

Imaging Basics

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Outline

- Basics of image formation
- How images are represented digitally
- Image manipulation: resampling

Learning outcomes

- By the end of the lecture, you should be able to:
 - Use the pinhole camera projection model to map between world and image points
 - Explain how camera parameters affect the appearance of an image
 - Explain how images are represented in a computer as 3D tensors
 - Explain why resampling is necessary for image manipulations, and the trade-offs of different methods

Image formation



What is an image?

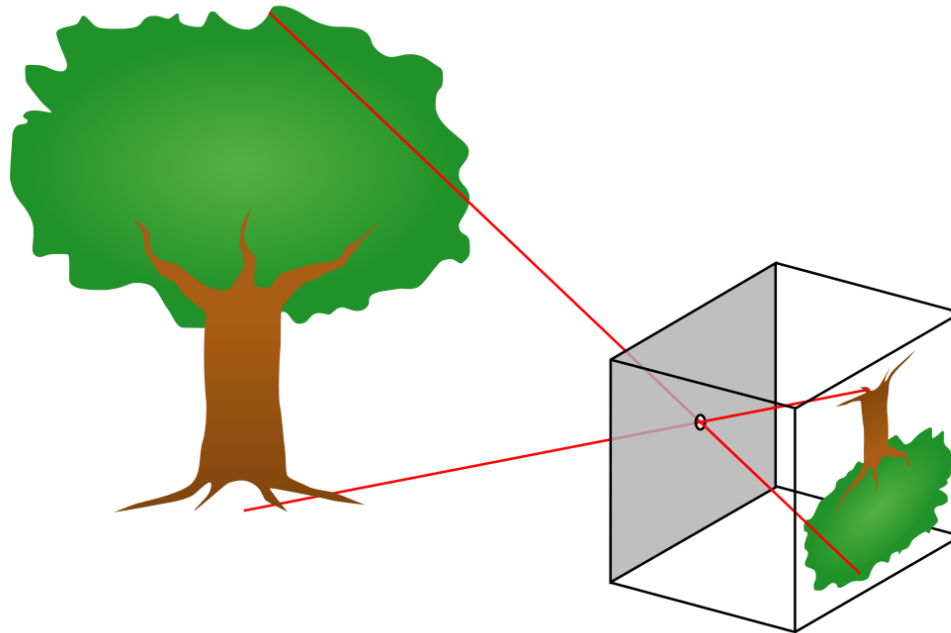
- Pattern formed by light falling on a photosensitive surface
 - Examples of photosensitive surfaces = camera sensor, retina
- Light is reflected off of objects in the world
- 2D projection of a 3D scene



A short account of the eye and nature of vision, James Ayscough (1755)

