Laboratory of Biomedical Signal and Image Processing

REPORT OF LAB6

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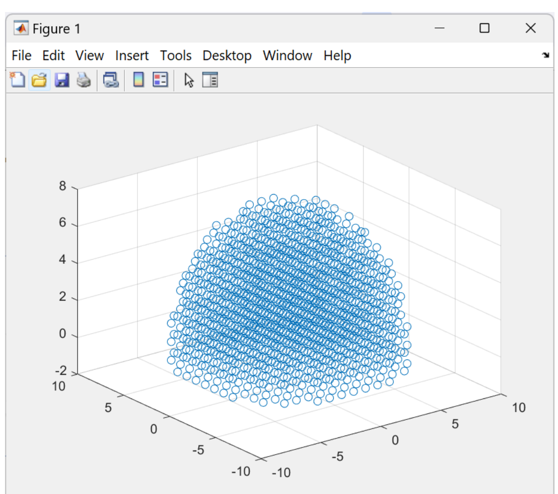
Alef)

```
%% Q1
%Forward Matrix
ModelParams.R = [8 8.5 9.2] ; % Radius of diffetent layers
ModelParams.Sigma = [3.3e-3 8.25e-5 3.3e-3];
ModelParams.Lambda = [.5979 .2037 .0237];
ModelParams.Mu = [.6342 .9364 1.0362];

Resolution = 1 ;
[LocMat,GainMat] = ForwardModel_3shell(Resolution, ModelParams) ;
scatter3(LocMat(1,:), LocMat(2,:), LocMat(3,:));
hold on;
```

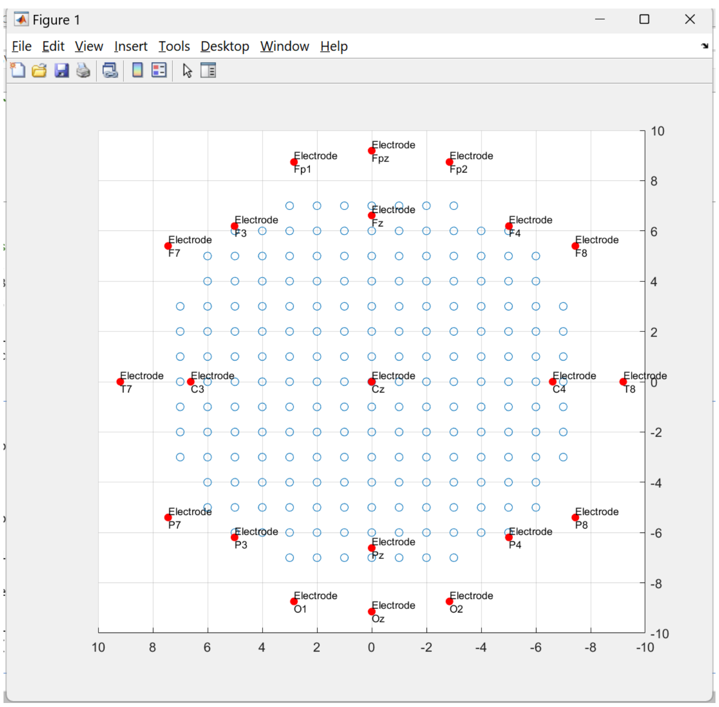
This code sets up a model for a three-layer spherical structure, defining properties like the layers' radii, conductivities, and other material characteristics. It calculates the spatial layout and data for the model using a function called `ForwardModel_3shell`. Finally, it creates a 3D scatter plot to visualize the points in the model, with the option to add more to the plot later.

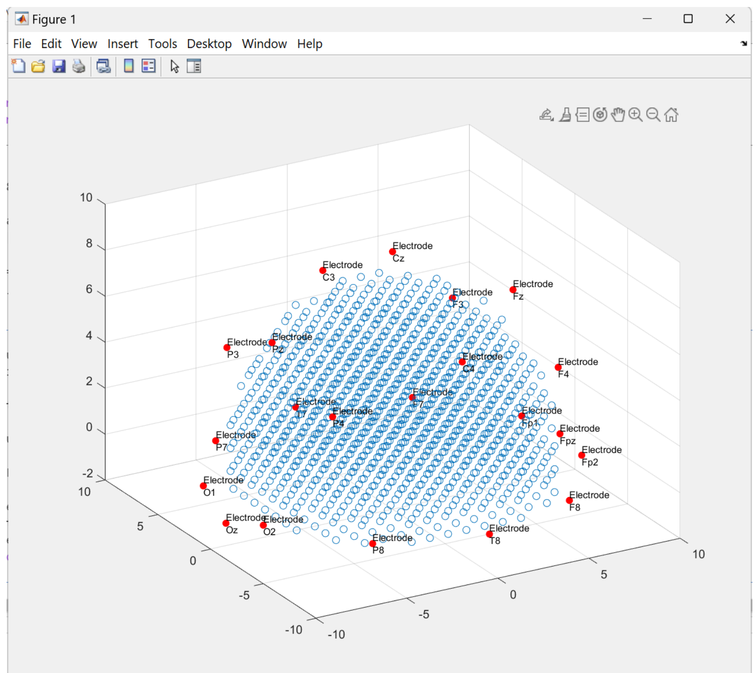


Be)

```
%% Q2
numElectrodes = numel(ElecPos);
ElectrodePosNumeric = zeros(numElectrodes, 3);
ElectrodeLabelS = cell(1,21);
for i = 1:numElectrodes
    for j=1:3
    ElectrodePosNumeric(i, j) = ElecPos{1,i}.XYZ(j).* ModelParams.R(3);
    end
        ElectrodeLabelS{i} = ElecPos{1,i}.Name;
end
scatter3(ElectrodePosNumeric(:,1), ElectrodePosNumeric(:,2), ElectrodePosNumeric(:,3), 'r', 'filled');
for i = 1:numElectrodes
    text(ElectrodePosNumeric(i, 1), ElectrodePosNumeric(i, 2), ElectrodePosNumeric(i, 3), ...
        ['Electrode ' ElectrodeLabelS(i)], 'FontSize', 8, 'Color', 'k');
end
```

We processed the electrode positions (`ElecPos`) by scaling their coordinates using the radius of the outermost layer (`ModelParams.R(3)`) and stored their labels. Then, we created a 3D scatter plot to visualize the electrode positions as red dots. Finally, we labeled each electrode in the plot with its name, placing the text near its corresponding position.

