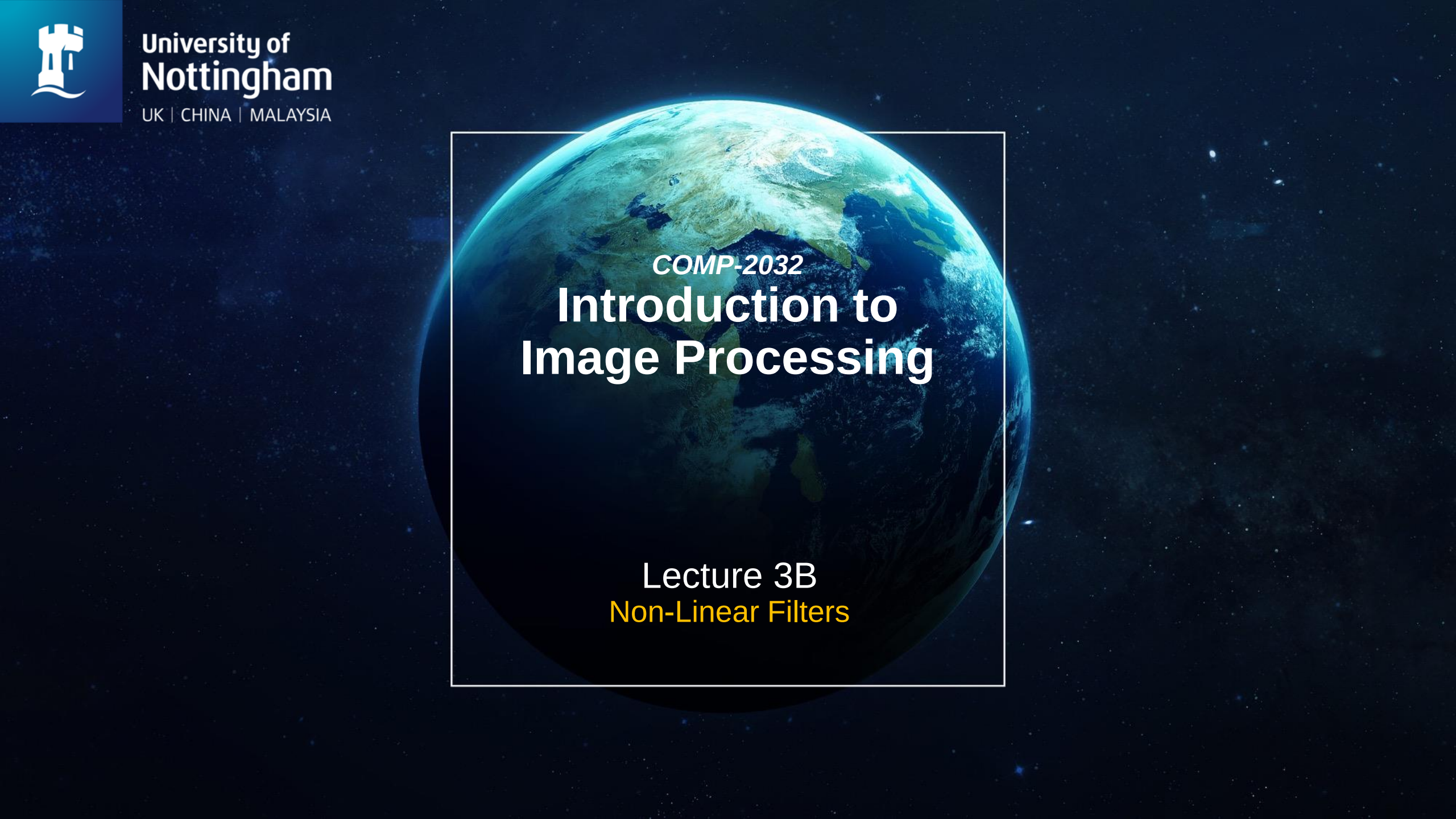
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COMP-2032
Introduction to
Image Processing
Lecture 3B
Non-Linear Filters