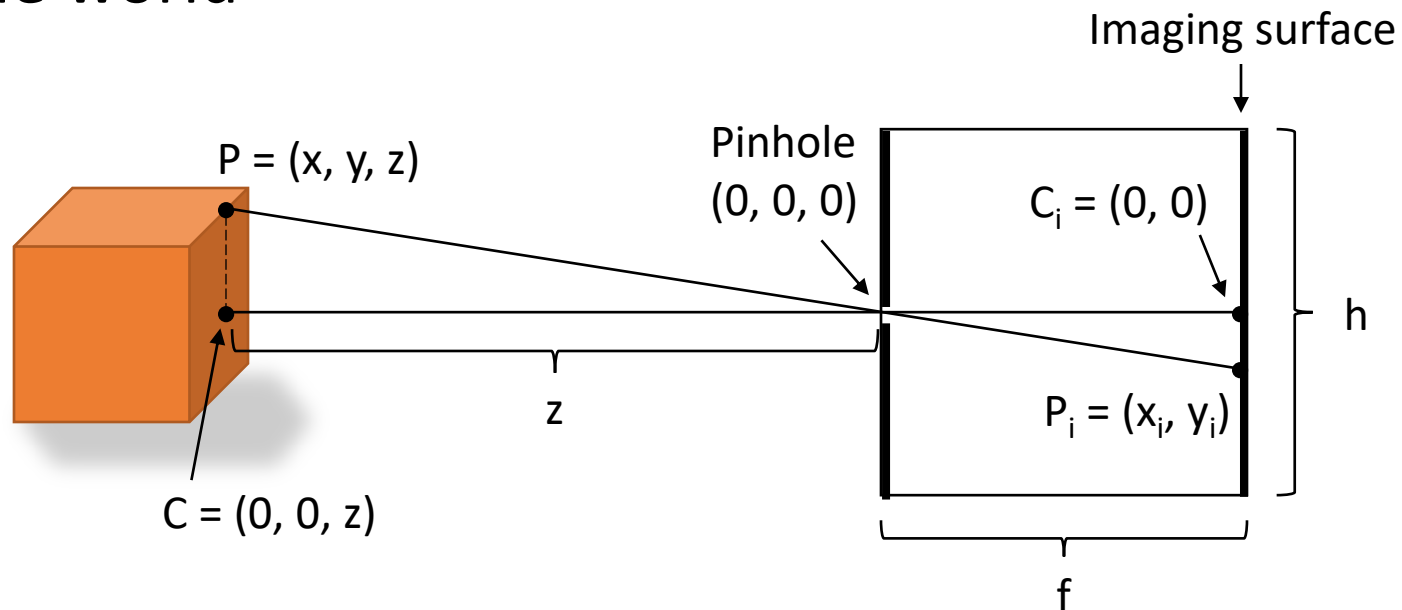
Creating an image

- Simple imaging system: pinhole camera or “camera obscura”



Creating an image

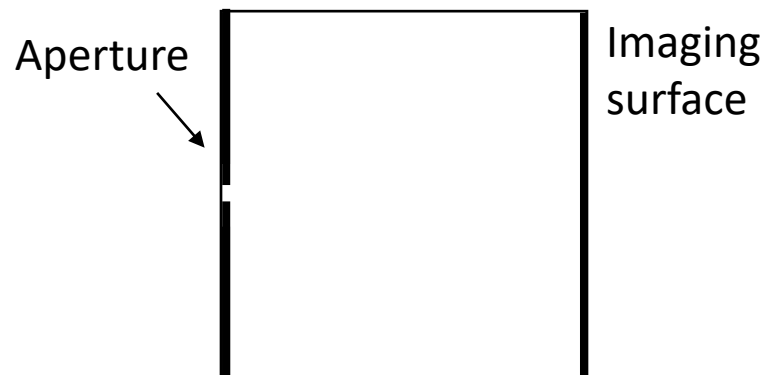
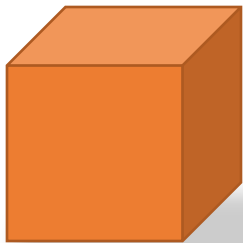
- Every point in the image corresponds to a point in the world



