ENGR 101 – Chapter 5

Working With Images

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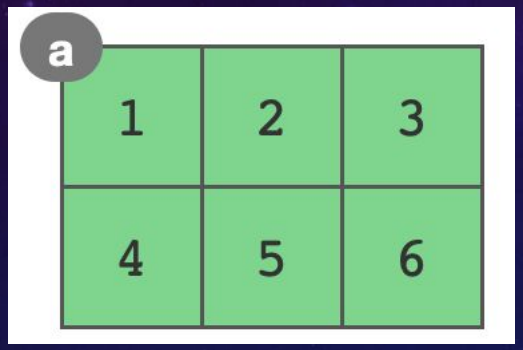
Functions for Manipulating Matrices

- MATLAB includes many functions for messing with the layout and shape of data within matrices.
- Here are a few, for your reference:
  - `rot90` – rotate the data in a matrix by 90 degrees counterclockwise
  - `fliplr` – flip the matrix "left to right" (i.e. horizontal flip)
  - `flipud` – flip the matrix "up to down" (i.e. vertical flip)
  - `reshape` – keep the same data, but pack it into a different number of rows/columns to "reshape" the matrix
  - `repmat` – create a larger matrix by replicating (i.e. "tiling") this one
- See the MATLAB documentation online for more details!

Transposing a Matrix

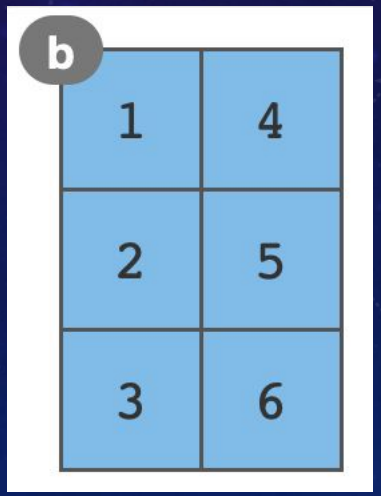
- Transposing a matrix takes the rows and turns them into columns:
  - Row 1 becomes column 1, Row 2 becomes column 2, etc.

```
b = a'  % b is the transpose of a
```



This single quote is the transpose operator.

WARNING
It's easy to miss this small operator!
Include a comment to remind yourself you transposed data.



Grayscale Image Representation

- We'll start with grayscale images (i.e. no color).
- Each pixel is simply a single **intensity value**.
  - The higher the value, the closer to white.

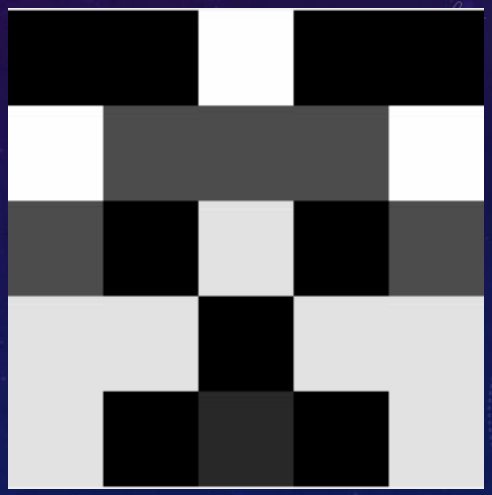
- There are two ways to represent intensity:
  - An **integer** between 0 and 255, inclusive.
  - A real number (a **double**) between 0 and 1, inclusive.

Internally, MATLAB considers integers and doubles to be different "types" of data.

Grayscale Image Representation

- A grayscale image is just a grid of intensity values.
- In MATLAB, this is just a matrix of numbers!

0	0	255	0	0
255	76	76	76	255
76	0	226	0	76
226	226	0	226	226
226	0	40	0	226

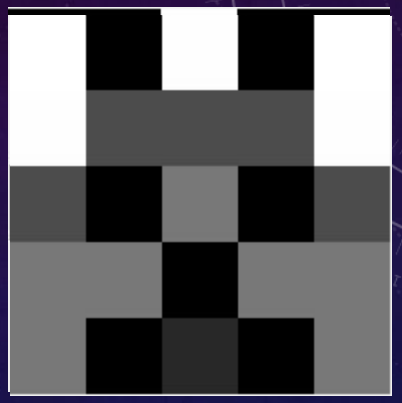


This is supposed to look like a dog. See it?

