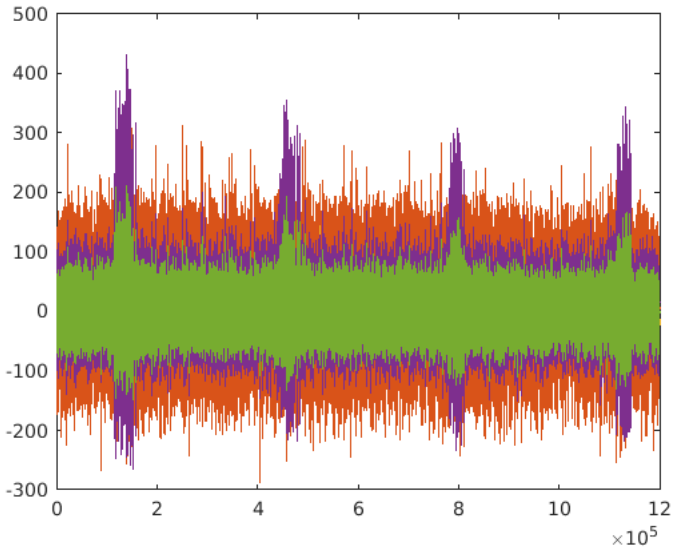
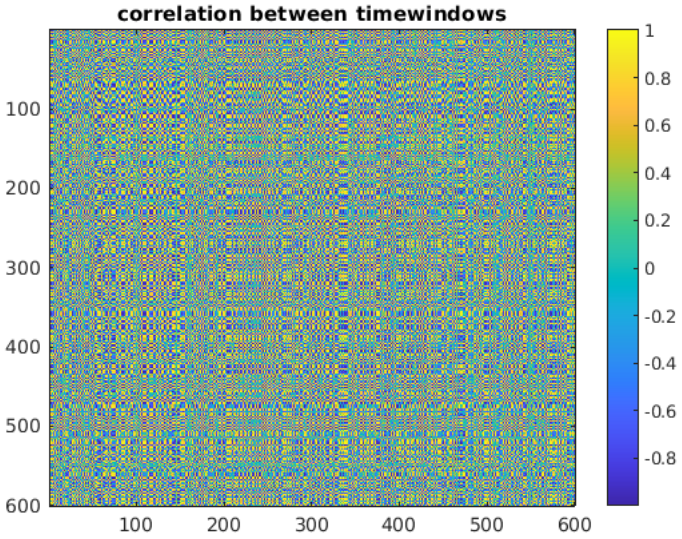
```
% MODE: BIPOLAR
% pos: e22
% neg: e64
%
% WAVEFORM:
% SHAPE: SQUARE BIPHASIC pos/neg
% DURATION/PHASE: 100 us ?
% AMPLITUDE/PHASE: 200 uA
%
% ----------------------------
%
%
% e22: labled ictal events only; interic1   tal events are hidden in the baseline noise.
%
% e64: labeled ictal events only; possibly, interictal events are hidden in the baseline noise.
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Author: LilyHeAsamiko
%
data1 = load('20171005_slice01_01_CTRL1_12.mat');
data2 = load('20171005_slice01_01_CTRL1_13.mat');
data3 = load('20171005_slice01_01_CTRL1_14.mat');
        data4 = load('20171005_slice01_01_CTRL1_22.mat');

datalabel = load('20171005_slice01_01_CTRL1_12_ICTAL_LABELS.mat');

% data1 = load('D:\TUT\Medical\biophysics\NolinearTimeSeriesAnalysis-new\data\20171005\01\20171005_01_mat_files\20171005_slice01_01_CTRL1_
% data2 = load('D:\TUT\Medical\biophysics\NolinearTimeSeriesAnalysis-new\data\20171005\01\20171005_01_mat_files\20171005_slice01_01_CTRL1_
% data3 = load('D:\TUT\Medical\biophysics\NolinearTimeSeriesAnalysis-new\data\20171005\01\20171005_01_mat_files\20171005_slice01_01_CTRL1_
% data4 = load('D:\TUT\Medical\biophysics\NolinearTimeSeriesAnalysis-new\data\20171005\01\20171005_01_mat_files\20171005_slice01_01_CTRL1_
%
% datalabel = load('D:\TUT\Medical\biophysics\NolinearTimeSeriesAnalysis-new\data\20171005\01\20171005_01_LABELS\20171005_slice01_01_CTRL1

fs = data1.fs;
MEA1 = data1.data;
MEA2 = data2.data;
MEA3 = data3.data;
MEA4 = data4.data;

ictals = table2array(datalabel.labels);
N = length(MEA1);%sample number
T = N/fs; %600s
bin = N/T; %samples per bin(1s)
N_bin = N/bin; % bin number
ch = 1;%12 13 14 22

% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% % tonic seizure
% % 3min , 1min pre-seizure, 1min seizure, 1min post-seizure
% MEA0 = data0.data0.data;
% MEA1 = data.data.data;
% seizures0 = table2array(data0.data0.labels);
% seizure1 = table2array(data.data.labels);
% fs = data0.data0.fs
%
% N = length(MEA0);%sample number
% T = N/fs; %180 s
% bin = N/T; %samples per bin(1s)
% N_bin = N/bin; % bin number
% ch = 1;%1 0

MEA_avg = mean([MEA1, MEA2, MEA3, MEA4], 2);
figure
%% onset detection
% average of the multi-channels

plot(MEA1)
hold on
plot(MEA2)
hold on
plot(MEA3)
hold on
plot(MEA4)
hold on
plot(MEA_avg)
```

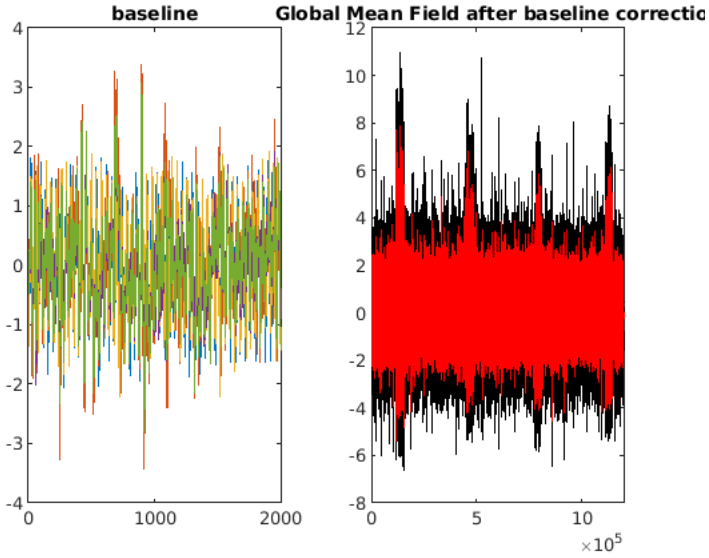



```
MEA_t = [MEA1 MEA2 MEA3 MEA4 MEA_avg];
for win = 1: N_bin
    MEA_t_avg(win, :) = mean(MEA_t((win-1)*bin+1:(win-1)*bin+bin,:),1);
end

% %%%%%%
% %another
% figure
% plot(MEA0)
% hold on
% plot(MEA1)
%
% MEA_t = [MEA0 MEA1];
% for win = 1: N_bin
%     MEA_t_avg(win, :) = mean(MEA_t((win-1)*bin/2+1:(win-1)*bin/2+bin,:),1);
% end

% onset based on decorrelation time: the first t ensures, local minimum of
% autocorrelation: abs(corr< 1/e),  here let e be 2
[rho,pval] = corr(MEA_t_avg');
figure,
%pcolor(rho);
imagesc(rho)
title('correlation between timewindows');
rho_dec = min(find(rho < 0.5));
t_onset = rho_dec;
colorbar
```

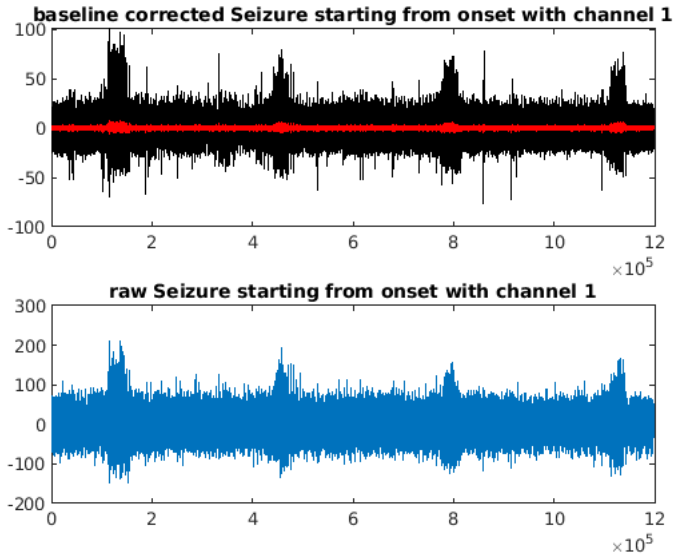



```
%[minr, t_row] = min(abs(rho));
```

