Masterclass Session Script

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This icon refers to the supporting slide in the presentation.

These icons indicate there is an activity to do, or a worksheet to complete.

This icon indicates there is a video to watch.

Satellite Vision OTS Masterclass	Slides/ Activity
Introduction (5 minutes) Welcome to our Satellite Vision computer science masterclass today! While you are waiting to get started, I want you to have a chat with the person next to you about what you think this image could be of! In a moment we will hear your ideas.	1
• **What could this be an image of?** • **What if I add more detail to the image? What do you think these light spots in the image could be?** Stars!	2
This is an image of the Dumbbell Nebula, a huge cloud of gas and dust over 1200 light years away from Earth. The nebula is the remnants of a dying star, that has shed its outer layers into space in a dramatic end. It is thought that our Sun could produce a similar nebula when it reaches the end of its lifecycle in 5 billion years. At the end of this session, you will use real space data to make your own image of the Dumbbell Nebula! • **Why don't we see space like this with our own eyes?** Everything is too far away, and our eyes can't see lots of detail from that far away! • **So how do we get these detailed images of space?** We use telescopes on the ground and satellites in space to take images, that have a much better resolution than our eyes have. Resolution is the measure of how much detail you can see in an image, the more detail you can see, the higher the resolution of the image.	
In computing, we consider an image to be a representation of something, showing us how an object looks visually. But in order for a computer to display the image, it has to be given instructions of what it looks like, and this is given to the computer as data, typically a series of numbers that explains what each part of the image looks like. There are lots of different ways we can take images, using different equipment. You might take an image on a camera or phone, using information from a type of light that we call optical light. This means that it takes an image using the information that humans can typically see. But there's actually a lot more detail in life that human eyes can't see! Take our hands for instance. We know that there are bones in our hands, but we can't see them through our skin. • **Has anyone ever broken a bone before?** If you had, you might have had to go to the hospital to get an image taken of the bone called an x-ray, because it takes an image using a type of light called x-rays, that we can't see with our eyes. There are other kinds of imaging we can do too, for example an MRI machine is a tool used to look at the soft stuff inside our bodies such as our brain, using a type of light called radio waves. We can also use light called infrared, to tell us the temperature of what we are imaging. The example on the slide shows a deer in a forest at night. The deer is much warmer than the rest of its surroundings. But how can we use this kind of imaging in space?	3

Pictures from Space (5 minutes)

4

These images were taken by various different telescopes, all making use of different types of light.

- **Any guesses on what the top left image is of?** The top left image shows the Sun, using x-ray and ultraviolet light.

The white sections in the image show where the most energetic activity is occurring, and represent a microflare taking place, an ejection of intense heat and radiation from the Sun. Scientists image our sun to understand solar events like these, so that we can better understand how this impacts our lives on Earth.

Below this image we have a view of a galaxy, a collection of stars and planets, called Andromeda, and in this ultraviolet light image, we can see the spiral sections of star formation, where new stars are being born. The Andromeda galaxy is expected to collide with our own galaxy, the Milky Way, in 4.5 billion years' time, but the Earth would likely survive this collision.

- **Does anyone know what the image on the right shows?** The image on the right shows Jupiter, an image taken using infrared light.

We can see Jupiter's rings, a feature that would not be spotted in optical light! This image was taken by a very special telescope, called the James Webb Space Telescope.

5

The James Webb Space Telescope, or JWST, was launched into space in December 2021, and it currently orbits between the Sun and the Earth, 1 million miles away. It is a huge telescope! The sun shield is the size of a tennis court. It studies stars, galaxies, our own solar system, and planets outside of our solar system, by taking images in infrared light.

- **Why do you think the telescope takes images in infrared light?** Lots of space is obscured by clouds of gas and dust, just like the Dumbbell nebula.

Optical light cannot show us what lies beyond that dust, but infrared can! You may think that infrared is good for detecting very hot objects, but the opposite is actually just as true. Infrared light can help us see cool objects, especially when they are next to warm objects, like planets next to hot stars. It's not just telescopes that use infrared light. You use infrared light too, when you pick up a remote and change the channel on the TV. The remote communicates with the TV using infrared light.

6

These are all images taken by JWST. The top left image is of the Carina Nebula. The image below this is a section of the Eagle Nebula, and the image on the right shows the top view of the Horsehead Nebula.

- **Hands up if you think these images are real… or fake.**

You're all correct! The colours we see here have been added in manually by scientists, to show off the different features. The colours are carefully picked and mapped onto the image, to try to display what the scene might look like in optical light. But how exactly do we create an image of anything, let alone of space?