Learning Outcomes

IDENTIFY

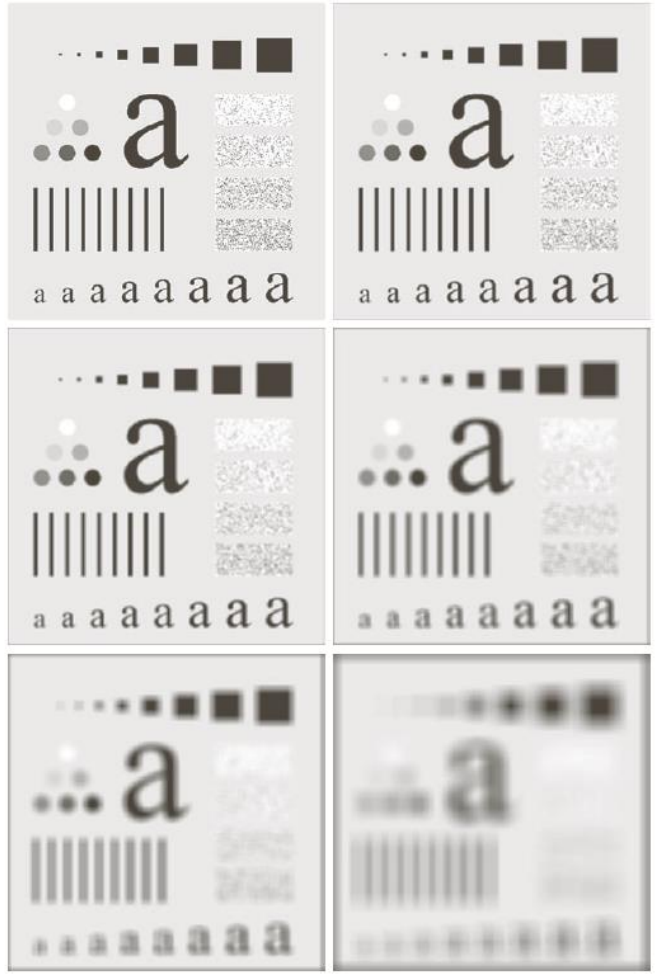
1. Median Filtering
2. Anisotropic Diffusion
3. Bilateral Filtering

Non-Linear Filters

- Convolution with a mask of weights compute a linear function of a set of pixel values
- Many operations can be implemented this way, but not all:

- *Median filtering*
- *Anisotropic diffusion/Bilateral filtering*

Linear filters smooth sharp image changes, **nonlinear filters** tend to preserve or even enhance them



Difference

Gaussian Smoothing

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Median Filtering

Salt and Pepper Noise

Sometimes sensors either fail to respond or saturate in error

- A false saturation gives a white spot in the image (salt)
- A failed response gives a black spot in the image (pepper)
- Sometimes called **speckle noise**

1%

10%

20%

An image with varying amounts of salt and pepper noise added

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Reducing Salt and Pepper Noise