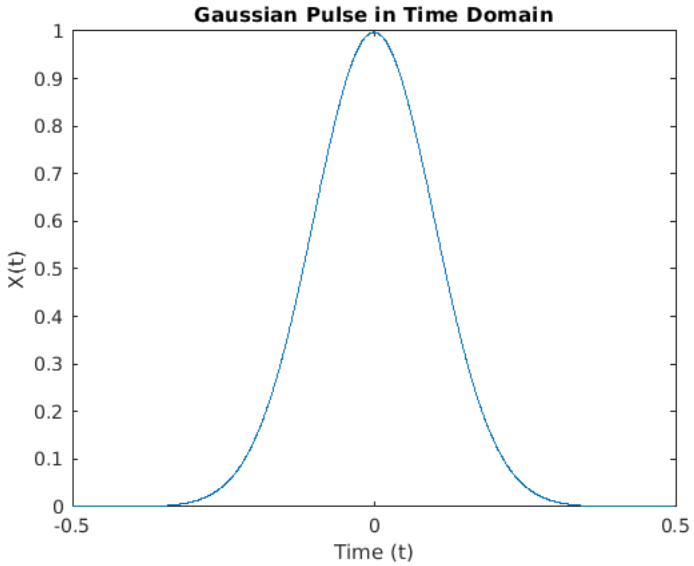
```
%[minrho, t_col] = min(minr);
%t_onset = min(t_col,t_row(t_col));

% onset based on ictals label
% onset_lb = floor(ictals(1));
% if t_onset > onset_lb
%    t_onset = onset_lb;
% end
onset = (t_onset-1)*fs;

MEA_seizure = MEA_t(onset+1: N,:);
MEA_ch = MEA_seizure(:,1);
%  baseline_corrected
MEA_seizure0 = MEA_seizure - repmat(mean(MEA_t_avg(1: t_onset,:), 1),size(MEA_seizure,1), 1);
% Z-score Normalization
MEA_seizure = MEA_seizure0./std(MEA_seizure0, 1);
% GMFP
m = mean(MEA_seizure, 2);
GMF = m;
k = length(MEA_seizure);
%GMF = sqrt(mean((MEA_seizure-repmat(m, 1, size(MEA_seizure, 2))).^2,2));

figure,
subplot(1, 2, 1)
plot(1:onset,MEA_seizure(1:onset,:));
%note wrong: xlim([0 onset+10])
%xticks(int32(1: k/7: onset))
title('baseline');
subplot(1, 2, 2)
plot(onset+1: N, MEA_seizure,'k');
hold on;
plot(onset+1: N, GMF,'r');
%xlim([onset+1 k+10+onset+1])
%xticks(int32(onset+1: k/5: N))
%xticklabels(num2str(onset+1: k/5: N))
title('Global Mean Field after baseline correction');
```




```
MEAy_ch = MEA_seizure0(:,ch);
Pnts = length(MEAy_ch);
figure,
subplot(2, 1, 1)
plot(MEAy_ch, 'k')
hold on
plot(GMF,'r')
title(['baseline corrected Seizure starting from onset with channel ',num2str(ch)]);
subplot(2, 1, 2)
plot(MEA_avg(onset+1: N))
title(['raw Seizure starting from onset with channel ',num2str(ch)]);
```




```
%% count spikes
threshold = 10;% spike: >10 muV
%threshold = 20;
delta = [0.5, 3];
theta = [4, 7];
alpha = [8, 12];
mu = [7.5, 12.5];
SMR = [12.5, 15.5];
beta = [16, 31];
gamma = [32, 100];
HF = 70;
ripple = [80, 250];
fastripple= 251;

t = -0.5:1/fs:0.5;  % Time vector
L = length(t)-1;      % Signal length
X = 1/(4*sqrt(2*pi*0.01))*(exp(-t(1:L).^2/(2*0.01)));

figure,
plot(t(1:L),X)
title('Gaussian Pulse in Time Domain')
xlabel('Time (t)')
ylabel('X(t)')
```

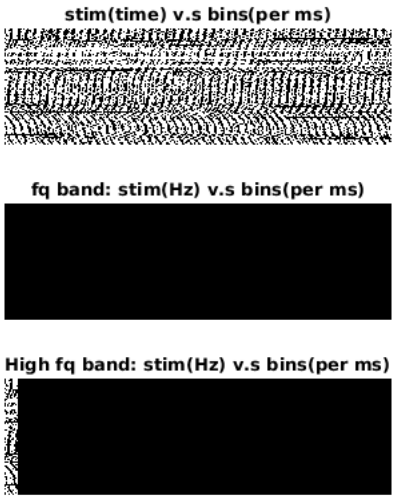



```
%single spikes
%Ns = length(MEAy_ch(MEAy_ch > threshold));

N_bin = ceil(Pnts/bin);
chf_bin_d = zeros(N_bin, bin);
chf_bin_th = zeros(N_bin, bin);
```

