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Midterm Exam

CMSC491

1. **Describe briefly about upper limb and lower limb amputations and disarticulations. (50 -100 words).**

Lower limb and upper limb amputations and disarticulations can occur in many cases, whether through injury, disease, or other. Both lower and upper limb movement relies on multi jointed control, however upper limbs tend to be used more for fine movement controls. Lower limb prosthetics generally need to hold more weight and be more durable. Upper limb prosthetics tend to hold more sensors for fine motor controls. Both amputations can occur between joints, and can include whole limb amputation or partial limb amputation. This means that a prosthetic may have access to some, or none, of the original neuron networks in the limb. Lower limb amputations usually affect patient mobility, while upper limp amputation affects patients ability to perform finer upper body tasks like writing. Both amputations can cause problems with overall body motor controls and functions.

2. Compare invasive and noninvasive brain recording modalities we have discussed in class. What are their advantages and disadvantages? (200-250 words).

Noninvasive brain recording is widely used and easily accessible to a larger group of people. Noninvasive recording allows for understanding of brain functions without the need for surgery or implants. This method of brain recording can provide a coarse understanding of brain waves, but has limitations on the depth of signals it can reach in the brain. This method also has trouble with isolating specific signals, and is used more often to provide a general analysis of brain waves in groups or clusters.

Invasive brain recording technologies utilizes the surgical insertion of sensors to get a finer, more isolated brain measurement. These methods are often costly and very difficult or dangerous to implement. With invasive brain recording, it is possible to analyze more specific parts of the brain. This allows for isolation and even specific stimulation of certain parts of the brain. With this technology, doctors and researchers can even attempt to stimulate or repair very specific sections of the brain. This can help understand and cure diseases like ALS or alzheimers on different parts of the brain. These methods are not accessible to as many people as noninvasive analysis, and are often used in more unique and specific applications than their noninvasive counterparts.

Both methods of recording can be used together to create a better mapping and understanding of the brain and its functions and signals. This allows us to get a better understanding of the entire brain, as well as specific brain functions from specific parts of the brain.

3. What are steps involved in motor control of a simple act of signing your name? Explain them briefly. (100 -150 words).

Identification: using neurons and visual signals to identify the writing instrument and paper and etc. Brain collects and processes signals from sensor neurons, creates plan for movement and calibration of body parts.

Communication: Brain communicates with motor neurons in arm, wrist, hand, spine. Tendons and muscles are activated to grip, move and steady pen. The brain must send a steady and constant signal, as the muscles cannot steadily orient without the brain sending adjustments.

Feedback Loop: Sensory feedback loop occurs as name writing begins and continues. Neurons send data to the brain for processing. Brain continuously updates motor neurons to adjust and move body and pencil and steady the arm. Pressure of writing, holding pen, and moving pen are all adjusted and compensated by this interaction. The brain will process, and then send back signals to and from the motor and sensor neurons continuously.

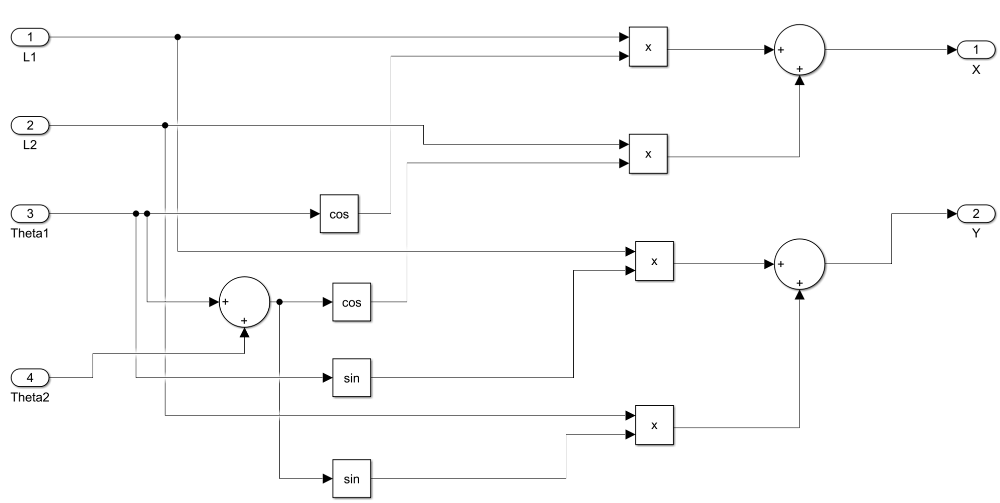
5. What are similarities between fNIRS and fMRI? (50-100 words).

Both fNIRS and FMRI can be performed non-invasivly to capture brain images and signals. These brain scanning systems both create optical topography(OT) graphings of signals picked up from brain functions. Both signals rely on Blood, FMRI using BOLD (blood oxygen sensing) and fNIRS using the Blood Hemoglobin content . Both systems use sensors attached to the scalp, fMRI relying on electrodes and magnetic resonance and fNIRS relying on infrared light sensors (optodes). fNIRS does not scan as deeply into the brain as fMRI, but both systems can be used to map brain activity on the outer cortex and skull of the brain. fMRI can image into deeper layers of the brain, but is much slower to scan, and utilizes much larger more costly equipment.