- That's it, really!

Images are Just Numbers in a Matrix

- Today we'll see how to perform a variety of image processing operations just by manipulating matrices.



- For example:
  - `grayImg(1, 1) = 255;`
    `grayImg(1, 5) = 255;`
  - `grayImg(grayImg == 226) = 120;`

255	0	255	0	255
255	76	76	76	255
76	0	120	0	76
120	120	0	120	120
120	0	40	0	120

grayImg

File Input/Output for Images

- To load an image from a file, use the `imread` function.

```
img = imread('filename.jpg')
```

- To save an image to a file, use the `imwrite` function.

```
imwrite(img, 'filename.jpg')
```

- MATLAB can handle most common image file formats:
  - `.jpg`, `.png`, `.gif`, `.bmp`, `.ppm`, etc.

The imshow Function

- First, load the file using imread:
  - `cat_gray = imread('cat_gray.jpg');`

If you forget this semicolon, MATLAB will try to print out a giant image matrix.

If it does, hit ctrl-c to tell it to stop.

- Now, you can use the imshow function to display the image.
  - `imshow(cat_gray);`

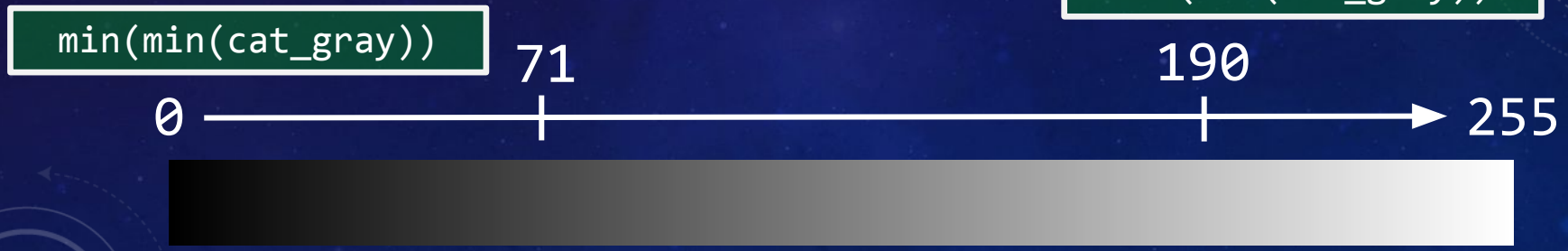
MATLAB will open another window to display the image.

What's wrong with this image?

cat_gray.jpg

It has very poor contrast. The cat kind of fades into the background.

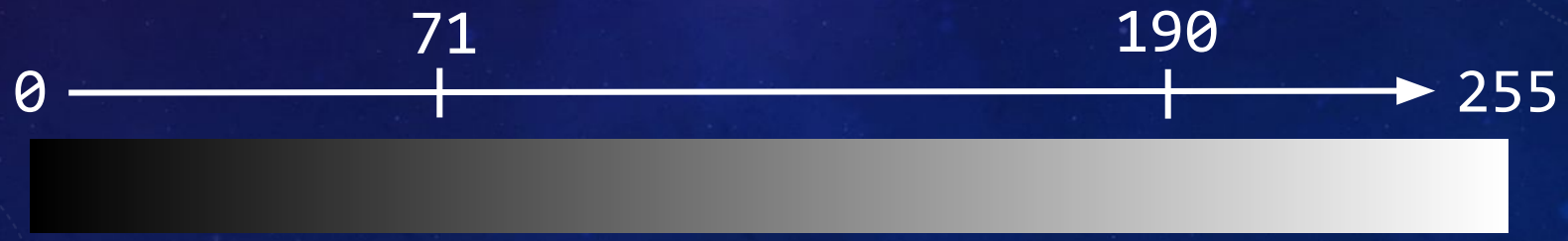
Question: What are the max/min intensities used in this image?



