Loughborough University

INDUSTRIAL MACHINE VISION WITH AI

22WSD911

Semester 2 2023 In-Person Exam paper

This examination is to take place in-person at a central University venue under exam conditions. The standard length of time for this paper is **2 hours**.

You will not be able to leave the exam hall for the first 30 or final 15 minutes of your exam. Your invigilator will collect your exam paper when you have finished.

Help during the exam

Invigilators are not able to answer queries about the content of your exam paper. Instead, please make a note of your query in your answer script to be considered during the marking process.

If you feel unwell, please raise your hand so that an invigilator can assist you.

You may use a calculator for this exam. It must comply with the University's Calculator Policy for In-Person exams, in particular that it must not be able to transmit or receive information (e.g. mobile devices and smart watches are **not** allowed).

Loughborough University

INDUSTRIAL MACHINE VISION WITH AI

(22WSD911)

Semester 2 2023 2 Hours

Answer **ALL QUESTIONS**.

All questions carry the marks shown.

Any approved University calculator is permitted.

1.

a) A CNN processes the image section shown in **Figure Q1b(i)** with the first hidden layer convolving the image with the filter shown in **Figure Q1b(ii).**

i. Determine the output values passed to the next layer, showing all working for the entire image area. You do not need to include any diagrams, just the calculations. [8 marks]

ii. Draw a diagram showing the output of the filtering operation. [2 marks]

0.36	0.79	0.33
0.14	0.88	0.42
0.62	0.39	0.51

Figure Q1b(i).

0.8	1.4
-1.2	0.45

Figure Q1b(ii).

b) Draw a diagram of the layout of the input layer and the first hidden layer for the CNN that takes the input image shown in **Figure Q1b(i)** with the first hidden layer weighted by **Figure Q1b(ii).** Include values in all nodes of the network. [8 marks]

c)

i. Describe the operation of a Max Pooling layer in a CNN, including a diagram showing the process being carried out on a single section of the image segment **Figure Q1c**. [6 marks]

ii. Draw the output image array of the max pooling operation carried out on the image segment in **Figure Q1c**. [2 marks]

4	3	8	5
9	1	3	6
6	3	5	3
2	5	5	2

Figure Q1c.

iii. For an input image of size 2048 by 768 pixels, calculate the size of the output image after the max pooling operation with a 2x2 pooling window and stride of 2. Show all working. [3 marks]

d) Batch Normalisation is often included in convolutional neural network hidden layers. Explain, including contour plot diagrams of the loss function:

i. The issue it addresses includes reference to varying contour width and steepness. [8 marks]

ii. Describe two benefits of including batch normalisation in the CNN and how the mean and standard deviation of the data is affected when the data are normalised. [6 marks]

2.

a) Support Vector Machines (SVMs) are simple but often very effective classifiers which allow linear partitioning of non-linearly separable data by transforming it to a higher dimension.

Why and how would we transform data to higher dimensions. Include descriptions of the **polynomial kernel** and the **radial basis function**. Include a diagram for each kernel to illustrate your answer. [10 marks]

b) Explain the differences between hard-margin SVMs and soft-margin SVMs. [8 marks]

c) For the data distribution shown in **Figure Q2c**, what is the hinge loss for the data points labelled A, B, C, and D? [8 marks]