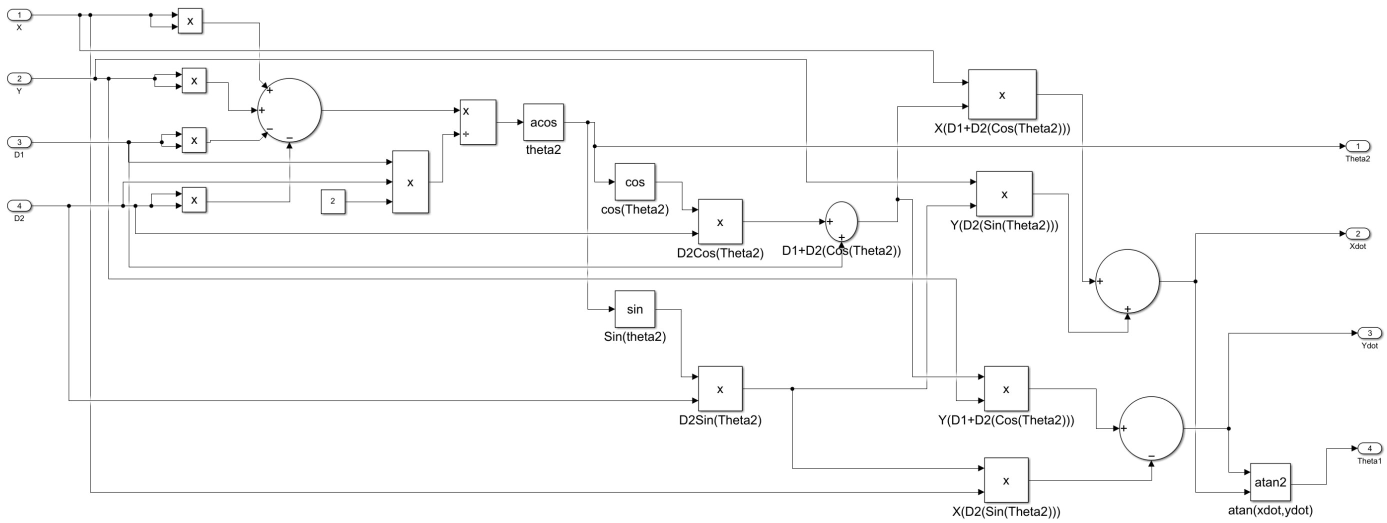
4. Create subsystems for forward and inverse kinematics we have developed in MATLAB® SIMUINK. Connect the outputs of inverse kinematics subsystem (Theta 1 and Theta 2) to the inputs of forward kinematics (Theta1 and Theta 2) respectively. Demonstrate that the inputs of inverse kinematic subsystem (x and y) match the outputs of forward kinematics subsystem (x and y). Please provide the screenshots for the model and five examples of matching x and y. Vary the lengths of the upper arm and forearm and comment on any differences you notice.

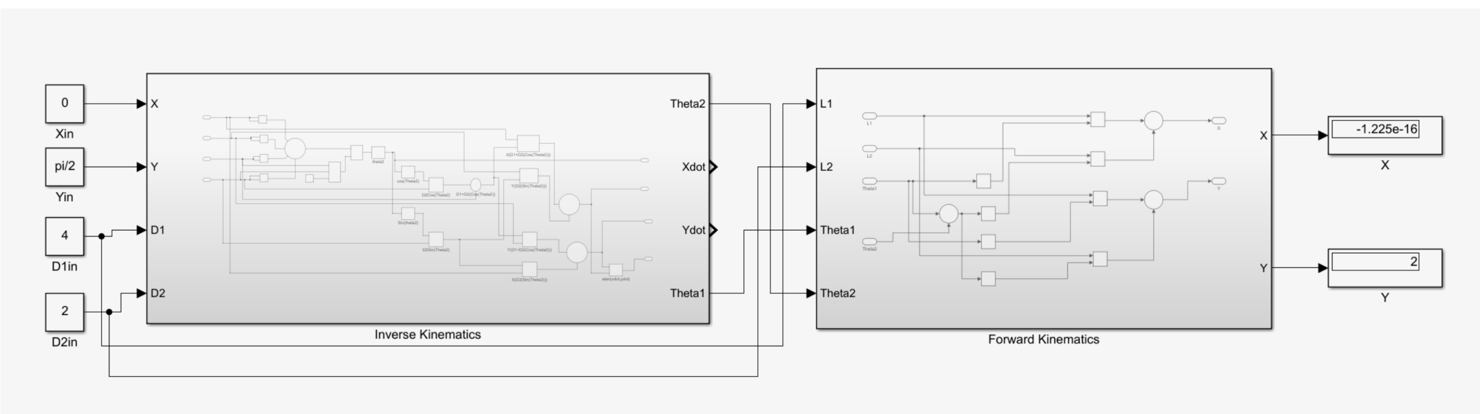
When varying the upper arm and forearm lengths the output x/y seem to scale by the ratio of change in length between the two arm lengths. When the lengths are equal (like D1=1 and D2=1) The input and output are the same (Y= pi/2 ~> 1.57, X= 0 ~> 0). When the lengths of D1=2 and D2=4, Y's output for pi/2 becomes 2.0, and X output remains 0. I'm guessing this occurs because when the formulas are applied, the theta angles stay the same, but the lengths of each triangle change, which changes the formula answers.