Exercise: Contrast Stretching

- We can improve the image by using more of the possible intensity values.
- This is a *linear interpolation* problem: stretch the range [71,190] to be [0,255].
- To do this:
  - Subtract 71 from all pixels
  - Then multiply all pixels by 2.14

cat_gray.jpg



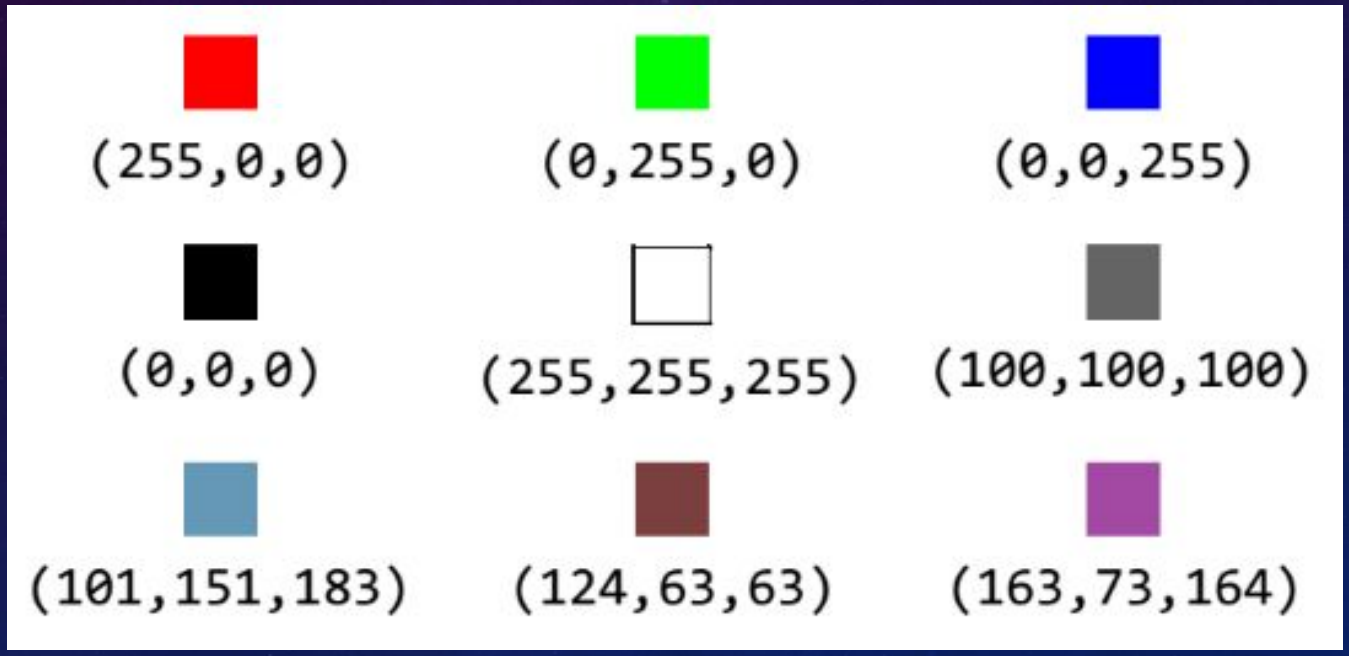
Solution: Contrast Stretching

```
cat_gray = (cat_gray - 71) .* 2.14
```

RGB Color Image Representation

- To represent a color, we need three different values for the amounts of the primary colors red, green, and blue.[1]

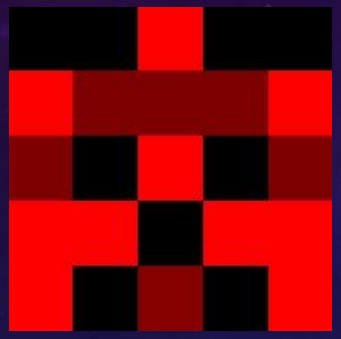
(R, G, B)



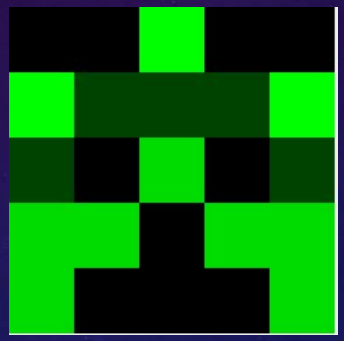
1 These are the primary colors of light. You may also be familiar with the primary colors of pigment, which are magenta, yellow, and cyan.

RGB Color Image Representation

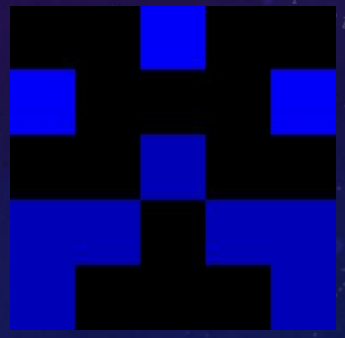
- In MATLAB, a color image is represented as three different color **channels**.