How do we create an image? (5 minutes)

7

When we want to make an image of something, we need to use a piece of equipment that can detect the light we wish to capture. This equipment has a detector within it, that can detect light. Detectors contain very, very small particles inside them called electrons, and when light hits a part of this detector, it releases an electron. The detector can still store the released electrons, in a pixel. It is these pixels that tell us what the image looks like!

- *(optional)* ***Can I have some volunteers to demonstrate this?***

You six will be our electrons and you will stand in a line to form our detector, and you two will be our light. In a moment our light will take it in turns to tap our electrons on the shoulder, and electrons when light touches you, you will vibrate forward to be stored in the pixel.

8

So how is this then turned into an image? The number of electrons for each pixel is a representation of how bright, or how dim, a specific part of the image is. If there is more light, more electrons will be released, meaning that the pixel will have a higher electron count, and so that part of the image will be brighter.

9

So now we know that images are made up of lots of tiny pixels, what does this look like in reality? Here we have a lovely photo of a dog, but what happens we zoom into the image. We get a close up of the dog's eye, but let's zoom in even more! Here we can see that this specific part of the dog's eye, to the right of its pupil, is made up of a grid of different coloured pixels. And if we zoom in as far as we can go, we can get one particular pixel from the dog. A pixel is also called a picture element, because it is the smallest element that makes up a picture.

Pixel Bingo (5 minutes)

10

We are now going to play a round of pixel bingo. In a moment, I will show you a row of numbers, that correspond to pixels in a grid. The grid has 10 pixels across, so the first number in the row of data represents the first box in the grid, or first pixel, the second represents the second, and so on.

11

Our first row of data is 0001001000.

- **Which pixels do we need to shade in?** The fourth and seventh pixel. Your image should look like this.

12

Our second row of data is 0100000010.

- **Which pixels do we need to shade in?** The second and ninth pixel. Your image should look like this.
- **Does anyone know what this image could be yet?**

13

Our final row of data is 0111111110.

- **Which pixels do we need to shade in?** All but the first and tenth.
- **What does your image show?** Your image should show a smiley face!

14

Now we are going to play a full game of pixel bingo, with ten rows of ten pixels. When you think you know what the image is of, shout Bingo! Here we go.

15

- **What is the image of?** A rocket!

16

But what would happen if we actually didn't have a 10 x 10 grid of 100 pixels to use to make our image, what if we had fewer, like 25 pixels!

- **How many red squares are there across?** Five.
- **How many down?** Five. So now we have a 5 x 5 grid – 25 pixels in total.
- **When we take an image of something, what would the image show if we took it in the dark?** Nothing!

17

Each pixel on an image only shows us something if light has hit the detector there. What that pixel looks like is also dependent upon how much light hit the detector. We will shade each of the new 25 pixels with a shade of grey, relative to how much light is in each square. If the whole square is very bright and full of light, we would leave it white. If there is no light in the image and it is completely dark, the new square will appear dark. We call this colour shading, greyscale, as it is a scale of different coloured greys, from light to dark.

- **How many light squares are in the first pixel in the first row?** Four.
- **And the second pixel in the first row?** Three.
- **What about the third pixel in the first row?** Zero.

18

If we count these up for the whole image and apply greyscale, we get this.

- **What does the image look like?**

When we compare our two images side by side, we can see that the fewer pixels we have, the less detail we can see in an image.

- **What do you think would happen if we increased the number of pixels in the image?**

19

What happens when we increase the pixels? (5 minutes)

20

Here's an example of what happens when the number of pixels increases. Mario has gone through a lot of changes since he first appeared in Nintendo's video games in the 1980s. They did not have the capability of modern video games, so the very first Mario was created out of a grid of only 16x16 pixels. This is why he was given a moustache; the developers did not have enough pixels to give him a proper mouth, so they gave him a moustache instead!

- **What details can you see emerge as Mario was created using more and more pixels?**

21

Now let's look at a space example! The first image shows Pluto and its moon Charon, taken by NASA's New Horizons spacecraft in April 2015, from a distance of 71 million miles away, and the resolution of these images increase as the spacecraft got closer. The final image was taken when the spacecraft was only 280,000 miles away from Pluto. We can see details on Pluto's surface, such as ice sheets, mountain ranges and impact craters. We can tell how old or new the surface is, depending on how many craters are present. Newer surface has less impact craters, because new ground has covered up the more ancient craters.

What else can satellites see? (10 minutes)

22

We know that telescopes and satellites can look outwards and view all of these things in space, but we can also use satellites to take images of the Earth.