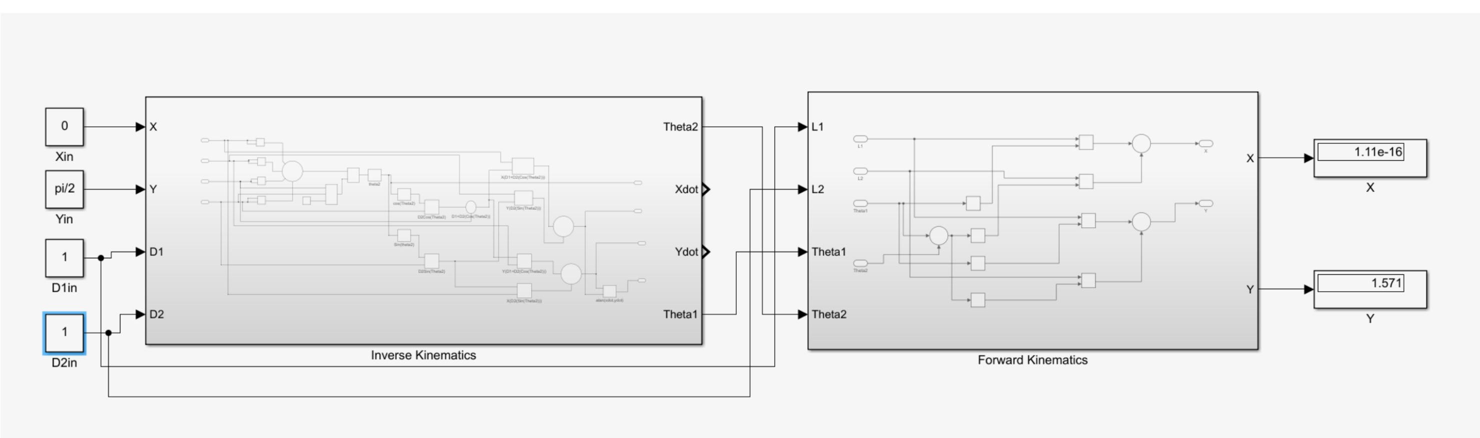
Forward Kinematics

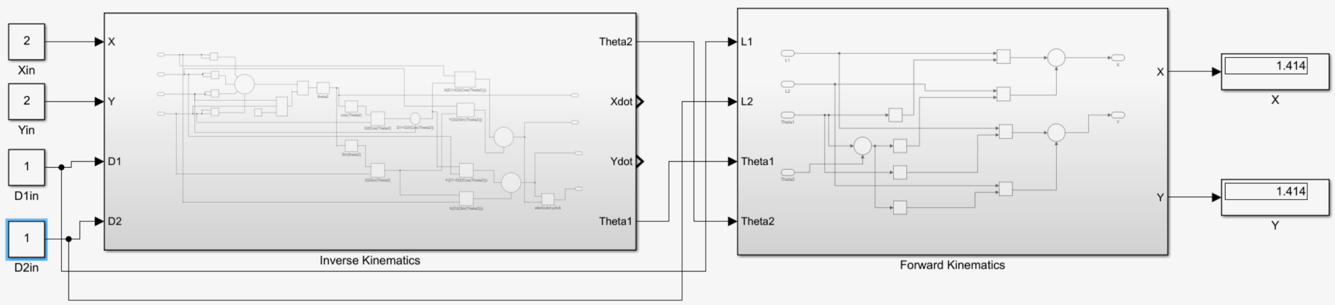


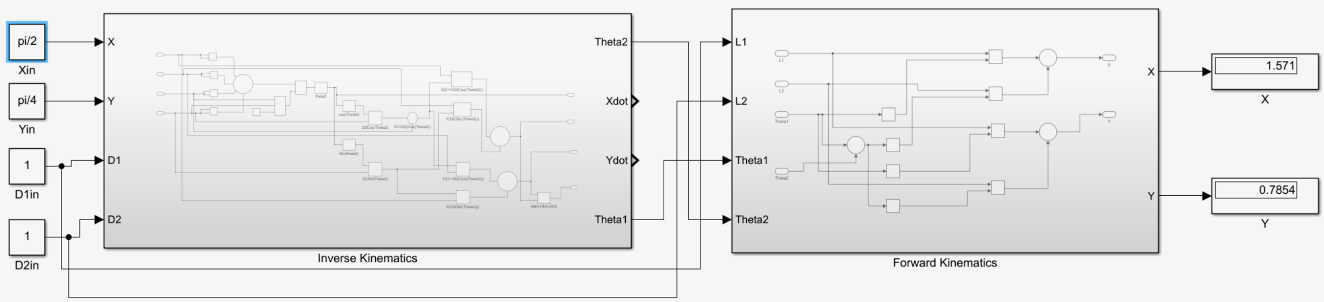
Inverse Kinematics








2
Xin
2
Yin
1
D1in
1
D2in
X
Y
D1
D2
Theta2
Xdot
Ydot
Theta1
Inverse Kinematics
L1
L2
Theta1
Theta2
X
Y
Forward Kinematics
1.414
X
1.414
Y


pi/2
Xin
pi/4
Yin
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D1in
1
D2in
X
Y
D1
D2
Theta2
Xdot
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Theta1
Inverse Kinematics
L1
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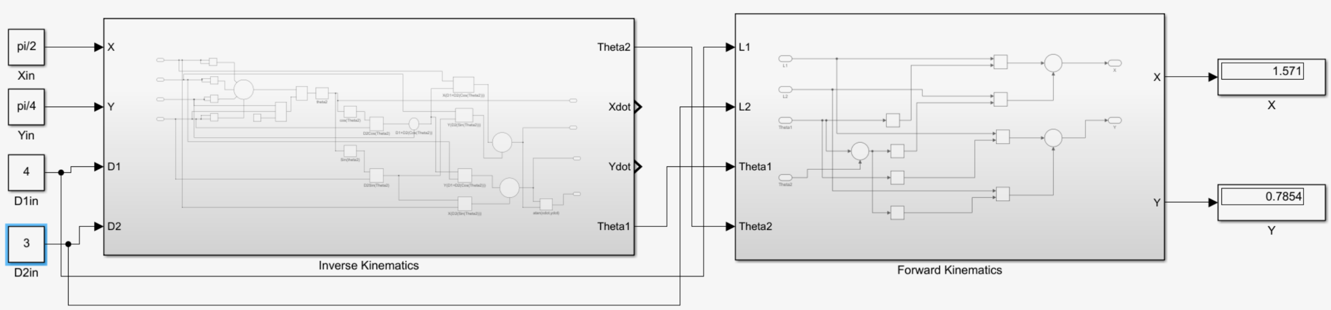
Theta1
Theta2
X
Y
Forward Kinematics
1.571
X
0.7854
Y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Y
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D2
Theta2
Xdot
Ydot
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Inverse Kinematics
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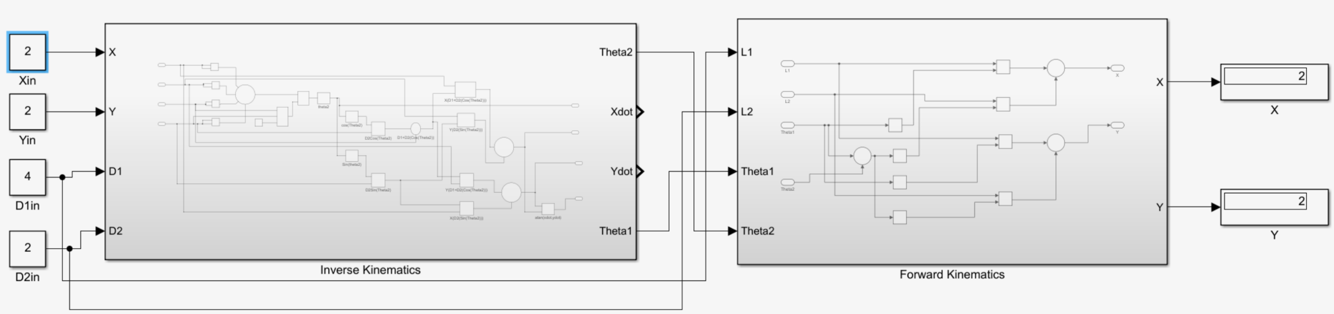
Theta1
Theta2
X
Y
Forward Kinematics
1.571
X
0.7854
Y


