## Introduction

- The subject of my project is 3D colour histograms
- My presentation will be split into three sections:
- Firstly I will introduce my project, it's aims, and motivations
- I will then go on to give some background information on the subject
- Finally I will finish up by talking about the progress I have made so far with developing a prototype

# 1. Introducing My Project

### 1.1. Project Aims

- The question that I am trying to answer in my project is "What are the effects of colour alteration tools…", such as brightness, contrast, and saturation "on an image's histogram?" and "Are these effects useful as a visualisation tool in image editing?"

- In brief, 3D histograms are graphs that display the distribution of colours in an image
- In this example, the x, y, and z axes represent the red, green, and blue colour components
- This creates a cube containing all RGB colours
- Each pixel of an image is inspected and it's colour plotted in the histogram, the size of the plot proportionate to how many pixels there are of that colour

- If my histogram is successful, I will also explore the possibility of using it as tool of image editing, rather than just a visualisation
- For example, to make the woman's red dress in this image stand out one could increase it's saturation
- Rather than isolating the dress by tracing it's outline, one could use a histogram to select the red colours in the image and increase their saturation
- This approach would be quicker than selecting spatially and allow greater control over effects such as mood and temperature

### 1.2. Project Development

- While the idea for my project is language and platform independent, I intend to implement it as a web-based application
- This will make it more accessible to users and allow me to use WebGL and three.js, two JavaScript libraries for 3D renderings, which I have previous experience with

### 1.3. Project Motivation

- The inspiration for my project came during my summer internship at Sony where I worked on visualisations of colour space transformations

- While there I found a website that allowed one to view the histogram of a series of stock images
- What caught my attention were the five of these images, seen here
- Each is the same picture but with slightly changes
- For example this one has increased saturation and contrast, this one has saturation reduced down to the point where it is black and white, and this one has had it's brightness increased
- I found the difference between these histograms fascinating and this is what inspired my project

# 2. Description of the Topic

- I will now share with you some of the findings from my preliminary research, giving you some of the background context surrounding my project

## 2.1. Colour Models and Spaces

- Colour spaces and models are fundamental to my project
- A colour model is an abstract model used to describe colours within a coordinate system, independent from physical representation
- A colour space is a complete set or range of colours within a model that can be displayed in a medium

- An example of a colour model is the RGB model
- In this model, different amounts of red, green, and blue light are added together to produce colours
- CIE-XYZ, seen here, is an example of a colour space within the RGB model
- It works on an X, Y, Z coordinate system and because Z represents lightness, this diagram is collapsed onto 2 dimensions by setting Z to a fixed value
- CIE-XYZ is special because it's tongue shape contains every colour perceivable to the human eye

- I will need to choose a colour model and space to use in my histogram
- During my research I have narrowed my choice of colour spaces down to two: sRGB and CIE-L*a*b*

## 2.2. sRGB

- sRGB is part of the RGB model and the set of colours used by most digital monitors
- It is widely used and easy to comprehend, making it a good choice for my histogram

- It can also be defined within the CIE-XYZ space using the location of it's three primaries and white point, as seen here
- One can also see where it fits within the CIE-XYZ space in this diagram
- This is relevant when transforming between colour spaces, but I will cover this later

- However sRGB is not a very large so colours in images captured by cameras with a larger gamut could not be displayed in sRGB

- Also it is not perceptually uniform
- What this means it that the perceived change in colour over a unit of distance in one part of the space will be different to that over the same unit of distance in another part

## 2.3. CIE-L*a*b*

- The other colour space that I am considering is CIE-L*a*b*
- CIE-L*a*b* is not part of the RGB model, but defines it's own model
- Rather than a red, green, and blue component, colours are defined by an L, a, and b value
- As you can see in this diagram, these represent a colour's luminosity, red/green component, and blue/yellow component, as a colour can not be both red and green, or blue and yellow at the same time

- Unlike sRGB, CIE-L*a*b* is very large and contains all perceivable colours, and then some
- This ensures that any image could be representing in the histogram
- It is also more perceptually uniform
- Because my project is concerned with changes in colour, perceptual uniformity is very import

- However because it works in it's own coordinate system, transformations would be required to convert input colours into the CIE-L*a*b* space