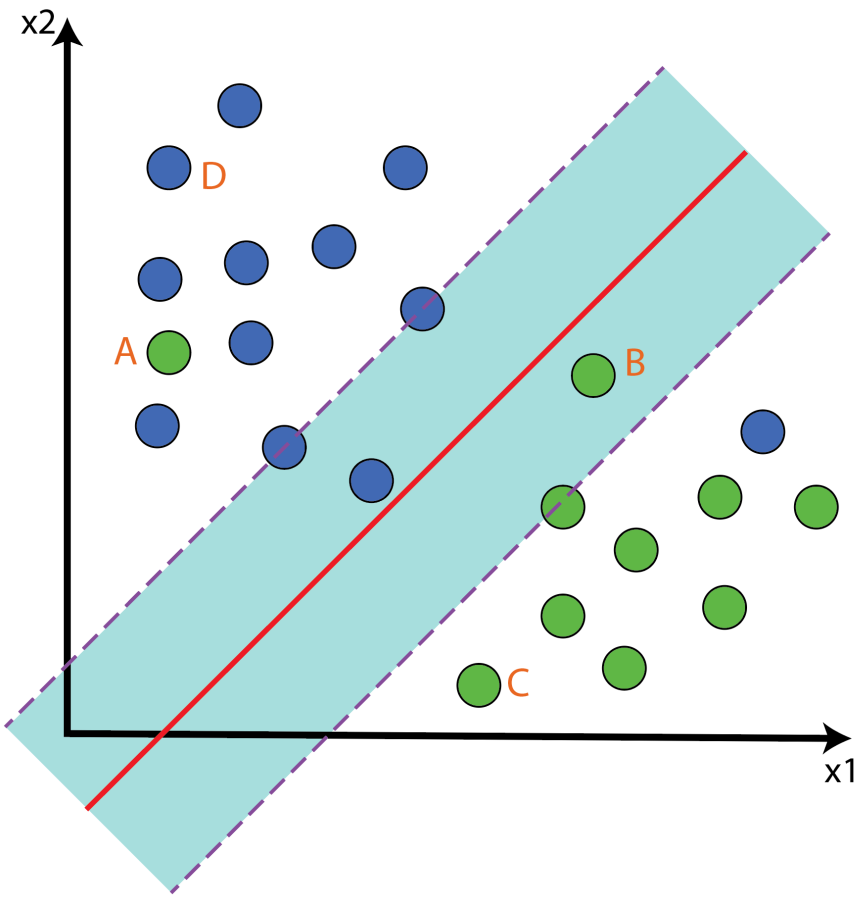

Figure Q2c.

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3.

a) A very common Neural network topology for image processing is the Convolutional Neural network (CNN). The convolution operation is best performed in the frequency domain.

Given the image section shown in **Figure Q3a** as the starting point, explain all steps in the conversion to its 2D FFT representation. You do not need to include formulae, calculations, or drawings in your answer but should explain where the DC bias appears, where high and low frequencies are situated, where the Fourier coefficients lie, where the Nyquist frequency lies, and how the Nyquist is usually repositioned at the end of the transformation. [10 marks]

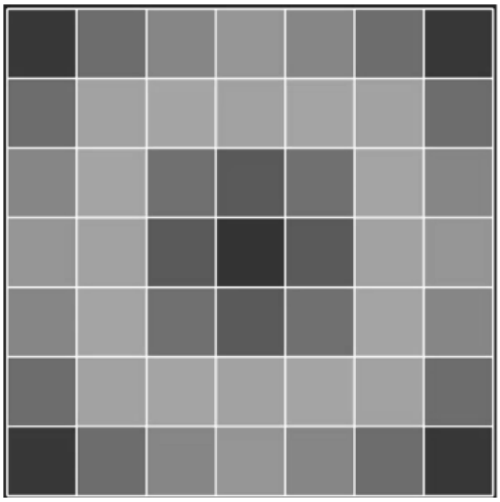

Figure Q3a.

b) **Figures Q3b(i), Q3b(ii), Q3b(iii), and Q3b(IV) (pages 5 & 6)** show four representations of greyscale sinusoids within an image.

Referring to the 2D FFT axes images provided on the last two pages of this examination paper, draw the approximate FFT output one would expect from each image and include a single sentence describing the image in terms of sinusoids. Take the centre frequency as 800hz.

Remove the last two pages (pages 8 & 9) from the examination paper and attach it to your answer sheet. [12 marks]

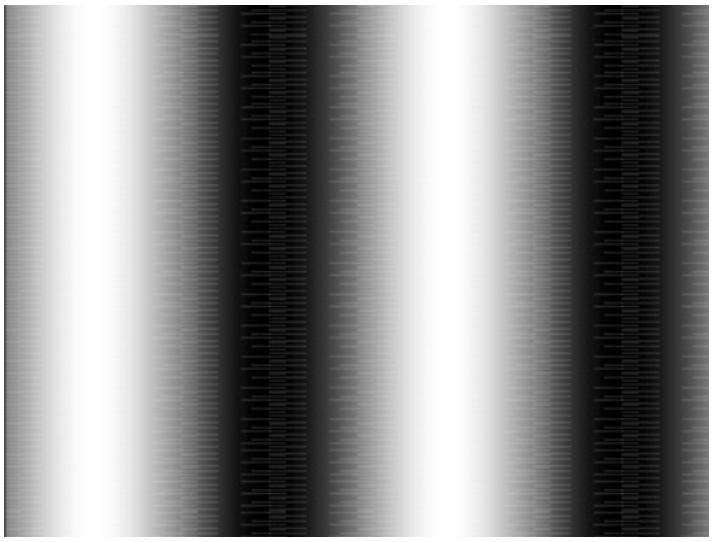

Figure Q3b(i)