$$x_i = fx/z \quad y_i = fy/z$$

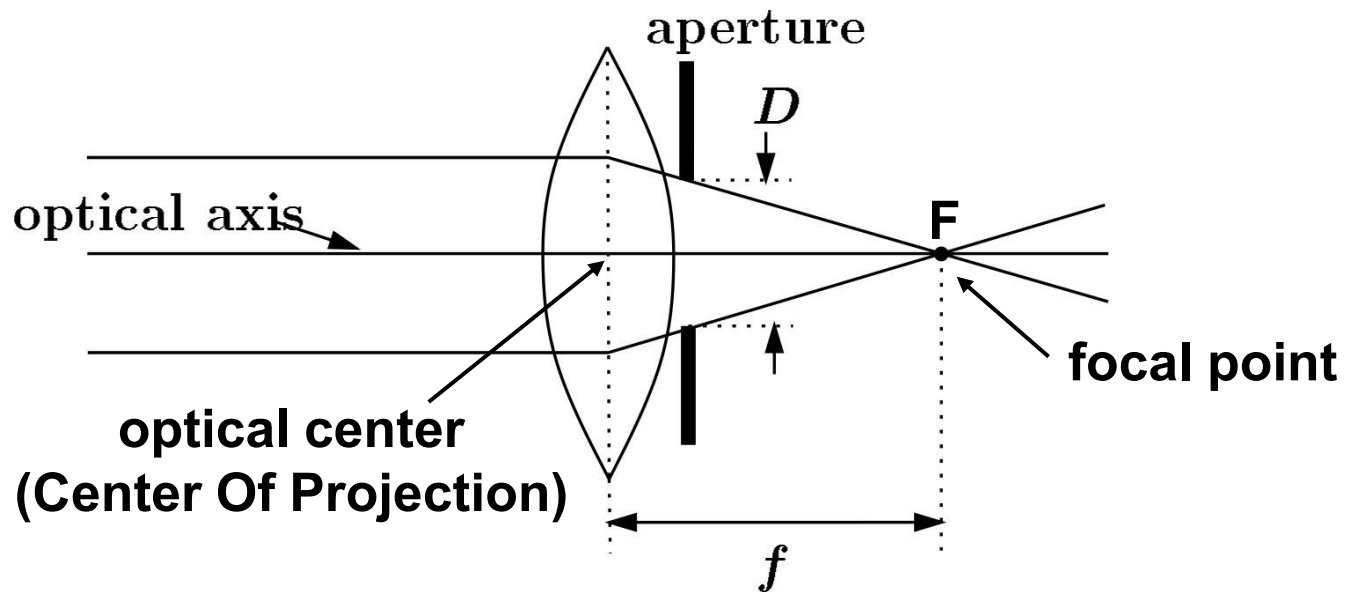
Creating an image

- Pinhole camera: simple design, not common in practice
 - Why not?
- Instead of a pinhole, most cameras use lenses
 - Why?



Lenses

- Lenses focus light rays onto a single point (F) at a distance (f) beyond the lens
- Aperture diameter (D) restricts the range of rays



Focal length / angle of view



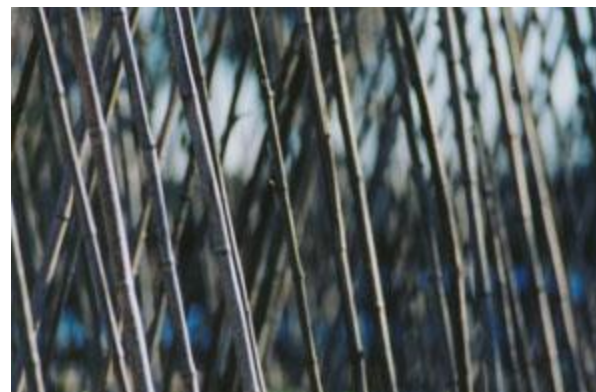
28 mm lens, $65.5^\circ \times 46.4^\circ$



50 mm lens, $39.6^\circ \times 27.0^\circ$



70 mm lens, $28.9^\circ \times 19.5^\circ$

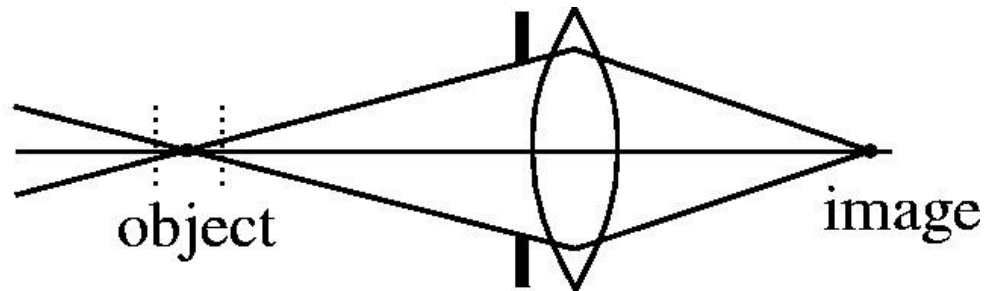


210 mm lens, $9.8^\circ \times 6.5^\circ$

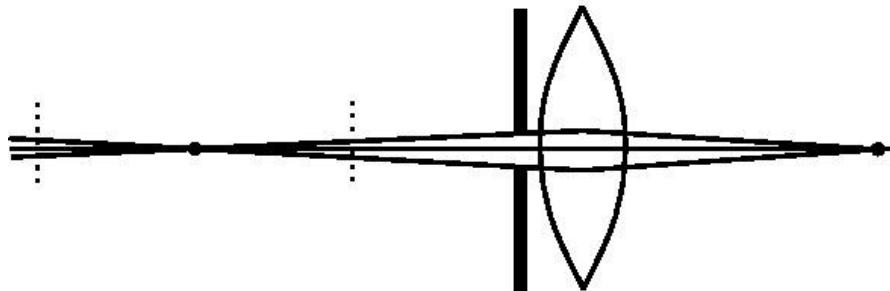
https://en.wikipedia.org/wiki/Angle_of_view

