eye

The human eye is a special sensory organ that is able to receive and process visual images by adjusting to light and sending signals to the brain. The eye ball is protected from any sort of mechanical injury by being surrounded by the bone which makes up the eye socket. It also has an apex that points backwards into the head (2). This houses the optic foramen which acts as an entrance through which the optic nerve runs backward into the brain alongside the ophthalmic artery. The eyelid protects the front surface of the eyeball known as the cornea (2).

The eye is made up of several different parts that all work together to create and image. As observed in figure 1, the sclera is the white part of the eye which protects the eyeball while the transparent portion is called the cornea. Beneath the cornea is a ring called the iris and this will determine the colour of your eye (2). The center of the ring contains the pupil. Because light which passes into the eye is not reflected back out, it appears black in colour. The eye consists of 3 coats which surround the optically clear aqueous humour, lens as well as the vitreous body. The cornea and sclera are contained in the outermost coat while the middle coat accommodates the main blood supply to the eye, ciliary body, the choroid and iris. The retina forms the innermost layer. Aqueous humour is a clear liquid that fills the spaces between the iris, lens and cornea. The vitreous body is a jelly-like liquid that fills the cavity enclosed by the sclera, ciliary body and lens (2).

The transparent window of the eye which allows light to pass through is known as the cornea. By changing the size of the pupil, the iris controls how much light passes into the eye. When the pupil dilates, it allows more light to pass through. As soon as the pupil constricts, less light passes through. The clear lens behind the pupil focusses light onto the retina at the back of the eye.

The retina houses the cells which respond to light. These are known as photoreceptors which can further be split into rods and cones (3). Rods are extremely sensitive to changes in light, shape and movement and they contain only one type of light-sensitive pigment. Rods are however not ideal for colour vision therefore they are used when in a dark setting.

Cones are not as sensitive to light in comparison to rods, but they are most sensitive to at least one of the three coloured (red, green, blue). Signals are passed from the cones to your brain which then converts messages to be perceived as colours. Cones only work in bright light settings therefore you cannot see colour as well when in a dark room. It can therefore we said that cones are used to define image detailing. The human eye contains roughly 6 million cones in the retina. Being colour-blind means that your eye does not contain a certain type of cone or the cones may be weaker (3). The centre of the retina is known as the macula as seen in figure 2 and at its centre is the fovea which contains only cone cells and provides the clearest vision. Light has a direct path to photoreceptors through here. The blind spot is the only area in the eye that doesn’t contain any photoreceptors. Images which fall in this region won’t be seen. It is here where all the optic nerves come together and connect to the brain (3). The eye is in fact not round, but curved because of the cornea therefore when light enters the eye, the light bends creating an upside-down image on the retina which is inverted by the brain as depicted in figure 3.

## The Light Spectrum and Visible Light

Signals are transmitted by the human eye to the brain via the optic nerve which then translates it to images. Sir Isaac Newton discovered that colour is not inherent in objects but rather the perception thereof since a surface reflects some colours and absorbs all the others. We then observe the reflected colours. To understand this better, when looking at a red wall as in figure 5, we see the colour red only because the wall is reflecting red wavelengths back at us while absorbing all other colours. A white wall would mean that the object is reflecting all wavelengths. Similarly, a black wall appears black because it absorbs all colours.

To understand how light works, we take a closer look at the electromagnetic spectrum (EM) which portrays the range of all types or EM radiation. Radiation can be defined as the energy emitted from a source and travels through space and has the ability to penetrate various types of materials (4). EM Radiation varies from microwaves to infrared light along with x-rays, ultraviolet light and gamma-rays. None of the latter are visible to humans, although we make use of them in radios, microwaves, night vision goggles, and x-ray machines. Figure 6 depicts the electromagnetic spectrum ranging from the lowest energy (top - longest wavelength) to the highest energy (bottom- shortest wavelength) (4). EM radiation is described in terms of energy, frequency or wavelength. Our key focus with regards to EM radiation is visible light since those are the wavelengths visible to most human eyes.

Between infrared (IR) and ultraviolet (UV) light on the EM spectrum is visible light. Frequencies range from roughly 4×1014 to 8×1014 cycles per second. Wavelengths vary from 740nm or 2.9×10−5 inches, to 380nm (1.5×10−5 inches) (5). The light at the lower end of the visible spectrum has longer wavelengths of roughly 740nm. This is seen as red while the observed the middle of the spectrum accounts for while the upper end houses lengths of 380nm as is seen as violet. All other colours that we see are mixtures of these colours (5).

When we consider yellow, we observe that it consists of both green and red; by combining green and blue we obtain cyan, while magenta is a mixture of blue and red. White light contains all colours. Black is the complete absence of light. Sir Isaac Newton was the first person to notice that white light consisted of the colours of the rainbow. In 1666 he passed sunlight through a tiny slit and then into a prism to portray the coloured spectrum onto a clear wall as seen in Figure 4.