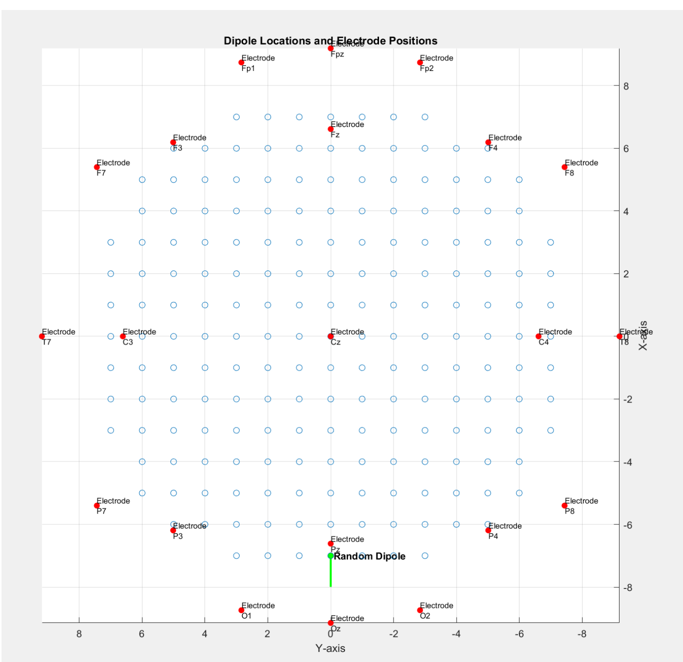


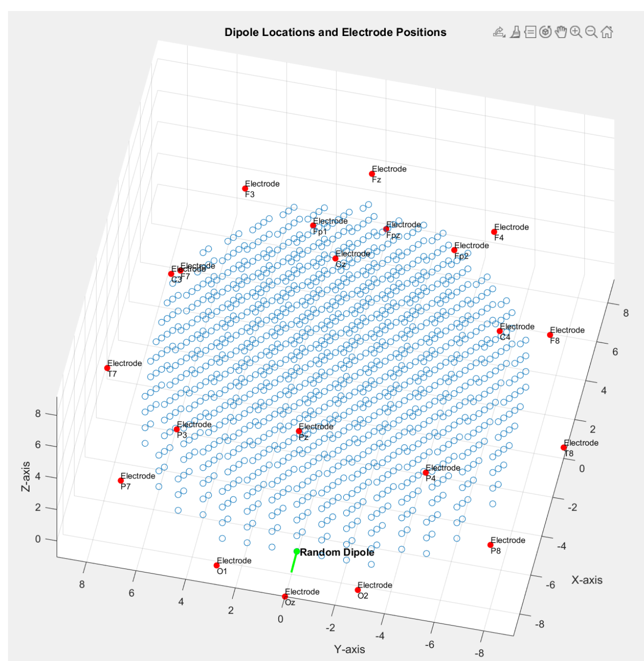


Pe)

```matlab
%% Q3
% Create LocMat from the electrode position coordinates
%LocMat = [ElectrodePosNumeric(:,1); ElectrodePosNumeric(:,2); ElectrodePosNumeric(:,3)];
% Randomly select a dipole index
rand_index = int32(21 * rand(1, 1) + 1); % Adjust your max index here if needed
% Plot the selected random dipole location
scatter3(LocMat(1, rand_index), LocMat(2, rand_index), LocMat(3, rand_index), 'g', 'filled');
% Create a radial line extending from the dipole position
startPoint = LocMat(:, rand_index); % Get the random dipole location
lineLength = 1; % Length of the line
% Define the end point of the line in radial direction
endPoint = startPoint + lineLength * normalize(startPoint);
% Plot the line
plot3([startPoint(1), endPoint(1)], [startPoint(2), endPoint(2)], [startPoint(3), endPoint(3)], 'g', 'LineWidth', 2);
% Label the random dipole
text(LocMat(1, rand_index), LocMat(2, rand_index), LocMat(3, rand_index), ' Random Dipole', 'FontSize', 10, 'Color', 'k', 'FontWeight', 'bold');
hold off;
xlabel('X-axis');
ylabel('Y-axis');
zlabel('Z-axis');
title('Dipole Locations and Electrode Positions');
grid on;
axis equal;
```

We visualized a randomly selected dipole location within the electrode coordinate matrix. First, we picked a random index (`rand_index`) to select a dipole from `LocMat`. Then, we plotted the dipole's position as a green dot in 3D space. Next, we created a radial line extending outward from the dipole's position by calculating an endpoint in the radial direction and plotted the line in green. We labeled the dipole with the text "Random Dipole" at its location. Finally, we added axis labels, a title, gridlines, and ensured the axes were scaled equally to maintain spatial accuracy.