Original

Salt & Pepper

Original

Salt & Pepper

Mean Filtering

Gaussian Filtering

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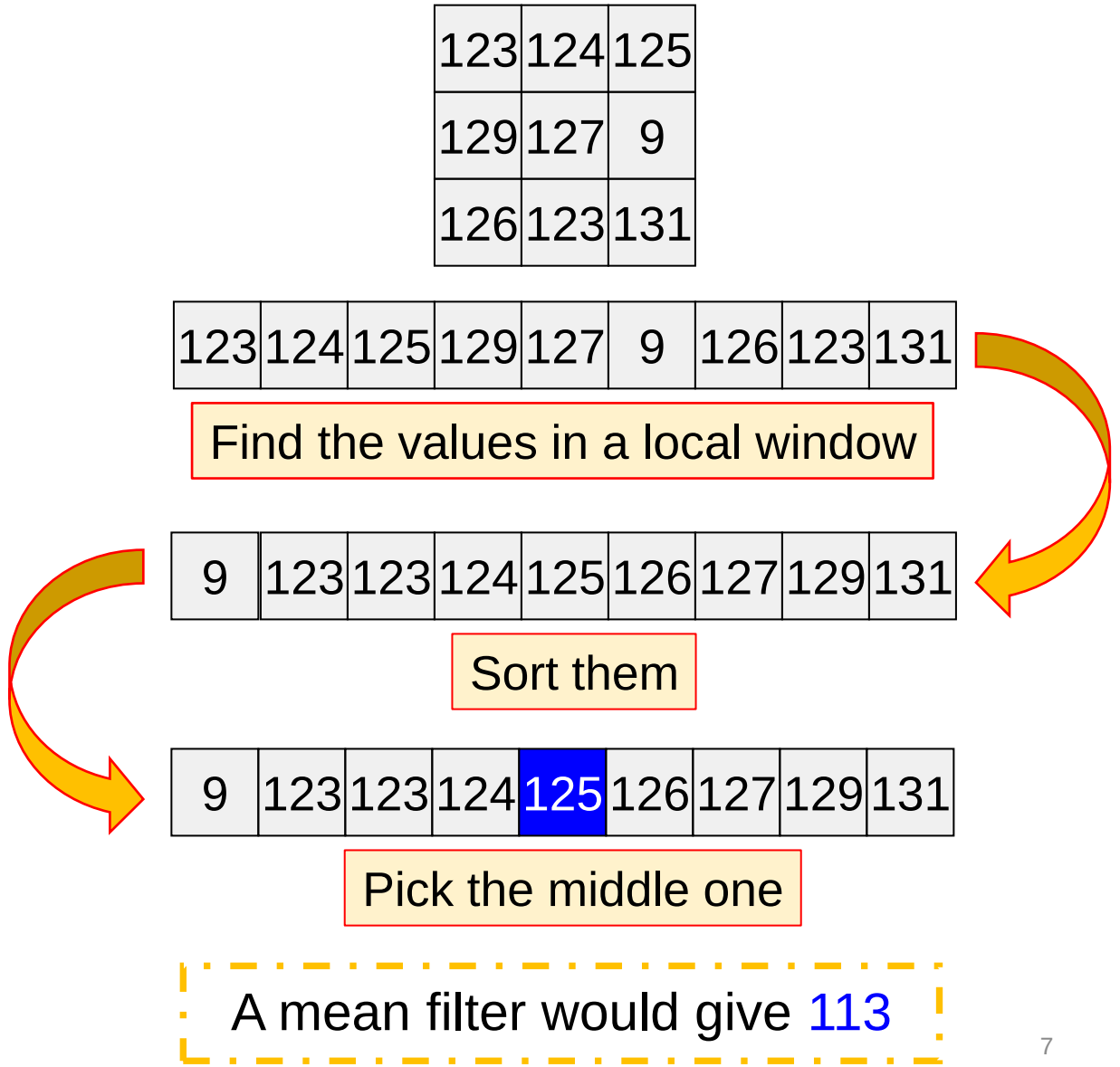
The Median Filter

Alternative: Median Filter

- Statistically the median is the middle value in a set
- Each pixel is set to the median value in a local window
- Result is a real pixel value, not a combination
- Noise pixels are outliers
- Noise would have to affect >1/2 the pixels to appear in the output



A mean filter would give 113

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The Median Filter

Original

Salt & Pepper

Gaussian

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Anisotropic Diffusion

Anisotropic Diffusion

- Median filtering is good given small regions of speckle noise, less good if edges are important
- There exist explicit edge-preserving smoothing ops

Diffusion

- Spreading out
- Mean and Gaussian filters can be seen as diffusion processes

Anisotropic

Not the same in all directions

Basic IDEA

- Mean and Gaussian filters make each pixel more like its neighbours
- Anisotropic diffusion makes each pixel more like those neighbours **that it is already similar to**

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Anisotropic Diffusion

We have a similar function, *s(p,q)*

- *s(p,q)* has values in the range from 0 to 1
- If the pixels *p* and *q* are similar then *s(p,q)* is close to 1
- If the pixel *p* and *q* are different then *s(p,q)* is close to 0

We use *s(p,q)* to compute a weighted average of pixel values

- The new value at a pixel *p*, is based on all its neighbours, *q*

$$p' = \frac{\sum q \times s(p,q)}{\sum s(p,q)}$$

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The Similarity Function

- The smoothing function, *s(p,q)* needs to be found
- If *d* is the difference between *p* and *q* and *D* is the maximum possible difference we can use:

$$\frac{D-d}{D}$$

Other functions often used include:

$$s(p,q) = e^{\left(\frac{p-q}{K}\right)^2}$$

$$s(p,q) = \frac{1}{1+\left(\frac{p-q}{K}\right)^2}$$

K determines the amount of smoothing

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Anisotropic Diffusion

The examples here used the similarity function:

$$s(p,q) = \frac{1}{1 + \left(\frac{p-q}{K}\right)^2}$$

With $K = 25$

Salt & Pepper

Gaussian

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Anisotropic Diffusion

A higher value of **K** gives greater smoothing, but **edges are still (quite) sharp**