Depth of field

- In cameras, aperture size controls depth of field (smaller aperture = greater range of depth in focus)



$f/5.6$



$f/32$



Distortion



Image formation model

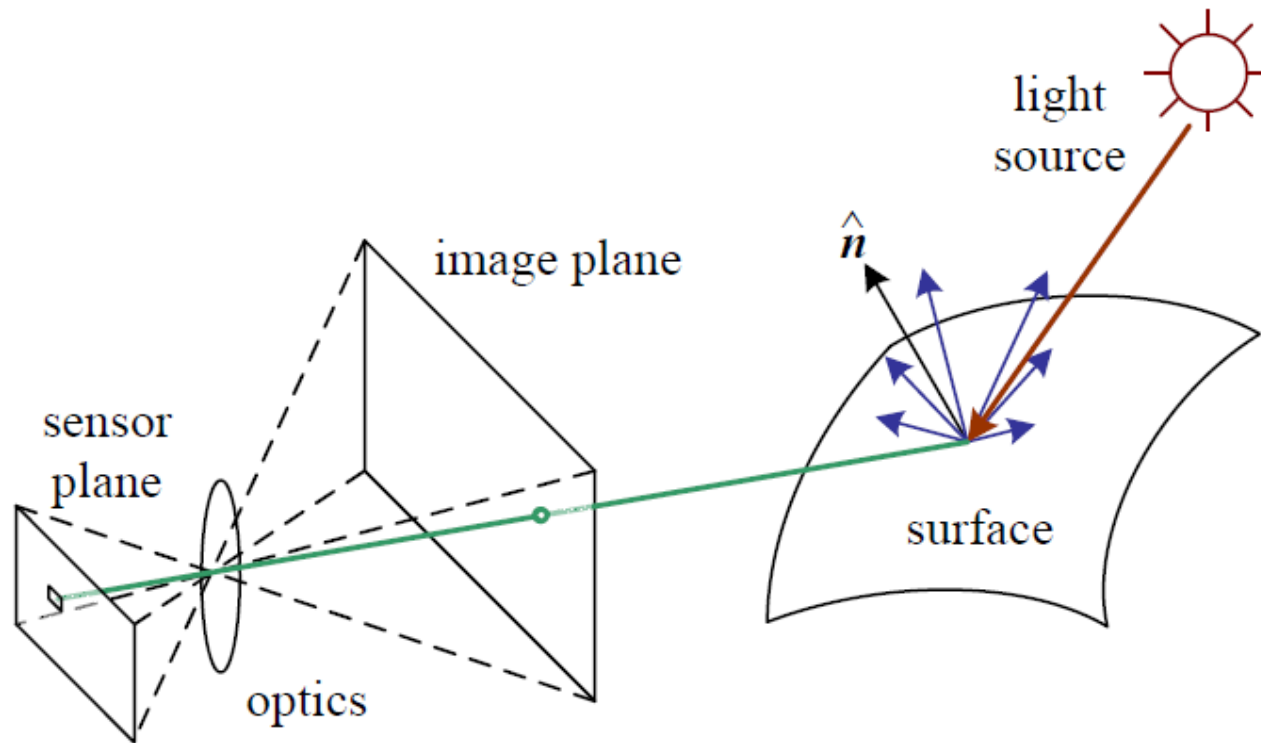


Image formation

- World parameters
 - Light source
 - Surface properties
- Camera parameters
 - Optical centre
 - Focal length / angle of view
 - Aperture size / depth of field
 - Lens distortion