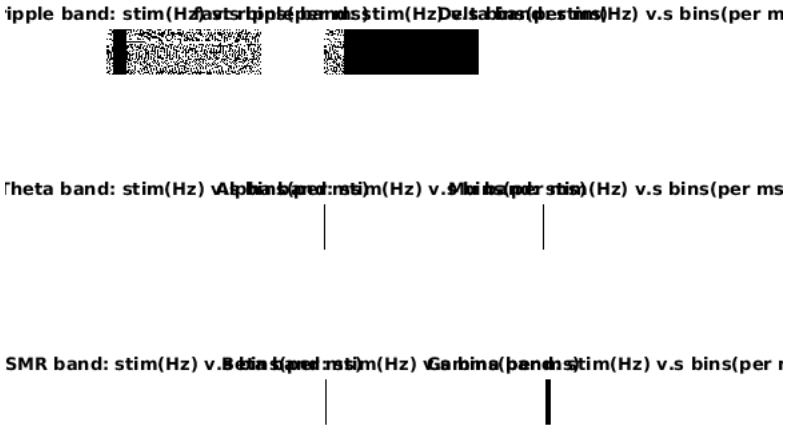
```
chf_bin_a = zeros(N_bin, bin);
chf_bin_m = zeros(N_bin, bin);
chf_bin_s = zeros(N_bin, bin);
chf_bin_b = zeros(N_bin, bin);
chf_bin_g = zeros(N_bin, bin);
chf_bin_h = zeros(N_bin, bin);
chf_bin_r = zeros(N_bin, bin);
chf_bin_fr = zeros(N_bin, bin);

chn_bin = zeros(N_bin, bin);
chf_bin = zeros(N_bin, bin);
MEAs_chft = zeros(N_bin, 0.5*bin);
MEAs_chsd = zeros(N_bin, 0.5*bin);

Ns_chn_bin = zeros(N_bin,1);
Nsft_chn_bin = zeros(N_bin,1);
Nssd_chn_bin = zeros(N_bin,1);
MEAs_chf = zeros(N_bin, bin);

fn = 0:bin-1;
f = 1.0*double(fn)/double(bin-1);

Chf_bin_d = find(f > (delta(1)/fs) & f < (delta(2)/fs));
Chf_bin_th = find(f > (theta(1)/fs) & f < (theta(2)/fs));
Chf_bin_a = find(f > (alpha(1)/fs) & f < (alpha(2)/fs));
Chf_bin_m = find(f > (mu(1)/fs) & f < (mu(2)/fs));
Chf_bin_s = find(f > (SMR(1)/fs) & f < (SMR(2)/fs));
Chf_bin_b = find(f > (beta(1)/fs) & f < (beta(2)/fs));
Chf_bin_g = find(f > (gamma(1)/fs) & f < (gamma(2)/fs));
Chf_bin_h = find(f > HF/fs);
Chf_bin_r = find(f > (ripple(1)/fs) & f < (ripple(2)/fs));
Chf_bin_fr = find(f > fastripple/fs);

if mod(Pnts, bin) > 0
    N_bin = ceil(Pnts/bin);
else
    N_bin = Pnts/bin;
end



%per second
for n = 1: N_bin
%    nn = 2*n-1;
    if n == N_bin
       if length(bin*(n-1)+1:Pnts) < bin
            MEAs_chn = [MEA_ch(bin*(n-1)+1:Pnts); zeros(bin-length(bin*(n-1)+1:Pnts), 1)];
       else
            MEAs_chn = MEA_ch(bin*(n-1)+1:Pnts);
       end
       MEAs_chft(n,:) = MEAs_chn(1:0.5*bin)'; %
       MEAs_chsd(n,:) = MEAs_chn(0.5*bin+1:bin)';
%         %test
%         MEAs_testn = MEA_test(bin*(n-1)+1:Pnts);
%         MEAs_testft = MEA_test(0.5*bin*(nn-1)+1:0.5*bin*nn);
%         MEAs_testsd = MEA_test(0.5*bin*nn+1:Pnts);
    else
       MEAs_chn = MEA_ch(bin*(n-1)+1:bin*n);
       MEAs_chft(n,:) = MEAs_chn(1:0.5*bin)'; %
       MEAs_chsd(n,:) = MEAs_chn(0.5*bin+1:bin)';
%        MEAs_chft = MEA_ch(0.5*bin*(n-1)+1:0.5*bin*n);
%        MEAs_chsd = MEA_ch(0.5*bin*n+1:0.5*bin*(n+1));
        %test
%         MEAs_testn = MEA_test(bin*(n-1)+1:bin*n);
%         MEAs_testft = MEA_test(0.5*bin*(nn-1)+1:0.5*bin*nn);
%         MEAs_testsd = MEA_test(0.5*bin*nn+1:0.5*bin*(nn+1));
    end
    size(fft(MEAs_chn'));
    if length(fft(MEAs_chn))< length(MEAs_chf(n,:))
        FFT_MEAs_chn = [fft(MEAs_chn') zeros(1, length(MEAs_chf(n,:))-length(fft(MEAs_chn)))];
        EXT_MEAs = [MEAs_chn' zeros(1, length(MEAs_chf(n,:))-length(MEAs_chn))];
    else
        FFT_MEAs_chn = fft(MEAs_chn');
        EXT_MEAs = MEAs_chn';
    end
    size(X);
    MEAs_chf(n,:) = FFT_MEAs_chn.*X;

%!!
%     chf_bin_d(n,:) = abs(MEAs_chf(n,:)) > delta(1) & abs(MEAs_chf(n,:)) < delta(2);
%     chf_bin_th(n,:) = abs(MEAs_chf(n,:)) > theta(1) & abs(MEAs_chf(n,:)) < theta(2);
```

```
%     chf_bin_a(n,:) = abs(MEAs_chf(n,:)) > alpha(1) & abs(MEAs_chf(n,:)) < alpha(2);
%     chf_bin_m(n,:) = abs(MEAs_chf(n,:)) > mu(1) & abs(MEAs_chf(n,:)) < mu(2);
%     chf_bin_s(n,:) = abs(MEAs_chf(n,:)) > SMR(1) & abs(MEAs_chf(n,:)) < SMR(2);
%     chf_bin_b(n,:) = abs(MEAs_chf(n,:)) > beta(1) & abs(MEAs_chf(n,:)) < beta(2);
%     chf_bin_g(n,:) = abs(MEAs_chf(n,:)) > gamma(1) & abs(MEAs_chf(n,:)) < gamma(2);

    chf_bin_h(n, Chf_bin_h) = abs(MEAs_chf(n, Chf_bin_h));
    chf_bin_r(n, Chf_bin_r) = abs(MEAs_chf(n, Chf_bin_r));
    chf_bin_fr(n, Chf_bin_fr) = abs(MEAs_chf(n, Chf_bin_fr));
    chf_bin_h(n,abs(EXT_MEAs) > threshold) = abs(MEAs_chf(n,abs(EXT_MEAs) > threshold))*(sum(abs(EXT_MEAs) > threshold)>=6);
    chf_bin_r(n,abs(EXT_MEAs) > threshold) = abs(MEAs_chf(n,abs(EXT_MEAs) > threshold))*(sum(abs(EXT_MEAs) > threshold)>=6);
    chf_bin_fr(n, abs(EXT_MEAs) > threshold) = abs(MEAs_chf(n,abs(EXT_MEAs) > threshold))*(sum(abs(EXT_MEAs) > threshold)>=6);
    chf_bin_d(n,Chf_bin_d) = abs(MEAs_chf(n, Chf_bin_d));
    chf_bin_th(n,Chf_bin_th) = abs(MEAs_chf(n, Chf_bin_th));
    chf_bin_a(n,Chf_bin_a) = abs(MEAs_chf(n, Chf_bin_a));
    chf_bin_m(n,Chf_bin_m) = abs(MEAs_chf(n, Chf_bin_m));
    chf_bin_s(n,Chf_bin_s) = abs(MEAs_chf(n, Chf_bin_s));
    chf_bin_b(n,Chf_bin_b) = abs(MEAs_chf(n, Chf_bin_b));
    chf_bin_g(n, Chf_bin_g) = abs(MEAs_chf(n, Chf_bin_g));


    Ns_chn_bin(n) = length(MEAs_chn(abs(MEAs_chn) > threshold));
    Nsft_chn_bin(n) = length(MEAs_chft(abs(MEAs_chft) > threshold));
    Nssd_chn_bin(n) = length(MEAs_chsd(abs(MEAs_chsd) > threshold));
    chn_bin(n,:) = EXT_MEAs.*(abs(EXT_MEAs) > threshold);
    if n == N_bin
        break;
    end
end
[normalizedACF, lags]= autocorr(chn_bin(:),'NumLags',573);
chns_rho = normalizedACF;
[normalizedACF, lags]= autocorr(MEAs_chf(:),'NumLags',573);
chf_rho = normalizedACF;
% [chnsd_rho,chnsd_p] = corr(chf_bin_d);
% [chnsth_rho,chnsth_p] = corr(chf_bin_th);
% [chnsa_rho,chnsa_p] = corr(chf_bin_a);
% [chnsm_rho,chnsm_p] = corr(chf_bin_m);
% [chnss_rho,chnss_p] = corr(chf_bin_s);
% [chnsb_rho,chnsb_p] = corr(chf_bin_b);
% [chnsg_rho,chnsg_p] = corr(chf_bin_g);

Ns = sum(Ns_chn_bin);

[normalizedACF, lags]= autocorr(chf_bin_d(:),'NumLags',573);
chnsd_rho = normalizedACF;
[normalizedACF, lags]= autocorr(chf_bin_th(:),'NumLags',573);
chnsth_rho = normalizedACF;
[normalizedACF, lags]= autocorr(chf_bin_a(:),'NumLags',573);
chnsa_rho = normalizedACF;
[normalizedACF, lags]= autocorr(chf_bin_m(:),'NumLags',573);
chnsm_rho = normalizedACF;
[normalizedACF, lags]= autocorr(chf_bin_s(:),'NumLags',573);
chnss_rho = normalizedACF;
[normalizedACF, lags]= autocorr(chf_bin_b(:),'NumLags',573);
chnsb_rho = normalizedACF;
[normalizedACF, lags]= autocorr(chf_bin_g(:),'NumLags',573);
chnsg_rho = normalizedACF;
[normalizedACF, lags]= autocorr(chf_bin_h(:),'NumLags',573);
chnsh_rho = normalizedACF;
[normalizedACF, lags]= autocorr(chf_bin_r(:),'NumLags',573);
chnsr_rho = normalizedACF;
[normalizedACF, lags]= autocorr(chf_bin_fr(:),'NumLags',573);
chnsfr_rho = normalizedACF;
% [chnsth_rho,chnsth_p] = mscohere(chf_bin_th, chf_bin_th);
% [chnsa_rho,chnsa_p] = mscohere(chf_bin_a, chf_bin_a);
% [chnsm_rho,chnsm_p] = mscohere(chf_bin_m, chf_bin_m);
% [chnss_rho,chnss_p] = mscohere(chf_bin_s, chf_bin_s);
% [chnsb_rho,chnsb_p] = mscohere(chf_bin_b, chf_bin_b);
% [chnsg_rho,chnsg_p] = mscohere(chf_bin_g, chf_bin_g);
% [chnsh_rho,chnsh_p] = mscohere(chf_bin_h, chf_bin_h);
% [chnsr_rho,chnsr_p] = mscohere(chf_bin_r, chf_bin_r);
% [chnsfr_rho,chnsfr_p] = mscohere(chf_bin_fr, chf_bin_fr);

chnsd_rho(isnan(chnsd_rho)) = 0;
chnsth_rho(isnan(chnsth_rho)) = 0;
chnsa_rho(isnan(chnsa_rho)) = 0;
chnsm_rho(isnan(chnsm_rho)) = 0;
chnss_rho(isnan(chnss_rho)) = 0;
chnsb_rho(isnan(chnsb_rho)) = 0;
chnsg_rho(isnan(chnsg_rho)) = 0;
chnsh_rho(isnan(chnsh_rho)) = 0;
```

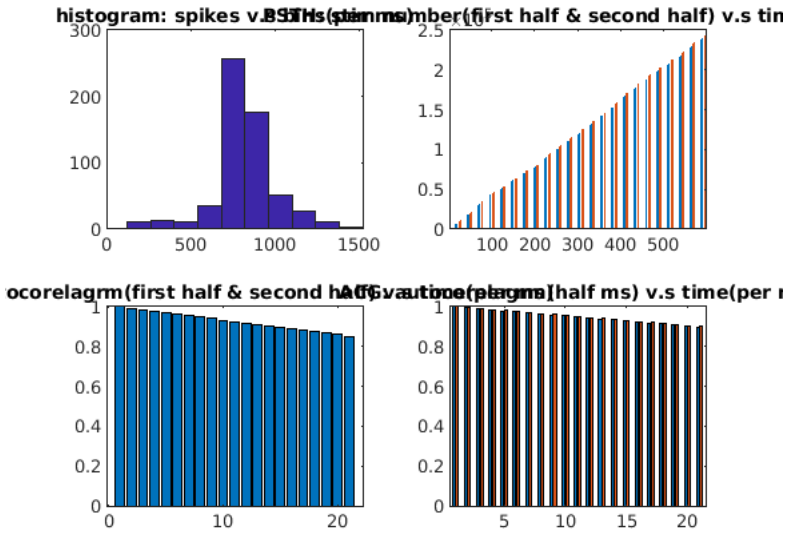
```
chnsr_rho(isnan(chnsr_rho)) = 0;
chnsfr_rho(isnan(chnsfr_rho)) = 0;

%0 black
figure,
subplot(3,1,1)
imshow(chn_bin==0);
title('stim(time) v.s bins(per ms)')
subplot(3,1,2)
imshow(abs(MEAs_chf) == 0);
title('fq band: stim(Hz) v.s bins(per ms)')
subplot(3,1,3)
imshow(abs(chf_bin_h) == 0);
title('High fq band: stim(Hz) v.s bins(per ms)')
```