K = 5

K = 25

K = 50

K = 100

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Anisotropic Diffusion

We can apply the filter repeatedly to give greater smoothing

Original | 1 Iteration | 2 Iteration | 3 Iteration

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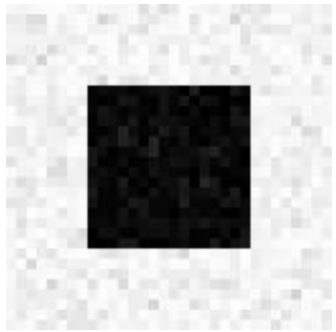
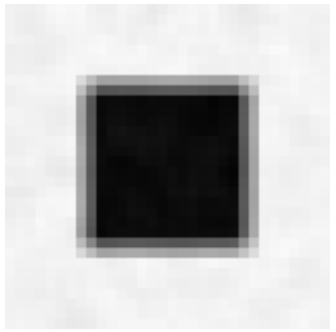
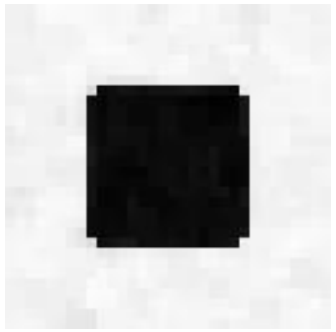
Reducing Noise near Edges



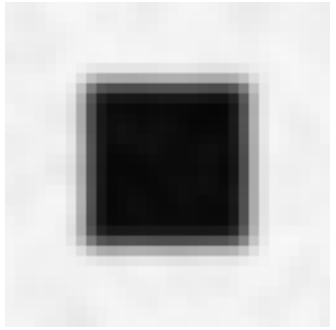
Noise Image



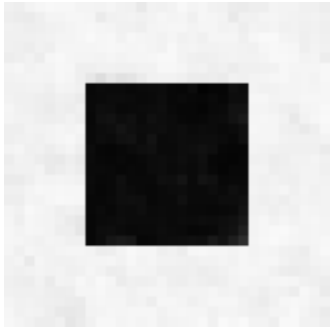
Mean



Median



Gaussian



Anisotropic Diffusion

Anisotropic diffusion is to mean filtering as ???? Is to Gaussian filtering…

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Bilateral Filtering

Bilateral Filtering

- Anisotropic Diffusion is related to mean filtering
- If the similarity function is always 1 we get a mean filter

$$p' = \frac{\sum q \times s(p,q)}{\sum s(p,q)}$$

Sums pixel values in a region

Counts pixel values in a region

Bilateral filters modify Gaussian smoothing in a similar way

- One Gaussian weights pixels that are near the source
- Another Gaussian weights pixels that have similar intensity to the source pixel

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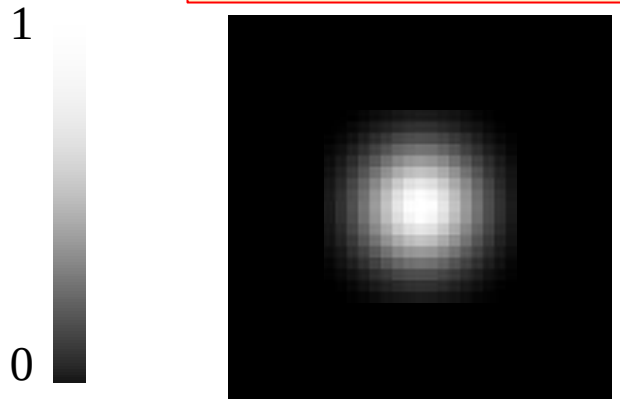
Gaussian Smoothing Again

$$GB[I]_{\mathbf{p}} = \sum_{\mathbf{q} \in S} G_{\sigma}\left(\| \mathbf{p} - \mathbf{q} \|\right) I_{\mathbf{q}}$$

normalized
Gaussian function



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Bilateral Filtering

$$BF[I]_{\mathbf{p}} = \frac{1}{W_{\mathbf{p}}} \sum_{\mathbf{q} \in S} G_{\sigma_s}(\|\mathbf{p}-\mathbf{q}\|)\, G_{\sigma_r}(|I_{\mathbf{p}} - I_{\mathbf{q}}|)\, I_{\mathbf{q}}$$