Colour is however an inherent property of light as well as an artefact of the human eye since objects do not really have colour, but rather reflect light which is then observed as colour. According to Glenn Elert, author of the website *The Physics Hypertext book*, colour only exists in the mind of the observer.

When we take a closer look at colour and temperature, objects that grow warmer radiate energy which is consists mainly of shorter wavelengths. This results in colour changes as the temperature rises. A good example of this is the flame of a blow-torch which changes from a shade of red to blue as it is adjusted to higher temperatures. Astronomers are also able to identify what objects are made of because each element absorbs light at a specific wavelength. This is known as the absorption spectrum. Astronomers are able to use spectroscopes to determine the chemical composition of dust clouds, stars and other distant objects by knowing the absorption spectra of elements (5).

# DESIGN AND METHODOLOGY

## Python Model

This model will allow the user to run the code from the command prompt window of Python. When the user double clicks anywhere on the image, the colour will automatically be generated using a database of colours based on the RGB vector values. Lastly, we calculate the distance from each of the colours to find the shortest one.

Colours are made up of 3 primary colours: red, green and blue (RGB). Colour are defined within a range value of 0 to 255 when working with computers. This translates to 256\*256\*256 = 16 581 375 different ways to represent a colour using a vector. Each colour in the dataset is mapped with its corresponding name. Our dataset includes 865 colours along with their RGB and hex values.

The model makes use of OpenCV and Pandas therefore these libraries are prerequisites before building or running the model. The argparse library is used to create an argument parser. The dataset is then read into a pandas DataFrame where we assign each column with a name. We made use of an interactive mouse therefore a mouse callback event was set on the window and it will be called upon when a mouse event (clicking on the window/image) happens. This will output the RGB values of the pixel that was clicked on.

The function parameters have an event name (x, y) which show the coordinates of the mouse position on the screen. We have to check if the event is double-clicked in the function, then the set the RGB values as well as the x, y positions of the mouse are calculated.

Since we obtained the RGB values above, we make use of another function to return the name of the colour using the RGB values. To retrieve the name, we calculate the distance (d) which is able to tell us how close we are to colour and choose the one which has the minimum distance. Distance is calculated using the formula below:

The model then needs to display the colour’s name and RGB values in the window each time the window is double-clicked. By using the cv2.imshow() function, we are able to draw the image on the window. When double-clicked, the colour name is displayed in a rectangle using the cv2.rectangle and cv2.putText() functions. As stated above, the Python file must be run from the command prompt window where a path must be specified and the path needs to contain all images to be used as inputs.

## Matlab Model

Our Matlab Model allows the user to run the code on the Matlab platform with preinstalled packages containing all the image processing functions we will need. The purpose behind this model is to only extract certain colours from a specific image and to test how accurate it is at isolating those specific colours. The specific colour can be chosen by the user using the impixel() function to select the range of pixels to extract a specific colour.

A colour image consists of three channels: red, green and blue. Blue would have the lowest pixels ranging from 0 to approximately 150, while green would be approximately greater than 150 and smaller than 230. This leaves red to be the highest pixel values approximately ranging from greater than 230. These limits or ranges can also be manipulated by the user to extract the exact colour from the image.

Below is a list of the functions we used in our model and what their purpose were:

Table 1

|  |  |  |
| --- | --- | --- |
| **No.** | **Function** | **Description** |
| 1 | imread() | Load the image only the Matlab environment |
| 2 | imshow() | Display the figure specified. |
| 3 | rgb2gray() | Convert a three-channel colour image into a gray single channel image. |
| 4 | imsubtract() | Used to subtract one image from another. |
| 5 | im2bw() | Converts an image into a black and white image. |
| 6 | cat() | Combines different channels into one multi-channeled image |
| 7 | imcomplement() | Used to get the complement of an image. In layman’s terms it is to get the “negative” of an image. |
| 8 | subplot() | Used to display the figure specified much like the imshow() function, but when combined with that function, it allows the user to display more than one image or figure on one plotting plane. |
| 9 | clear all | Delete variables within a workspace. |
| 10 | close all | Closes all the figure handles. |
| 11 | clc | Clear the command window. |

# RESULTS AND ANALYSIS

## Python Results and Analysis

We use the following code to run the model in the command prompt window and specify the image name each time: *python color\_detection.py -i image03.jpg*

In this case, we used an image with various fruits. By double-clicking anywhere on the window, we are able to identify the colour name and RGB value which are associated with one another and obtained from the colours dataset that was loaded. Below are 4 figures displaying how the model works.

Below are figures displaying how the model works when a different image is read in.

To account for very light colours that are clicked on, we have inserted an *if-statement* to make the font of the colour name and RGB value black so improve the visibility thereof. As soon as the user presses the escape key, the program is terminated.

