Lab 4: Understanding 1-D and 2-D signals in time, space, and frequency

GAIA Statement: I did use a form of generative AI during the completion of this assignment. If I did, I understand that I must also turn in a completed copy of the course's GAIA Disclosure Worksheet for this assignment.

Part 1: Experimental Setup

[Nothing required]

Part 2: ECG Cable Setup and Electrode Placement

[Nothing required]

Part 3: Electrooculogram (EOG) Activity: VOR

	Filenames (.iwxdata and .mat)
Large, fast rotation	lab4p3_large_fast.mat and lab4p3_full.iwxdata
Small, fast rotation	lab4p3_half_fast.mat and lab4p3_half.iwxdata
Large, slow rotation	lab4p3_large_slow.mat and lab4p3_full_slow.iwxdata
Small, slow rotation	lab4p3_half_slow_Export.mat and lab4p3_half_slow.iwxdata

Part 4: Electrooculogram (EOG) Activity: Saccades

	Filename (.iwxdata and .mat)
Large, fast saccade	lab4p4_long_fast_Export.mat and lab4p4_long_fast.iwxdata
Small, fast saccade	lab4p4_short_fast_Export.mat and lab4p4_short_fast.iwxdata
Large, slow saccade	lab4p4_long_slow_Export.mat and lab4p4_long_slow.iwxdata
Small, slow saccade	lab4p4_short_slow_Export .mat and lab4p4_short_slow.iwxdata

Part 5: Electrooculogram (EOG) Activity: Muscle Fatigue

	Filename (.iwxdata and .mat)
Eyelids closed tightly	lab4p5_brannon_Export.mat and lab4p5_brannon.iwxdata

Part 6: Visualizing EOG data in MATLAB

1) Include Figure 1 that you generated in Step 2. How does the movement of your eyes correspond to the features of the EOG?

All head movements produced a waveform signal as seen in Figure 1. A fast head movement produced a higher frequency of the signal with a larger difference in signal magnitude relative to slow movements. The short and fast head movement (Subplot 3) produced a higher frequency than the large and fast head movement (Subplot 1), but this is expected because there is a shorter distance to cover by the head, however the difference in amplitude is very close (~1000 mV to ~ 800 mV). The large and sow head movement (Subplot 2) and the short and slow head movement (Subplot 4) have very similar frequencies, however the peaks in subplot 4 are much sharper than the peaks in subplot 2. The difference in amplitude is also almost the same.

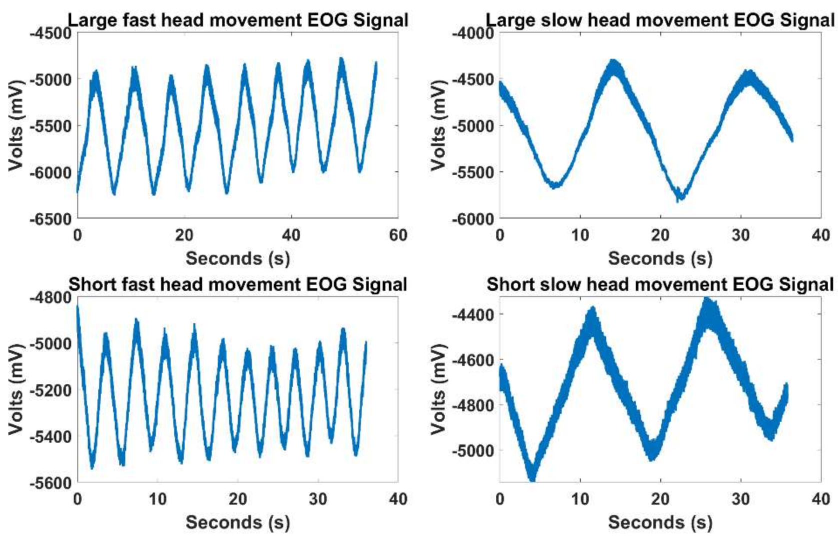

Figure 1. EOG signal of different types of head movements

2) Include Figure 2 that you generated in Step 4. How does the movement of your eyes differ from that in the previous step and how does it affect the features of the EOG?

