Detection and Extraction of Colours in Digital Images and Computer Vision

Ibidun Christiana Obagbuwa (orcid.org/0000-0002-7965-2823), Kerrin Klaaste, Atwell Jocelyn Jasmin
Department of Computer Science and Information Technology
Sol Plaatje University, Kimberley, South Africa
Ibidun.obagbuwa@spu.ac.za, 201727404@spu.ac.za, 201800014@spu.ac.za
Correspondence should be addressed to Ibidun Christiana Obagbuwa; ibidun.obagbuwa@spu.ac.za

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Abstract— **Colour detection plays a pivotal role in our daily lives. This study explains how colour is perceived by the rods and cones in human and animal eyes and transferred to the brain to create images. There are different applications of colour detection, and one of the most effective uses of colour is marketing. Colour can evoke emotion, affect purchases in stores, affect mood, and alter how one perceives food based on colour. Further advancements include the applications of colour detection in technology such as x-ray machines, night vision goggles, and infrared technology. In this work, two models were presented: a MATLAB model which extracts specific colours from an image using the pixel values. The second model is a python model that allows the user to identify a colour in any image and correctly predict the name of that colour along with its hex values. We concluded that the easiest colours to extract are red, green, and yellow. The most challenging colour to extract is purple.**

Keywords— Colour detection, colour extraction, digital image processing, MATLAB, Python, computer vision, human vision, animal vision, electromagnetic spectrum.

I. INTRODUCTION

According to the *Medium* website [1], 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, transmit these signals to our brains. The brain is the organ that recognizes colour. Colour detection can be relevant for humans and animals alike. However, some animals can see more colours than we do from other spectrums, while others only see a few [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, which is this work's aim. We decided on two models for this colour detection project. The first is 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 that allows 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. In nature, colour detection is used by animals to spot their Prey, such as snakes or eagles use ultraviolet detection to spot a prey's heat signature. Animals also use it to discern whether the Prey is poisonous or not. Humans use colour detection to find their 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 unable to, and heat signature detectors used by the fire brigade during fire emergencies.

The rest of the paper proceeds: Section II presents the background. Section III presents the applications of colour detection. Section IV explains the design and methodology. Section V describes the experiments, results, and discussion. Finally, Section VI concludes the paper with a summary of the main points and outcomes with a recommendation.

II. BACKGROUND

A. The Human Eye

The human eye is a unique sensory organ that can receive and process visual images by adjusting to light and sending signals to the brain. The eyeball is protected from mechanical injury by being surrounded by the bone that makes up the eye socket. It also has an apex that points backward into the head [2]. It houses the optic foramen, an entrance through which the optic nerve runs back into the brain alongside the ophthalmic artery. The eyelid protects the eyeball's front surface, known as the cornea [2].

The eye is composed of several parts that all work together to create an image. As observed in Figure 1, the

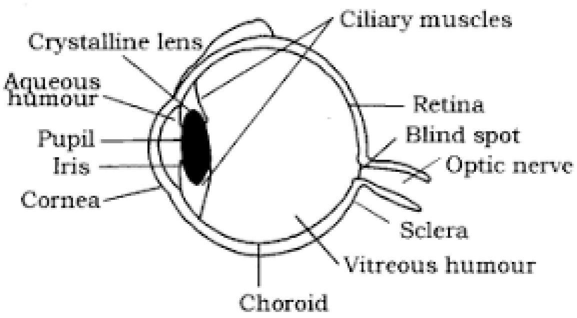


Figure 1: The human eye (https://www.learncbse.in/human-eye-and-colourful-world-cbse-notes-for-class-10-science/)

The sclera is the white part of the eye that protects the eyeball, while the transparent portion is called the cornea. Beneath the cornea is a ring called the iris, which determines eye color [2]. The center of the ring contains the pupil. Because light that passes into the eye is not reflected out, it appears black. The eye consists of 3 coats surrounding the optically clear aqueous humour, lens, and vitreous body. The cornea and sclera are contained in the outer coat, while the middle coat accommodates the main blood supply to the eye, ciliary body, 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].

Figure 2: How the eye sees the light (Erion Cuko)

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 focuses light onto the retina at the back of the eye.