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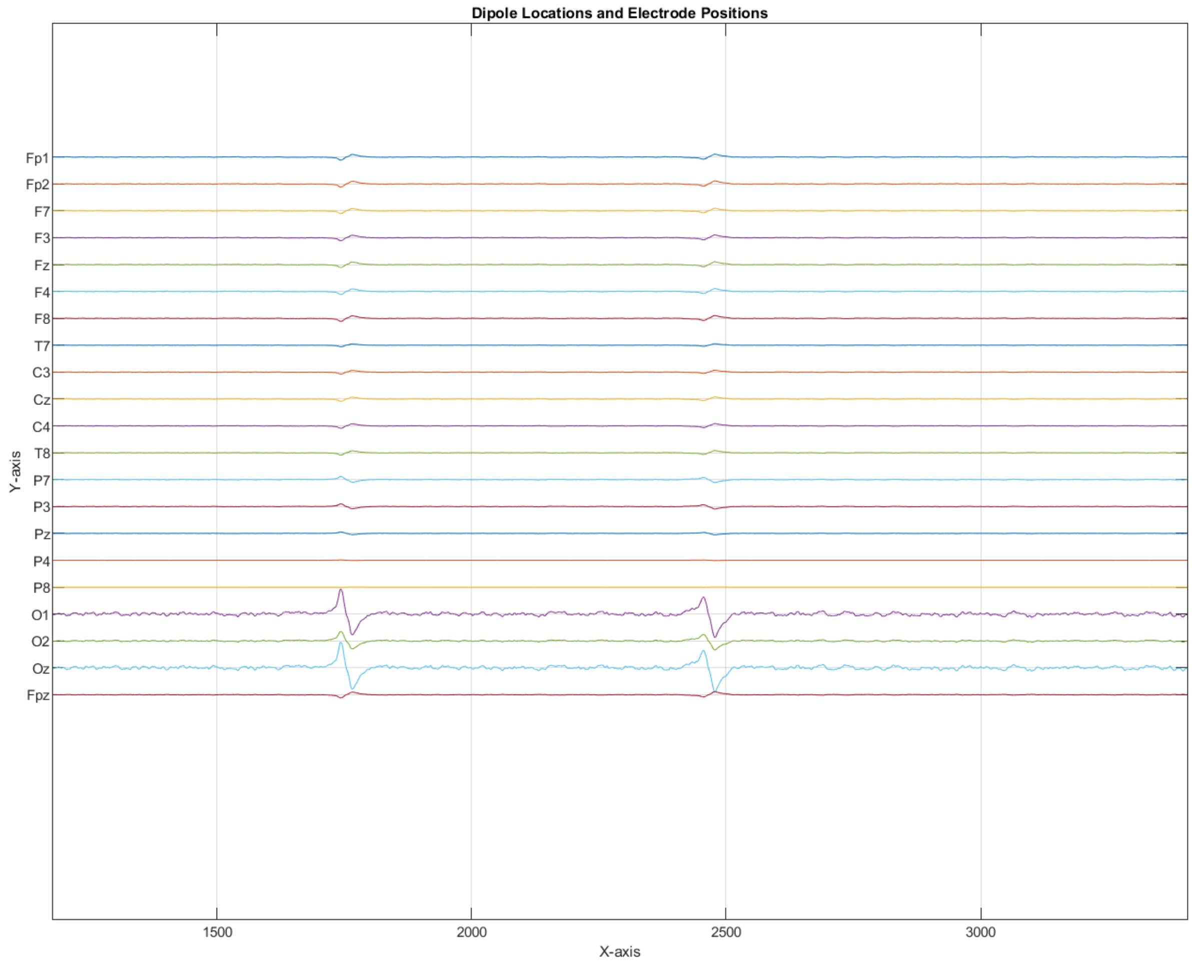
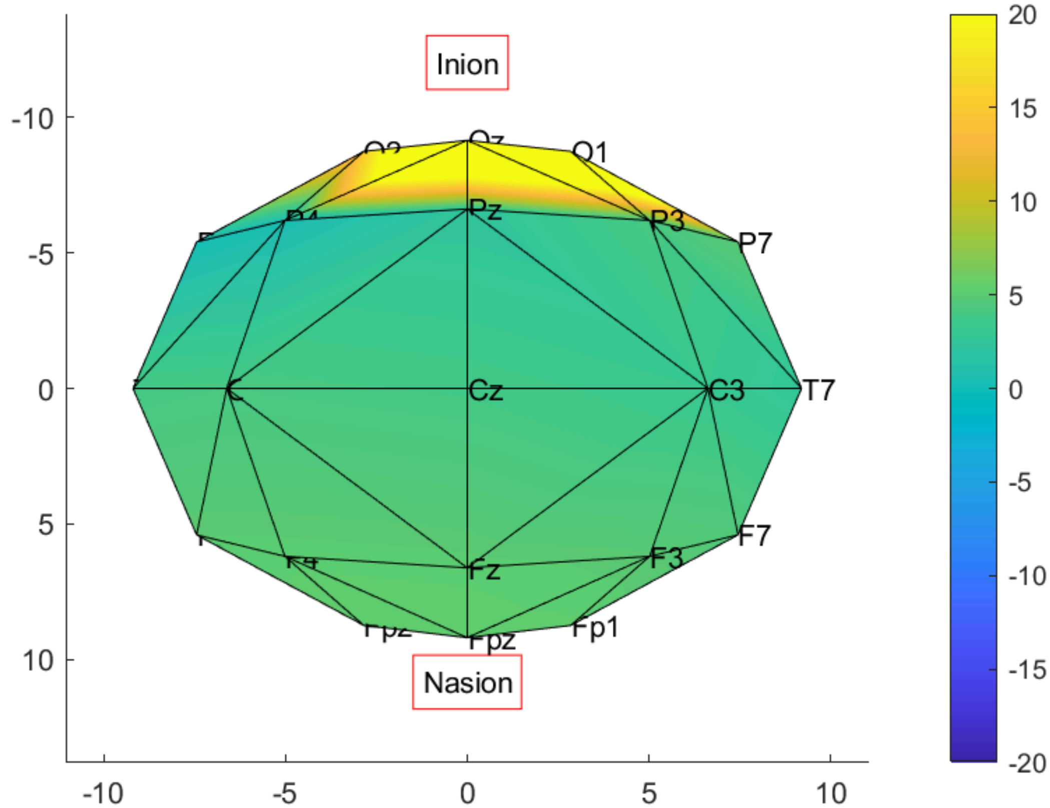