The model accuracy has been really good considering that only 826 colours and RGB values were preloaded. A larger dataset along with an image with an extensive amount of hues and saturations containing an array of colours will improve the accuracy of the model.

## Matlab Results & Analysis

#### Part 1

We load the original colour image into Matlab and display it (figure 16). The original image is then converted to a grey image (figure 17). We then create a red matrix from the original image and subtract the red from the image (figure 18). The output image (figure 19) is then converted to a binary image where the red objects are masks and a 3 channel masked image is created. Red and green now need to be segmented so we create a green matrix from the original image and subtract the grey from the green image (figure 20). This image is then converted into a binary image (figure 19).

#### Part 2

We convert the red subtracted image (figure 21) into a binary image. Next the complement of that image is found and converted into a binary image once more. A mask is created of the red subtracted image and displayed as red objects extracted. Now you may notice that image contains orange and yellow in it as well. This is because the orange is a lighter shade of red and both the orange and yellow peppers contain traces of red in their tonal shadows (figure 22).

We then find the green matrix of the image and subtract the grey image from the green matrix of the original image (figure 23). The green subtracted image is converted into a binary image with a threshold of 0.01 (figure 24). Next, we create a mask for the green subtracted image by finding the complement of that image and converting it into a binary image, thereafter creating a 3 channel image displayed as the green objects extracted (figure 25). Now you may notice that this image contains yellow as well, because yellow is adjacent to green and may share similar tonal colour features.

The next step would be to subtract the red binary image from the green binary image and applying the absolute function to that image. Masks are then created for the combination of both the green and red binary images as well as the red binary image without the green (figure 26).

#### Part 3

This part of our project focuses on the extraction of the red peppers only excluding the orange and yellow from the image. Firstly, we subtract the green matrix from the red matrix. Then we subtract the grey image from the green matrix we have subtracted before from the red matrix. The next step would be to apply a mask on the red binary image by finding the complement of that image and converting it into a binary image. We then create a 3 channel image using that mask to produce an image extracting the red peppers only without any orange or yellow peppers present (figure 27).

#### Part 4

This portion of the code is run from the command window. First we load the image we want to work on (figure 28). Then we choose pixel values from that image we want to extract. It could be pixels at random or pixels from a specific colour shade.

Thereafter, we display the pixel values. Using the pixel values we have just extracted, we manipulate the red, green and blue matrices on which ranges of pixels to choose within the original image. As an example, we extracted pixels from the bright yellow shade on the yellow pepper and displayed the image as a binary image below (figure 29). For the final few steps, we would create a mask to display the extracted bright yellow binary image into a colour image by finding the complement of the yellow binary image and converting it into a binary image. Furthermore, a 3 channel image is created from the mask and displayed as the bright yellow colours extracted (figure 30).

# APPLICATIONS OF COLOUR DETECTION

## Humans

### How Colours Evoke Emotion in Humans

Colours are never seen in isolation, but always observed together with other colours. It is therefore incorrect to apply a single colour scheme to identify the emotion evoked by colour images.

For instance, the colour “red” may have several meanings, such as danger, love, aggressive, powerful, important, dynamic and mellow, depending on what colour it is combined with and the context in which it is being viewed. Therefore, colour combinations are always preferred over single colours to evoke specific emotions. The same effect can be achieved through the use of different shades of the same colour. Colours are used to manipulate humans and their thought process as well as catch their attention. Shades of red are associated with heighted awareness as it increases blood circulation, metabolism and breathing rates (6). Green can however be associated with the environment and outdoors suggesting nature and organic quality. It represents balance and stability which is why it can be linked to money and financial safety. Surgeons first made use of “spinach-leaf green” to their clothing (scrubs) design in 1914 to decrease the effects of glare from regular hospital whites. Since green is associated with nature, growth and recovery which was ideal for a hospital setting where colour is needed for its ability to heal and comfort, it was used by decorators to affect the mood of the patients in the 1930’s (7).

Since the colour blue is associated with trust, it is extremely popular in web designing. It provides the user with a sense of calmness and serenity which inspires a feeling of safety which is necessary on networking platforms. Many banks have opted to take the same approach to evoke a feeling of trust and it can further we linked to Facebook and Twitter taking the same approach to ensure that their users feel safe. Since blue is such a versatile colour, it is generally the link between a fresh and free feeling because of its association with water and the sky (7).

### The effect of colour on the perception of taste, quality and preference of fruit flavoured drinks

A study was conducted on twenty-four (24) psychology students from Covenant University to determine how colour affected the perception of quality, taste and preference of fruit flavoured drinks. The independent variable was the colour of the fruit drink while dependent variables such as taste, quality and liking perception were measured. Six different research hypotheses were stated and tested.