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

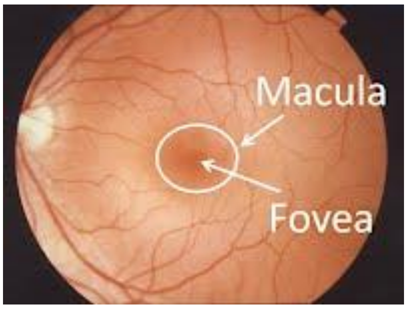


Figure 3: The fovea in the macula of the retina (https://sites.google.com/site/crvoquickstart/macular-edema)

Cones are not as sensitive to light as rods but are most sensitive to at least one of the three coloured (red, green, blue). Signals are passed from the cones to the brain, which converts messages to be perceived as colours. Cones only work in bright light settings; therefore, they cannot see colour as well when in a dark room. Cones are used to define image detailing. The human eye contains roughly 6 million cones in the retina. Being colour-blind means that the eye does not contain a specific type of cone, or the cones may be weaker [3]. The retina's center 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 does not contain any photoreceptors. Images that fall in this region will not be seen. It is here where all the optic nerves come together and connect to the brain [3]. The eye is 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.

B. The Light Spectrum and Visible Light

The human eye transmits signals to the brain via the optic nerve, which then translates them into 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.

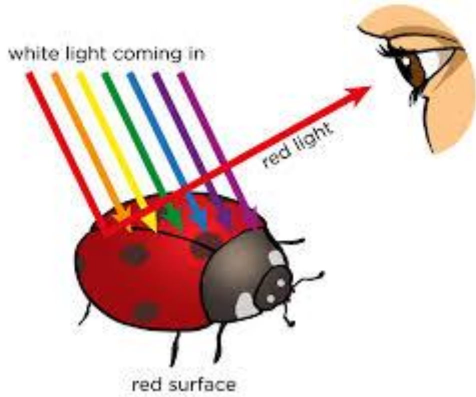


Figure 4: How light waves are reflected from surfaces (https://intl.siyavula.com/read/science/grade-8/visible-light/12-visible-light?id=toc-id-6)

We then observe the reflected colours. To understand this better, when looking at a red wall, as in Figure 4, we see the colour red only because the wall reflects red wavelengths 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

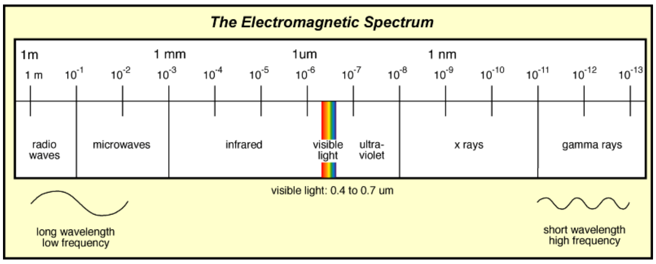


Figure 5: Electromagnetic spectrum (http://www.columbia.edu/~vjd1/electromag_spectrum.htm)

of all types of EM radiation. Radiation can be defined as the energy emitted from a source that travels through space and can 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 5 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 crucial focus concerning 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.

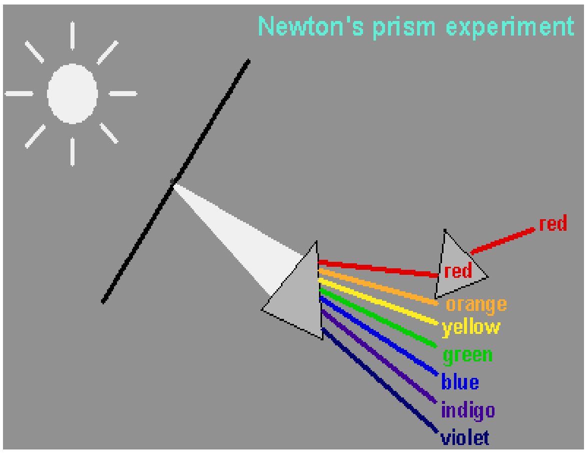


Figure 6: Light prism as observed by Newton (http://web.mit.edu/bcs/schillerlab/research/A-Vision/A10-1.html)

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 middle of the spectrum accounts for the upper-end houses' lengths of 380nm as is seen as violet. All other colours 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 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 transparent wall, as seen in Figure 6.