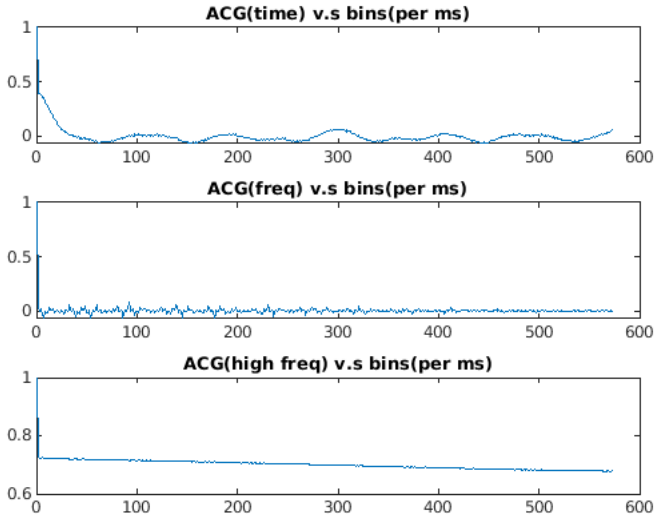

```
figure,
subplot(3,3,1)
imshow(chf_bin_r==0);
title('ripple band: stim(Hz) v.s bins(per ms)')
subplot(3,3,2)
imshow(chf_bin_fr==0);
title('fast ripple band: stim(Hz) v.s bins(per ms)')
subplot(3,3,3)
imshow(chf_bin_d==0);
title('Delta band: stim(Hz) v.s bins(per ms)')
subplot(3,3,4)
imshow(chf_bin_th==0);
title('Theta band: stim(Hz) v.s bins(per ms)')
subplot(3,3,5)
imshow(chf_bin_a==0);
title('Alpha band: stim(Hz) v.s bins(per ms)')
subplot(3,3,6)
imshow(chf_bin_m==0);
title('Mu band: stim(Hz) v.s bins(per ms)')
subplot(3,3,7)
imshow(chf_bin_s==0);
title('SMR band: stim(Hz) v.s bins(per ms)')
subplot(3,3,8)
imshow(chf_bin_b==0);
title('Beta band: stim(Hz) v.s bins(per ms)')
subplot(3,3,9)
imshow(chf_bin_g==0);
title('Gamma band: stim(Hz) v.s bins(per ms)')
```



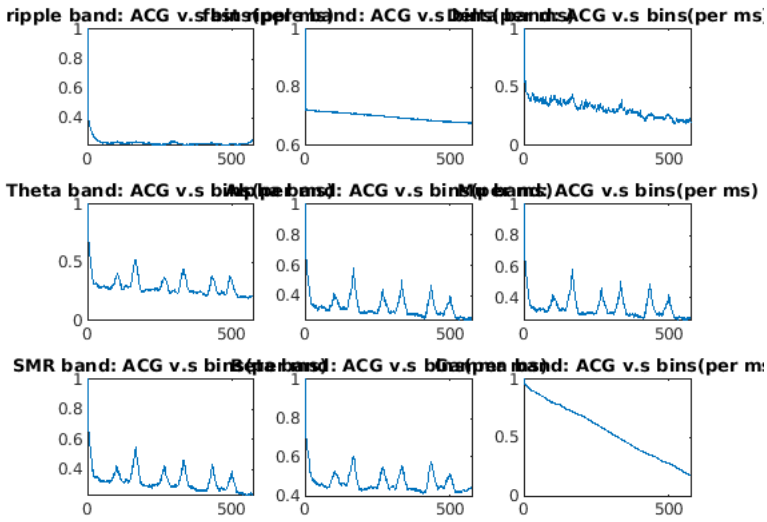

```
figure,
subplot(2,2,1)
hist(Ns_chn_bin);
title('histogram: spikes v.s bins(per ms)')
subplot(2,2,2)
bar([Nsft_chn_bin,Nssd_chn_bin]);
title('PSTH: stim number(first half & second half) v.s time(per ms)')
subplot(2,2,3)
bar(autocorr([Nsft_chn_bin', Nssd_chn_bin']));
title('ACG: autocorelagrm(first half & second half) v.s time(per ms)')
subplot(2,2,4)
bar([autocorr(Nsft_chn_bin), autocorr(Nssd_chn_bin)]);
title('ACG: autocorelagrm(half ms) v.s time(per ms)')
```



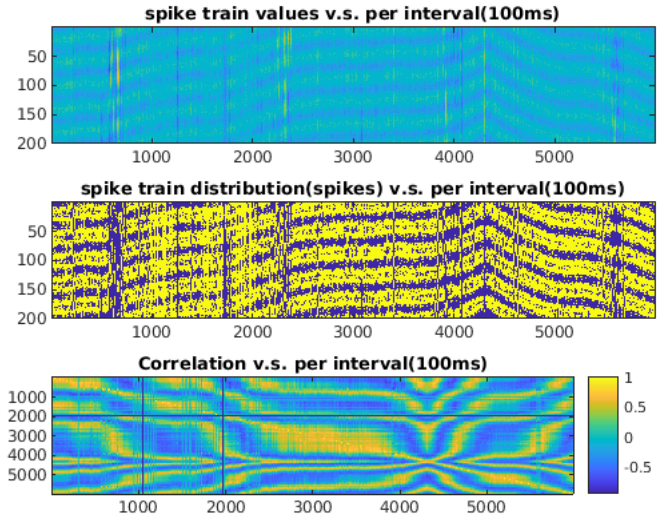

```
figure,
subplot(3,1,1)
plot(chns_rho);
title('ACG(time) v.s bins(per ms)')
%colorbar
subplot(3,1,2)
plot(chf_rho);
title('ACG(freq) v.s bins(per ms)')
%colorbar
subplot(3,1,3)
plot(chnsh_rho);
title('ACG(high freq) v.s bins(per ms)')
```




```
%colorbar

figure,
subplot(3,3,1)
plot(chnsr_rho);
title('ripple band: ACG v.s bins(per ms)')
%colorbar
subplot(3,3,2)
plot(chnsfr_rho);
title('fast ripple band: ACG v.s bins(per ms)')
%colorbar
subplot(3,3,3)
plot(chnsd_rho);
title('Delta band: ACG v.s bins(per ms)')
%colorbar
subplot(3,3,4)
plot(chnsth_rho);
title('Theta band: ACG v.s bins(per ms)')
%colorbar
subplot(3,3,5)
plot(chnsa_rho);
title('Alpha band: ACG v.s bins(per ms)')
%colorbar
subplot(3,3,6)
%colorbar
plot(chnsm_rho);
title('Mu band: ACG v.s bins(per ms)')
%colorbar
subplot(3,3,7)
plot(chnss_rho);
title('SMR band: ACG v.s bins(per ms)')
%colorbar
subplot(3,3,8)
plot(chnsb_rho);
title('Beta band: ACG v.s bins(per ms)')
%colorbar
subplot(3,3,9)
plot(chnsg_rho);
title('Gamma band: ACG v.s bins(per ms)')
```

