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Question 1 (4 marks)

The following Python/SimpleITK code is intended to make a copy of the 3D medical image file `grayscale.nrrd`, storing the result in `grayscaleCopy.nrrd`

```
1    import SimpleITK
2    input_image = sitk.ReadImage('grayscale.nrrd')
3    sitk.WriteImage(input_image, 'grayscaleCopy.nrrd' )
```

a) **(1 mark)** When you try execute the above code in a Jupyter Notebook cell where SimpleITK was installed properly, the following error was generated:

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
<ipython-input-1-7aefec2f379c> in <module>()
      1 import SimpleITK
----> 2 input_image = sitk.ReadImage('grayscale.nrrd')
      3 sitk.WriteImage(input_image, 'grayscaleCopy.nrrd')
```

Why is this error happening?

the name sitk is not found / recognised

✓

b) **(1 mark)** Write down the line of code required to fix the above problem, including the line number it replaces.

1. import SimpleITK as sitk

✓

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c) **(1 mark)** After applying the correct fix in part b): one line of code in the above needs to be modified in order to write the output file in `.nii` format instead of `.nrrd` format. Write down this modified line of code, and indicate the line number to be modified.

3. sitk.WriteImage(input_image, 'grayscaleCopy.nii')

d) **(1 mark)** After applying the correct fix in part b): Suppose we remove line 2 and 3 from the above. This code can then be made to work in exactly the same way as the above that 1) in a single line of code, and 2) without creating the object `input_image`. Write down the modified line 2 as a replacement to line 2 and 3 that enables the above code to read `grayscale.nrrd` and write a copy of it to `grayscaleCopy.nrrd`.

sitk.WriteImage(sitk.ReadImage('grayscale.nrrd'), 'grayscaleCopy.nrrd')

Question 2 (7 marks)

The following Python/SimpleITK code is intended to perform seeded region growing segmentation on the input `A1_grayT1.nrrd` file, writing the output segmentation to `A1_grayT1_segmented.nrrd`.

```
1  import SimpleITK as sitk
2  img_T1 = sitk.ReadImage("A1_grayT1.nrrd")
3  initial_seed_point_indexes = [(132, 142, 96)]
4  seg_implicit_thresholds = sitk.ConfidenceConnected(img_T1,
5                                                     seedList=initial_seed_point_indexes,
6                                                     numberOfIterations=1,
7                                                     multiplier=2,
8                                                     initialNeighborhoodRadius=1,
9                                                     replaceValue=1)
10 sitk.WriteImage("A1_grayT1_segmented.nrrd")
```

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a) **(1 mark)** The code does **not** work properly. When executed inside a Jupyter Notebook cell, it returns with an error message:

```
NotImplementedError: Wrong number or type of arguments for overloaded function
```

The `A1_grayT1.nrrd` file is present in the correct directory, so this is not the reason for the error. Specify the line number of the above code that would generate this error message, and the reason why?

line 10 A1_grayT1_segmented.nrrd does not have a soure file.
write what file to A1_grayT1_segmented.nrrd ✓

b) **(1 mark)** Write down the line of code required to fix the above problem. That is, your code should replace the line of code you identified in part a) that generates the error message.

sitk.WriteImage (seg_implicit_thresholds, "A1_grayT1_segmented.nird") ✓

c) **(1 mark)** One line of code needs to be modified in order to make the interior of the segmentation in `A1_grayT1_segmented.nrrd` have a value of 255. Write down this modified line of code and its line number.

10. sitk.WriteImage (sitk.Cast (seg_implicit_thresholds, sitk.sitkUInt8),
"A1_grayT1_segmented.nrrd")

or 4. replaceValue = 255 ✓

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d) **(3 mark)** Suppose the 26-connected neighborhood of the seed has a mean pixel intensity value of 100 and a standard deviation of 10. On the 96th slice, the 8-connected neighborhood surrounding the seed is:

68	95	101
78	100 (seed)	111
82	105	129

$M = 100$. $\sigma = 10$.