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

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

III. APPLICATIONS OF COLOUR DETECTION

A. Humans

1) How Colours Evoke Emotion in Humans

Colours are never seen in isolation but are always observed together with other colours. Therefore, applying a single colour scheme to identify the emotion evoked by colour images needs to be corrected.

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 using different shades of the same colour. Colours manipulate humans and their thought processes and catch their attention. The red shade is associated with heightened 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 used "spinach-leaf green" in 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, ideal for a hospital setting where color is needed for its ability to heal and comfort. Decorators used it to affect the mood of patients in the 1930s [7].

Since the colour blue is associated with trust, it is prevalent in web design. It provides the user with a sense of calmness and serenity, which inspires a feeling of safety necessary on networking platforms. Many banks have opted to take the same approach to evoke a feeling of trust, which can further be linked to Facebook and Twitter taking the same approach to ensure 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].

2) The effect of colour on the perception of taste, quality, and preference of fruit-flavored 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 for fruit-flavored drinks [8]. 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 associate 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 and 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 significantly toward likability.

It was concluded that colour has a significant effect on quality perceptions and taste, however, the result could have been more conclusive about 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 influence consumers' decision-making and buying behaviour. People associate specific colours with particular tastes and can often be dissuaded from purchasing simply because the two do not align.

3) *How Colours Affect Store Purchases*

Colours could draw consumers' attention 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 typically results in premature termination of shopping [9].

Using red during sales at stores attracts customers' attention almost immediately. It increases their probability of purchasing compared to if the product was not tagged with a red tag. Customers are more likely to purchase simply because the item has a reduced red tag.

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

Impulse shoppers tend to gravitate toward the colours red, orange, black, and royal blue. These types of shoppers will make unnecessary purchases simply because the observation of colour has ignited a particular 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 the primary reason they purchase a specific product. 93% look at the visual appearance, 6% consider the texture, and the other 1% choose based on smell or sound. Researchers have found that people make subconscious judgments about products within 90% of initially seeing them. 62%-90% of that assessment is purely based on colour only [9].

4) *How Cameras Work*

Camera lenses collect and focus light. Previously, photographers possessed chemist skills that allowed them to produce a film that 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 from them. The film 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 digital cameras is more like a solar panel than a strip of film. Every sensor is divided into millions of red, green, and blue pixels, known as megapixels. When light strikes each pixel, the sensor converts it into energy which a built-in computer reads how much energy is being produced.

The sensor can 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 camera's computer checks what other nearby pixels are registered since each pixel has a color value. The information from all the pixels is compiled, and the computer can estimate the shapes and colours in the scene.

Camera sensors with more megapixels can capture more detail since each pixel collects light information. The higher the megapixels, the higher and better the quality of the captured image. Larger sensors can gather more light, making them better performers in scenes with low light.

5) *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 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 time, whereas lower doses can increase the risk of radiation-induced cancer [11].

X-rays can pass through nonmetallic objects such as human tissues and organs. X-ray machines are like huge cameras allowing doctors to view what is happening internally in a patient without having surgery [11].

It took years before scientists made x-rays safe for medical use. An anode is an x-ray tube that 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 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 like skin and organs cannot absorb 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 is responsible for the higher amount of radiation absorbed [12]. Darker areas in x-rays account for tissue and fluid. Their ability to identify a bone structure without having to perform 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.

6) *Infrared Technology*

Infrared technology has allowed us to visualize the difference in heat energy emitted by objects. An example 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, producing an image called a thermogram, as seen in Figure 7 (Fries-Gaither, 2009). To understand Figure 7, 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 are emitted. In contrast, the darker shades, such as purple and dark blue/black, represent cooler temperatures, which shows less heat and infrared radiation being released. This image shows an area with a bright yellow/orange area which indicates an electrical fault.

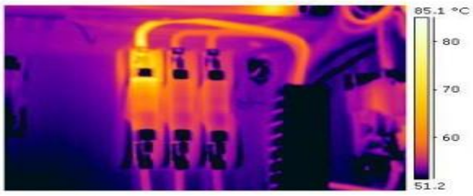


Figure 7: Thermogram of an electric fuse block [23]

Figure 8: Thermogram of a lion [23]

Figure 9: Thermogram of polar bear [23]

When we look at Figure 8, 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 lion's eyes, ears, and belly since those areas showcase shades of red, orange, and yellow. In contrast to the lion, Figure 9 shows a polar bear thermogram with exceptionally thick fur, which acts as an excellent insulator and accounts for the purple shades in the thermogram. This indicates that the polar bear's body 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 its body. 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 [23].