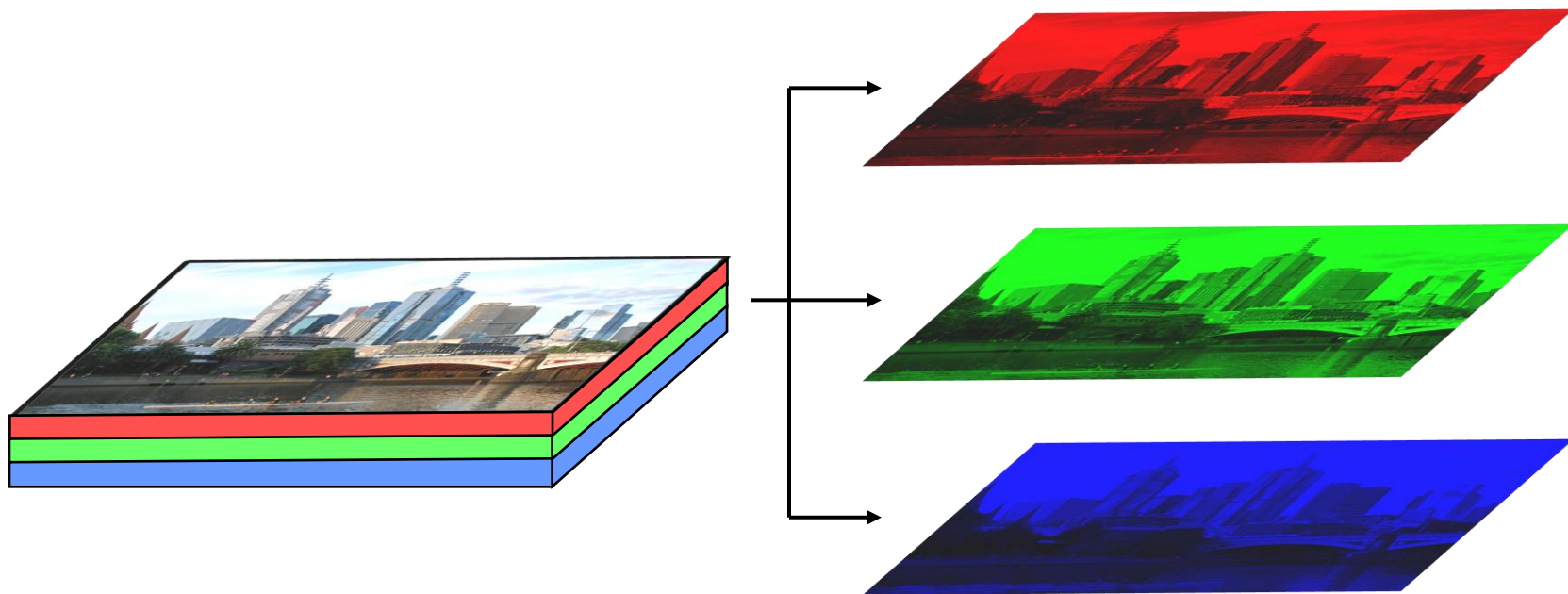
Digital images



What is a (digital) image?

- A tensor (3D dimensional array of values)
 - Width x height x channel
 - 3 channels = RGB colour image (red, green, blue)
 - 1 channel = grayscale image

What is a (digital) image?



Colour channels

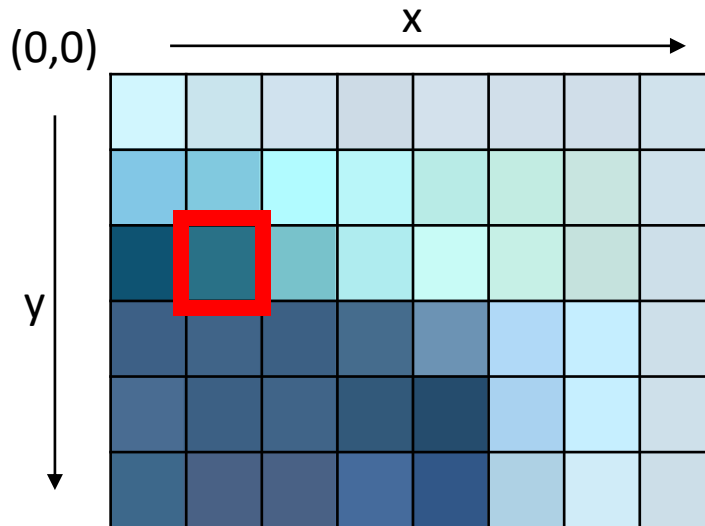


What is a (digital) image?

- A tensor (3D dimensional array of values)
 - Width x height x channel
 - 3 channels = RGB colour image (red, green, blue)
 - 1 channel = grayscale image
- Note: the exact format can vary across libraries / languages!
 - E.g., “channel-first” = channel x height x width
 - Height x width x channel
 - BRG = blue, red, green

What is a (digital) image?

- Pixel = smallest unit of an image
 - Grayscale image: pixel is a grayscale value
 - Colour image: pixel is a 1x3 vector



Pixel location:

x =

y =

Values = [41, 113, 135]

What is a (digital) image?