Based on gender (t =. 29, p>0.05), there was zero significant difference in the association of colour with taste (8). The experiment proved that colour has a significant effect on taste and quality perception (t=2.10, p<0.05) and (t=3.0, p<0.05) respectively meaning that people associated colour and taste together so when that is mixed up, it alters their premediated perception of what to expect.

The experiment observed the relationship between colour along with three dependent variables. This resulted in a negative relationship between taste perception and colour as well as liking perception and colour. A positive but not significant relationship was noted between colour and quality perception. Quality and liking perception showed a significant positive relationship which was expected since quality contributes greatly towards likability.

It was concluded that colour has a huge effect on quality perceptions and taste, however the result were inconclusive with regards to the effect of colour on how much participants liked the drink (8). The study then recommended that food designers make the colour of food products a top priority as it would have an effect on consumers' decision making and buying behaviour. People associate certain colours with certain tastes and can often be dissuaded from making a purchase simply because the two do not align.

### How Colours Affect Store Purchases

Colours have the ability to draw both consumer’s attentions and possess image visualization potential in store designing and layouts. All consumers have their personal colour preferences yet they gravitate towards warm colours like yellow and red. Warm colours such as yellow or red are better choices than cooler colours like green or blue used to physically draw the consumers to display areas in a retail store. Appropriate colours where consumers tend to deliberate over purchase decisions are cooler colours. Warmer colours in situations where deliberation is common results in premature termination of shopping (9).

Using the colour red during sales at stores attracts the attention of customers almost immediately and increases the probability of them making a purchase in comparison to if the product was not tagged with a red tag. Customers are more likely to make the purchase simply because the item has a reduced red tag on it.

Restaurants use colourful images of their items on their menu to persuade customers to order those items since the image was able to create a visualization of what they are ordering. This method is very effect when considering children. This tactic has several applications of manipulation to boost sales in all aspects of marketing. It’s an effective strategy when used correctly.

Impulse shoppers tend to gravitate towards the colours red, orange, black and royal blue. These type of shoppers will make unnecessary purchases simply because the observation of a colour has ignited a certain emotion within them to justify their need for the product.

Budget shoppers tend to be associated more with navy blue and teal. This is a reflection of the trust factor inflicted by the colour blue. 84.7% of consumers state colour as their primary reason they purchase a specific product. 93% look at the visual appearance while 6% consider texture and the other 1% make their choice based off of smell or sound. Researchers have found that people make sub-conscious judgements about products within 90% of initially seeing it. 62%-90% of that assessment is purely based on colour only (9).

### How Cameras Work

Camera lenses collect and focus light. Previously, photographers possessed chemist skills which allowed them to produce film which is made up of light sensitive materials. When light from the lens hits these materials, they capture the shape of the object and details similar to how much light is coming off of them. The film that is exposed to the light is again put through a series of chemical baths to create the image when working in a dark room (10).

Digital cameras operate a little differently. Although the techniques, lenses and terms are the same, the sensor of a digital cameras is more similar to a solar panel than a strip of film. Each and every sensor is divided up into millions of red, green and blue pixels known as megapixels. When light strikes each pixel, the sensor then converts it into energy which a built-in computer reads how much energy is being produced.

The sensor is able to determine which areas of the image are light and dark by measuring how much energy each pixel has. To approximate the colours in the scene, the cameras computer checks at what other nearby pixels registered since each pixel has a color value. The information from all the pixels is compiled and the computer is able to estimate the shapes and colours in the scene.

Camera sensors with more megapixels are able to capture more detail since each pixel is collecting light information. The higher the megapixels, the higher and better the quality of the captured image. Larger sensors are able to gather more light which makes them better performers in scenes with low light.

### X-ray Machines

X-rays possess shorter wavelengths (higher energy) than UV waves which have longer wavelengths (lower energy) than gamma rays. X-rays are known as ionizing radiation and since they have higher energy and are therefore able to harm living tissue. Radiation sickness is caused by a very high radiation dosage over a short amount of time, whereas lower doses can give you an increased risk of radiation-induced cancer (11).

X-rays are able to pass through nonmetallic objects such as human tissues and organs. X-ray machines are similar to a huge cameras which allows doctors to view what is happening internally in a patient without having to perform surgery (11).

It took years before scientists made x-rays safe for medical use. An anode in an x-ray tube interacts with the stream of electromagnetic radiation (ER) produced by the machine. These x-rays are then directed toward the part of the body which needs to be examined. To reduce the effects of radiation exposure, x-ray machines aim the x-rays at only at the area being examined (12).

Lower doses of X-ray radiation have scientifically been proven to be very effectively used in medical radiography and X-ray spectroscopy. In the medical field of radiography, the benefits of using X-rays for examination far outweighs the risk.