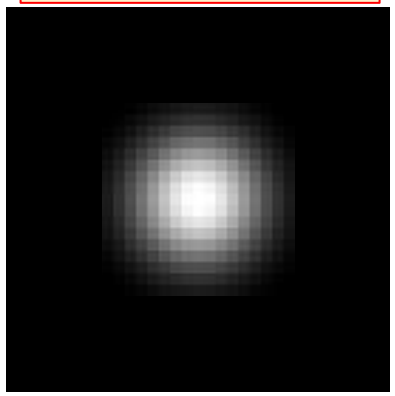
new

not new

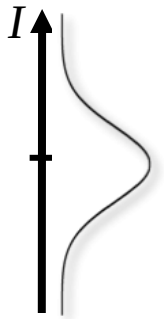
new

normalization factor

space weight



range weight



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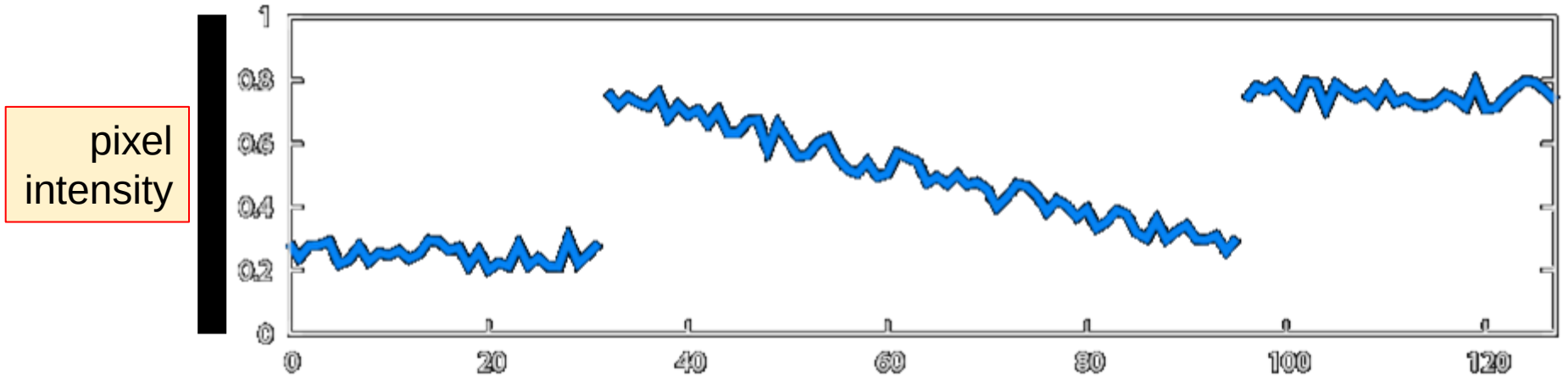
A One Dimensional Example

1D image = line of pixels

Better visualised as a plot



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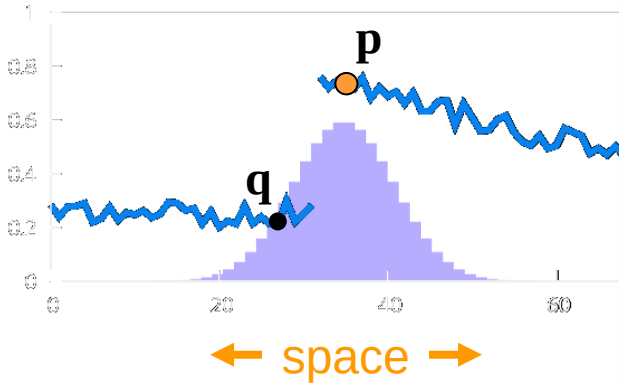
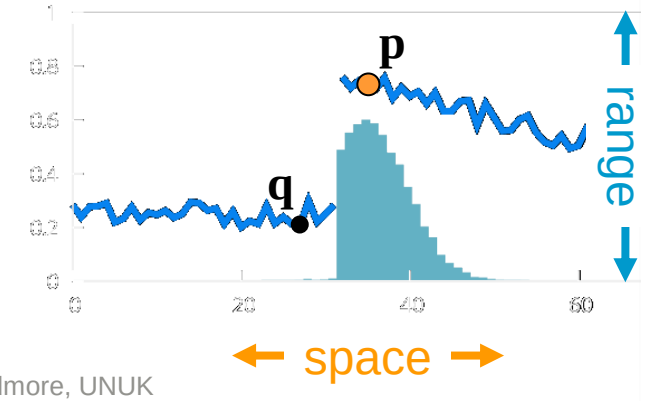
Gaussian & Bilateral Smoothing