- Most common data type is uint8 (unsigned 8-bit integers)
 - Range = 0 – 255
 - “24-bit colour” = 3 uint8 channels
- But you may encounter other data types:
 - double (range 0.0-1.0)
 - uint16, uint32: medical images
 - float32: high dynamic range (HDR) images

Common file formats

- Lossy compression:
 - JPEG (.jpg, .jpeg)
- Lossless compression:
 - PNG (.png), BMP (.bmp), GIF (.gif), TIF (.tif, .tiff)

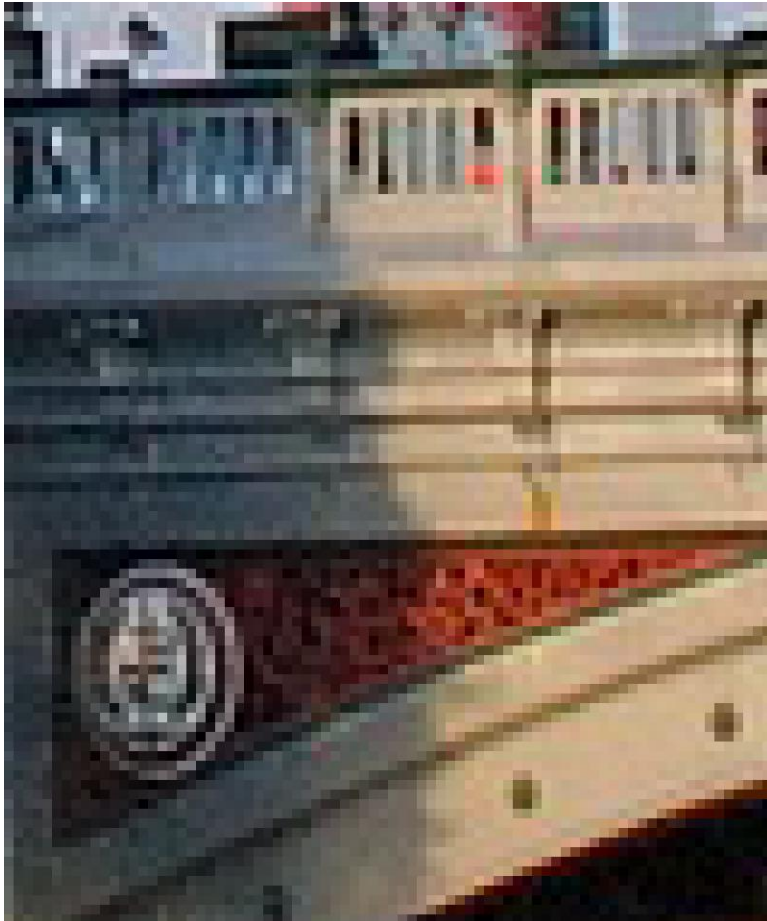
Original: 760 KB



Compressed: 144 KB



JPEG compression



Digital images

- Stored as a tensor (3D array) of values
- Colour is represented through multiple colour channels (typically red, green, blue = RGB)
- Values are typically uint8 (0-255)
- Some image formats discard information to save space (lossy compression)

Image manipulation

Image scaling



Original: 768 x 512 pixels



Crop to 512 x 512



Resize to 512 x 512
(does not preserve
aspect ratio)



Resize to 512 x 341
(preserves aspect ratio)