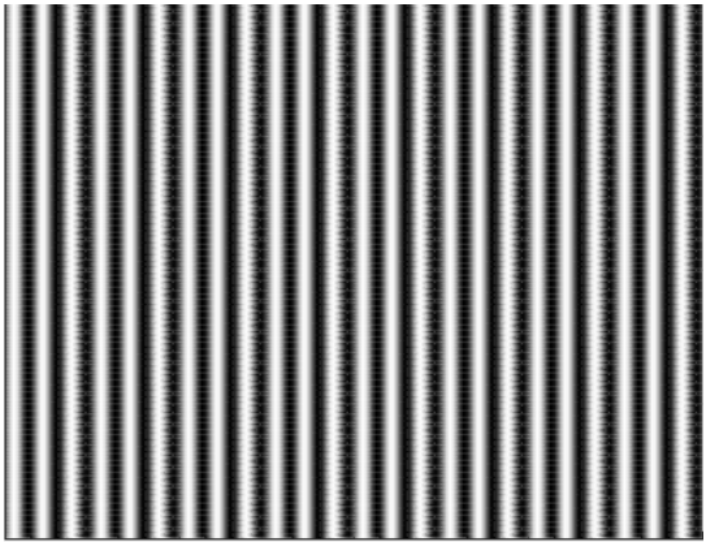

Figure Q3b(ii)

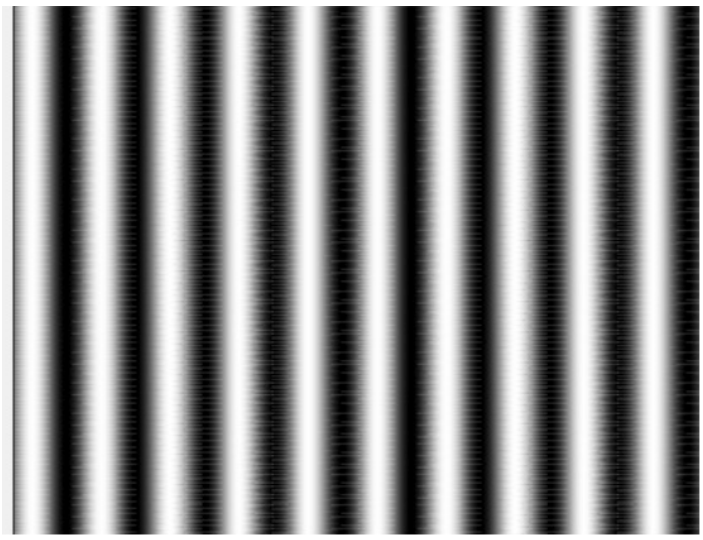

Figure Q3b(iii)

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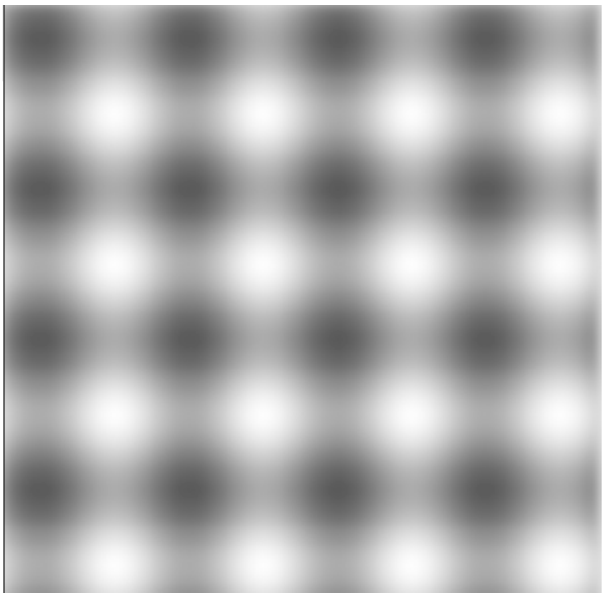

Figure Q3b(IV)

c) Another application for the 2D FFT is in image filtering and correlation. **Figure Q3c(i) (page 7)** shows the ubiquitous Lenna reference Image from MIT and its associated FFT. **Figure Q3c(ii) (page 7)** shows a Gaussian function.