Gaussian blur



Bilateral filter



$$GB[I]_{\mathbf{p}} = \sum_{\mathbf{q}\in S} G_{\sigma}(\|\mathbf{p}-\mathbf{q}\|) I_{\mathbf{q}}$$

space

$$BF[I]_{\mathbf{p}} = \frac{1}{W_{\mathbf{p}}} \sum_{\mathbf{q}\in S} G_{\sigma_s}(\|\mathbf{p}-\mathbf{q}\|) G_{\sigma_r}(|I_{\mathbf{p}}-I_{\mathbf{q}}|) I_{\mathbf{q}}$$

space range

normalization

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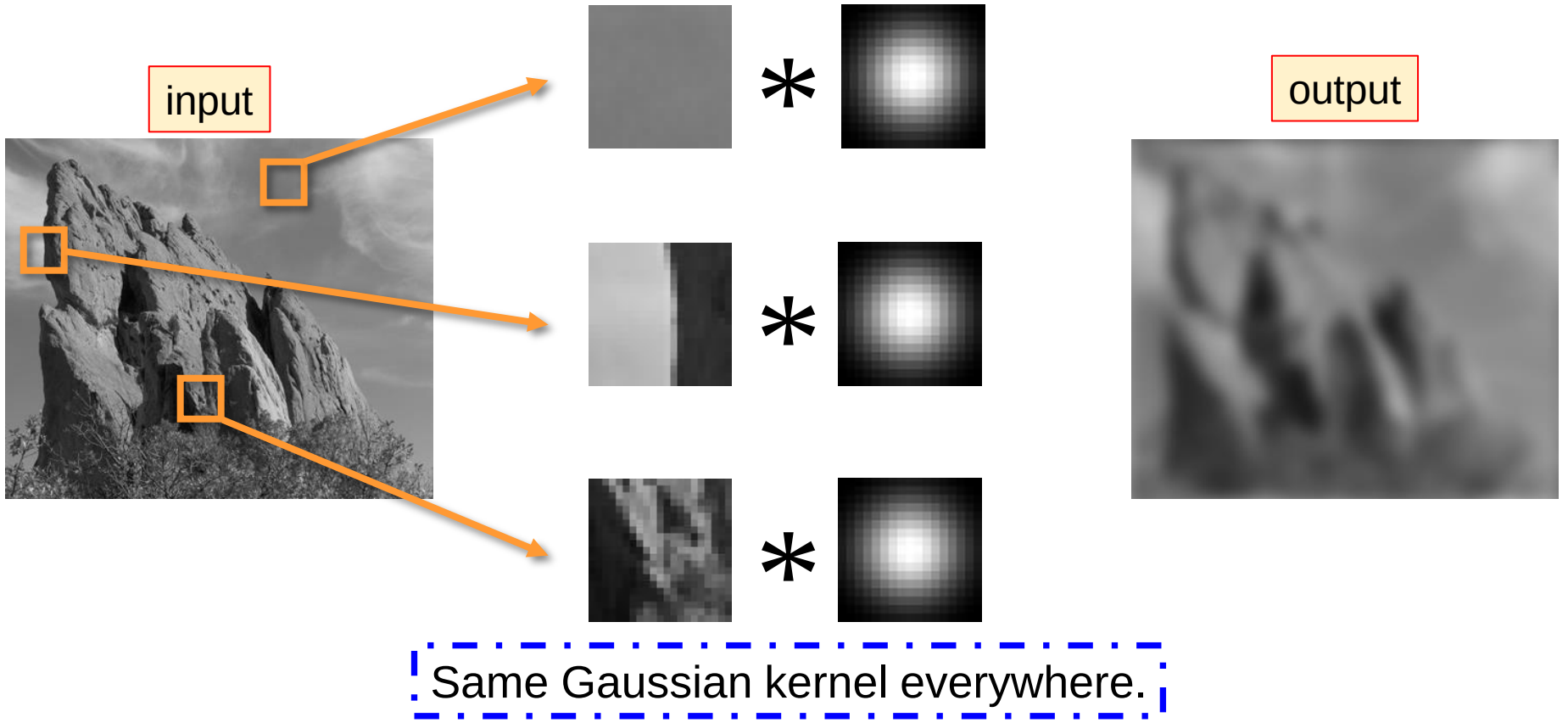
In 2D: Gaussian Smoothing