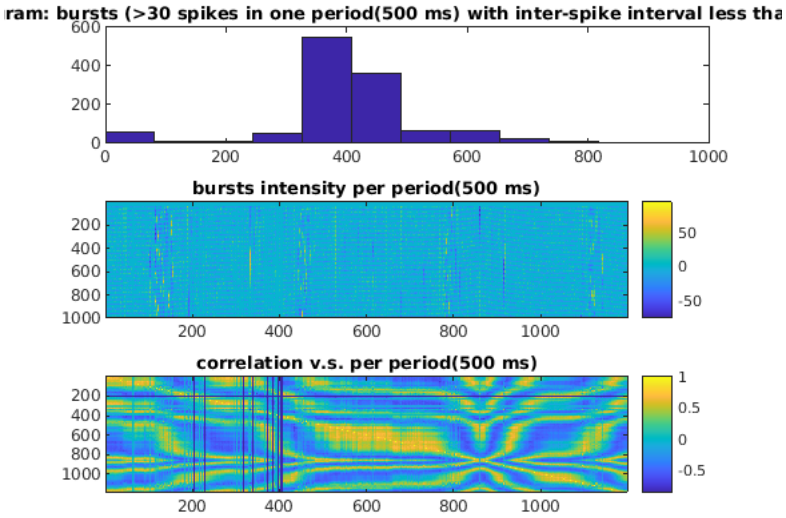



```
%colorbar
%ylabel(Stim)

% spike train: >5 spikes in one interval
% mark (laptop does not take correct v)
interval = bin/10;% interval: 100ms
if mod(Pnts, interval) > 0
    Nint = floor(Pnts/interval);
else
    Nint = Pnts/interval;
end
Nt_int = zeros(Nint, 1);
s_int = zeros(interval,Nint);
Nr_int = zeros(interval,Nint);

for n = 1: Nint
    nn = 2*n - 1;
    if n == Nint
        MEAint_ch = [MEA_ch(interval*(n-1)+1:Pnts); zeros(length(interval) - length(interval*(n-1)+1:Pnts), 1)];
%         MEAint_ch = MEA_ch(interval*(n-1)+1:Pnts);
    else
        MEAint_ch = MEA_ch(interval*(n-1)+1:interval*n);
    end
    Ns_int = length(MEAint_ch(abs(MEAint_ch) > threshold));
    if (Ns_int > 5)
        Nt_int(n) = Ns_int;
        s_int(:,n) = Ns_int.*(abs(MEAint_ch) > threshold);
        Nr_int(:,n) = MEAint_ch.*(abs(MEAint_ch) > threshold);
    end
end
Ntr = sum(Nt_int);
[chni_rho,chni_p] = corr(Nr_int);
figure,
subplot(3,1,1)
imagesc(Nr_int);
title('spike train values v.s. per interval(100ms)')
subplot(3,1,2)
imagesc(s_int==0);
title('spike train distribution(spikes) v.s. per interval(100ms)')
subplot(3,1,3)
imagesc(chni_rho);
title('Correlation v.s. per interval(100ms)')
colorbar
```

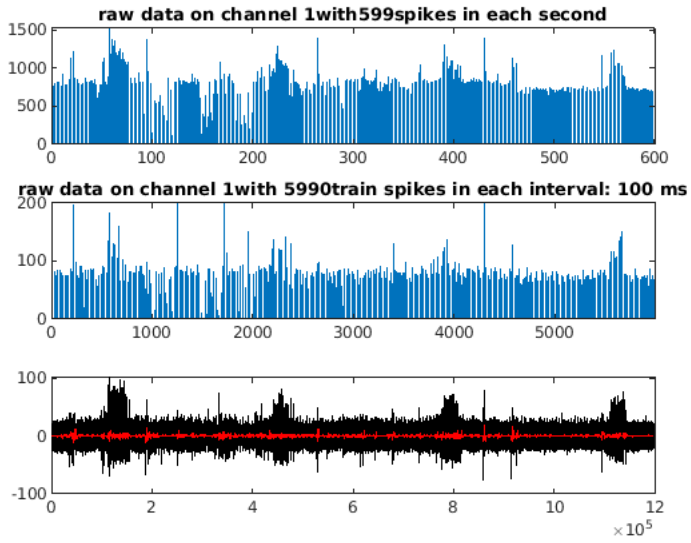



```
% burst: >30 spikes in one period(500 ms with inter-spike interval less than 20 ms)
interval2 = round(interval/5);
period = 5*interval;

if mod(Pnts, period) > 0
    Nperiod = floor(Pnts/period) + 1;
else
    Nperiod = Pnts/period;
end
Nb_per_int2 = zeros(Nperiod,1);
b_per_int2 = zeros(period,Nperiod);

if mod(period, interval2) > 0
    Nint2 = floor(period/interval2) + 1;
else
    Nint2 = period/interval2;
end

for n = 1: Nperiod
    if n == Nperiod
        MEAper_ch = [MEA_ch(period*(n-1)+1:Pnts);zeros(length(period) - length(period*(n-1)+1:Pnts))];
    else
        MEAper_ch = MEA_ch(period*(n-1)+1:period*n);
    end
    Nb_per = zeros(Nint2,1);
    b_per = zeros(interval2,Nint2);
    for nn = 1: Nint2
        if nn == Nint2
            MEAper_int2_ch = [MEAper_ch(interval2*(nn-1)+1:interval2*nn);zeros(length(interval2) - length(interval2*(nn-1)+1:interval2*nn)
        else
                MEAper_int2_ch = MEAper_ch(interval2*(nn-1)+1:interval2*nn);
        end
        Nb_per(nn) = length(MEAper_int2_ch(abs(MEAper_int2_ch) > threshold));
        if nn > 1
            if Nb_per(nn-1)*Nb_per(nn) == 0
                Nb_per(nn) = 0;
            elseif nn < Nint2
                b_per(:, nn) = MEAper_int2_ch.*(abs(MEAper_int2_ch) > threshold);
            else
                b_per(1:interval2, nn) = MEAper_int2_ch.*(abs(MEAper_int2_ch) > threshold);
            end
        end
    end
%    MEAper2_int2_ch = MEAper_ch(interval2*Nint2+1:interval2*Nint2+interval2);
    Nb_per_int2(n) = sum(Nb_per);
    temp = b_per.*(b_per ~= 0);
    b_per_int2(:,n) = temp(:);
end
Nburst = sum(Nb_per_int2);
[chnp_rho,chnp_p] = corr(b_per_int2);
figure,
subplot(3,1,1)
hist(Nb_per_int2);
title('histogram: bursts (>30 spikes in one period(500 ms) with inter-spike interval less than 20 ms)')
subplot(3,1,2)
```

```
imagesc(b_per_int2);
title('bursts intensity per period(500 ms)')
colorbar
subplot(3,1,3)
imagesc(chnp_rho);
title('correlation v.s. per period(500 ms)')
colorbar
```



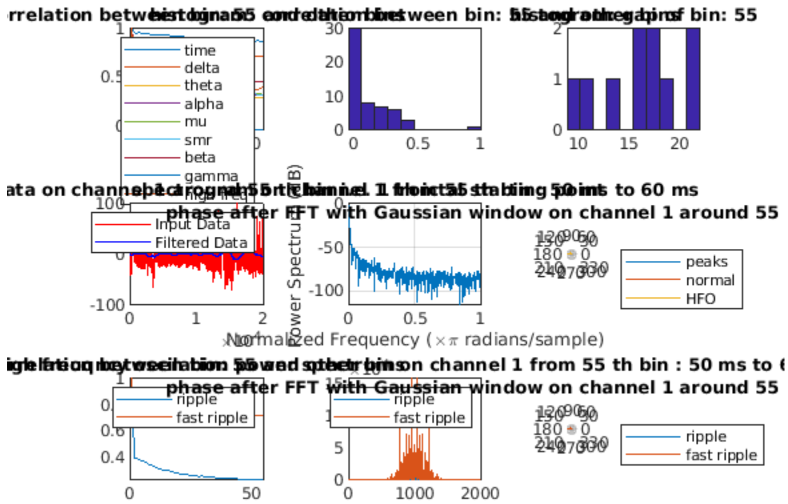

```
figure,
subplot(3,1,1)
bar(Ns_chn_bin);
title(['raw data on channel ', num2str(ch),'with', num2str(length(Ns_chn_bin)), 'spikes in each second']);
subplot(3,1,2)
bar(Nt_int);
title(['raw data on channel ', num2str(ch),'with ', num2str(length(Nt_int)), 'train spikes in each interval: 100 ms']);
subplot(3,1,3)
bar(Nb_per_int2);
title(['raw data on channel ', num2str(ch),'with ', num2str(length(Nb_per_int2)), 'bursts in each period: 500 ms']);
%display(['raw data on channel ', num2str(ch), ' ', 'has ', num2str(Ns),' single spikes,', num2str(Ntr),' spike trains and ', num2str(Nbur

% preprocess
winlen = bin; %samples per window
b = (1/winlen)*ones(1,winlen);
a = 1;

%filter
MEA_t = filter(b, a, MEAy_ch);
plot(MEAy_ch,'k');
hold on
plot(MEA_t,'r');
```