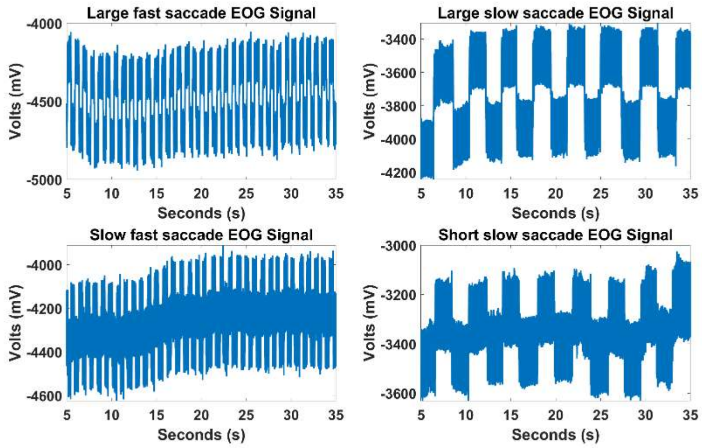

Figure 2. EOG signal of eye movements between long and short Saccades

The movement of the subject's eyes between the saccades creates more of a square wave in comparison to the sinusoidal wave created during the head movements. The eye movements also have a much higher frequency in comparison to the head movements as seen in Figure 2, there are many more cycles in each of the subplot in comparison to Figure 1.

3) Include Figure 3 that you generated in Step 5. What kind of a curve does this EOG signal remind you of? How might you model it?

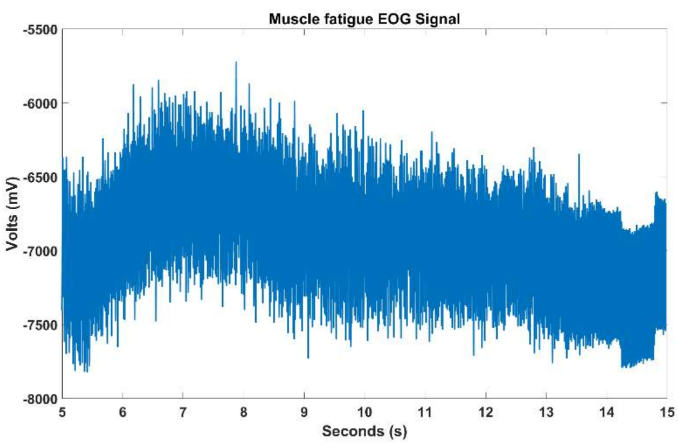

Figure 3. EOG signal of eye muscles during and after clenching

The curve in Figure 3 reminds me of a damping curve which is a sin wave that gradually decreases in amplitude. This is visible in Figure 3 as the curve begins at a high amplitude once the subject squeezed her eyes, and then gradually decreases in amplitude and plateaus to the same amplitude as before the eyes were squeezed due to muscle fatigue.

Part 7: Analyzing your VOR data in the time domain

	# Cycles	Total time (s)	Frequency (cyc/s)
Large, fast rotation	8	52.805	0.152
Small, fast rotation	12	35.960	0.334
Large, slow rotation	2.25	36.380	0.062
Small, slow rotation	2.75	35.664	0.077

	Peak-to-Peak Amplitudes (mV)	Cycle Durations (s)
Large, fast rotation	1355, 1396, 1264, 1401, 1295, 1192, 1228, 1252	7.41, 6.45, 6.73, 7.21, 6.19, 5.56, 6.09
Small, fast rotation	569.1, 618.7, 541.6, 560.7, 518.0, 441.7, 482.9, 471.5, 445.5, 555.4	3.66, 3.56, 3.73, 3.61, 2.96, 2.93, 3.06, 3.06, 2.91
Large, slow rotation	1403 1440	16.71
Small, slow rotation	778.2 728.6	13.95

t-test for amplitude (fast, large and fast, small)

Null hypothesis: The fast, large head movement rotation amplitudes and the fast, small head rotation peak amplitudes are equal

t-value: 1

p-value: 5.1418×10^{-14}

Conclusion of test: The null hypothesis is rejected

t-test for amplitude (fast, large and slow, large)

Null hypothesis: The fast, large head movement rotation amplitudes and the slow, large head rotation peak amplitudes are equal

t-value: 0

p-value: 0.066243

Conclusion of test: The null hypothesis was failed to be rejected

t-test for cycle duration (fast, large and fast, small)

Null hypothesis: The fast, large head movement rotation cycle times and the fast, small head rotation cycle times are equal

t-value: 1

p-value: 3.924×10^{-9}

Conclusion of test: The null hypothesis is rejected

t-test for cycle duration (fast, large and slow large)

Null hypothesis: The fast, large head movement rotation cycle times and the slow, large head rotation cycle times are equal

t-value: 1

p-value: 6.2628×10^{-6}

Conclusion of test: The null hypothesis is rejected

Part 8: Analyzing your VOR data in the frequency domain

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1) Include Figure 4 that you generated in Steps 3 & 4.