We selected the 6th row of the corresponding matrix as the spike activity and then found the dipole direction by dividing the positions by their norm. Finally, using the obtained direction, the gain matrix and the value of the variable spike signal M were constructed.

se)



We obtained the average potential of all electrodes in the windows around all spikes as follows:

```
%% Q5
figure;
mean_Pot = zeros(21, 1);
for i=1:21
    [pks, locs] = findpeaks(M(i,:), 'MinPeakProminence', 0.9*max(M(i,:)));
    epochs = zeros(length(locs), 7);
    for j=1:length(locs)
       epochs(j, :) = M(i, locs(j)-3:locs(j)+3);
    end
    mean_Pot(i) = mean(epochs, 'all');
end

Display_Potential_3D(ModelParams.R(3), mean_Pot)
colorbar;
caxis([-20, 20])
```

je)

Q

3951x10240 double

	1	2	3	4	5	6	7	8	9	10	11
1	-0.0114	-0.0128	-0.0123	-0.0102	-0.0078	-0.0063	-0.0042	-0.0028	-0.0035	-0.0043	-0.0038
2	-0.0062	-0.0070	-0.0067	-0.0056	-0.0043	-0.0034	-0.0023	-0.0015	-0.0019	-0.0024	-0.0021
3	0.0102	0.0115	0.0110	0.0091	0.0070	0.0056	0.0037	0.0026	0.0032	0.0039	0.0034
4	-9.2700e-04	-0.0010	-0.0010	-8.3173e-04	-6.3860e-04	-5.1311e-04	-3.4041e-04	-2.3202e-04	-2.8656e-04	-3.5483e-04	-3.0818e-04
5	-0.0275	-0.0310	-0.0298	-0.0247	-0.0190	-0.0152	-0.0101	-0.0069	-0.0085	-0.0105	-0.0092
6	0.0108	0.0122	0.0117	0.0097	0.0075	0.0060	0.0040	0.0027	0.0033	0.0041	0.0036
7	0.0261	0.0294	0.0283	0.0234	0.0180	0.0145	0.0096	0.0065	0.0081	0.0100	0.0087
8	-0.0284	-0.0320	-0.0308	-0.0255	-0.0196	-0.0157	-0.0104	-0.0071	-0.0088	-0.0109	-0.0095
9	0.0053	0.0060	0.0058	0.0048	0.0037	0.0029	0.0020	0.0013	0.0016	0.0020	0.0018
10	0.0554	0.0624	0.0600	0.0497	0.0382	0.0307	0.0203	0.0139	0.0171	0.0212	0.0184
11	-0.0078	-0.0088	-0.0085	-0.0070	-0.0054	-0.0043	-0.0029	-0.0020	-0.0024	-0.0030	-0.0026
12	0.0061	0.0069	0.0066	0.0055	0.0042	0.0034	0.0022	0.0015	0.0019	0.0023	0.0020
13	0.0335	0.0377	0.0363	0.0300	0.0231	0.0185	0.0123	0.0084	0.0103	0.0128	0.0111
14	0.0111	0.0125	0.0120	0.0100	0.0077	0.0062	0.0041	0.0028	0.0034	0.0043	0.0037
15	0.0030	0.0034	0.0033	0.0027	0.0021	0.0017	0.0011	7.5808e-04	9.3625e-04	0.0012	0.0010
16	0.0227	0.0256	0.0246	0.0204	0.0156	0.0126	0.0083	0.0057	0.0070	0.0087	0.0075
17	0.0086	0.0097	0.0093	0.0077	0.0059	0.0047	0.0031	0.0021	0.0026	0.0033	0.0028
18	-2.7816e-04	-3.1327e-04	-3.0130e-04	-2.4958e-04	-1.9162e-04	-1.5397e-04	-1.0215e-04	-6.9623e-05	-8.5987e-05	-1.0647e-04	-9.2474e-05
19	0.0177	0.0199	0.0191	0.0159	0.0122	0.0098	0.0065	0.0044	0.0055	0.0068	0.0059
20	0.0109	0.0123	0.0118	0.0098	0.0075	0.0060	0.0040	0.0027	0.0034	0.0042	0.0036
21	-0.0010	-0.0011	-0.0011	-9.0475e-04	-6.9467e-04	-5.5815e-04	-3.7029e-04	-2.5239e-04	-3.1171e-04	-3.8598e-04	-3.3523e-04
22	-0.0015	-0.0017	-0.0016	-0.0013	-0.0010	-8.2150e-04	-5.4500e-04	-3.7148e-04	-4.5879e-04	-5.6810e-04	-4.9340e-04
23	-0.0023	-0.0026	-0.0025	-0.0020	-0.0016	-0.0013	-8.3388e-04	-5.6838e-04	-7.0197e-04	-8.6922e-04	-7.5493e-04
24	1.2089e-04	1.3615e-04	1.3095e-04	1.0847e-04	8.3284e-05	6.6917e-05	4.4394e-05	3.0259e-05	3.7371e-05	4.6275e-05	4.0191e-05
25	-0.0013	-0.0015	-0.0015	-0.0012	-9.2699e-04	-7.4482e-04	-4.9413e-04	-3.3680e-04	-4.1596e-04	-5.1507e-04	-4.4734e-04
26	-0.0040	-0.0045	-0.0043	-0.0036	-0.0027	-0.0022	-0.0015	-9.9626e-04	-0.0012	-0.0015	-0.0013
27	0.0010	0.0011	0.0011	8.9993e-04	6.9097e-04	5.5518e-04	3.6832e-04	2.5105e-04	3.1005e-04	3.8393e-04	3.3345e-04
28	-7.1954e-04	-8.1035e-04	-7.7938e-04	-6.4559e-04	-4.9568e-04	-3.9827e-04	-2.6422e-04	-1.8010e-04	-2.2243e-04	-2.7542e-04	-2.3921e-04
29	-0.0072	-0.0081	-0.0078	-0.0065	-0.0050	-0.0040	-0.0026	-0.0018	-0.0022	-0.0028	-0.0024