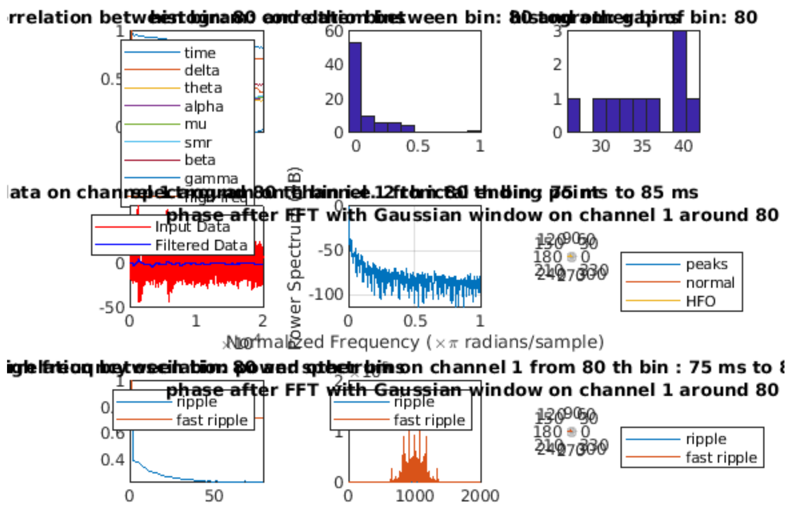


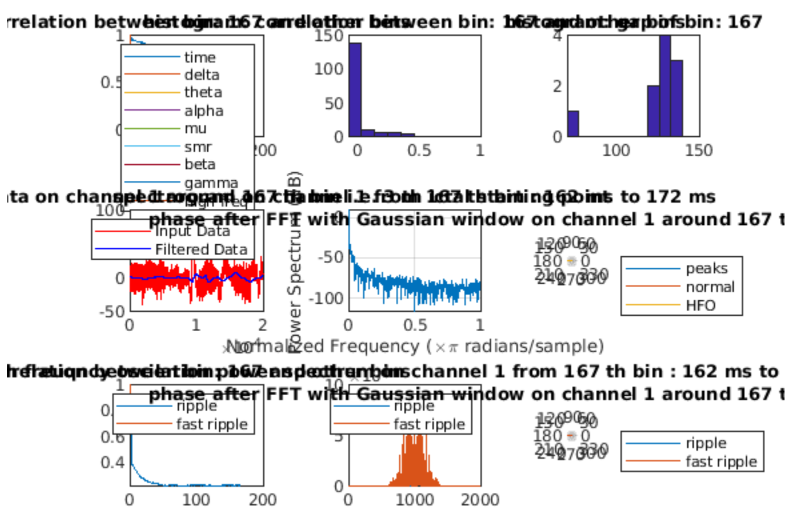

```
%spikes of ictals (narrow and broad with/without filter)
```

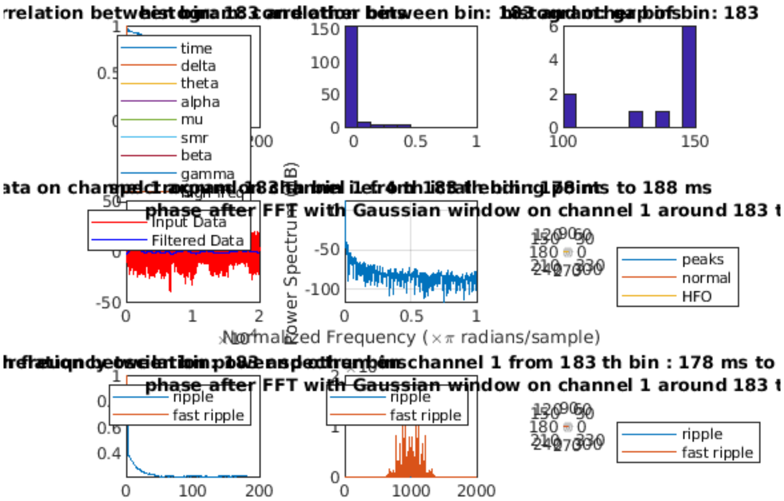
```
asym = zeros(length(ictals(:)),1);
dur = zeros(length(ictals(:)),1);
starts = ictals(:,1);
ends = ictals(:,2);
gap = cell(length(ictals(:)));
NBIN = zeros(length(ictals(:)),1);

for n = 1:length(ictals(:))
    if mod(n, 2) == 1
        nbin = floor(starts((n+1)/2));
    else
        nbin = floor(ends(n/2));
    end

    NBIN(n) = nbin;

    MEA_ictal_bin = zeros(bin,1);

    n_interv = (nbin-5)*bin: (nbin+5)*bin;
    MEA_ictal_bin = MEA_t(bin*(nbin-1)+1:bin*nbin);
    fire_n_interv(:,n)= MEA_ictal_bin;

    au = chns_rho(1:nbin);
    aud = chnsd_rho(1:nbin);
    auth = chnsth_rho(1:nbin);
    aua = chnsa_rho(1:nbin);
    aum = chnsm_rho(1:nbin);
    aus = chnss_rho(1:nbin);
    aub = chnsb_rho(1:nbin);
    aug = chnsg_rho(1:nbin);
    auhh = chnsh_rho(1:nbin);
    aur = chnsr_rho(1:nbin);
    aufr = chnsfr_rho(1:nbin);

    figure,
    subplot(3,3,1)
    plot(au)
    hold on
    plot(aud)
    hold on
    plot(auth)
    hold on
    plot(aua)
    hold on
    plot(aum)
    hold on
    plot(aus)
    hold on
    plot(aub)
    hold on
    plot(aug)
    hold on
    plot(auhh)


    title(['correlation between bin: ', num2str(nbin), ' and other bins']);
    legend([{'time'},{'delta'},{'theta'},{'alpha'},{'mu'},{'smr'},{'beta'},{'gamma'},{'high freq'}]);

    [auh, Bin] = hist(au);
    subplot(3,3,2)
    hist(au)
    title(['histogram: correlation between bin: ', num2str(nbin), ' and other bins']);


    qa1 = quantile(au, 0);
    qa2 = quantile(au, 0.75);
    gapn = au(au <= qa2 & au >= qa1);
    Bini = find(au <= qa2 & au >= qa1);
    [count, center] = hist(gapn);
    for i = 1:length(center)
        B(1+(i-1)*length(Bini(abs(gapn - center(i))< 0.1)):i*length(Bini(abs(gapn - center(i))< 0.1))) = Bini(abs(gapn - center(i))< 0.1);
    end
    gap{n} = hist(B(B > 0));
    subplot(3,3,3)
    hist(gap{n})
    title(['histogram: gap of bin: ', num2str(nbin)]);
    clear B gapn Bini count center

    subplot(3,3,4)
    plot(MEAy_ch(n_interv),'r');
    hold on
```

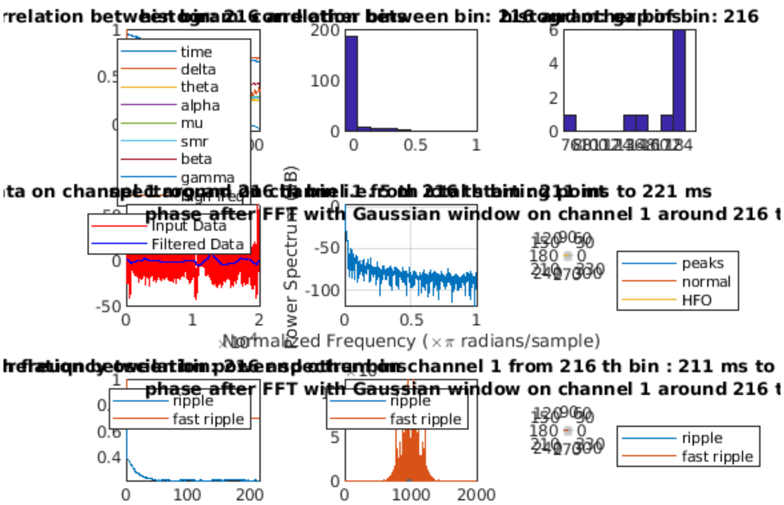
```
    plot(MEA_t(n_interv),'b');
    if mod(n,2) == 1
        title(['raw data v.s filtered data on channel ', num2str(ch),' around ', num2str(nbin), ' th bin i.e. ', num2str(n), ' th ictal st
    else
        title(['raw data v.s filtered data on channel ', num2str(ch),' around ', num2str(nbin), ' th bin i.e. ', num2str(n), ' th ictal er
    end
    legend('Input Data','Filtered Data')


    subplot(3,3,5)
    pspectrum(MEA_ictal_bin);
    title(['spectrogram on channel ', num2str(ch),' from ', num2str(nbin), ' th bin : ', num2str(nbin-5),' ms to ', num2str(nbin+5), ' ms'


    [pks, locs] = findpeaks(MEA_ictal_bin);
    [MAX, MAXI] = max(MEA_ictal_bin);
    [MIN, MINI] = min(MEA_ictal_bin);
    a = MAX - MIN;
    b = pks(length(pks)) - MIN;
    asym(n) = (a - b)/(a + b);
    dur(n) = locs(length(pks)) - MINI;

    [phi,w] = phasez(pks);
    A = abs(pks);
   [phi1,w1] = phasez(MEA_ictal_bin);
    A1 = abs(MEA_ictal_bin);

    [phih,wh] = phasez(chf_bin_h(nbin,:));
    Ah = abs(chf_bin_h(nbin,:));
   [phir,wr] = phasez(chf_bin_r(nbin,:));
    Ar = abs(chf_bin_r(nbin,:));
   [phifr,wfr] = phasez(chf_bin_fr(nbin,:));
    Afr = abs(chf_bin_fr(nbin,:));

    subplot(3,3,6)
    polarplot(w(1:min(length(A),length(w))),A(1:min(length(A),length(w))), w1(1:min(length(A1),length(w1))),A1(1:min(length(A1),length(w1)
    title(['phase after FFT with Gaussian window on channel ', num2str(ch),' around ', num2str(nbin), ' th bin : ', num2str(nbin-5),' ms',
    legend([{'peaks'},{'normal'},{'HFO'}]);

    subplot(3,3,7)
    plot(aur)
    hold on
    plot(aufr)
    title(['correlation between bin: ', num2str(nbin), ' and other bins']);
    legend([{'ripple'},{'fast ripple'}]);

    subplot(3,3,8)
    plot((chf_bin_r(nbin,:).^2)');
    hold on
    plot((chf_bin_fr(nbin,:).^2)');
    title(['high freuqncy oscilation power spectrum on channel ', num2str(ch),' from ', num2str(nbin), ' th bin : ', num2str(nbin-5),' ms
    legend([{'ripple'},{'fast ripple'}]);



    subplot(3,3,9)
    polarplot(wr(1:min(length(Ar),length(wr))),Ar(1:min(length(Ar),length(wr))), wfr(1:min(length(Afr),length(wfr))),Afr(1:min(length(Afr)
    title(['phase after FFT with Gaussian window on channel ', num2str(ch),' around ', num2str(nbin), ' th bin : ', num2str(nbin-5),' ms',
    legend([{'ripple'},{'fast ripple'}]);
end
```