0	0	255	0	0
255	126	126	126	255
126	0	255	0	126
255	255	0	255	255
255	0	134	0	255



0	0	255	0	0
255	66	66	66	255
66	0	219	0	66
219	219	0	219	219
219	0	0	0	219

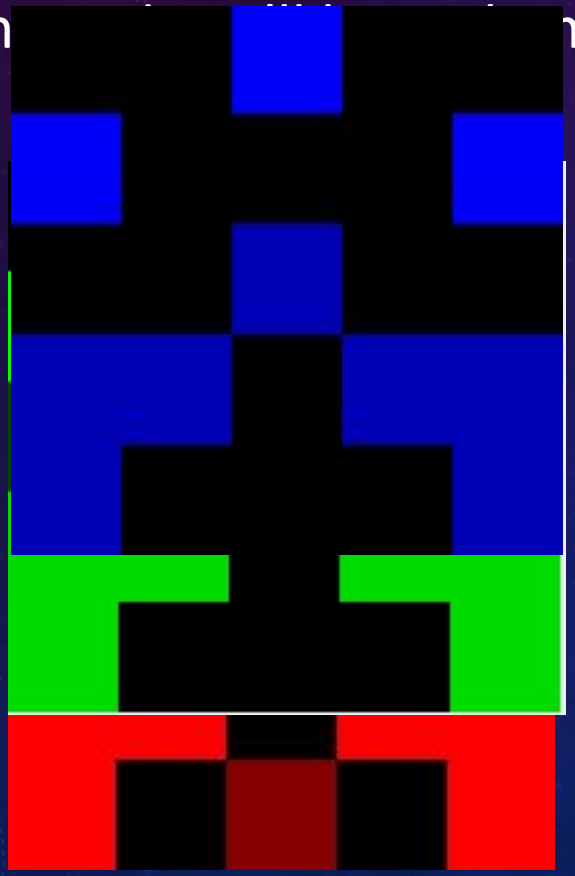


0	0	250	0	0
250	0	0	0	250
0	0	183	0	0
183	183	0	183	183
183	0	0	0	183

1 These are the primary colors of light. You may also be familiar with the primary colors of pigment, which are magenta, yellow, and cyan.

RGB Color Image Representation

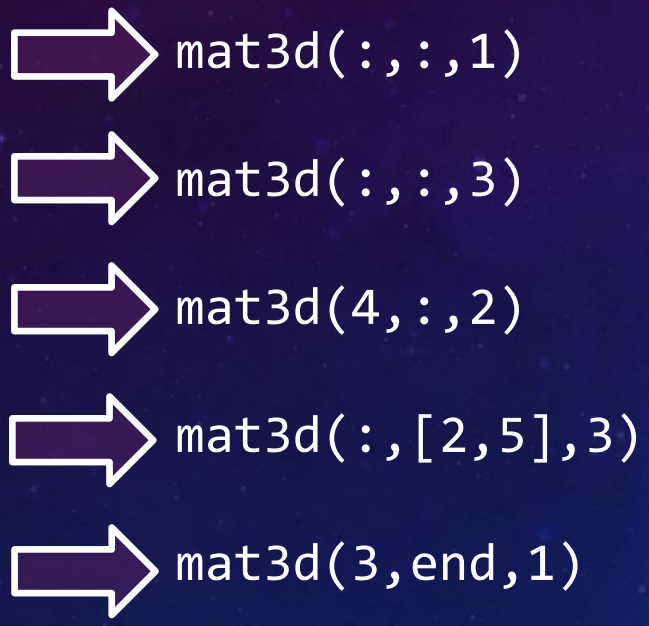
- We could store these color channels as three individual matrices, but then we have more things to keep track of…
- In m on top of each other in a 3D array!



0	0	250	0	0
250	0	0	0	250
0	0	183	0	0
183	183	0	183	183
183	0	0	0	183
219	219	0	219	219
219	0	0	0	219
255	0	134	0	255

Accessing Parts of a 3D Array

- Layers in a 3D array are controlled by a 3rd dimension.
- Row/column indexing becomes row/column/layer indexing.