7) *Night Vision Technology*

Night vision functions in one of 2 ways: thermal imaging or image enhancement. Thermal imaging is a technology that captures 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

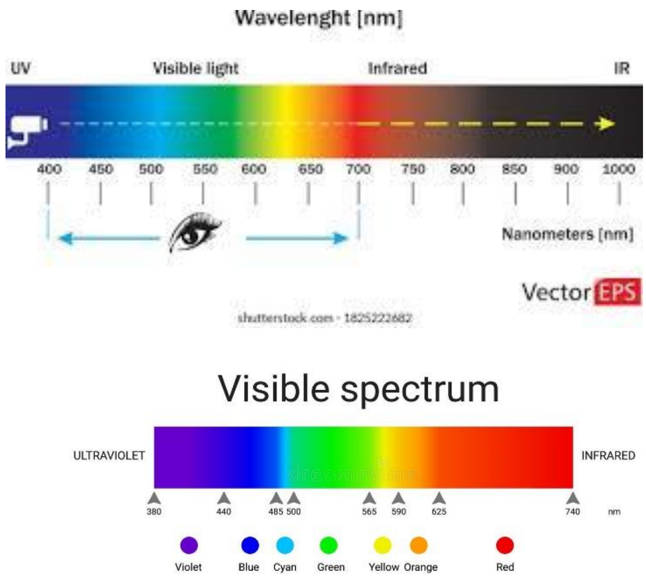


Figure 10: Visible Spectrum (https://www.dreamstime.com/illustration/electromagnetic-spectrum-sun.html)

amplifying enough so that we can easily observe the image [12]. Infrared light occupies only a small portion of the light spectrum as observed in Figure 10. Wavelength refers to the amount of energy in a light wave meaning that shorter wavelengths have higher energies. Red has the least energy when referring to visible light, and violet has the most energy. Infrared light can further be split into three categories: Thermal-infrared (thermal-IR), Mid-infrared (mid-IR), and Near-infrared (near-IR). Thermal-IR is emitted by an object instead of reflected off it, unlike the other two types. An object emits infrared light because of the level of activity at the atom level [12].

a *b* *c*

Figure 11: (a) Vision during the day; (b) Vision at night; (c) Vision using thermal imaging technology

The string of Figure 11a-c shows how easy it is to see during the day; however, it becomes more complex at night since there is less light available. Thermal imaging technology allows us to see better at night by creating more explicit images of black, white, and grey shades.

B. *Nature and Animals*

1) *How Animals Perceive Colour*

Like humans, the eyes capture the light while the optic nerve sends the light signal to the brain, which is processed into an image (Figure 12). Scientifically, humans see more colours than animals [13]. 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:

- Spiders 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 for South American monkeys, which cannot see red very well.

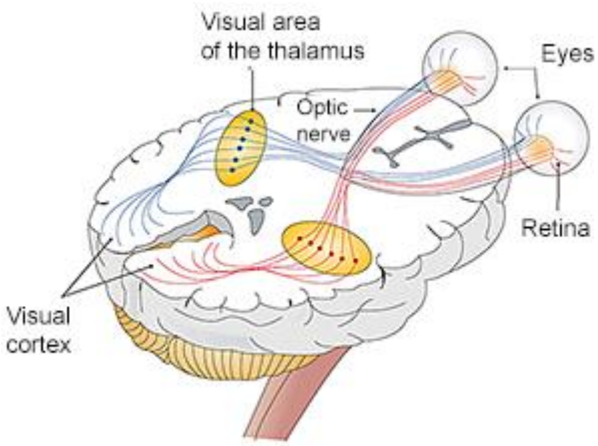


Figure 12: The animal eye [13]

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].
The eyes are the most complex part of an animal's structure in nature [20]. Below we will address the comparison between specific animals and humans in terms of vision:

a) Cat Vision Vs. Human Vision

The most significant 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 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 need clarification with shades of red and pink. Reds would appear green, and purples would appear bluer [20].