$M \pm C\sigma$ $C = 2$ $80 - 120$

Assume the thresholding filter (line 4 to line 9) works as intended, fill in the output of the segmentation of the following 3x3 grid corresponding to the above 3x3 input:

0	1	1
0	1	1
1	1	0

e) **(1 mark)** The program as it is (after applying the correct fix in part b)) reads an input file of type .nrrd and writes the segmentation to disk as a file also of type .nrrd. One line of code needs to be modified to make the program write the segmentation to disk in NIFTI format (with a .nii extension) instead. Write down this modified line of code and its line number.

10. sitk.WriteImage(seg_implicit_thresholds, "A1_gray T1- Segmented.nii")

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Question 3 (1 marks)

Suppose you have a 3D image with 128 voxels along X, 256 voxels along Y, and 60 voxels along Z. It covers a physical area of 20 mm × 20 mm × 20 mm.

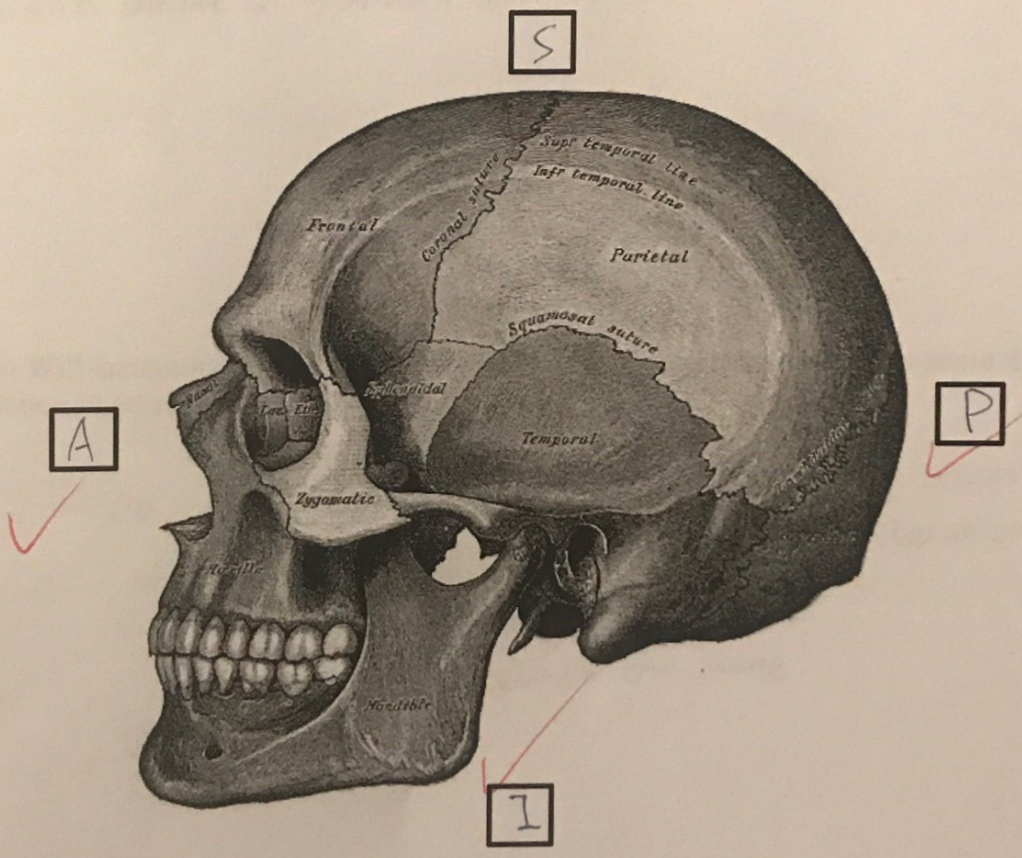
a) **(1 mark)** What is the size of each voxel? I.e. how much does each voxel measure along X, Y, and Z?