0	0	250	0	0
250	0	0	0	250
0	0	255	0	0
0	0	183	0	0
255	66	66	66	255
183	183	255	183	183
66	0	219	0	66
255	126	126	126	255
219	219	0	219	219
126	0	255	0	126
219	0	0	0	219
255	255	0	255	255
255	0	134	0	255

Note: The animations on this slide won't show up well in a PDF.

Working With Images as 3D Arrays

- There are two main modes of operation…

"I want the whole image."

```
img(___, ___, :)
```

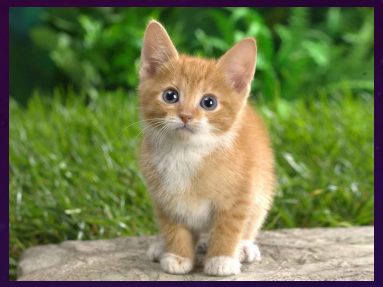
Use the : to select all channels.

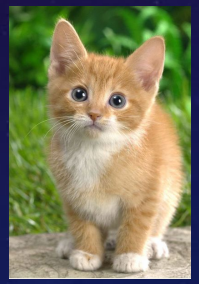
"I want a single channel."

```
img(___, ___, 2)
```

Select only the channel you want.

Working With the Whole Image





```
cat = imread('cat_color.jpg');
imshow(cat);

% Vertical Flip
vf = cat([end:-1:1], :, :);
imshow(vf);

% Crop the image
cropped = cat(:, [200:600], :);
imshow(cropped);
```

We want to flip all the channels.

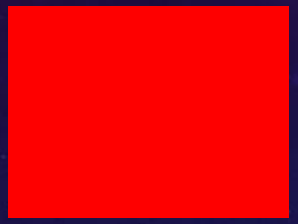
Again, select all channels to be cropped.

Select ONLY columns 200 through 600.

Working With a Single Channel (General Pattern)

- A pattern for working with single channels:

red



red

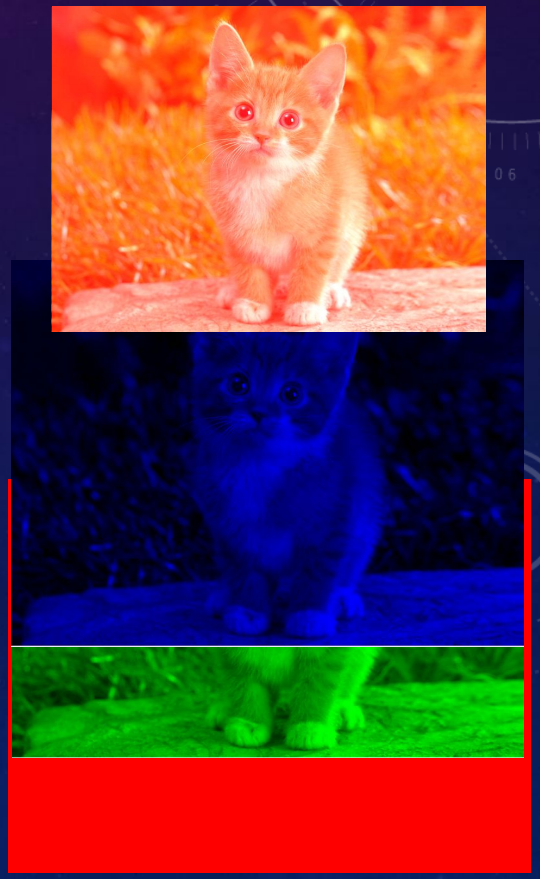
```
% Pull out the red channel
% to work with it individually
red = cat(:,:,1);

% Make changes to the red channel
red(:) = 255;

% Put the red channel back in
cat(:,:,1) = red;
```

IMPORTANT
red is a **copy** of the red channel. You need this assignment to copy the changes back in.

cat



Working With a Single Channel (Shortcut)

- A shortcut – just work with the channel in place:

```
cat(:,:,1) = 0;   % Set all values in the red channel to 0
cat(:,:,2) = 2 .* cat(:,:,2); % Multiply green channel values by 2
```