b) 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 also nearsighted, even more so than humans [19,20].

c) Horse Vision VS Human Vision

Horses see well with shades of green and blue but confuse their shades of red and pink just like a dog or a cat would. They do, however, have 350 degrees 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 than a dog's or a cat's [20].

d) 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, allowing them to see far and near objects. Eagles, however, see more colours than humans 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 [20].

e) Shark Vision VS Human Vision

Unlike humans, sharks' eyes come in different sizes and shapes. Their eye structure is so like 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 [20].

f) Bug Vision VS Human Vision

Insects have several more eyes than humans do. Insects, however, cannot see well because each compound eye has smaller eyes with poor vision. Most insects can only differentiate between light and dark. They cannot see vivid colours the way that humans can. The bee is the only insect that can see more colours than humans [20].

2) Reproduction in Animals as a Product of Colour Detection

Courtship behavior 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 colour detection involves an animal manipulating its colour patch by covering it or altering the environment in which they display its colour patch to catch the attention of a potential mate. Many colourful animals perform behavioural displays which are greatly affected by the environment, such as the lighting conditions or the background colour against which the colour is presented [21].
Colourful traits increase the probability of a mate spotting some, if not all, of their behavioural display. In nature, males are the most colourful to obtain tremendous reproductive success when searching for a mate. Lizards do push-up alert displays to attract a mate [22]. 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 [21,22]. 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 [21].

Broad-tailed hummingbirds are the most famous examples of animals that use colouration displays to impress a potential mate (Figure 13). 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 use a close courtship display known as the shuttle display.

Figure 13: Hummingbird's colouration 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 [14].

After an experiment was conducted by two ways to display Male hummingbirds showing different colour-display tactics based on sun orientation, the following conclusion can be drawn. The hummingbirds did not conduct their shuttle display in a specific manner, whether away or towards the sun. The experiment produced average results on this matter. Their pattern during their display is uniform and special [14].

3) Predator VS Prey

According to *Visual Illusions in Predator-prey Interactions,* birds find moving Prey with unique 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 [15]. This makes it hard for predators to catch their Prey while moving. The article was based on an experiment using great wild tits as 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 and the black with interrupted yellow patterned colour properties were taken to resemble that of a dart-poison frog [15].

The experiment aimed 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 toward the Prey, with different elongated colour patterns moving in a straight line. However, they did discover that the colour-patterned Prey was more challenging to catch than the uniformly brown-coloured Prey.

In nature, the purpose of colouration is to avoid predators. Aposematic Prey shows warnings of toxicity through their colouration. They are usually brightly coloured animals. Camouflage uses 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 predator's perception. This is called motion dazzle. This uses markings, including bars, stripes, and zigzag patterns. There is a correlation between the colour pattern of an animal and the type of movement of the animal or how they escape.

Uniform 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 the detection of predation 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 could attack and capture the artificial Prey of uniform brown colour with a success rate of 75%. In comparison, 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 zigzag 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 to cause the motion dazzle [15].

4) How genetic modification and evolution over the years have allowed the 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). Two processes determine how colour change evolves: natural selection and sexual selection [14]. Natural selection involves the evolution of camouflage, while sexual selection involves the evolution of signaling functions in communication, thermoregulation, and camouflage. The animal with the most significant capability to change colour according to the first process should have the following:

- show a broader range of patterns found on the body
- occupy habitats where predators roam
- roam areas where predators are found with a great range of sensitivities visually
- occupy habitats where backgrounds vary significantly compared to the movement patterns of the animal. Species showing the most significant colour change predicted according to the second process should have:
- more elaborate and social signaling
- more intense sexual selection (high reproductive success)
- signals that need to be more recognizable and understandable by conspecific receivers.

On the other hand, Chameleons have the most extraordinary capacity to change colour and have social signals that are more conspicuous but do not occupy more significant variance in the background colour.

Evolution driven by selection for sexual signaling is evident in the colour change in fish, excluding the flatfish. In amphibians, the colour change is slow and is primarily for background matching and thermoregulation [14].