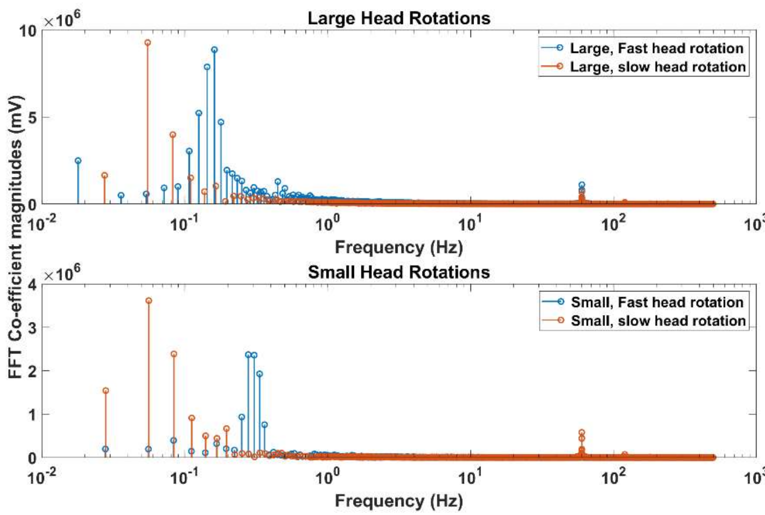

Figure 4. FFT of EOG signal head rotations

2) Determine the (non-zero) frequency where the FFT has the largest amplitude in each case and complete the following table:

	frequency (Hz)
Large, fast rotation	0.161
Small, fast rotation	0.278
Large, slow rotation	0.054
Small, slow rotation	0.055

3) Include Figure 5 that you generated in Step 6.

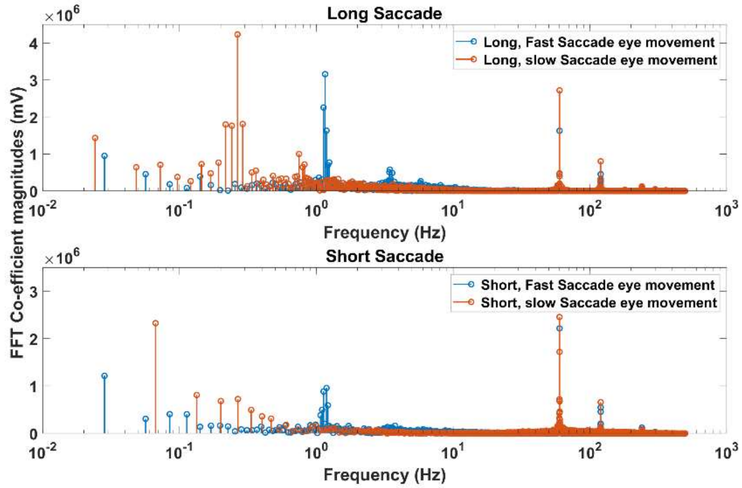

Figure 5. FFT of EOG Saccade eye movements

4) Determine the (non-zero) frequency where the FFT has the largest amplitude in each case and complete the following table:

	Frequency (Hz)
Large, fast rotation	1.158
Small, fast rotation	59.96
Large, slow rotation	0.265
Small, slow rotation	59.96

5) Describe how making small/large head movements and fast/slow head movements changed the FFTs you observed.

Making large head movements had higher amplitudes with lower frequencies. Small head movements had higher frequencies and lower amplitudes. Fast head movements have higher frequencies with wider peaks where as slow head movements had lower frequencies with sharp peaks. The main noise (60 Hz) frequency also had a much higher amplitude in the short saccade data.

Part 9: Visualizing images in space and spatial frequency

1) Include Figure 6 that you generated in Steps 1-7.