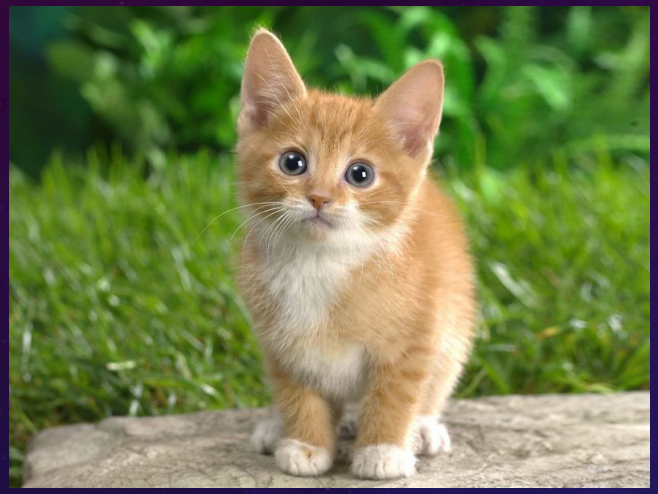
- This doesn't always work. For example, to use logical indexing, you need the general pattern on the previous slide.
  - e.g. Set all red channel values less than 50 to be 0.

```
cat(:,:,1)(cat(:,:,1) < 50) = 0;
```

DOES NOT WORK

MATLAB doesn't allow a logical indexing operation right after a regular indexing operation. Instead, assign the channel to a variable, then use the logical indexing.

This looks artsy. Let's try it. Any ideas?



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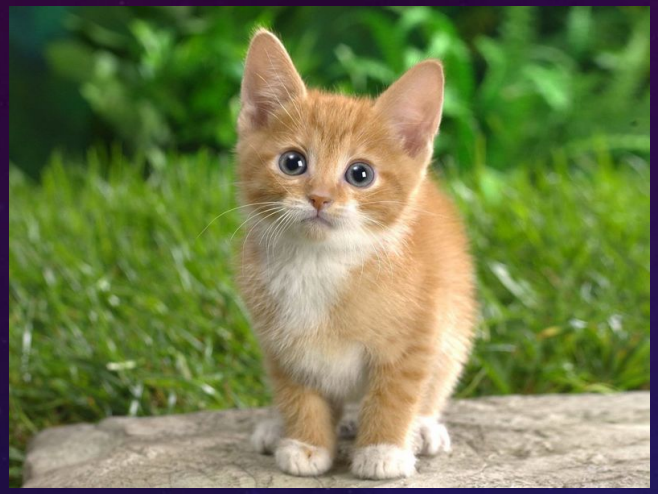
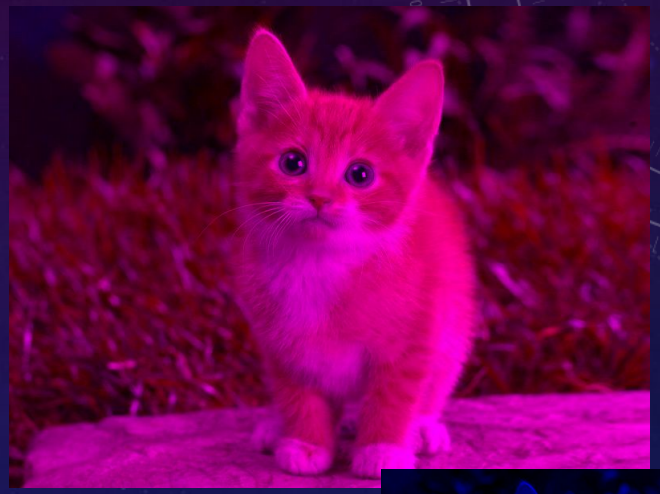
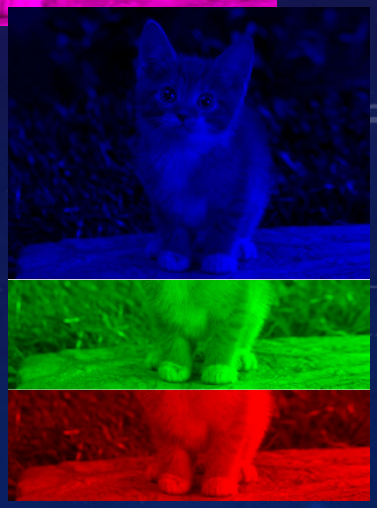




```
green = cat(:,:,2); % copy green channel
green(:) = 0;       % set to zero
cat(:,:,2) = green; % copy back into image
% It doesn't work O.o
```



HSV Color Image Representation

- RGB is only one of several image representations.
- HSV is an alternate that works well for certain applications.
  - **Hue**: "which color?"
  - **Saturation**: "how strong is the color?"
  - **Value**: "how bright?"