	12	13	14	15	16	17	18	19	20	21
1	-0.0024	-0.0017	-1.4792e-04	4.0534e-04	-8.6171e-04	-0.0017	-0.0021	-0.0015	2.4555e-05	0.0023
2	-0.0013	-9.0814e-04	-8.0543e-05	2.2070e-04	-4.6919e-04	-9.0464e-04	-0.0012	-8.4125e-04	1.3370e-05	0.0013
3	0.0022	0.0015	1.3268e-04	-3.6356e-04	7.7289e-04	0.0015	0.0019	0.0014	-2.2024e-05	-0.0021
4	-1.9691e-04	-1.3606e-04	-1.2067e-05	3.3065e-05	-7.0293e-05	-1.3553e-04	-1.7428e-04	-1.2603e-04	2.0031e-06	1.8990e-04
5	-0.0058	-0.0040	-3.5841e-04	9.8210e-04	-0.0021	-0.0040	-0.0052	-0.0037	5.9496e-05	0.0056
6	0.0023	0.0016	1.4104e-04	-3.8647e-04	8.2161e-04	0.0016	0.0020	0.0015	-2.3413e-05	-0.0022
7	0.0055	0.0038	3.3995e-04	-9.3153e-04	0.0020	0.0038	0.0049	0.0036	-5.6433e-05	-0.0053
8	-0.0060	-0.0042	-3.7024e-04	0.0010	-0.0022	-0.0042	-0.0053	-0.0039	6.1460e-05	0.0058
9	0.0011	7.8085e-04	6.9253e-05	-1.8977e-04	4.0342e-04	7.7783e-04	0.0010	7.2333e-04	-1.1496e-05	-0.0011
10	0.0118	0.0081	7.2104e-04	-0.0020	0.0042	0.0081	0.0104	0.0075	-1.1969e-04	-0.0113
11	-0.0017	-0.0012	-1.0211e-04	2.7981e-04	-5.9485e-04	-0.0011	-0.0015	-0.0011	1.6951e-05	0.0016
12	0.0013	8.9369e-04	7.9261e-05	-2.1719e-04	4.6173e-04	8.9024e-04	0.0011	8.2787e-04	-1.3157e-05	-0.0012
13	0.0071	0.0049	4.3579e-04	-0.0012	0.0025	0.0049	0.0063	0.0046	-7.2341e-05	-0.0069
14	0.0024	0.0016	1.4464e-04	-3.9634e-04	8.4257e-04	0.0016	0.0021	0.0015	-2.4010e-05	-0.0023
15	6.4337e-04	4.4453e-04	3.9425e-05	-1.0803e-04	2.2967e-04	4.4281e-04	5.6942e-04	4.1178e-04	-6.5446e-06	-6.2045e-04
16	0.0048	0.0033	2.9533e-04	-8.0925e-04	0.0017	0.0033	0.0043	0.0031	-4.9024e-05	-0.0046
17	0.0018	0.0013	1.1156e-04	-3.0569e-04	6.4987e-04	0.0013	0.0016	0.0012	-1.8519e-05	-0.0018
18	-5.9088e-05	-4.0826e-05	-3.6208e-06	9.9218e-06	-2.1093e-05	-4.0668e-05	-5.2296e-05	-3.7819e-05	6.0106e-07	5.6983e-05
19	0.0038	0.0026	2.3004e-04	-6.3035e-04	0.0013	0.0026	0.0033	0.0024	-3.8187e-05	-0.0036
20	0.0023	0.0016	1.4217e-04	-3.8958e-04	8.2821e-04	0.0016	0.0021	0.0015	-2.3601e-05	-0.0022
21	-2.1420e-04	-1.4800e-04	-1.3126e-05	3.5968e-05	-7.6464e-05	-1.4743e-04	-1.8958e-04	-1.3710e-04	2.1789e-06	2.0657e-04
22	-3.1527e-04	-2.1783e-04	-1.9319e-05	5.2938e-05	-1.1254e-04	-2.1699e-04	-2.7903e-04	-2.0178e-04	3.2070e-06	3.0404e-04
23	-4.8237e-04	-3.3329e-04	-2.9559e-05	8.0998e-05	-1.7219e-04	-3.3200e-04	-4.2693e-04	-3.0874e-04	4.9069e-06	4.6519e-04
24	2.5681e-05	1.7744e-05	1.5737e-06	-4.3122e-06	9.1673e-06	1.7675e-05	2.2729e-05	1.6437e-05	-2.6123e-07	-2.4766e-05
25	-2.8584e-04	-1.9750e-04	-1.7516e-05	4.7997e-05	-1.0204e-04	-1.9673e-04	-2.5298e-04	-1.8295e-04	2.9077e-06	2.7566e-04
26	-8.4551e-04	-5.8419e-04	-5.1812e-05	1.4197e-04	-3.0182e-04	-5.8194e-04	-7.4832e-04	-5.4116e-04	8.6008e-06	8.1539e-04
27	2.1306e-04	1.4721e-04	1.3056e-05	-3.5776e-05	7.6057e-05	1.4664e-04	1.8857e-04	1.3637e-04	-2.1673e-06	-2.0547e-04
28	-1.5284e-04	-1.0561e-04	-9.3662e-06	2.5665e-05	-5.4561e-05	-1.0520e-04	-1.3528e-04	-9.7828e-05	1.5548e-06	1.4740e-04
29	-0.0015	-0.0011	-9.3826e-05	2.5710e-04	-5.4657e-04	-0.0011	-0.0014	-9.7999e-04	1.5575e-05	0.0015

We apply the MNE algorithm to the electrode potential using the following equation:

$$\hat{Q}_{MNE} = G^T(GG^T + \alpha I_N)^{-1}M$$

And we also put alpha = 0.5.