X-rays produce a gray-scale image on a metal film when they come into contact with our body tissue. Soft tissue, such as skin and our organs cannot absorb the high-energy rays therefore the beam passes through them however denser materials such as our bones absorb the radiation and account for the white areas in the image that is produced (x-ray). Calcium in our bones are responsible for the higher amount of radiation which is absorbed (12). Darker areas in x-rays account for tissue and fluid. Being able to identify a bone structure without having to perform a surgery to find the root cause of a problem has massively assisted the growing medical field. This is only possible thanks to the application of radiation and colour detection.

### Infrared Technology

The use of infrared technology has allowed us to visualize the difference in heat energy emitted by objects. An example of this is a weather map or military usage to detect whether people are in a building. Thermography uses cameras to identify infrared radiation released by objects purely based on their temperature which in turn produces an image called a thermogram as seen in figure 31 (Fries-Gaither, 2009). To understand figure 31, we consider the scale beside the image which indicates that the brighter colours (red, orange and yellow) represent warmer temperatures because more heat and infrared radiation is emitted whereas the darker shades such as purple and dark blue/black represent cooler temperatures which is a sign of less heat and infrared radiation being released. This images shows an area with a bright yellow/orange area which indicates and electrical fault.

When we look at figure 32 which shows a thermogram of a lion, we can see that heat is being released from most of the animal excluding its mane. The most heat is released from the eyes, ears and belly of the lion since those areas showcase shades of red, orange and yellow. In contrast to the lion, figure 33 shows a thermogram of a polar bear that has extremely thick fur which acts as an excellent insulator and accounts for the purple shades in the thermogram. This is an indication that the body of the polar bear is well insulated because less heat is being emitted. The only area with shades of red, orange and yellow are the eyes and mouth of the polar bear since those areas release more heat than the rest of it body. (Fries-Gaither, 2009) This is an excellent example of how colour detection is applied in the real-world. The same concept can be used during natural disasters to locate missing persons through heat and colour detection in infrared technology.

### Night Vision Technology

Night vision functions in one of 2 ways: thermal imaging or image enhancement. Thermal imaging is a form of technology used to capture the higher part of the infrared light spectrum which is emitted as heat by objects instead of only being reflected as light. Warmer objects emit more infrared light than cooler objects. Image enhancement includes collecting tiny amounts of light mainly from the lower portion of the infrared light spectrum that is present, and then amplifying enough so that we are able to easily observe the image (12).

Infrared light occupies only a small portion of the light spectrum as observed in figure 34. Wavelength refers to the amount of energy in a light wave meaning that shorter wavelengths have higher energies. When referring to visible light, red has the least energy and violet has the most energy. Infrared light can further be split into 3 categories: Thermal-infrared (thermal-IR), Mid-infrared (mid-IR) and Near-infrared (near-IR). Thermal-IR is emitted by an object instead of being reflected off it unlike the other 2 types. Infrared light is emitted by an object because of the level of activity at the atom level (12).

The string of figures above show how easily it is to see during the day, however at night it becomes harder since there is less light available. Thermal imaging technology allows us to see better at night by creating clearer images of different shades of black, white and grey.

## Nature and Animals

### How Animals Perceive Colour

Like humans, the eyes are used to capture the light while the optic nerve sends the light signal to the brain where it is processed into an image. Scientifically, humans see more colours than animals. However, some animals see colours that we cannot because these colours are out of our visible light spectrum range. Below is a list of animals and which colours they can see:

* Spider see ultraviolet and green
* Crayfish see blue and red
* Snakes see infrared and some other colours
* Birds can see between five and seven colours
* Cats and dogs see two colours, green and blue
* Rats see blue, green and ultraviolet
* Squirrels see yellow and blue
* Butterflies see ultraviolet
* Squids see blue only
* Apes, chimps, and monkeys can see the same as humans except South American monkeys which cannot see red very well.

Snakes who see in infrared do this by receiving the infrared wavelengths from the heat released by objects naturally. Snakes use pit organs on its head for thermal sensing (13).

According to the *Eyesight Opticians* website, the eyes are the most complexed part of an animal’s structure in nature. Below we will address the comparison between specific animals and humans in terms of vision:

#### Cat Vision VS Human Vision

The biggest difference between a human and a cat or any feline animal for that matter, is the retina. Humans have a high concentration of cone receptors and a low concentration of rod receptors, while the opposite is found with cats. Therefore, human beings see better during the day, yet they struggle to see at night and why felines see better at night. A cat sees colour in the same way a colour blind human would. Cats see tones and shades of green and blue but get confused with shades of red and pink. Reds would appear green, and purples would appear bluer.

#### Dog Vision VS Human Vision

Dogs have a similar vision to cats but have two different types of cone receptors in their retina. They often see shades of green and blue extremely well but confuse their reds and pinks too. Their reds would appear greener, and their shades of purple would appear bluer. Dogs are near sighted as well, even more so than human beings.