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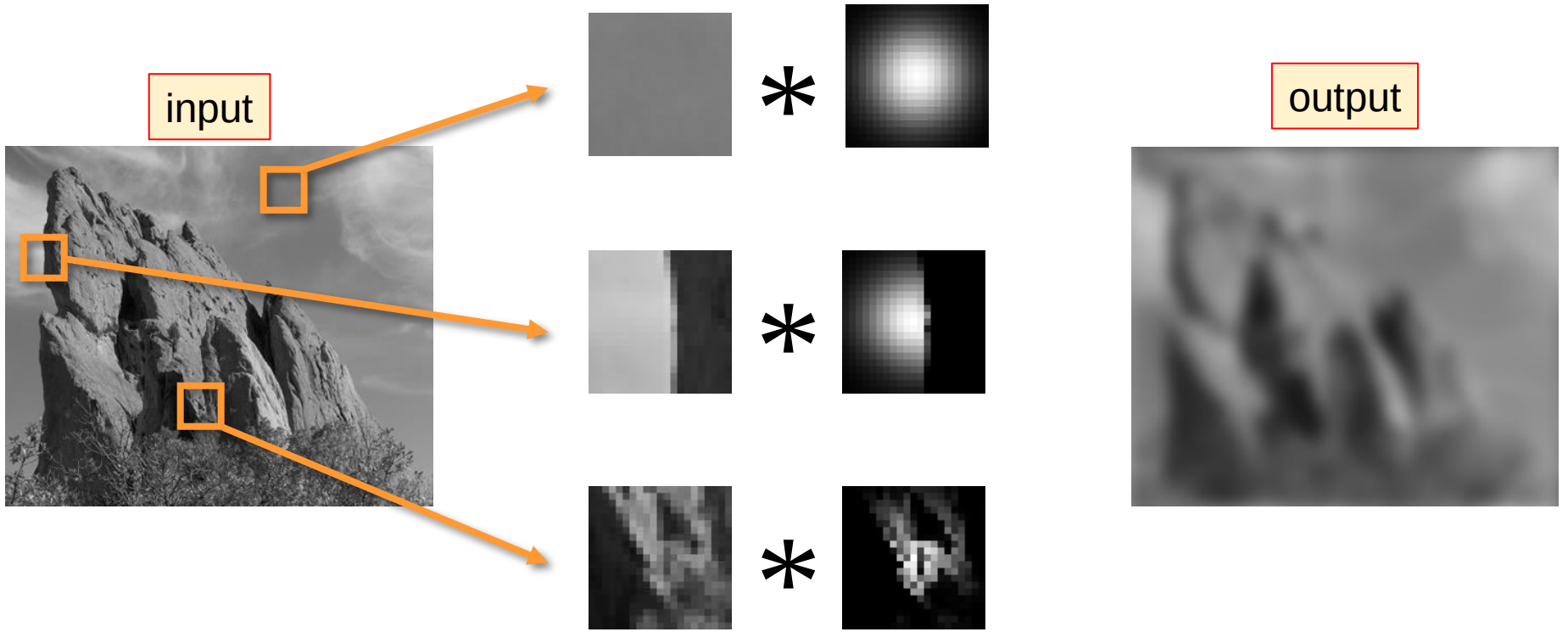
In 2D: Bilateral Filtering



The kernel shape depends on the image content.