- **What things on Earth do you think we use these satellite images to see?** *(Paired discussion activity)*

Taking images using satellites in space can help us to forecast the weather and track storms and rain patterns, like Hurricane Irma on the Bahamas. We can also track other natural disasters, such as flooding, volcanic eruptions, and wildfires, like this one in Spain. We can also track the migration patterns of wildlife, or monitor habitat change, for example the British Antarctic Survey counted whale populations using satellite imagery. Satellites can also tell us a lot about climate change, giving important information on deforestation, ice coverage, air quality, pollution, and coastal erosion, and we can use satellite imagery to find hidden archaeological sites. We can learn a lot about the oceans, including temperatures and what the seafloor looks like, and we can assess how our cities and infrastructure has changed, and even spot some famous landmarks from space.

A message from space (10 minutes)

23

You are now going to try to match up some low-resolution satellite images, to their high-resolution counterparts. Each high-resolution image has a letter within in, so when you match them up, you are given a location of each letter. There are more high-resolution images than low resolution, so not every letter will match a location. On the back of the worksheet, you will match the four descriptions to the images, in order to spell a four-letter space themed word. Once you have got this, you can have a go at the extension activity.

- **What was the secret space word?** JWST!
- **Was it hard trying to identify the features in the images? What made it difficult?** The images were in greyscale, so details such as beaches, rivers, trees, and fields, might have been hard to identify.
- **What else could we do to improve our image, to be able to identify features better?** Add colour!

Let's add colour! (5 minutes)

24

In order to make a colour image, we need to take multiple images of a scene. Each image has a filter, that blocks all colour of light from getting to the detector, besides the colour we want.

- *(optional)* **How does the world look through the light filters?**

In the top image, we can see that red, green and blue filters were used. These images are then processed and coloured with their respective colours, and then merged together to get a full colour image.

- **What happens when we mix red, green and blue paint?**

We get a dark brown colour usually. This is the opposite with light. When you combine different types of light, you actually get white! So instead of getting a dark brown smudge when we combine space images together, we actually get lighter images, filled with different colours.

The image below shows a set of 7 images of a galaxy, NGC 1512, taken using 7 different coloured light filters, including ultraviolet and infrared. Sometimes, we can take more filter images and merge them, to get even more detail! How do we get these colours?

Create a Light Spinner **(15 minutes - *optional*)**

25

We are now going to have a go at seeing this in action, by making a Newton spinner, or light spinner! You need to follow the instructions in order to make your spinner.

- **What happens when the spinner turns really fast?**

The colours merge to form a white/grey blur. This is because the colours are moving so fast our eyes cannot distinguish them, so they merge the light together to form white light.

26

When we view our images on a computer screen, each pixel is given a colour. This colour is decided using something called the RGB model, where it has a value for red, green, and blue, taken from the three filters that merge together to make it.

Each of the red, green, and blue channels are given a value from 0 to 255, so there are 256 different intensities for each colour.

- **How many total possible colours would there be?** (256 x 256 x 256 = 16,777,216 different colours!)
- **How many colours do you think humans can see on average?** We can see around 10 million different colours!

What is interesting about this, is that our eyes can only distinguish 10 million colours, which means almost 7 million colours in the RGB model look the same to us!

Guess the RGB colour (10 minutes)

27

- **What colour is described the RGB value (0, 0, 255)?**

You have nothing in the red channel, nothing in the green channel, and 255 in the blue channel! Our colour is blue!

- **What would the red and green colour value be?** Red (255, 0, 0), Green (0, 255, 0).

28

- **What colour is described the following RGB value (255, 255, 0)?**

You have nothing in the blue channel, and 255 in the red and green channel! Our colour would be yellow!

• **What colour is described the RGB value (50, 200, 200)?** You have lots more light in the green and blue channels, and much less in the red channel! Our colour would be Turquoise! • **What colour is described the RGB value (255, 255, 255)?** You have the most light possible in all three channels! Our colour would be White! • **What values would black have?** (0, 0, 0). Black is a complete lack of light. • **What colour is described the RGB value (237, 125, 49)?** Our colour would be orange!	29 30 31
Turning space data into an image (20 minutes) You will now have your own go at processing real space data! Following along with my tutorial, or the instructions on the worksheet, you will make your own images of the Dumbbell Nebula! For each image you colour and process, remember to answer the questions on the worksheet – think about what the lightest and darkest part of the images are, and what detail does each colour channel give you?	32
End of session – recap Thank you very much for joining this masterclass today, we hope you enjoyed it and learnt a lot about space, satellites, and image processing! If you would like to have a go at some extension activities, there are these activities available on similar topics. If you have any questions, comments or thoughts we would be happy to hear them now. You can also ask the Ri, by emailing any questions to masterclasses@ri.ac.uk.	33