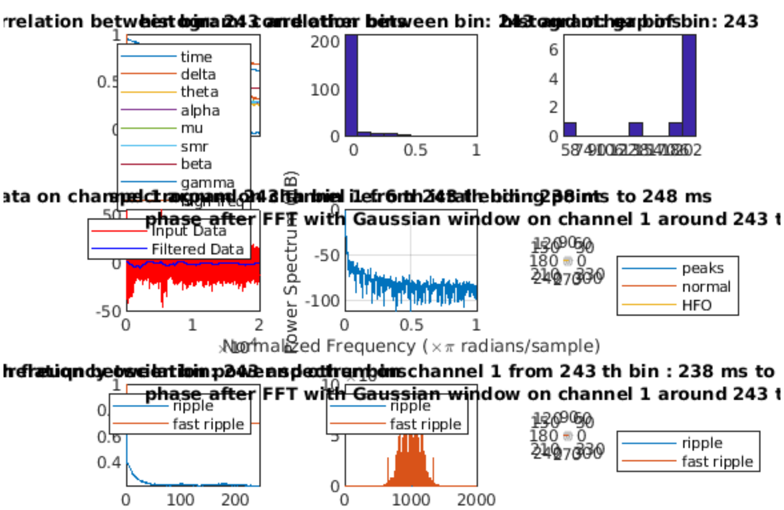

time
delta
theta
alpha
mu
smr
beta
gamma
Input Data
Filtered Data
phase after FFT with Gaussian window on channel 1 around 55
Normalized Frequency (×π radians/sample)
peaks
normal
HFO
ripple
fast ripple

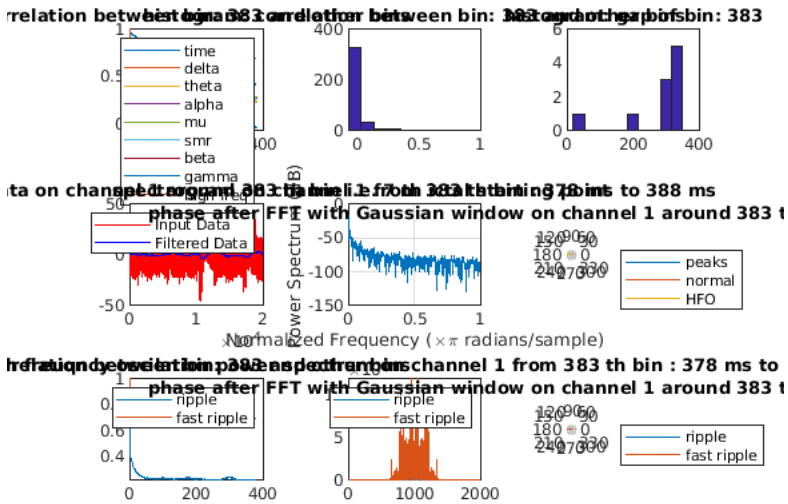

time
delta
theta
alpha
mu
smr
beta
gamma
Input Data
Filtered Data
phase after FFT with Gaussian window on channel 1 around 80
Normalized Frequency (×π radians/sample)
peaks
normal
HFO
ripple
fast ripple

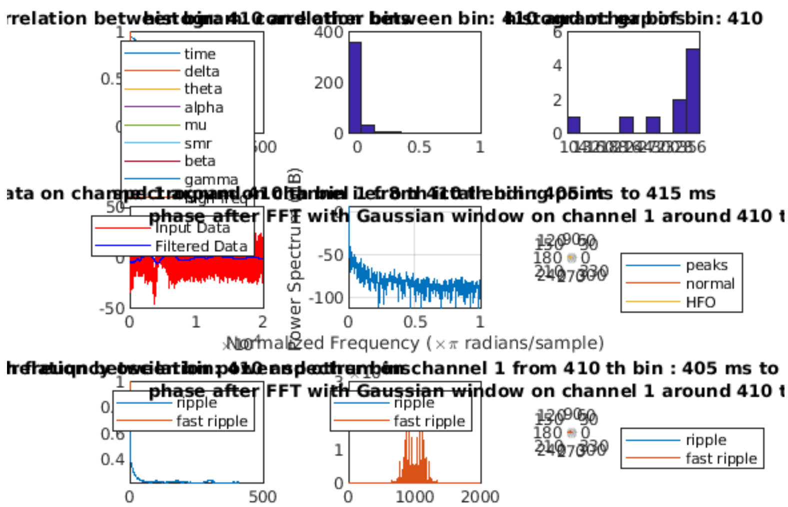

time
delta
theta
alpha
mu
smr
beta
gamma
Input Data
Filtered Data
Normalized Frequency (×π radians/sample)
peaks
normal
HFO
ripple
fast ripple

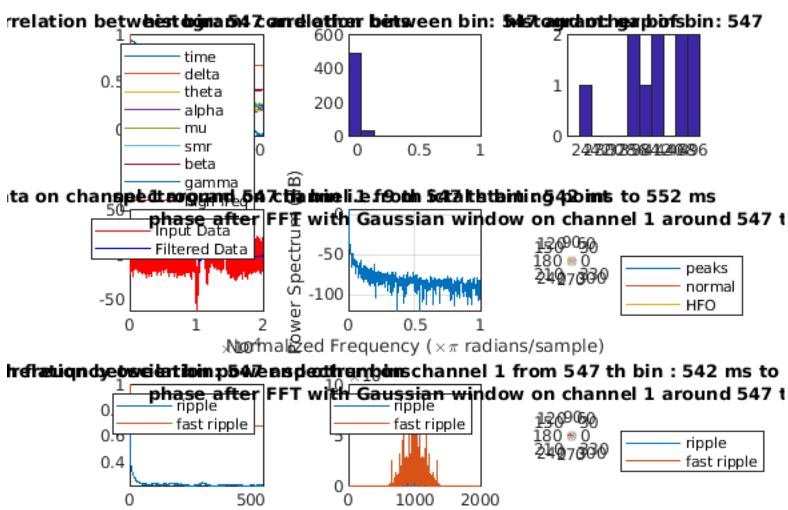

time
delta
theta
alpha
mu
smr
beta
gamma
Input Data
Filtered Data
phase after FFT with Gaussian window on channel 1 around 183
peaks
normal
HFO
Normalized Frequency (×π radians/sample)
ripple
fast ripple

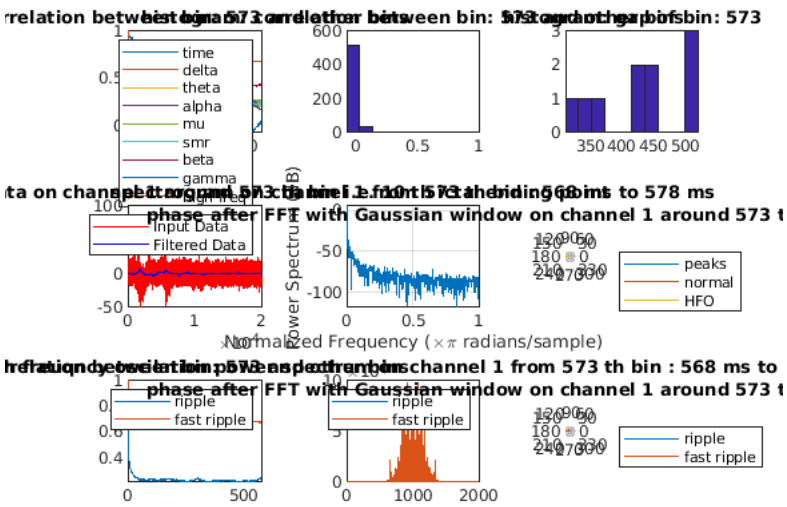

time
delta
theta
alpha
mu
smr
beta
gamma
Input Data
Filtered Data
phase after FFT with Gaussian window on channel 1 around 216
peaks
normal
HFO
Normalized Frequency (×π radians/sample)
ripple
fast ripple


time
delta
theta
alpha
mu
smr
beta
gamma
Input Data
Filtered Data
phase after FFT with Gaussian window on channel 1 around 243
peaks
normal
HFO
Normalized Frequency (×π radians/sample)
ripple
fast ripple


time
delta
theta
alpha
mu
smr
beta
gamma
Input Data
Filtered Data
phase after FFT with Gaussian window on channel 1 around 383 t
Normalized Frequency (×π radians/sample)
peaks
normal
HFO
ripple
fast ripple


time
delta
theta
alpha
mu
smr
beta
gamma
Input Data
Filtered Data
phase after FFT with Gaussian window on channel 1 around 410 t
Normalized Frequency (×π radians/sample)
peaks
normal
HFO
ripple
fast ripple