We can use this Gaussian function to filter the Lenna image by taking its FFT and pointwise multiplying the two FFTs together. We see the resulting filtered image when we take the inverse FFT.

i. Including a brief description, draw the FFT of the Gaussian function. [3 marks]

ii. Including a short description, draw the output FFT after pointwise multiplication. [3 marks]

iii. What type of filter will this produce, and what effect will the filter have on the Lenna image? [3 marks]

Figure Q3c(i)

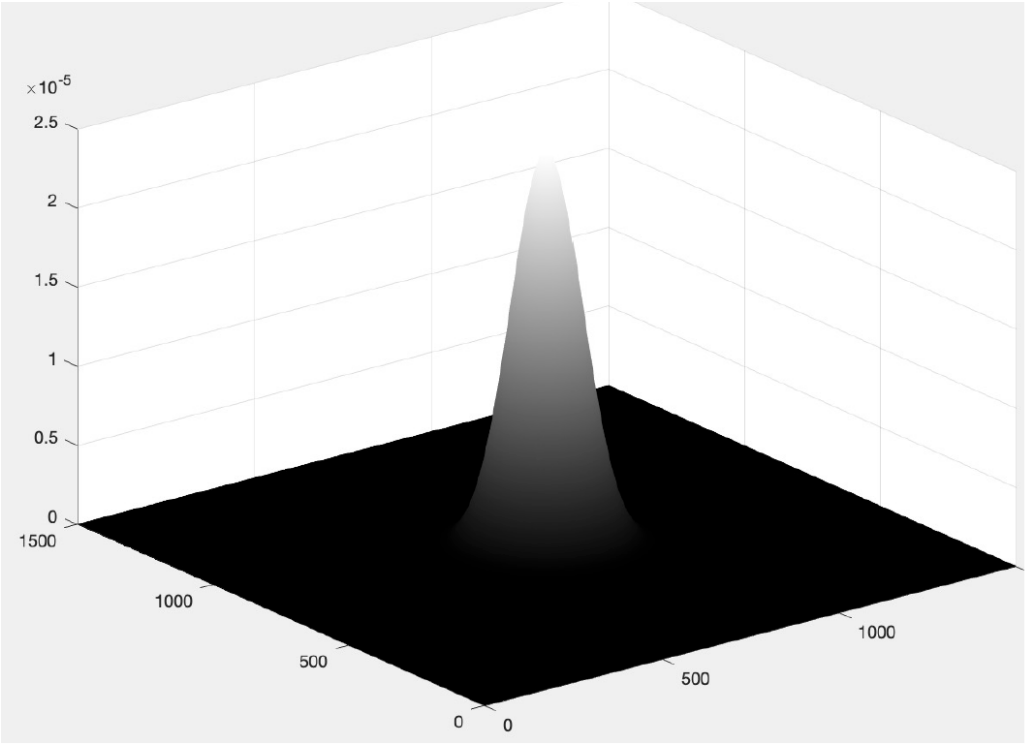

Figure Q3c(ii).

Tony Sutton

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For Q3 part b, complete these diagrams and detach the two sheets from the booklet, then attach them to your answer booklet.