che)

"Normalized Direction : 0.98409"

"Normalized Direction : 0.14091"

"Normalized Direction : 0.10818"

In this code, We first calculate the average Q values by taking the maximum of each row from the matrix Q. Then, we initialize an array to store the norms for 1317 dipole vectors. Using a loop, we extract each dipole's components, compute their norms, and store the results. Afterward, we determine the maximum norm and its index in the array. Finally, we normalize the direction corresponding to this maximum norm and display the normalized direction.

```
%% Q7
% Calculate average Q values
avgQ = max(Q, [], 2);

% Initializing norms array
norms = zeros(1, 1317);

% Calculate norms for each dipole vector
for idx = 1:1317
    vec = avgQ(3*idx-2:3*idx); % Get dipole components
    norms(idx) = norm(vec);     % Compute norm
end

% maximum norm and its index
[maxNorm, maxIdx] = max(norms);

% Get the direction corresponding to the maximum norm
normDir = avgQ(3*maxIdx-2:3*maxIdx) / maxNorm; % Normalize direction
disp("Normalized Direction : "+normDir);
```

he)

Location estimation error: 4.4721

Bipolar direction error: 11.3718

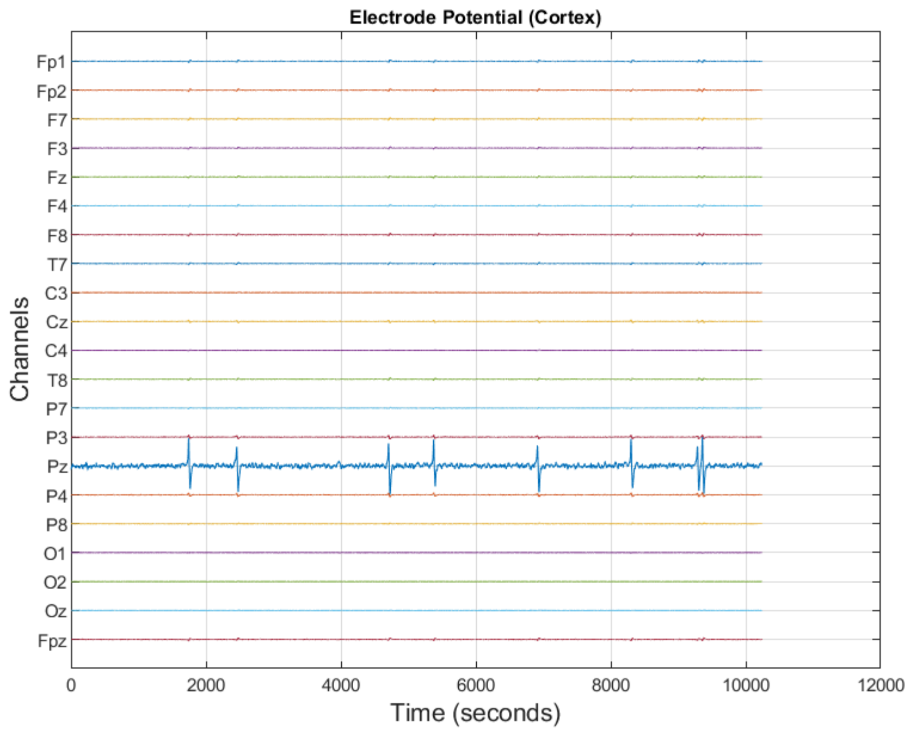
In this code, we calculate two types of errors: `dirError`, which measures the difference between the actual dipole location and the normalized direction, and `posError`, which assesses the distance between a random location in `LocMat` and the location associated with the maximum index. We then display both the location estimation error and the bipolar direction error.

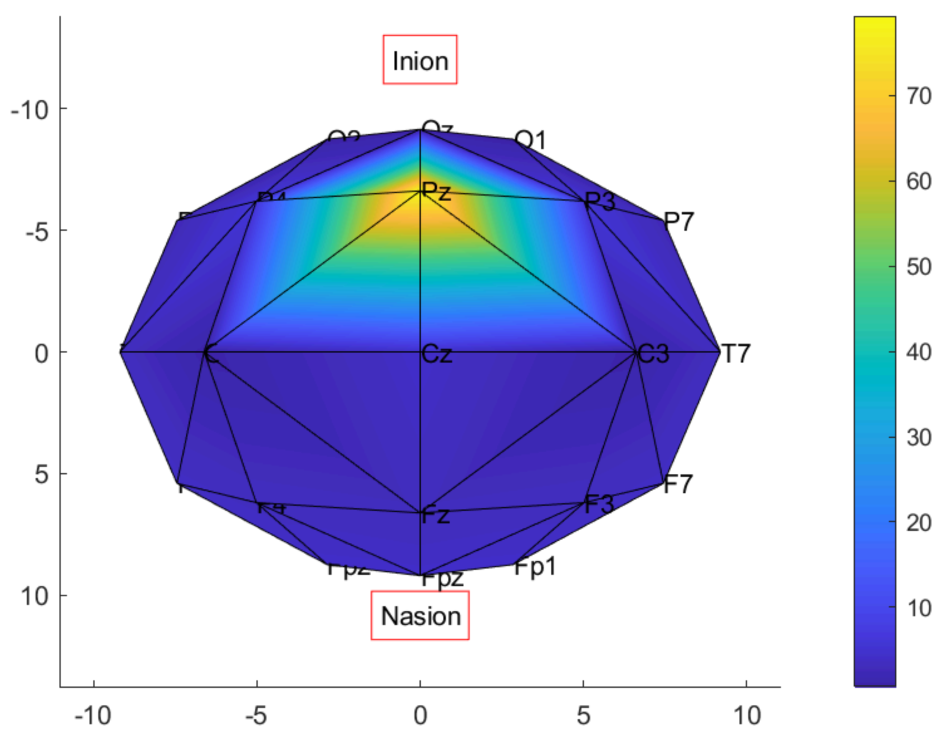
```
%% Q8
dirError = norm(dipole_loc - normDir);
posError = norm(LocMat(:, rand_index) - LocMat(:, maxIdx));
disp("Location estimation error: "+posError);
disp("Bipolar direction error: "+dirError);
```

khe)