#### Horse Vision VS Human Vision

Horses see well with shades of green and blue but confuse their shades of red and pinks just like a dog or a cat would. They do however have a 350 degree of monocular vision. Horses have more rods in their retina than humans do. They have a low concentration of cones and a substantially high concentration of rods. Their vision is better or superior at night compared to a dog or a cat.

#### Eagle Vision VS Human Vision

The eagle has light detecting cone cells. Their lens can change shape just like a human. Their cornea can change shape as well allowing them to see far and near objects clearly. Eagles however see more colours than what a human does due to their superior range and clarity of their vision. Eagles can see ultraviolet light, but humans cannot. Using their ultraviolet light detecting vision, they can spot traces of urine left by prey from a great height.

#### Shark Vision VS Human Vision

Unlike humans, sharks’ eyes come in different sizes and shapes. Their eye structure is so similar to humans that sometimes their cornea is used in human cornea replacement surgery. Electric vibrations can be detected through their eyes. Sharks have a mirrored crystal behind their retina to see clearer in dark water. They see ten times better in clear water than humans.

#### Bug Vision VS Human Vision

Insects have several more eyes than humans do. Insects however cannot see too well because each compound eye has smaller eyes which have poor vision. Most insects can only differentiate between light and dark. They cannot see vivid colours the way that humans can. The only insect that can see more colours than humans is a bee.

### Reproduction in Animals as a Product of Colour Detection

Courtship behaviour is an action that occurs during the mating season of animals where they search for a mate by either displaying their dominance or by an act such as dancing, repetitive movements or sounds. Courtship in terms of colour detection involves an animal to manipulate their colour patch like covering it or to alter the environment in which they display their colour patch to catch the attention of a potential mate. Many colourful animals perform behavioural displays which is greatly affected by the environment such as the lighting conditions or the background colour against which the colour is presented.

Colourful traits increase the probability of a mate to spot some if not all their behavioural display. In nature, it is the males that are the most colourful to obtain a greater reproductive success when searching for a mate. Lizards do push-up alert displays to attract a mate. Golden-collared manikin birds clear leaf litter as a display to show off their colourful bodies. Red-winged blackbirds reveal their colourful epaulets during a social encounter with other birds. The appearance of the colour depends on the illumination and observation in terms of angles. This also affects how an animal behaves to show off those colours.

Broad tailed hummingbirds are the most popular examples of animals who use colouration displays to impress a potential mate. They possess iridescent colour patches located at the throat in males. This is highly angle dependent. The females in this case do not have it. Broad tailed hummingbirds which make use of a close courtship display known as the shuttle display. The shuttle display involves males repeatedly and rapidly flying back and forth in front of the female. They also erect their colourful ventral or frontal chest feathers to create a flatter and bigger surface. The males display their movements facing the sun to illuminate their colour match.

After an experiment was conducted by Two ways to display Male hummingbirds show different colour-display tactics based on sun orientation, the following conclusion can be drawn. The humming birds did not conduct their shuttle display in a specific manner whether it could be away or towards the sun. The experiment produced average results on this matter. The pattern in which they move during their display was uniform and special (14).

### Predator VS Prey

According to *Visual Illusions in Predator–prey Interactions,* birds find moving prey with special patterns harder to catch, while others are easier to catch. They also state that some colour patterns of prey can create visual illusions while moving. This makes it hard for predators to catch their prey while moving. The article was based on an experiment using wild great tits as a natural prey and artificial prey having one or all these three colours’ patterns: uniform brown, black with white elongated yellow patterns, and black with interrupted yellow patterns. The black with white elongated yellow patterns as well as the black with interrupted yellow patterned colour properties were taken to resemble that of a dart-poison frog.

The aim of the experiment was to test whether visual illusions can be created with colour patterns when moving in a straight line. There are no differences in the number of successful attacks towards the prey with different elongated colour patterns moving in a straight line. However, they did discover that the colour patterned prey were more difficult to catch than the uniformly brown coloured prey.

In nature, the purpose of colouration is to avoid predators. Aposematic prey show warnings of toxicity through their colouration. They are usually brightly coloured animals. Camouflage makes use of colouration to make them hard to detect or to be recognized by predators. These forms of colouration reduce their chance of being attacked. Some colour patterns are used to slow down prey while they are in motion creating visual illusions to alter the perception of the predator. This is called motion dazzle. This makes use of markings including bars, stripes, and zig zag patterns. There is a correlation between the colour pattern of an animal and the type of movement of the animal or the manner in which they escape.