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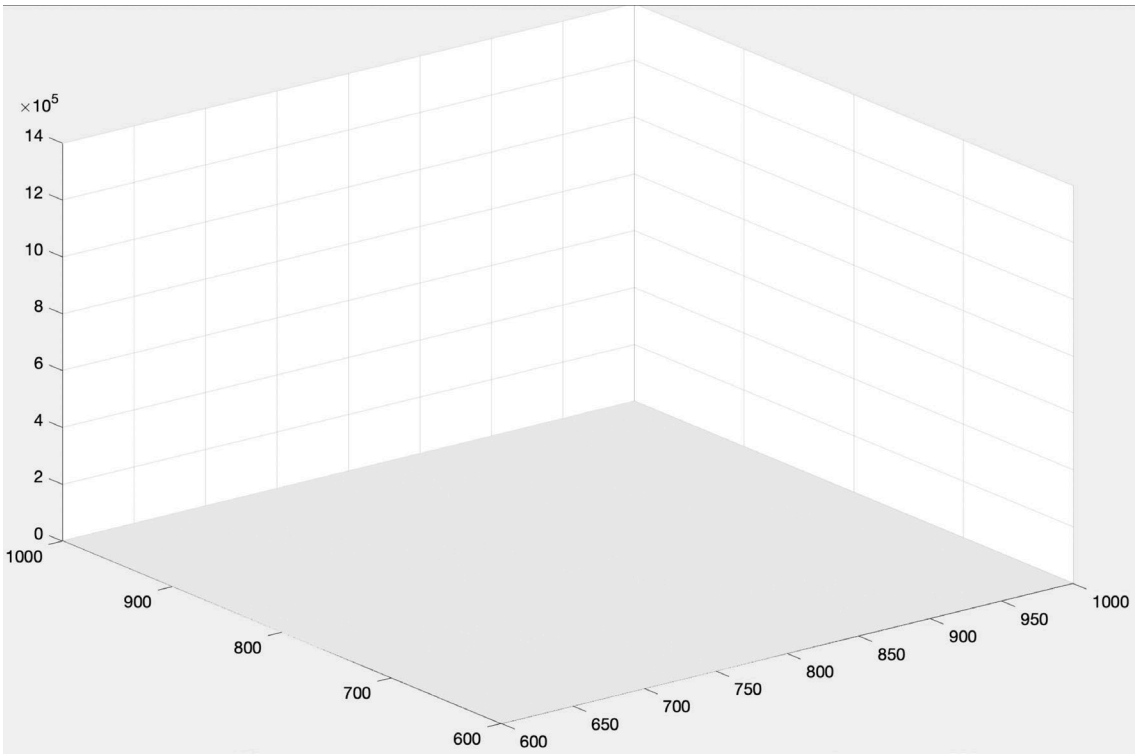
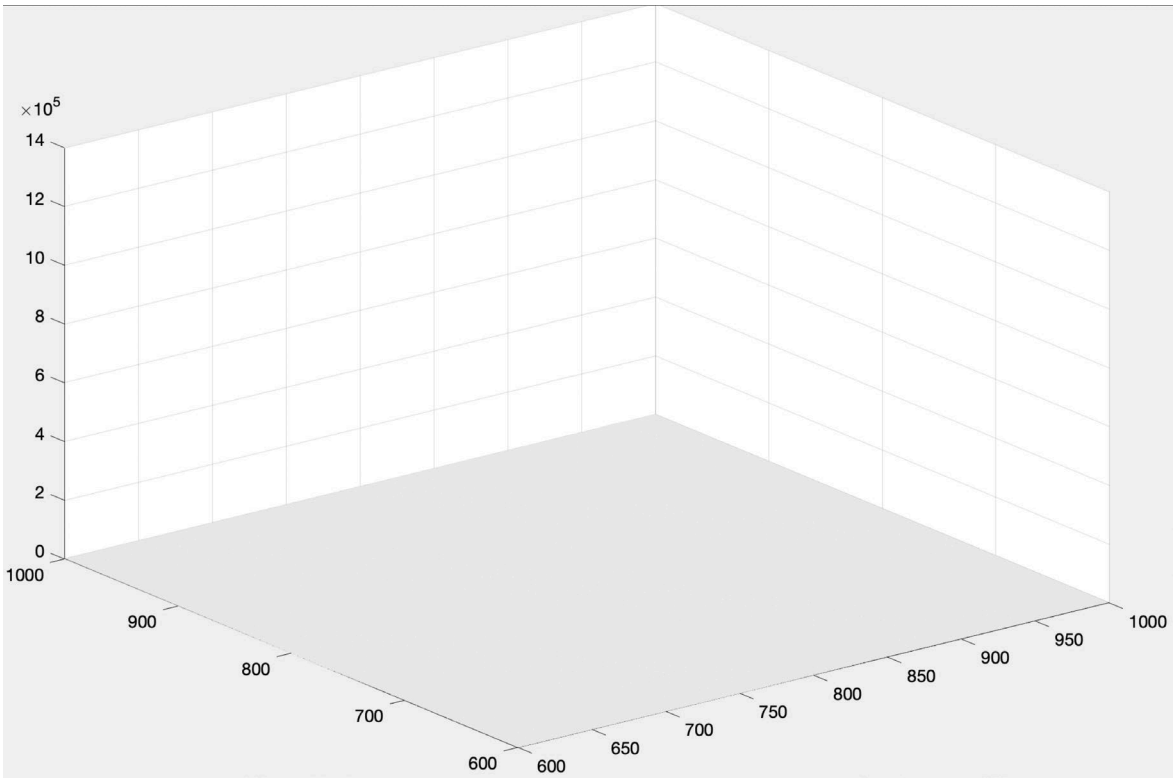
Please draw your output FFT for Figure Q3b(i) in the diagram below.