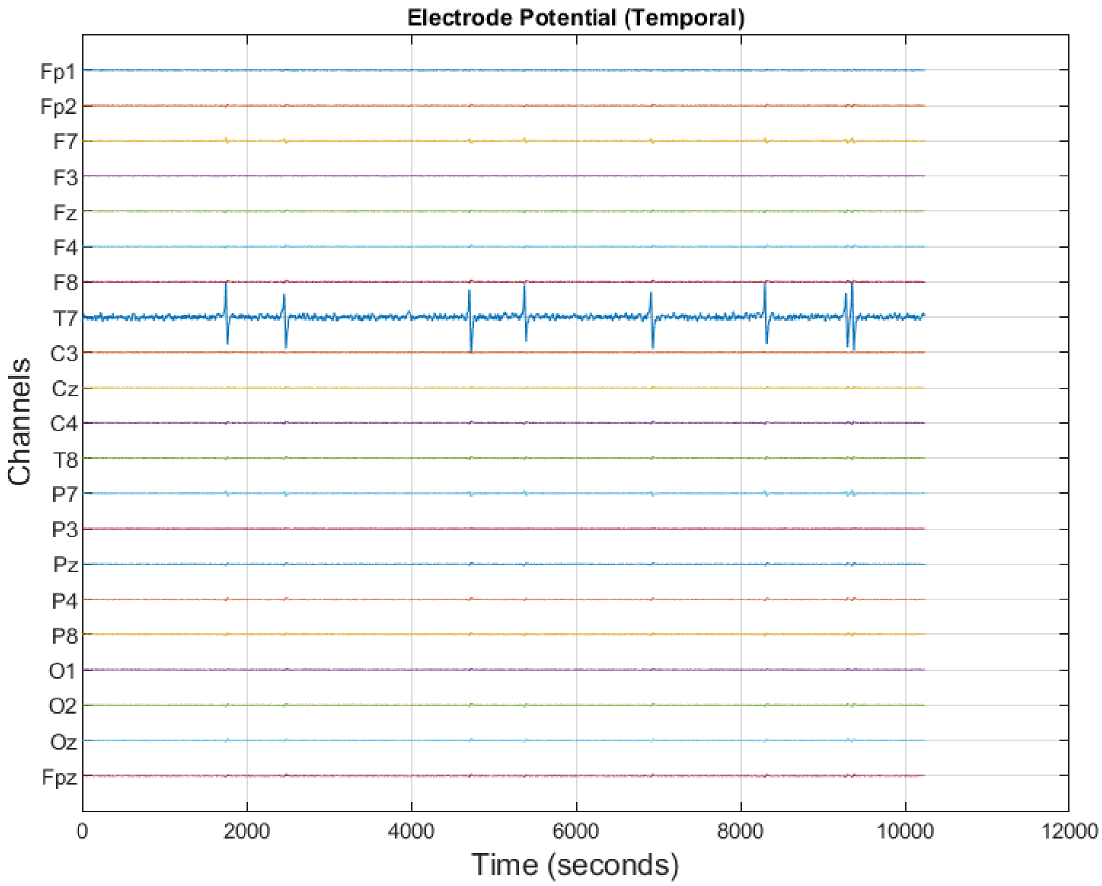
Analyzing Dipole Locations and Potentials

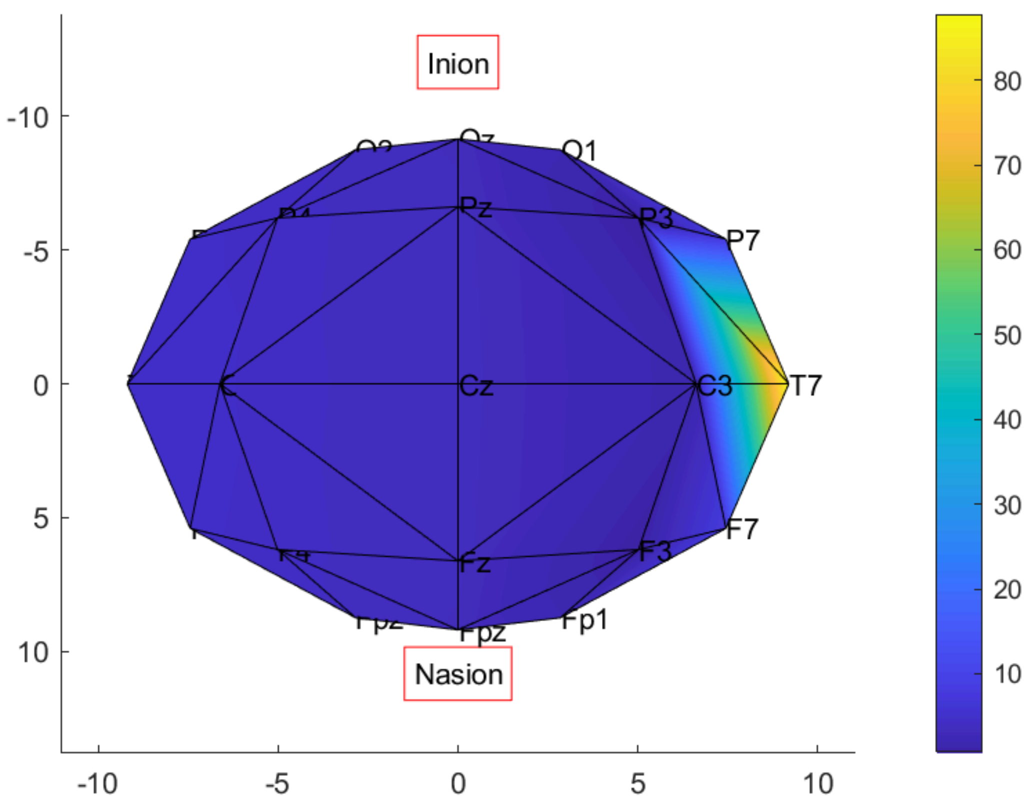
First index (cortex):