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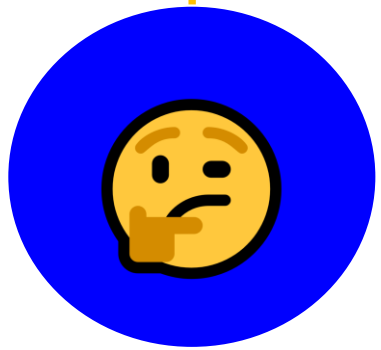
Summary

1. Median Filtering
2. Anisotropic Diffusion
3. Bilateral Filtering



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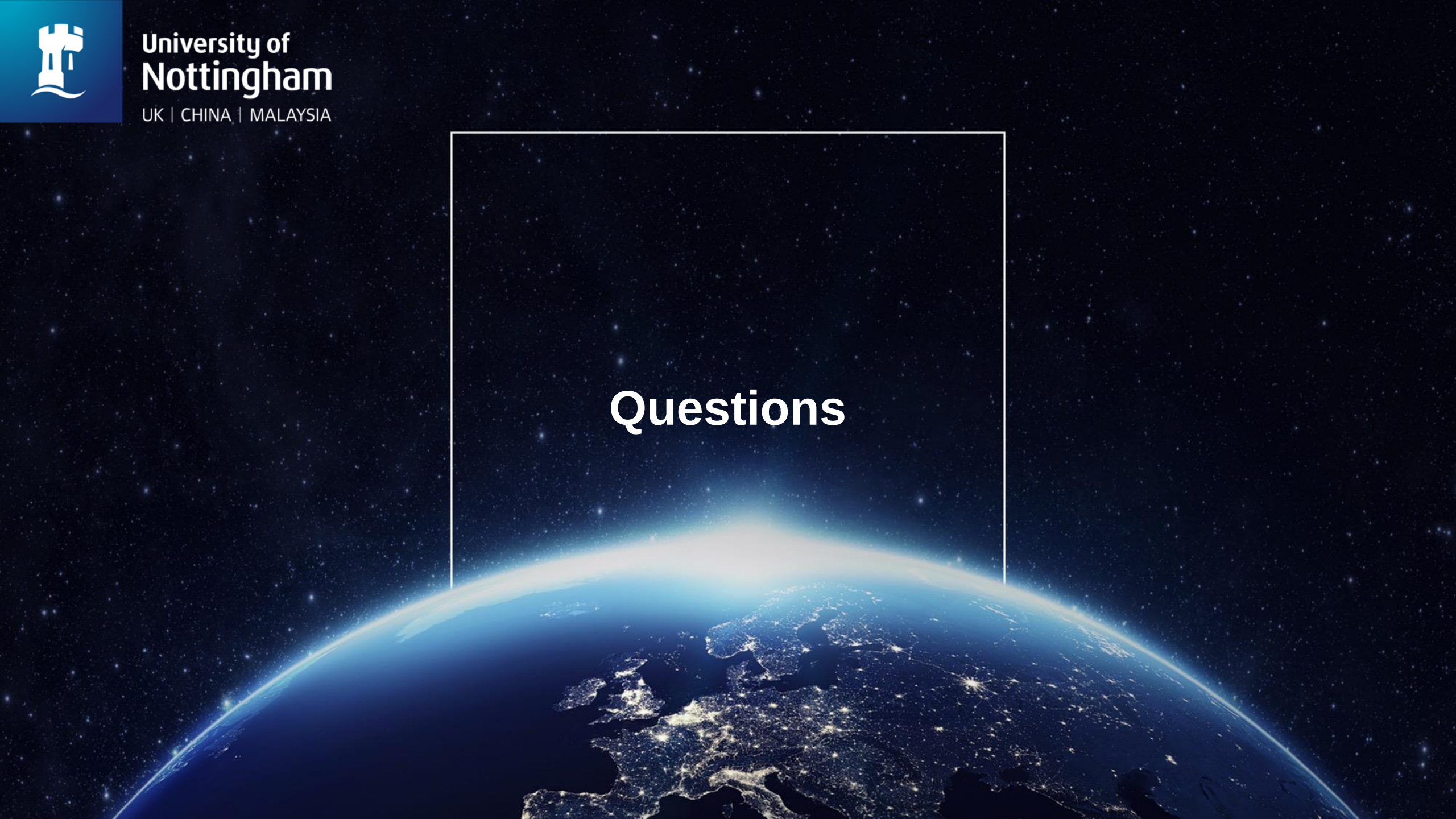
Questions

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NEXT:
Thresholding
&
Binary Images