2
Xin
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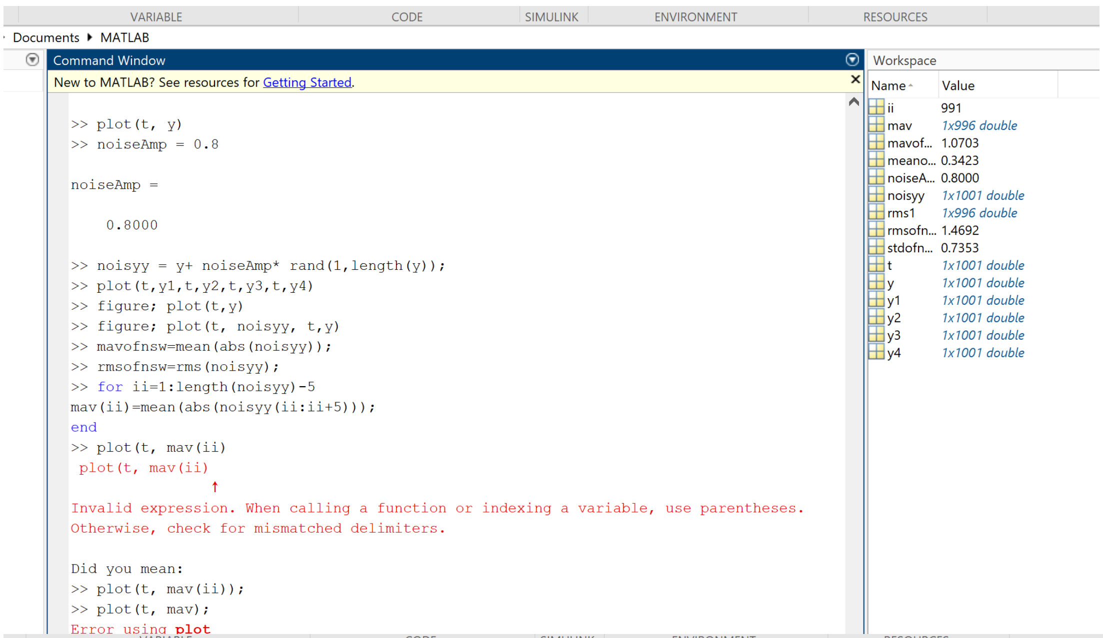
Yin
4
D1in
2
D2in
X
Y
D1
D2
Theta2
Xdot
Ydot
Theta1
Inverse Kinematics
L1
L2
Theta1
Theta2
X
Y
Forward Kinematics
2
X
2
Y

6. To simulate a neural signal recorded from an electrode placed in the brain, create a signal in MATLAB that is a combination of four sinewaves at four different frequencies. Plot the signal. Add some noise to the signal. Plot the noisy signal. Using an overlapping sliding window compute mean absolute value (MAV) and root mean squared (RMS) value for this signal and plot them. Double the sliding window and recompute the MAV and RMS values and plot them for comparison. Please include your well commented MATLAB code.



VARIABLE | CODE | SIMULINK | ENVIRONMENT | RESOURCES

Documents ▸ MATLAB

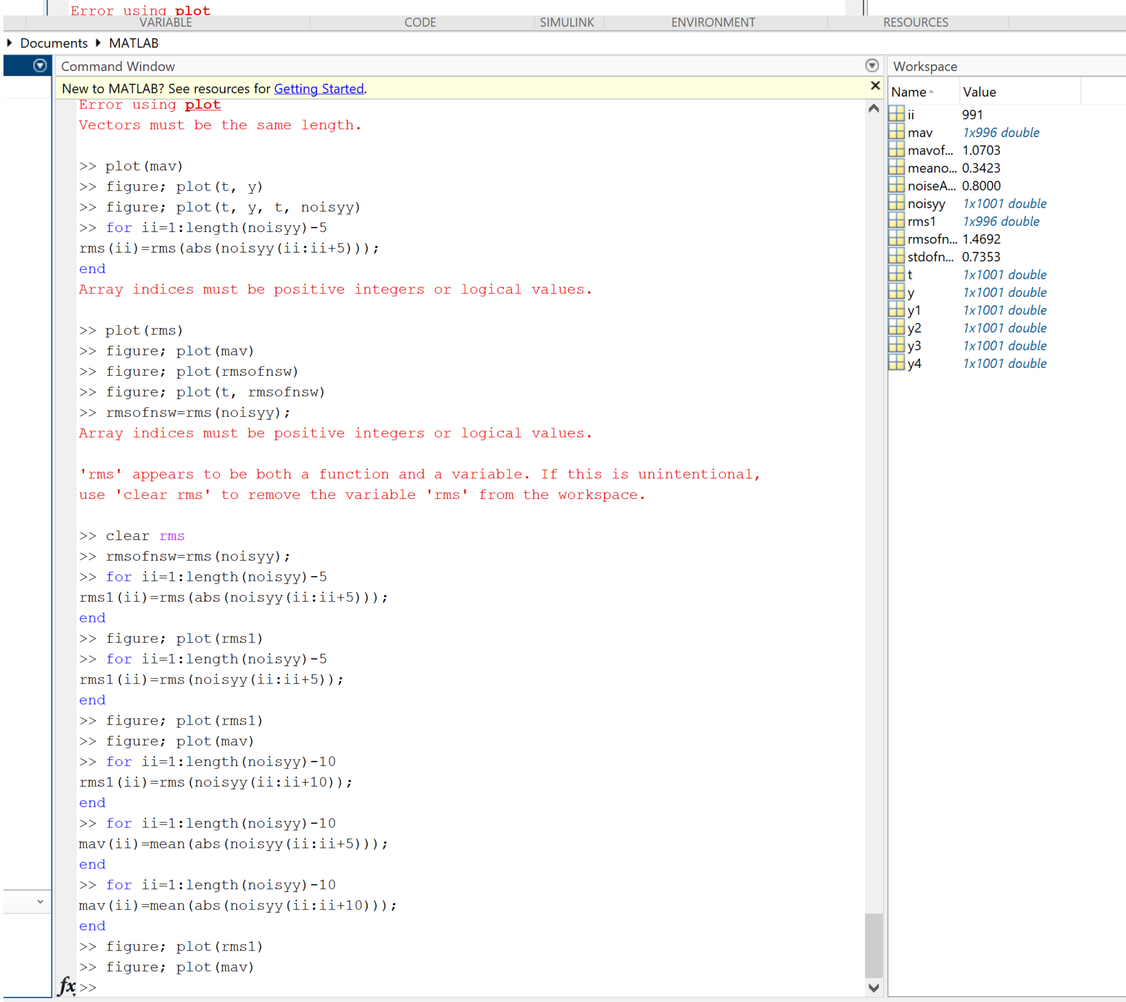
Command Window

New to MATLAB? See resources for Getting Started.

```
>> plot(t, y)
>> noiseAmp = 0.8

noiseAmp =

    0.8000

>> noisyy = y+ noiseAmp* rand(1,length(y));
>> plot(t,y1,t,y2,t,y3,t,y4)
>> figure; plot(t,y)
>> figure; plot(t, noisyy, t,y)
>> mavofnsw=mean(abs(noisyy));
>> rmsofnsw=rms(noisyy);
>> for ii=1:length(noisyy)-5
mav(ii)=mean(abs(noisyy(ii:ii+5)));
end
>> plot(t, mav(ii)
 plot(t, mav(ii)
                ↑
Invalid expression. When calling a function or indexing a variable, use parentheses.
Otherwise, check for mismatched delimiters.

Did you mean:
>> plot(t, mav(ii));
>> plot(t, mav);
Error using plot
```