## 2.4. Transformations (I)

- So let's talk a little more about transformations

- To transform a colour between two different models, such as CIE-XYZ and CIE-L*a*b*, one can simply apply a formula
- This is the formula for converting between CIE-XYZ and CIE-L*a*b*
- It calculates three variables from the input X, Y, Z coordinates, various constants, and these if statements
- The Lab coordinates are then calculated from this formula at the bottom

## 2.5. Transformations (II)

- However converting between two RGB spaces, such as sRGB and CIE-XYZ, is slightly more complicated

- As seen previously, sRGB can be defined within CIE-XYZ using the coordinates of it's primaries and white point
- This will be important when converting between the two but first we must consider the spaces' luminance
- The luminance of sRGB is exponential, as this is what we perceive as linear, but CIE-XYZ's luminance is linear. This can be seen on these two grey scales
- A gamma correction function must be applied to sRGB so that both spaces are linear

- Now it can be observed that sRGB and CIE-XYZ are both linear vector spaces and a transformation matrix can be applied to convert between the two
- The coordinates of the sRGB primaries and white point are used to derive this matrix
- Applying this matrix to the vector of a colour in the linearised sRGB space converts it to CIE-XYZ space
- And the inverse of this matrix is used to convert back to sRGB

- Any RGB space can fit within CIE-XYZ
- And one can also convert between CIE-XYZ and other models, such as CIE-L*a*b* as seen previously
- CIE-XYZ is therefore often used as an intermediate step when transforming between colour spaces

## 2.6. Colour Histograms

- Some might be familiar with conventional 2D luminosity or colour histograms from digital cameras or image editing software
- This image here is an example of a 2D histogram
- They plot light levels against how frequently they occur in an image
- Luminosity histograms plot absolute brightness values, while colour histograms plot three separate graphs, one for each colour channel: red, blue, and green
- This example contains both a luminosity and colour histogram

- 2D histograms are used to check for over-exposure in an image
- In the image above, one can see that blue and red graphs peak at the x-axis extremes
- This shows that there are values beyond the x limits that are being clipped, indicating over exposure

- 3D histograms however assigning a colour channel to each axis
- Frequency is indicated by the size of the plot, rather than the y-axis value

- 3D histograms can also be used to check exposure, but they are particularly useful to view the distribution of colours in an image, as unlike 2D histograms individual colours can be identified

## 2.7. Colour Alterations

- My project investigates the effects of colour alterations, so I will have to decide which colour controls to use
- iPhoto provides controls as well as a 2D histogram, seen here
- This has allowed me to experiment with different tools and their effects on a histogram
- I concluded that either exposure, saturation, and contrast, or highlights and shadows had the largest effect

- Exposure, saturation, and contrast can be applied to an image using algorithms
- However I am yet to work out the particulars of these algorithms

- Highlights and shadows can be applied using the lift/gamma/gain formula, seen here
- Lift, gamma, and gain affect an image's highlights, mid-tones, and shadows respectively

### 2.8. Technologies

- As I said previously, the idea for my project is independent of platform or language, but I will implement it as a web-based application
- If I was integrating my project with image editing software, Java or C++ would be more suitable, but my project is merely a proof of concept
- There are also two advantages of choosing a web-based application: it increases my project's accessibility and allows me to use WebGL and three.js, which are JavaScript 3D rendering libraries

- WebGL, based on OpenGL, is widely used for rendering 2D and 3D graphics and is supported by most browsers
- It integrates the HTML5 canvas element also makes it very easy to upload and process images
- It also incorporates OpenGLSL a shading language that gives the developer control over graphics run on the GPU, abstracted from hardware-specific languages
- Using OpenGLSL allows me to assign calculations to the GPU, increasing the speed of my renderings

- I will also use three.js, another JavaScript library that wraps up WebGL's often overcomplicated code into a neat and easy to understand package
- It also has many prewritten functions for common features, such as mouse or touch controlled movement within the rendering

## 3. Current and Future Work

- Finally, I will now talk a little bit about the progress that I've made so far in developing a prototype

### 3.1. Prototype

- Visual: Prototype demo

- Over the past term I have been developing a prototype for my project
- This prototype has been used as a proof of concept to accompany my preliminary research
- So far, I have successfully created a 3D rendering using WebGL and three.js, extracted the colours from an image, and plotted them on the histogram
- This is my histogram of the image of two cats

- My histogram currently uses the sRGB colour space but over the next few weeks I will implement the CIE-L*a*b* space to compare the two
- I will also begin to create the colour control tools for my project