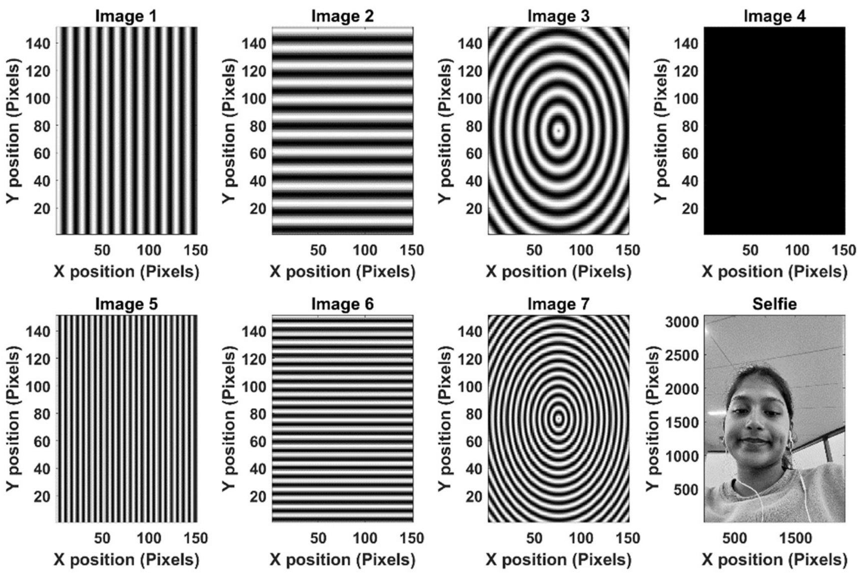

Figure 6. sine waves images in different spaces and spatial frequencies, and a selfie

2) Include Figure 7 that you generated in Steps 8 & 9. Describe why the Fourier transforms of the synthetic images you created look the way they do. Note any similarities/differences with the Fourier transforms of EOG signals.

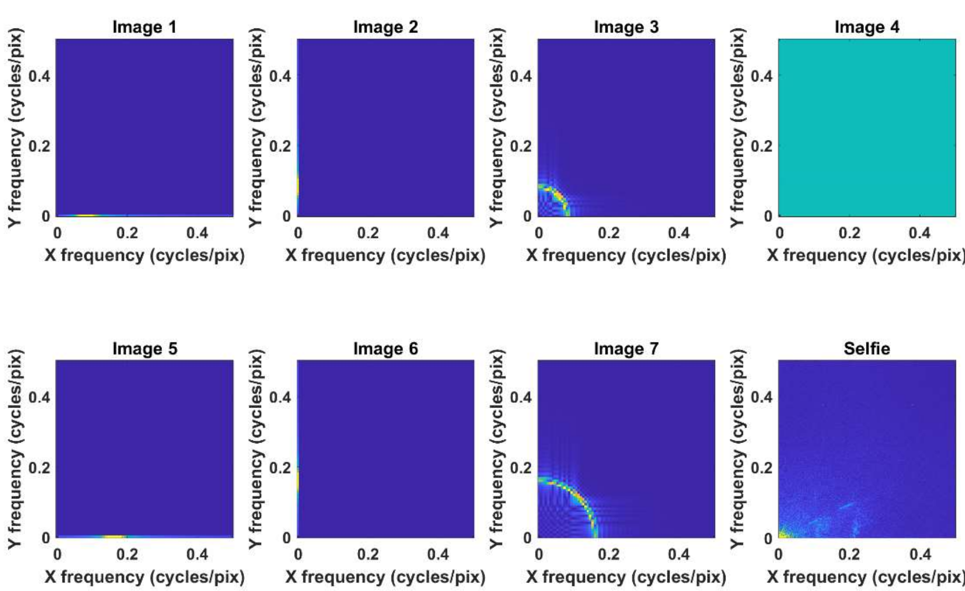

Figure 7. FFT of images in different spaces and spatial frequencies

Image 1 consists of a sinusoidal wave pattern varying along the horizontal axis and its Fourier transform reveals a bright spot positioned along the X-axis at an amplitude of 0.5 and a frequency between 0 and 0.2, representing dominant frequencies present in the sinusoidal wave. Image2 is a 90-degree rotation of Image 1. The Fourier transform of Image 2 preserves the frequency content of Image1 but rotated by 90 degrees, maintaining the spatial orientation of the dominant frequencies.

Image 3 combines a sinusoidal wave pattern with circular modulation, exhibiting both radial and horizontal/vertical variations. Fourier transform shows a quarter of a circle at the corner of the image with frequency of 0.5, representing radial frequencies from the circular modulation. Image 4 represents a single point in the bottom left corner of the image. The Fourier transform of Image 4 is a uniform spectrum, depicted by a single bright pixel at the bottom left indicating a wide range of frequencies contributing equally at that point and amplitude. Image 5, 6 and 7 features the same wave patterns as Images 1, 2, and 3 with higher spatial frequency. The Fourier transform of these images produce the same results as Images 1,2, and 3, just with the bright spots located at a higher frequency (twice the frequency).

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