Workspace

Name	Value
ii	991
mav	1x996 double
mavof...	1.0703
meano...	0.3423
noiseA...	0.8000
noisyy	1x1001 double
rms1	1x996 double
rmsofn...	1.4692
stdofn...	0.7353
t	1x1001 double
y	1x1001 double
y1	1x1001 double
y2	1x1001 double
y3	1x1001 double
y4	1x1001 double



VARIABLE | CODE | SIMULINK | ENVIRONMENT | RESOURCES

Documents ▸ MATLAB

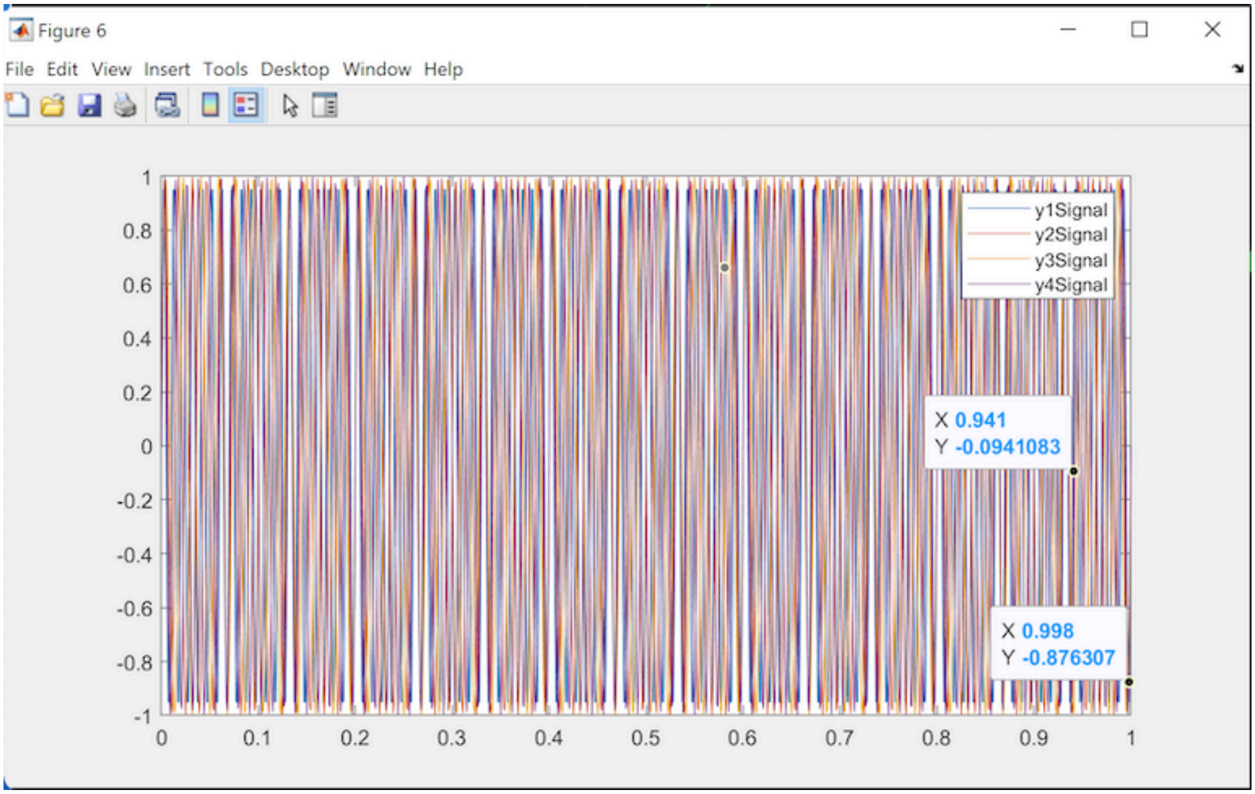
Command Window

New to MATLAB? See resources for Getting Started.