Image scaling

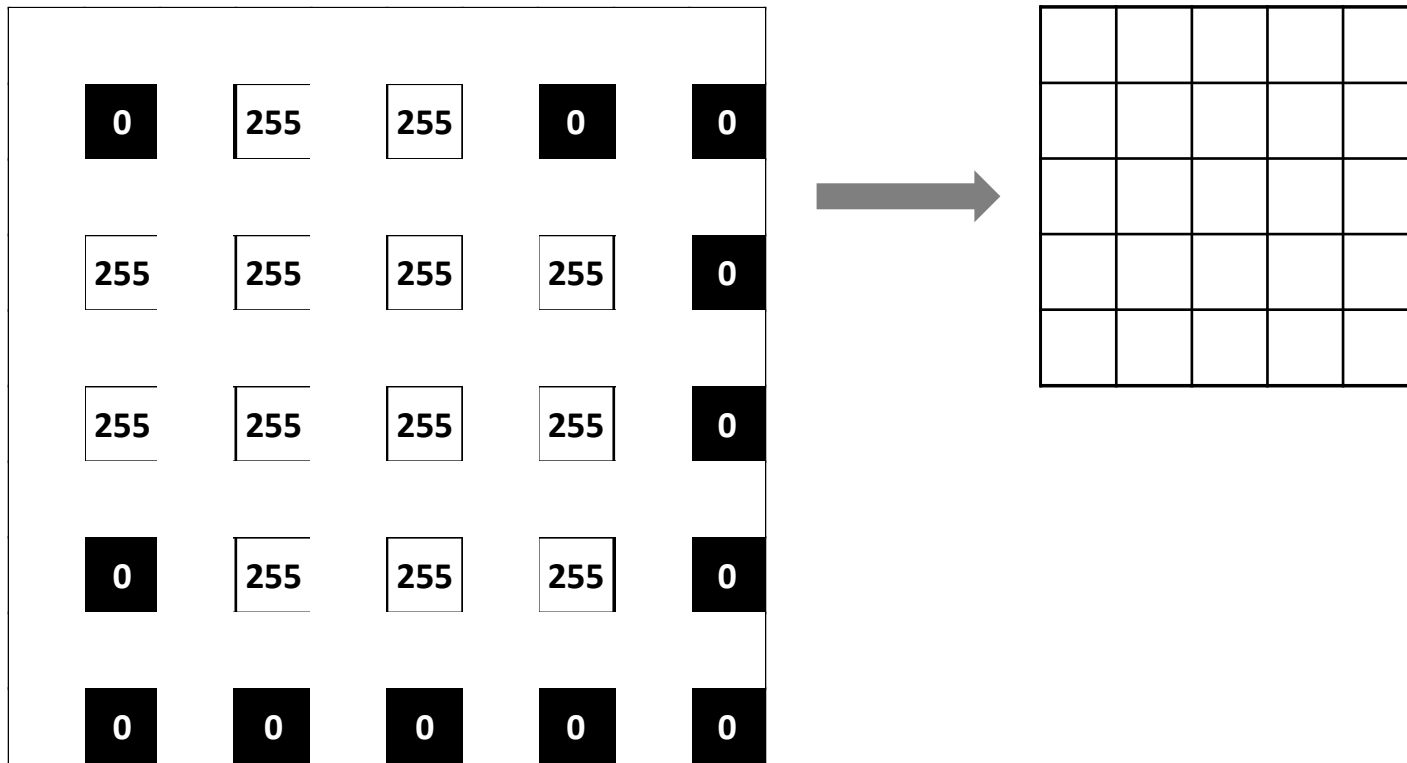


Image resampling



Original

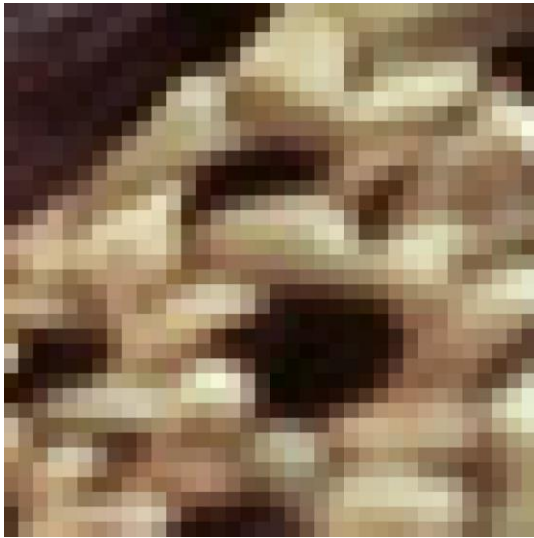


1/10 size
Nearest neighbour



1/10 size
Bilinear

Image resampling



Nearest neighbour



Bilinear



Bicubic

Image manipulations

- Crop = extract a subset of the image array (doesn't require resampling)
- Resize = change the dimensions of the image array (requires resampling)
- Different resampling methods give different results

Summary

- An image is a pattern of light from the world, projected onto a 2D surface
- A digital image is a sample of this pattern, represented as a tensor
- Images of the same scene can vary widely at the pixel level, due to:
 - Camera parameters (focus, field of view)
 - Digital processing steps (compression, resampling)