Hue

Saturation

Value

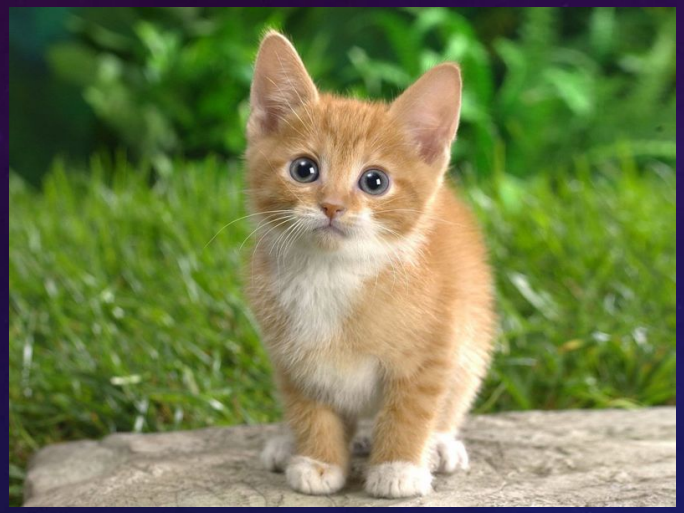
HSV Color Image Representation

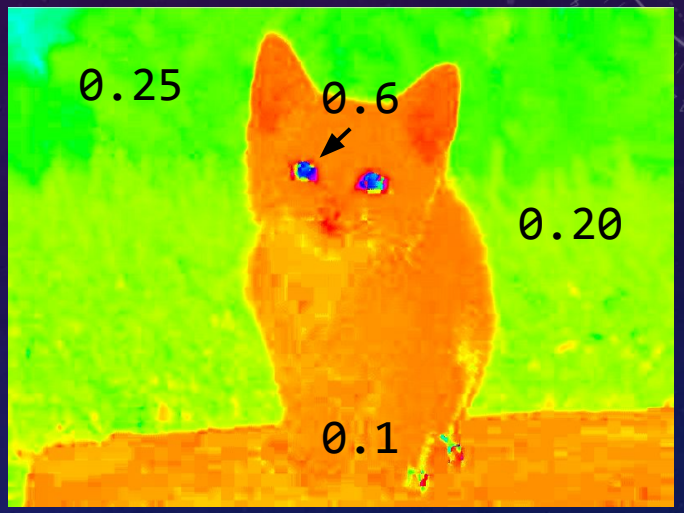
- HSV images are also stored as a 3D array.
- However, in MATLAB HSV channel values range from 0 to 1.
  - (In MATLAB, RGB values range between 0 and 255)

- To convert between RGB and HSV, use built-in functions:
  - ```
    % convert img from RGB to HSV
    hsvImg = rgb2hsv(img);
    ```
  - ```
    % convert hsvImg from HSV back to RGB
    img = hsv2rgb(hsvImg);
    ```