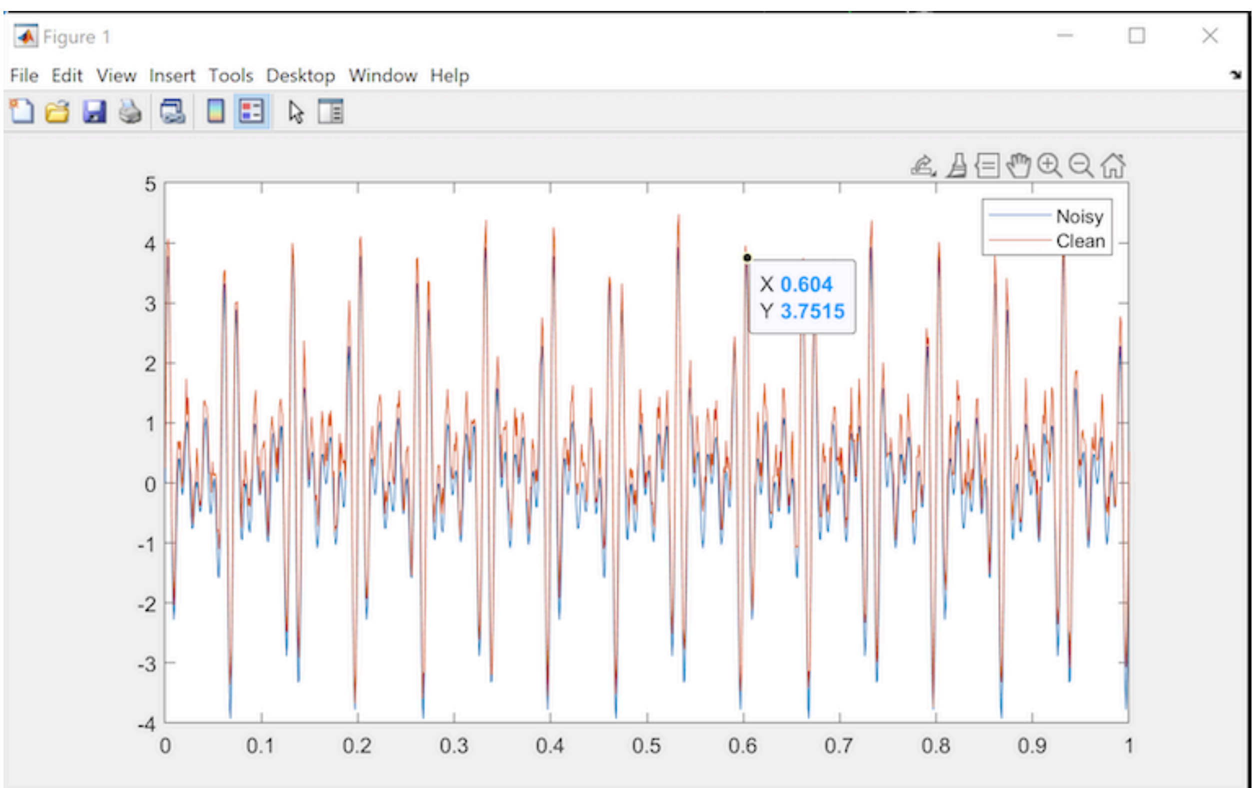
```
Error using plot
Vectors must be the same length.

>> plot(mav)
>> figure; plot(t, y)
>> figure; plot(t, y, t, noisyy)
>> for ii=1:length(noisyy)-5
rms(ii)=rms(abs(noisyy(ii:ii+5)));
end
Array indices must be positive integers or logical values.

>> plot(rms)
>> figure; plot(mav)
>> figure; plot(rmsofnsw)
>> figure; plot(t, rmsofnsw)
>> rmsofnsw=rms(noisyy);
Array indices must be positive integers or logical values.

'rms' appears to be both a function and a variable. If this is unintentional,
use 'clear rms' to remove the variable 'rms' from the workspace.

>> clear rms
>> rmsofnsw=rms(noisyy);
>> for ii=1:length(noisyy)-5
rms1(ii)=rms(abs(noisyy(ii:ii+5)));
end
>> figure; plot(rms1)
>> for ii=1:length(noisyy)-5
rms1(ii)=rms(noisyy(ii:ii+5));
end
>> figure; plot(rms1)
>> figure; plot(mav)
>> for ii=1:length(noisyy)-10
rms1(ii)=rms(noisyy(ii:ii+10));
end
>> for ii=1:length(noisyy)-10
mav(ii)=mean(abs(noisyy(ii:ii+5)));
end
>> for ii=1:length(noisyy)-10
mav(ii)=mean(abs(noisyy(ii:ii+10)));
end
>> figure; plot(rms1)
>> figure; plot(mav)
fx >>
```

Workspace

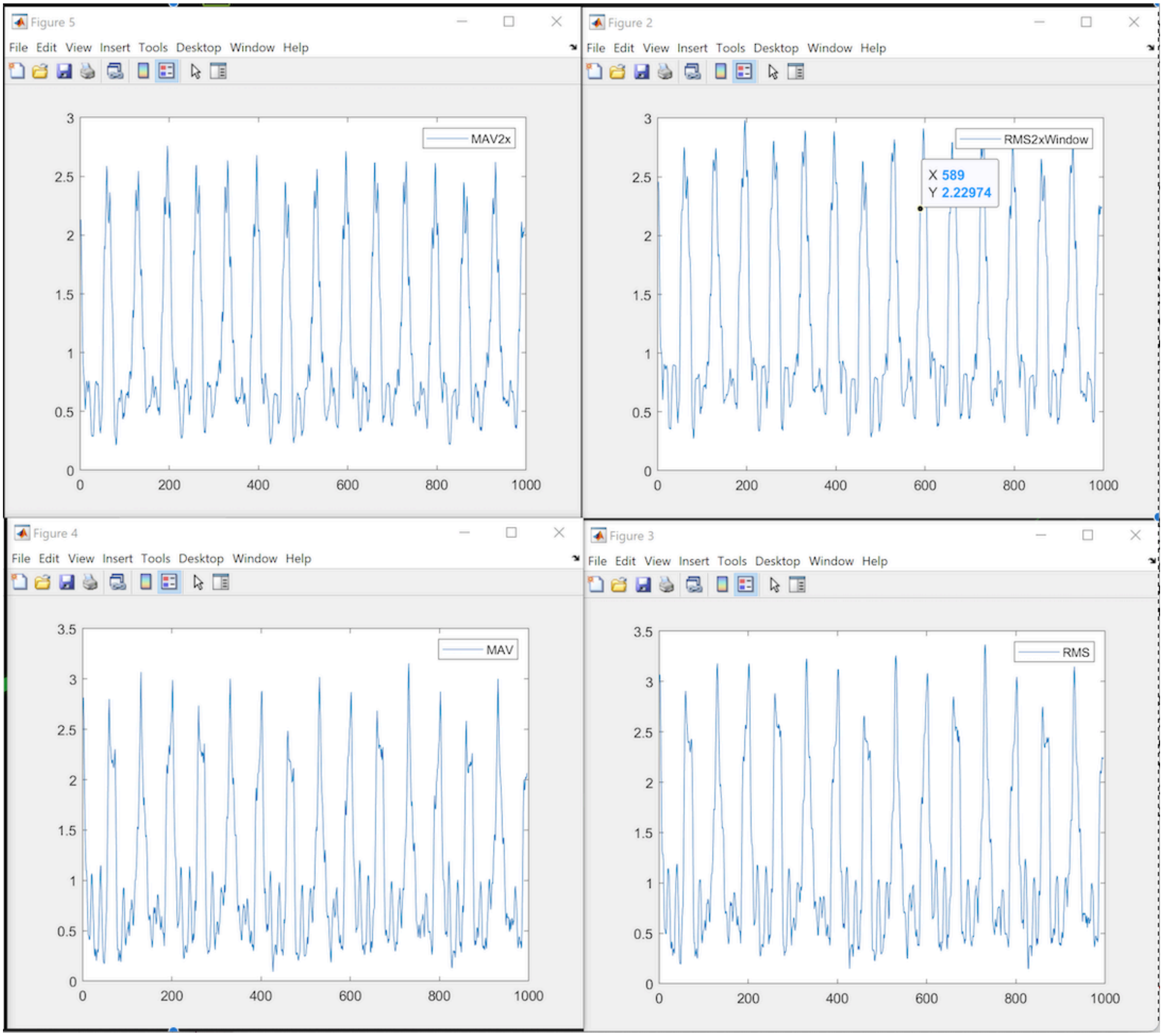
Name	Value
ii	991
mav	1x996 double
mavof...	1.0703
meano...	0.3423
noiseA...	0.8000
noisyy	1x1001 double
rms1	1x996 double
rmsofn...	1.4692
stdofn...	0.7353
t	1x1001 double
y	1x1001 double
y1	1x1001 double
y2	1x1001 double
y3	1x1001 double
y4	1x1001 double