Uniformly colours and striped patterned snakes rely on fleeing to avoid predators. This generates an illusion of immobility, because the patterns do not have a reference point to allow the predator to detect any forward movement. Spotted snakes avoid detection of predations by relying on disruptive elements of colouration. They rely on direct flight as well as change in direction while fleeing. Overall, the results were that the predator birds were able to attack and capture the artificial prey of uniform brown colour with a success rate of 75%, while the black with white elongated yellow patterns and the black with interrupted yellow patterns had a success rate of being attacked at around 60 to 65%. Another thing they realized was that in nature, animals with zig zag or more elaborate patterns tend to move slower than those of uniform colour due to the difficulty of spotting the beginning of the animal when in a herd, or when moving causing the motion dazzle (15).

### How genetic modification and evolution over the years has allowed prey to adapt and blend into their surroundings (camouflage)

Some species of animals have evolved in terms of camouflage while others can only do brief acts of camouflage taking longer to occur or not at all. There are four main types of camouflage: disruptive coloration, concealing coloration, mimicry and disguise). There are also two processes that determine how colour change evolves and they are natural selection and sexual selection. Natural selection involves the evolution of camouflage, while sexual selection involves the evolution of signaling functions in terms of communication, thermoregulation and camouflage. The animal with the greatest capability to change colour according to the first process should have:

* show a broader range of patterns found on the body
* occupy habitats where predators roam
* roam areas where predators are found with great range of sensitivities visually
* occupy habitats where with backgrounds vary greatly compared to the movement patterns of the animal.

Species showing the greatest colour change predicted according to the second process should have:

* more elaborate and social signaling
* more intense sexual selection (high reproductive success)
* signals that are less recognizable and understandable by conspecific receivers.

Chameleons on the other hand have the greatest capacity to change colour have social signals that are more conspicuous, but do not occupy greater variance in background colour.

Evolution driven by selection for sexual signaling is evident in the colour change in fish are excluding the flatfish. In amphibians colour change is slow and is mostly for background matching and thermoregulation (14).

### Aposematism

Aposematism is the phenomena animals use to flaunt their brightly coloured bodies as warnings signaling toxicity. According to Survival by Aposematism and Mimicry, “The Evolution of Bright Colour Patterns, a predator would not attack a potentially dangerous prey that would harbour toxins or special defenses. Harsh odours and loud sounds among those warning signals including brightly coloured body parts. Many toxic substances in nature tastes bitter, which would be distasteful to predators as well” (16).

According to the *American Museum of Natural History*, there are many coloured animals that indicate toxicity, all of which should not be physically touched. Aposematism consists of colours yellow, red, orange, black and white. Examples thereof are:

* Golden Poison Frogs are highly toxic. They are yellow in colour. They should not be touched. They are the most poisonous animal on the planet. They secret the toxins from their skin to avoid being eaten.
* Gila Monsters are orange in colour with black scales. They have a venomous bite.
* Zebra Lionfish have stripes and toxic spines. They usually have bold patterns and colours (17).

### How Chameleons Change Colour Based on their Environment

According to *Camouflage, communication, and thermoregulation: lessons from colour changing organisms*, there are two types of colour change that have different consequences for adaptive camouflage. The first is morphological change occurring due to the changes in the quality and number pigment-containing cells during the duration of days or months. The second is the physiological colour change occurring due to the movement of pigment granules within chromophores. This occurs rapidly for the duration a few milliseconds to hours. The second is usually a camouflage response to different backgrounds as well as different predators. Chameleons are one of these animals.

The bullet-head parrotfish exploit different camouflage including disruptive camouflage or motion dazzle as mentioned under heading 3. Predator vs Prey, deflecting attention towards its tail, intimidation of predators and background matching. It is proven that texture, size, edges, contrast and configuration of background objects has influence over the type of camouflage pattern used by the animal under the circumstances.

The octopus is one animal that can mimic the movement and behaviour of venomous animals to have a different guise in response to different types of predators. Chameleons use background matching instead of mimicry or warning signals. Colour changing animals may adapt specific stripes or patterns when background matching is ineffective. Chameleons make use of motion camouflage which involves the slow jerky walk resembling the movement of the vegetation which also benefits them with the combination of their green colour resemblance as well. Coloration can also signal toxicity of an animal (18).

# CONCLUSION AND RECOMMENDATIONS

There are many applications for colour detection. We decided to focus on the practical aspect of extracting specific colours from an image. The easiest colours to extract are red, green and yellow. The most difficult colours to extract is purple. This is because purple is a combination of blue and red. Two extreme ranges of pixel values.

The Matlab model works very well and it quite accurate in extracting specific colours from an image. However, when we tried extracting the colour purple from the image, the extracted output contained all the colours within the image. A possible reason for this could be because purple is a combination of red and blue. This a problem, because blue has such low ranges of pixel values while red contains the highest ranges of pixel values so essentially, the model chooses all the pixel values between blue and red which is all the pixel values contained in a colour image.