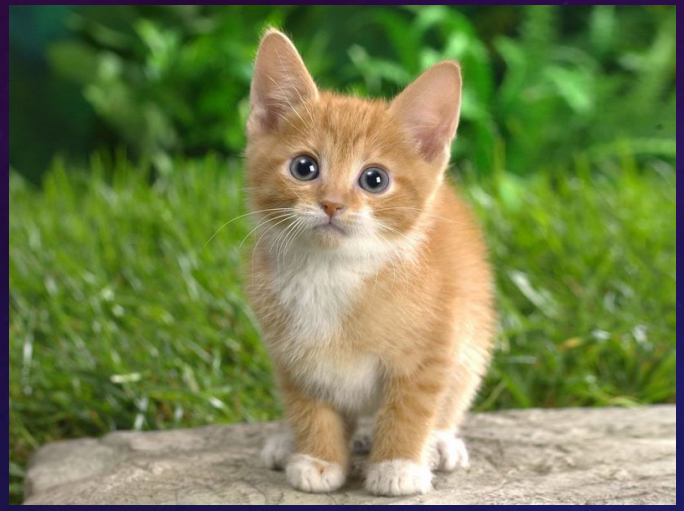
Hue

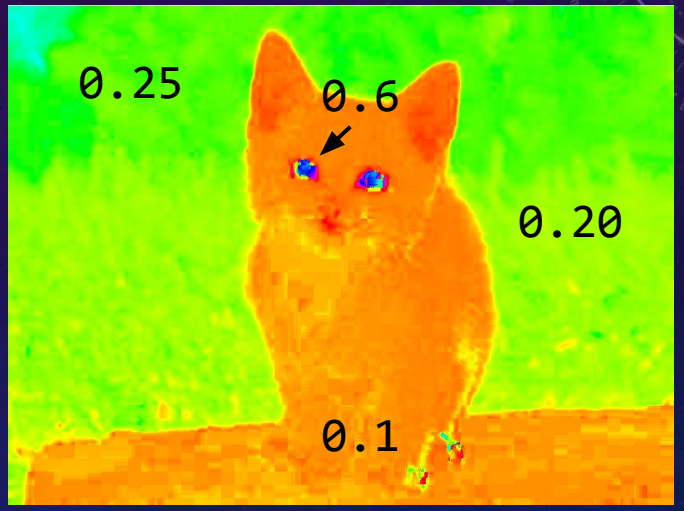
- The hue channel encodes a color as a number between 0 and 1



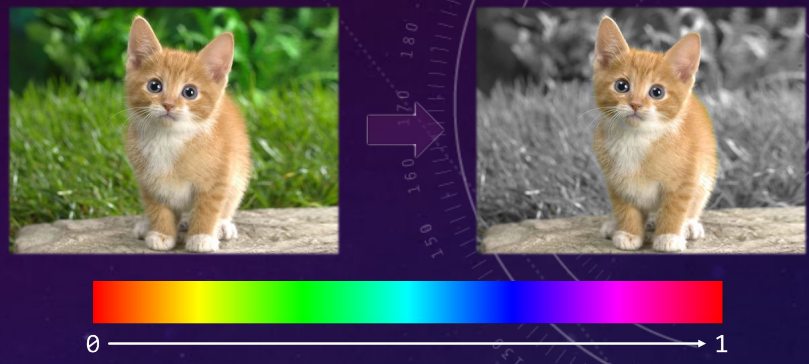


Can we use HSV to do this?





Exercise: Removing a Color



- First, convert to HSV:

```
cat = imread('cat_color.jpg');
hsv = rgb2hsv(cat);
```

- Next, make copies of the hue and saturation channels to work with.

```
hue = hsv(:,:,1);
sat = hsv(:,:,2);
```

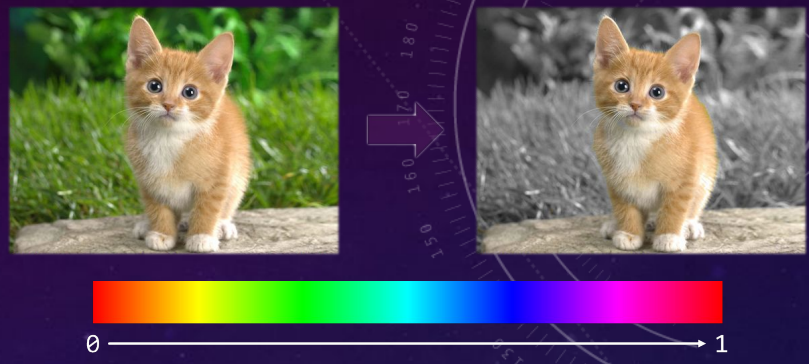
- Now, the tricky part. Find all locations with a hue between 0.14 and 0.5, and set the saturation to 0 (i.e. meaning color "strength" of 0). *Hint: Use logical indexing.*

  You do this part…

- Finally, copy the saturation channel back in (it's the one we changed), convert back to rgb format, and display using `imshow`.

```
hsv(:,:,2) = sat;
imshow(hsv2rgb(hsv));
```

Solution: Removing a Color



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hue = hsv(:,:,1);
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```

- Now, the tricky part. Find all location with a hue between 0.14 and 0.5, and set the saturation to 0 (i.e. meaning color "strength" of 0). *Hint: Use logical indexing.*

```
sat(0.14 < hue & hue < 0.5) = 0;
```

- Finally, copy the saturation channel back in (it's the one we changed), convert back to rgb format, and display using `imshow`.

```
hsv(:,:,2) = sat;
imshow(hsv2rgb(hsv));
```