Four sin signals of differing frequency



Graph of Signal of y1+y2+y3+y4 and Noise added signal

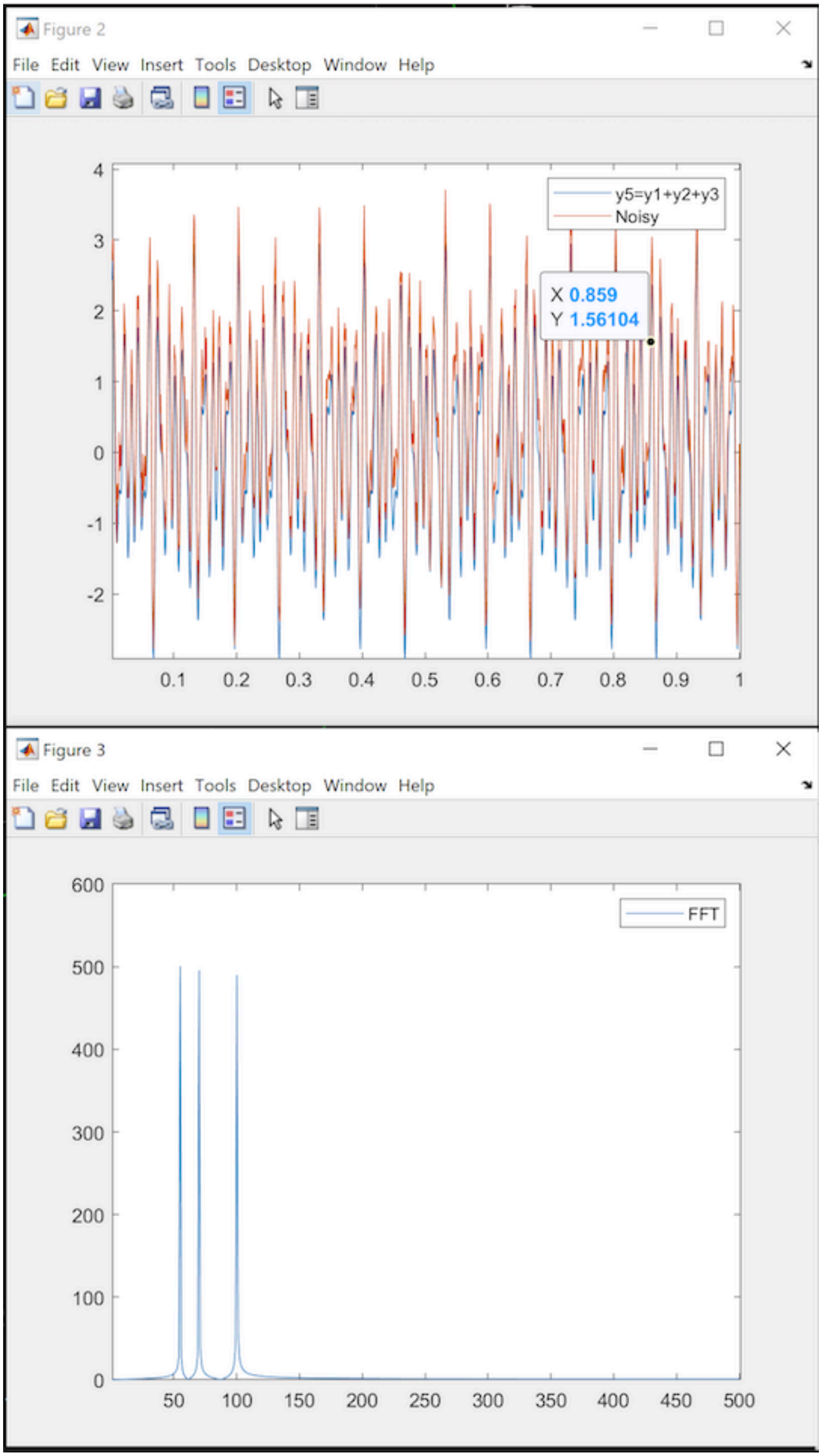


MAV and RMS, as well as with 2x window size

7. To simulate a neural signal recorded from an electrode placed in the brain, create a signal in MATLAB that is a combination of three sinewaves at three different frequencies. Plot the signal. Add some noise to the signal. Plot the noisy signal. Compute the FFT of the signal and plot the frequency spectrum of the signal. For the same noisy signal, perform time-frequency analysis (TFA) and show the spectrogram depicting three frequencies across time. Increase the amplitude of noise and comment on any changes you observe in the FFT and TFA. Please include your well commented MATLAB code.

```
>> plot(t,y5)
>> figure; plot(t,y1,t,y2,t,y3)
>> noiseAmp = 0.85

noiseAmp =

    0.8500

>> noisyy2 = y+ noiseAmp* rand(1,length(y));
>> plot(t,y5,t,noisyy)
>> ffty=abs(fft(y));
>> noisyy2 = y5+ noiseAmp* rand(1,length(y5));
>> plot(t,y5,t,noisyy)
>> plot(t,y5,t,noisyy2)
>> figure; plot(t,y1,t,y2,t,y3)
>> ffty=abs(fft(y5));
>> sr=1000;
>> ff=linspace(0,sr/2,length(y5)/2);
>> figure; plot(ff, ffty(1:length(y)/2));
Warning: Integer operands are required for colon operator when used as index.

>> figure; plot(t5,noisyy2); title TimeDomainRepresentation;
Unrecognized function or variable 't5'.

>> figure; plot(t,noisyy2); title TimeDomainRepresentation;
>> [S, F, T] = spectrogram(noisyy2, 128, 120, 128, 1000); %spectrogram(signal, windowsize
>> figure; imagesc(T,F,abs(S));title FrequencyDomainRepresentation %plot of FDR
>> noiseAmp = 0.95 %increase NoiseAmplitude

noiseAmp =

    0.9500

>> noisyy2 = y5+ noiseAmp* rand(1,length(y5));
>> [S, F, T] = spectrogram(noisyy2, 128, 120, 128, 1000); %spectrogram(signal, windowsize
>> figure; plot(t5,noisyy2); title TimeDomainRepresentationMoreNoise;
Unrecognized function or variable 't5'.

>> figure; plot(y5,noisyy2); title TimeDomainRepresentationMoreNoise;
>> figure; plot(t,noisyy2); title TimeDomainRepresentationMoreNoise;
>> figure; imagesc(T,F,abs(S));title FrequencyDomainRepresentationMoreNoise %plot of FDR
fx >>
```