5) *Aposematism*

Aposematism is the phenomenon 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. Those warning signals include harsh odours and loud sounds, including brightly coloured body parts. Many toxic substances in nature taste bitter, which would be distasteful to predators as well" [16]
According to the *American Museum of Natural History*, many coloured animals 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. 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].

6) *How Chameleons Change Colour Based on Their Environment*

According to *camouflage, communication, and thermoregulation: lessons from colour-changing organisms*, two types of colour change have different consequences for adaptive camouflage [18]. The first is morphological change occurring due to the changes in the quality and number of pigment-containing cells during 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 of a few milliseconds to hours. The second is usually a camouflage response to different backgrounds and predators. Chameleons are one of these animals.

The bullet-head parrotfish exploit different camouflage, including disruptive camouflage of 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 influence the type of camouflage pattern the animal uses 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 use motion camouflage which involves a slow, jerky walk resembling the movement of the vegetation, which benefits them with the combination of their green colour resemblance. Coloration can also signal the toxicity of an animal [18].

Section IV presents colour detection using MATLAB and Python models

IV. DESIGN AND METHODOLOGY

A. *Python Model*

This model will allow the user to run the code from the command prompt window of Python. When the user doubles click 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). Colours are defined within a range of 0 to 255 when working with computers. This translates to 256*256*256 = 16 581 375 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 uses 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 panda DataFrame, where we assign each column a name. We used an interactive mouse; therefore, a mouse callback event was set on the window and 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 shows the mouse position coordinates on the screen. We must check if the event is double-clicked in the function, then the set RGB values and the mouse's x and y positions are calculated.
Since we obtained the RGB values above, we used another function to return the name of the colour using the RGB values. To retrieve the name, we calculate the distance (d), which can tell us how close we are to the colour, and choose the one with the minimum distance. Distance is calculated using the formula below:

$$distance = abs(Red - ithRedColour) + (Green - ithGreenColour) \\ + (Blue - ithBlueColour)$$

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 can 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.

B. *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 of this model is only to extract certain colours from a specific image and to test how accurate it is at isolating those specific colours. The user can choose the specific color 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 as the highest pixel value, approximately greater than 230. The user can also manipulate these limits or ranges to extract the exact colour from the image. Table 1 depicts the Matlab functions used in our model and their purpose.

TABLE 1: MATLAB FUNCTIONS USED IN OUR MODEL

No.	Function	Description
1	imread()	Load the image only in 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()	It is 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.

V. EXPERIMENTS, RESULTS, AND DISCUSSION

A. *Python Results and Discussion*

The python model could correctly detect every object on an image and specify its name.

We used an image with various fruits (Figure 14a). By double-clicking anywhere on the window, we can identify the colour name and RGB value, which are associated with one another and obtained from the loaded colors dataset. Figure 14b-e displays how the model works.

a

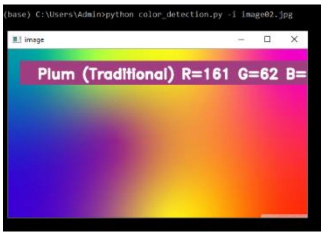
c

d

e

Figure 14: (a) Original Image with various fruits; (b) Crimson R=214 G=24 B=62; (c) Golden yellow R=253 G=221 B=0; (d) Farm Green R=61 G=113 B=65; (e) Lapis lazuli R=48 G=88 B=139

Figures 15 (a-d) display how the model works when a different image is read.



a

b

c

d

Figure 15: (a)Plum (Traditional); (b) Pastel Red; (c)Coral Red; (d)Blue Green

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 to improve visibility. The program is terminated when the user presses the escape key.
The model accuracy has been good, considering that only 826 colours and RGB values were preloaded. A larger dataset and an image with many hues and saturations containing various colours will improve the model's accuracy.