X: $\frac{20}{128} = 0.1563\ mm$ Y: $\frac{20}{256} = 0.07813\ mm$

Z: $\frac{20}{60} = 0.3333\ mm$

Question 4 (1 mark)

Correctly fill in the four boxes below with: S for superior, I for inferior, A for anterior, P for posterior.



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Question 5 (2 marks)

Recall the region-growing segmentation algorithm we covered in class:

Put one or more seed points in the 3D point set P.
Repeat the following for a fixed number of iterations:
Calculate the mean intensity in the neighbourhoods of the points in P.
Find all points that (1) are connected to the points in P, and (2) have intensities within N standard deviations of the calculated mean intensity.
Add those points to P.

a) **(1 mark)** Describe one assumption that needs to be satisfied by the appearance (on the image) of an object that is to be **successfully** segmented by this algorithm. (Hint: One way to think about this is to imagine the appearances of objects that this algorithm would fail to segment properly.)

when the surface of the object is not uniform or reflective couldn't define a standard deviation.

-1

b) **(1 mark)** Will increasing the number of iterations of the above algorithm always cause the resulting segmentation to grow in size? Why or why not?

no. this algorithm calculates the mean intensity of the segmented area after the 1st iterations. the mean value will become stable the result size stays the same

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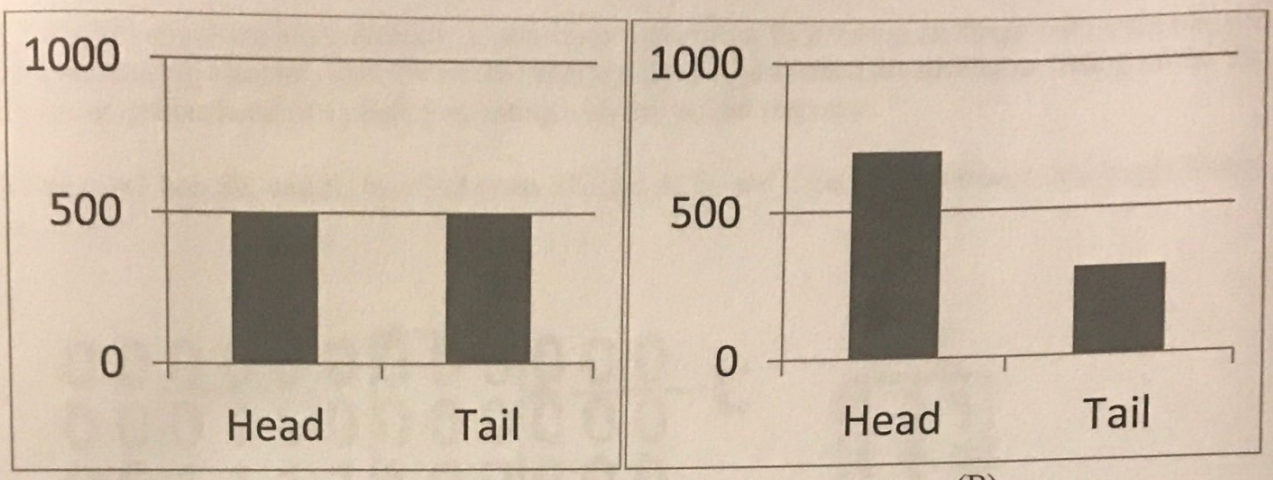
Question 6 (2 marks)



Shown above are two histograms giving the results of 1,000 coin flips. Recall that this is the formula for information entropy:

$$H(X) = -\sum_{x} p(x) \log_2 p(x)$$

a) **(1 mark)** Which one has **higher** information entropy? (A) or (B)?

B ✗

b) **(1 mark)** The log in the information entropy formula has base 2. How does this affect the interpretation of the number calculated by the formula?