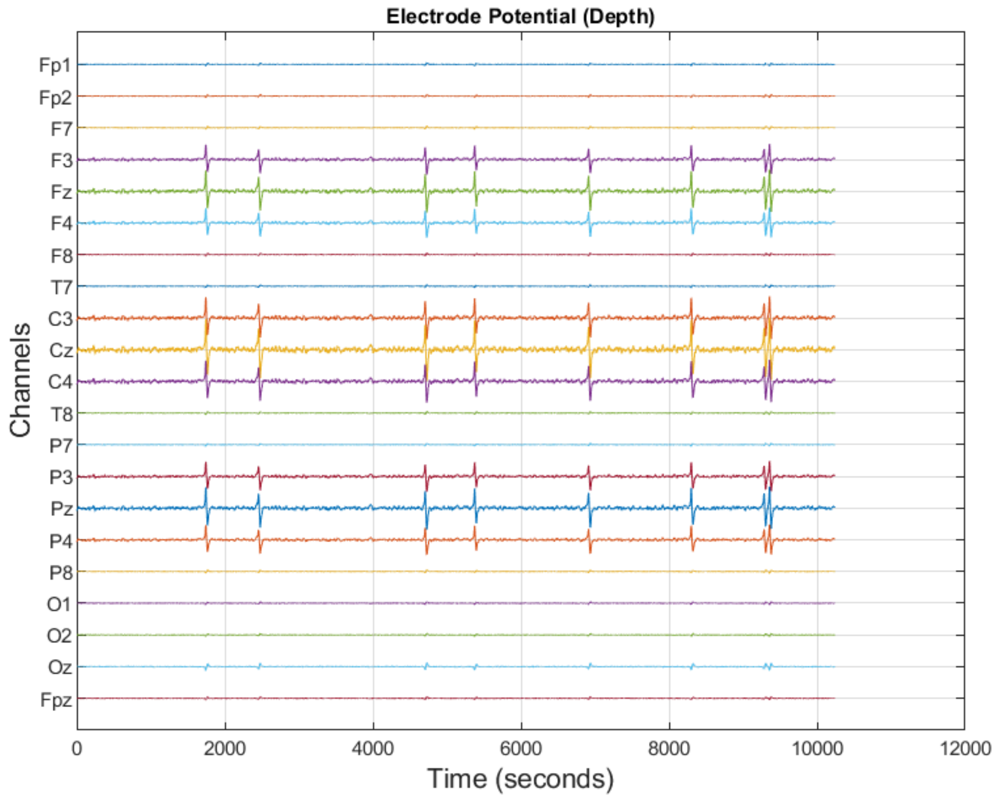


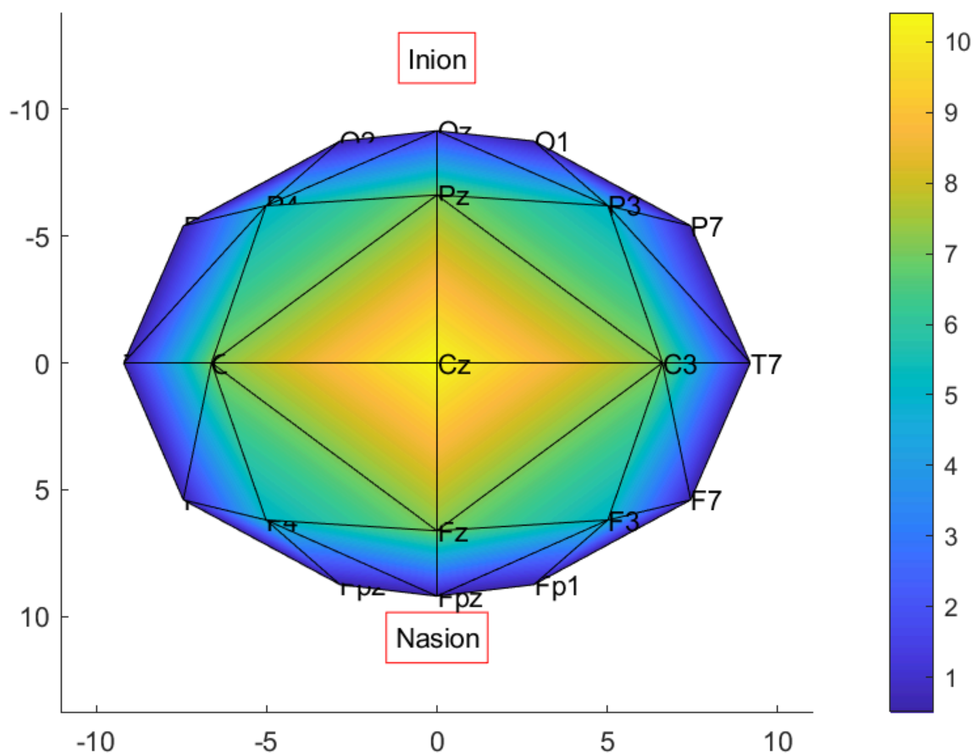
Second index (temporal)





Third index (depth)





Location estimation error: 4.4721

Bipolar direction error: 11.3718

Cortex Position Error: 1.4142

Cortex Direction Error: 0.73386

Temporal Position Error: 1

Temporal Direction Error: 0.40433

Depth Position Error: 7.8102

Depth Direction Error: 0.031425

In this section, if the selected bipolar norm is smaller than half the brain diameter, it will be accepted. It is well observed that the estimate is the least smooth for the tendency towards surface sources.