Please draw your output FFT for Figure Q3b(ii) in the diagram below.



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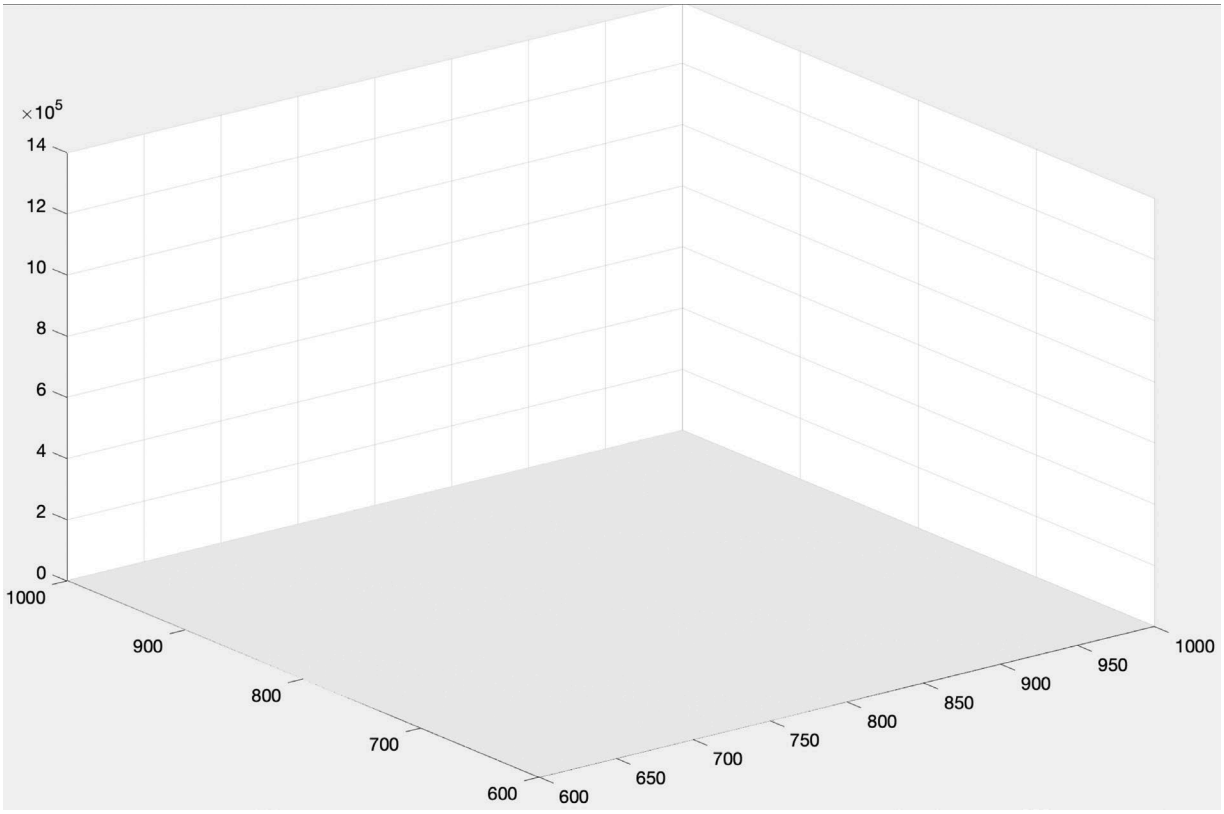
Student ID_____

Please draw your output FFT for Figure Q3b(iii) in the diagram below.



Please draw your output FFT for Figure Q3b(iv) in the diagram below.