2 - bits e - nats 10 - bans

It does not affect the interpretation ✓

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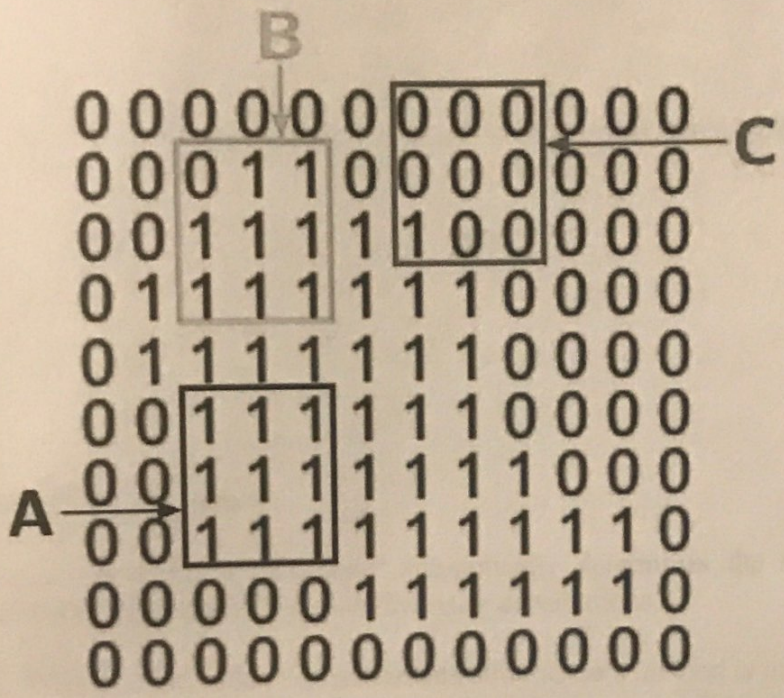
Question 7 (4 marks)

Morphological operation is a collection of non-linear operations by *probing* an image with a simple, pre-defined, structuring element (SE). Two non-linear operations performed are **hitting** or **fitting** of the SE within the neighbourhood of a pixel, generating a binary output response.

Let S1 be a 3x3 box SE, and S2 be a 3x3 cross SE, and A, B, and C be 3x3 sub-image of a larger binary image.



S_1

1 1 1
1 1 1
1 1 1

S_2

0 1 0
1 1 1
0 1 0

Tabulate the following 8 entries with either a **YES** or a **NO** as the response for probing B and C with S1 and S2 for **fitting** and **hitting** operations. The response for probing the sub-image A is done for you:

		A	B	C
FIT	S_1	yes	No	No
	S_2	yes	Yes	No
HIT	S_1	yes	Yes	Yes
	S_2	yes	Yes	No

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Question 8 (2 marks)

Morphological opening and closing operations are performed with dilation and erosion in sequence. Circle the correct answer for the following statements:

a) Dilated image ***J*** has ones in all locations (x,y) of an origin of the SE ***S*** at **which *S* FITS the input image I.**

YES or **NO** ✓

b) Morphological opening of an image by a structuring element **is an erosion followed by a dilation.**

YES ✓ or **NO**

Question 9 (2 marks)

Otsu's thresholding technique automatically determines the optimal thresholding value based on some statistical measures of the pixel intensity distributions.

1) Which of the following statements about Otsu's method is true? Circle it.
   a) It minimizes the intra-class variance between the foreground and background pixels
   b) It minimizes the inter-class variance between the foreground and background pixels
   c) It maximizes the inter-class entropy between the foreground and background pixels

2) Otsu's thresholding technique works well when
   a) The pixel intensity has a Gaussian distribution
   b) The pixel intensity has a bimodal distribution with a clear/sharp valley
   c) The pixel intensity has a Rayleigh distribution where the intensity value is related to its directional component, such a case is often observed in ultrasound images.