F	65x1 double
ff	1x500 double
ffty	1x1001 double
ii	991
mav	1x996 double
mavof...	1.0703
meano...	0.3423
noiseA...	0.9500
noisyy	1x1001 double
noisyy2	1x1001 double
rms1	1x996 double
rmsofn...	1.4692
S	65x110 complex d...
sr	1000
stdofn...	0.7353
t	1x1001 double
T	1x110 double
y	1x1001 double
y1	1x1001 double
y2	1x1001 double
y3	1x1001 double
y4	1x1001 double
y5	1x1001 double



Signals and noisy signal graph, Fast Fourier transform

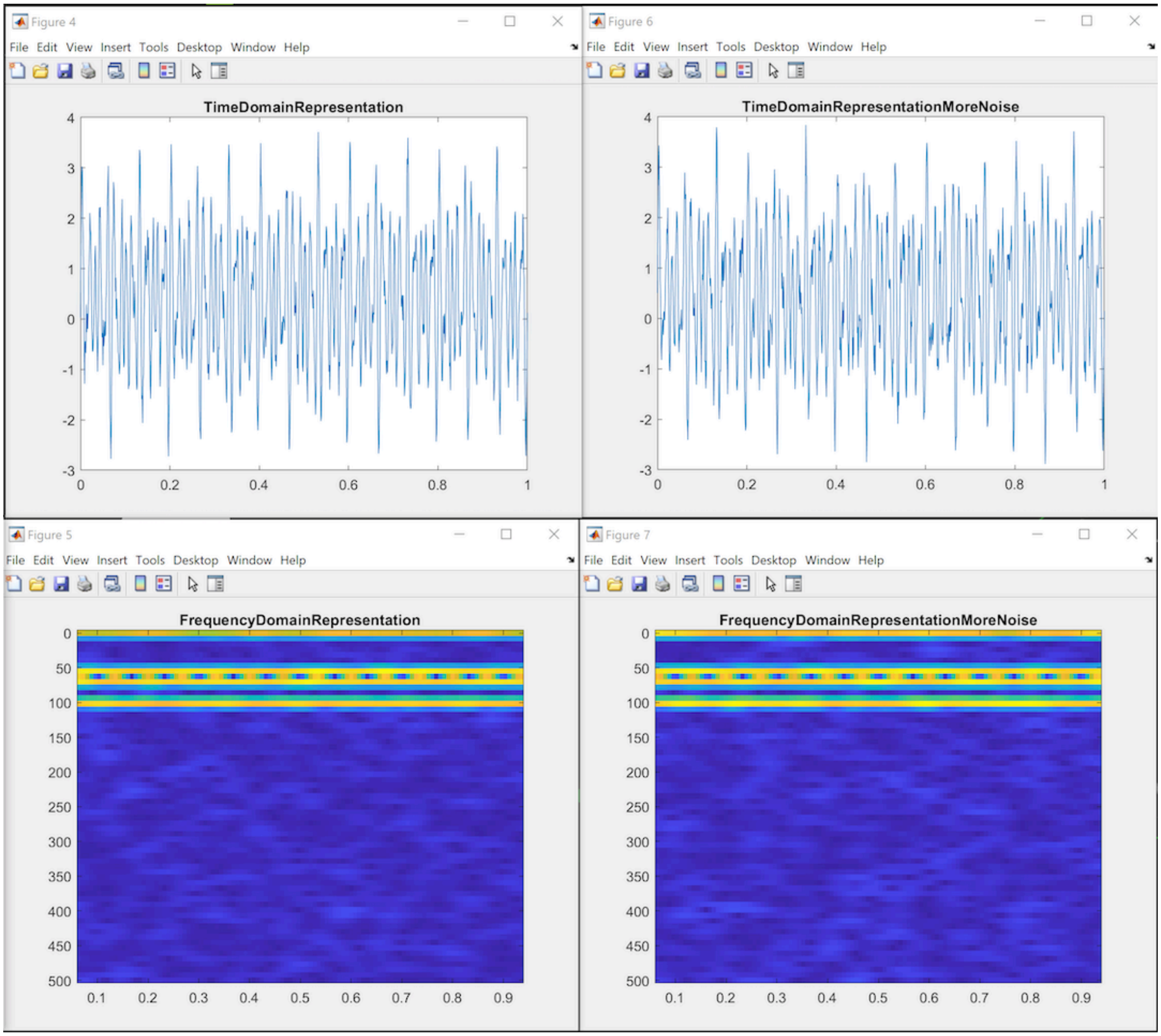


Figure 4
File Edit View Insert Tools Desktop Window Help
TimeDomainRepresentation
4 3 2 1 0 -1 -2 -3
0 0.2 0.4 0.6 0.8 1
Figure 6
File Edit View Insert Tools Desktop Window Help
TimeDomainRepresentationMoreNoise
4 3 2 1 0 -1 -2 -3
0 0.2 0.4 0.6 0.8 1
Figure 5
File Edit View Insert Tools Desktop Window Help
FrequencyDomainRepresentation
0 50 100 150 200 250 300 350 400 450 500
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
Figure 7
File Edit View Insert Tools Desktop Window Help
FrequencyDomainRepresentationMoreNoise
0 50 100 150 200 250 300 350 400 450 500
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9

Bonus Question:

8. What are different brain stimulation methodologies? Explain them briefly. (50-100 words).

Brain stimulation can be done invasively or non-invasively. Noninvasive stimulation can be done through trans cranial magnetic stimulation or a trans cranial ultrasound. Invasive stimulation can be done using multi-electrode arrays, ECoG, or optical stimulation. Invasive stimulation is more effective at targeting very specific parts of the brain, and can be used to stimulate dying or malfunctioning neurons. This is often done by sending electrical impulses through the neurons to reset or enhance their functionality. Noninvasive stimulation can excite neurons in the brain through magnetic fields, and is more useful for brain regions near the skull.