B. *Matlab Results and discussion*

a) *Part 1*

The original colour image was loaded into MATLAB and displayed (Figure 16a). The original image is then converted to grey (Figure 16b). We then create a red matrix from the original image and subtract the red from the image (Figure 16c). The output image (Figure 16d) 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 16e). This image is then converted into a binary image (Figure 16d).

b) *Part 2*

We convert the red subtracted image (Figure 17a) 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 the image contains orange and yellow in it as well. This is because the orange is a lighter shade of red, and the orange and yellow peppers contain traces of red in their tonal shadows (Figure 17b).

a

b

c

d

e

Figure 16: (a) Original image; (b)Grey image; (c) Red subtracted image; (d) Green binary image; (e) Green subtracted image

We then find the green matrix of the image and subtract the grey image from the green matrix of the original image (Figure 17c). The green subtracted image is converted into a binary image with a threshold of 0.01 (Figure 17d). Next, we create a mask for the green subtracted image by finding the complement of that image and converting it into a binary image, creating a 3-channel image displayed as the green objects extracted (Figure 17e). One may notice that this image contains yellow because yellow is adjacent to green and may share similar tonal colour features.
The next step would be subtracting 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 the green and red binary images and the red binary image without the green (Figure 17 f & g).

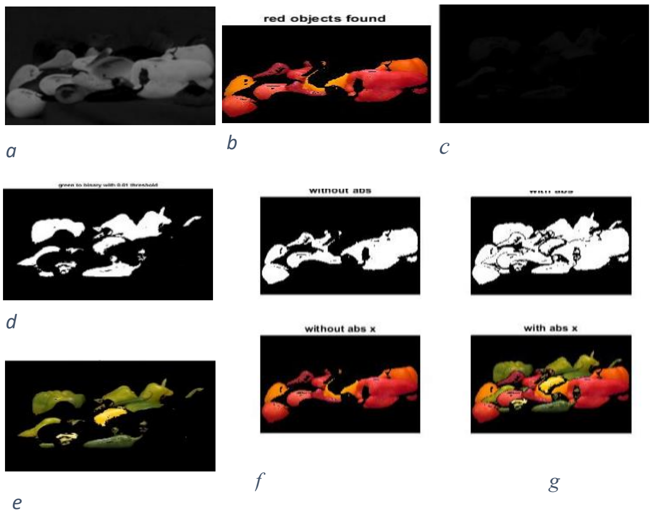


Figure 17: (a) Red subtracted image; (b)Red object subtracted;(c) green subtracted image; (d) green subtracted binary image; (e)Green object extracted; (f)Absolute red extracted image without green object extraction; (g) Absolute red extracted image with green object extraction.

*c) **Part 3***

This part of our project only focuses on extracting the red peppers, 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 18).

Figure 18: Red-only objects extracted

*d) **Part 4***

This portion of the code is run from the command window. First, we load the image we want to work on (Figure 19a). Then we choose pixel values from the image we want to extract. It could be pixels at random or pixels from a specific colour shade. After that, 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. For example, we extracted pixels from the yellow shade of the yellow pepper and displayed the image as a binary image below (Figure 19b). 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 are extracted (Figure 19c).

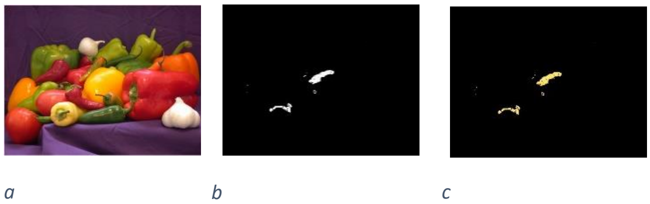


Figure 19: (a) original image; (b) Bright yellow extracted binary image; (c) Bright yellow extracted colour image

VI. 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 challenging colour 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 accurately extracts 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 that purple is a combination of red and blue. This is a problem because blue has such low ranges of pixel values. At the same time, red contains the highest range of pixel values, so essentially, the model chooses all the pixel values between blue and red, all the pixel values contained in a colour image.

Colour detection and extraction have been done from existing images loaded into our models. To further improve 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 could be solved by implementing the Python model. However, there have been two limitations with the python model: images need to be sized correctly before loading the image as they 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 colour's 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.

In the future extension of this work, colour detection will be done in real-time.

There are several practical applications of colour detection in the real world, whether amongst humans or animals and nature. Colour can 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 applying colour detection in technology such as x-ray machines, night vision goggles, and infrared technology. Furthermore, colour detection is pivotal as it dramatically impacts the predator vs. prey cycle and reproduction within certain species. Understanding how animals' anatomy differs from human 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.

DATA AVAILABILITY

The image data used for the work is available upon request from the corresponding author.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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