We have not managed to detect colour in real time. Colour detection or extraction can only be done from existing images that are loaded into our models. As a further improvement of our project, we would like to extract all the colours within the visible spectrum and not only the preloaded dataset contained in the csv file. This problem can only be solved by implementing the Python model. There have been two limitations with the python model, namely the fact that images need to be sized correctly before loading the image as it can often be too large or too small to function effectively. The second flaw is that once the mouse is double-clicked anywhere on the image, the rectangular block pops up with the colours name and hex value which covers a small portion of the image. The area beneath the rectangular block is concealed therefore the user cannot identify any colours below it.

There are several practical applications of colour detection in the real world, whether it’s amongst humans or amongst animals and nature. Colour has the ability to evoke emotion, affect purchases in stores, affect mood and alter how one perceives food based on colour. One of the most effective uses of colour is in marketing. Further advancements include the application of colour detection in technology such as x-ray machines, night vision goggles and infrared technology. Furthermore, colour detection is pivotal in nature as it greatly impacts the predator vs prey cycle as well as reproduction within certain species. Understanding how animal’s anatomy differs from human’s anatomy gives us insight into how they perceive colours. Observing how animals such as chameleons and octopuses naturally change colours contributes to their survival in nature.

##### References

1. Praveen. Color Detection using OpenCV Python [Internet]. 2020 [cited 2021 Jun 24]. Available from: https://medium.com/programming-fever/color-detection-using-opencv-python-6eec8dcde8c7

2. Davson H. human eye | Definition, Structure, & Function | Britannica [Internet]. 2007 [cited 2021 Jun 18]. Available from: https://www.britannica.com/science/human-eye

3. Chudler EH. Neuroscience For Kids - Retina [Internet]. 2017 [cited 2021 Jun 18]. Available from: https://faculty.washington.edu/chudler/retina.html

4. Matthews JA. electromagnetic spectrum. In: Encyclopedia of Environmental Change [Internet]. 2014 [cited 2021 Jun 21]. Available from: https://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html

5. Lucas J. What Is Visible Light? | Live Science [Internet]. Live Science. 2015 [cited 2021 Jun 21]. Available from: https://www.livescience.com/50678-visible-light.html

6. Cao J. 12 colours and the emotions they evoke [Internet]. creativebloq.com. 2018 [cited 2021 Jun 21]. Available from: https://www.creativebloq.com/web-design/12-colours-and-emotions-they-evoke-61515112

7. Babin S. Color Theory: The Effects of Color in Medical Environments. Color Theory Eff Color Med Environ [Internet]. 2013; Available from: https://aquila.usm.edu/honors\_theses/115

8. Ndom R, Elegbeleye A, Ademoroti A. The effect of colour on the perception of taste, quality and preference of fruit flavoured drinks. Vol. 19, IFE PsychologIA. 2011.

9. Kaushik R. Impact of colours in marketing . IJCEM Int J Comput Eng Manag [Internet]. 2011;13(July):2230–7893. Available from: www.IJCEM.orgIJCEMwww.ijcem.org

10. CreativeLive. How does a camera work? [Internet]. The ultimate guide to learning photography. [cited 2021 Jun 22]. Available from: https://www.creativelive.com/photography-guides/how-does-a-camera-work

11. LumenCandela. The Electromagnetic Spectrum | Boundless Physics [Internet]. 2017. 2017 [cited 2021 Jun 22]. Available from: https://courses.lumenlearning.com/boundless-physics/chapter/the-electromagnetic-spectrum/

12. How Does an X-Ray Work? | Wonderopolis [Internet]. [cited 2021 Jun 22]. Available from: https://www.wonderopolis.org/wonder/how-does-an-x-ray-work

13. CJ Kazilek KC. Colors Animals See | Ask A Biologist [Internet]. Arizona State University School of Life Sciences Ask A Biologist. 2011 [cited 2021 Jun 18]. Available from: https://askabiologist.asu.edu/colors-animals-see

14. Simpson RK, McGraw KJ. Two ways to display: Male hummingbirds show different color-display tactics based on sun orientation. Behav Ecol. 2018;29(3):637–48.

15. Hämäläinen L, Valkonen J, Mappes J, Rojas B. Visual illusions in predator–prey interactions: birds find moving patterned prey harder to catch. Anim Cogn. 2015;18(5):1059–68.

16. Winsor A. Survival by Aposematism and Mimicry: The Evolution of Bright Color Patterns [Internet]. EARTH’S ORGANISMS. 2019 [cited 2021 Jun 24]. Available from: http://thatslifesci.com/2019-10-21-aposematism-mimicry-color-awinsor/

17. History AM of N. Warning Colors in the Animal World [Internet]. 2014 [cited 2021 Jun 24]. Available from: https://www.amnh.org/explore/news-blogs/on-exhibit-posts/animal-colors-warning

18. Stuart-Fox D, Moussalli A. Camouflage, communication and thermoregulation: Lessons from colour changing organisms. Philos Trans R Soc B Biol Sci. 2009;364(1516):463–70.