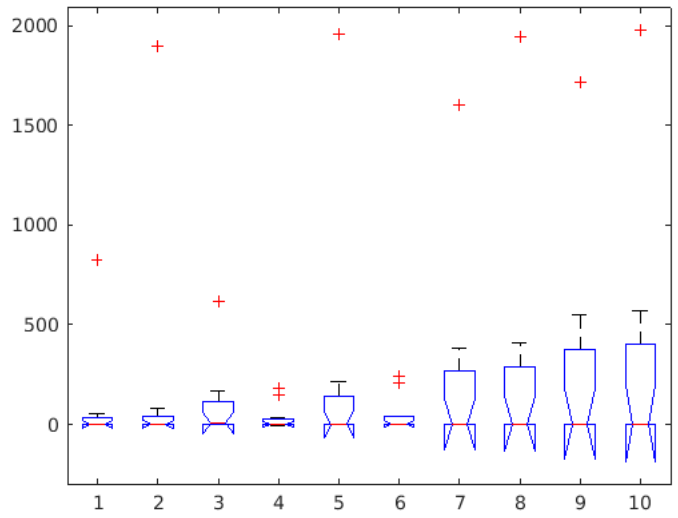

time
delta
theta
alpha
mu
smr
beta
gamma
Input Data
Filtered Data
phase after FFT with Gaussian window on channel 1 around 547 t
Normalized Frequency (×π radians/sample)
peaks
normal
HFO
ripple
fast ripple




```
CORRTF= [chns_rho(NBIN);chnsd_rho(NBIN);chnsth_rho(NBIN);chnsa_rho(NBIN);chnsm_rho(NBIN);chnss_rho(NBIN);chnsb_rho(NBIN);chnsg_rho(NBIN)];

% figure,
% subplot(3,2,1)
% bar(asym);
% title('asymmetry');
% subplot(3,2,2)
% bar(dur);
% title('duration');

for n = 1: length(ictals(:))
    Q3BIN(n) = gap{n}(length(ictals(:)));
    QBINDIST(n) = abs(gap{n}(length(ictals(:)))- gap{n}(1));
    TrSIGMADIST(n) = abs(gap{n}(length(ictals(:)))- NBIN(n));
    MaxIctal(n) = max(abs(fire_n_interv(:, n)),[],1);
    MinIctal(n) = min(abs(fire_n_interv(:, n)),[],1);
    StdIctal(n) = std(abs(fire_n_interv(:, n)),1);
    MeanIctal(n) = mean(abs(fire_n_interv(:, n)),1);
end


CORRTF= CORRTF(1:10);
%MeanCorr = mean(abs(CORRTF),1);
%StdCorr = std(abs(CORRTF),1);
type = ["broad","broad", "broad", "narrow",  "broad","narrow","broad","broad","broad","broad"];
%X = [NBIN; Q3BIN;QBINDIST; TrSIGMADIST;ictal_n_interv;CORRTF];
X1 = [asym'; dur'; NBIN'; Q3BIN;QBINDIST; TrSIGMADIST;MaxIctal;MinIctal;StdIctal;MeanIctal;[-1,-1,-1,1,-1,1,-1,-1,-1,-1]];
%X(isnan(X))= 0;
X1(isnan(X1))= 0;

%%
%[asym_test,dur_test,NBIN_test,Q3BIN_test,QBINDIST_test,TrSIGMADIST_test,fire_n_interv_test,CORRTF_test,MaxIctal_test,MinIctal_test,StdIct
%%
y = [-1,-1,-1,1,-1,1,-1,-1,-1,-1];
%X = [NBIN; Q3BIN;QBINDIST; TrSIGMADIST;ictal_n_interv;CORRTF];
%X1 = [asym'; dur'; NBIN; Q3BIN;QBINDIST; TrSIGMADIST;MaxIctal;MinIctal;StdIctal;MeanCorr;StdCorr;y];
%X(isnan(X))= 0;
%X1(isnan(X1))= 0;

NNBIN = size(NBIN,1);
NQ3BIN = size(Q3BIN,1);
NQBINDIST = size(QBINDIST,1);
NTrSIGMADIST = size(TrSIGMADIST,1);
Nfire_n_interv = size(fire_n_interv,1);
NCORRTF = size(CORRTF,1);
NMaxIctal = size(MaxIctal,1);
NMinIctal  = size(MinIctal ,1);
NStdIctal = size(StdIctal,1);
NMeanIctal  = size(MeanIctal ,1);
NStdIctal  = size(StdIctal ,1);
%type'
group = [0;0;0;1;0;1;0;0;0;0];

R = corr(X1);
[p,tbl,stats] = anova1(X1)
```

ANOVA Table

Source	SS	df	MS	F	Prob>F
Columns	867323.9	9	96369.3	0.49	0.8795
Error	19739767.4	100	197397.7		
Total	20607091.3	109			

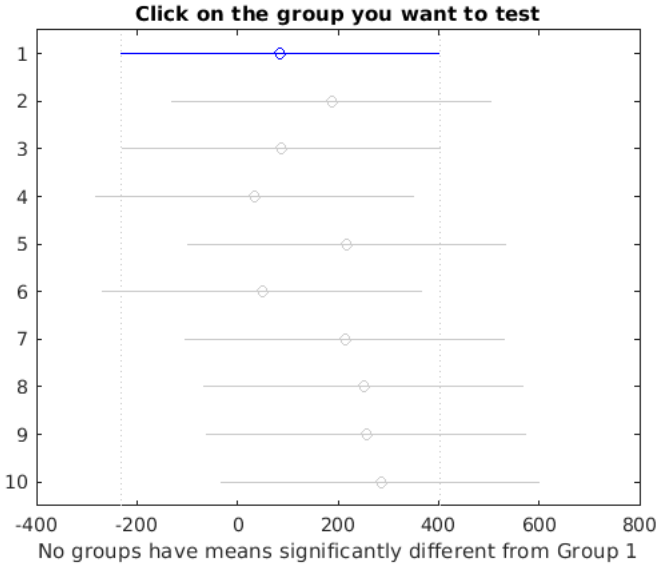



```
p = 0.8795
tbl = 4×6 cell
```

	1	2	3	4	5	6
1	'Source'	'SS'	'df'	'MS'	'F'	'Prob>F'
2	'Columns'	8.6732e+05	9	9.6369e+04	0.4882	0.8795
3	'Error'	1.9740e+07	100	1.9740e+05	[ ]	[ ]
4	'Total'	2.0607e+07	109	[ ]	[ ]	[ ]

```
stats = struct with fields:
    gnames: [10×2 char]
         n: [11 11 11 11 11 11 11 11 11 11]
    source: 'anova1'
     means: [85.7203 187.3282 88.2381 35.3217 218.1385 49.3024 215.1493 252.4356 257.7328 285.1929]
        df: 100
         s: 444.2946
```

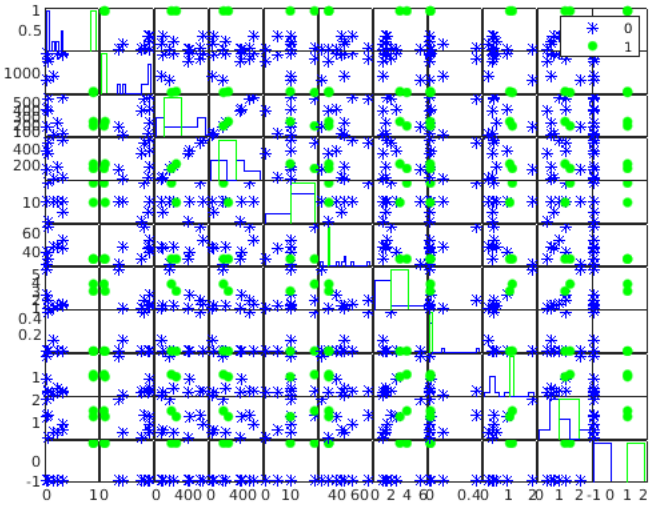
```
[results,means] = multcompare(stats,'CType','bonferroni')
```




```
results = 45×6
```

```
    1.0000    2.0000 -737.8030 -101.6079  534.5873    1.0000
    1.0000    3.0000 -638.7130   -2.5178  633.6773    1.0000
    1.0000    4.0000 -585.7966   50.3986  686.5937    1.0000
    1.0000    5.0000 -768.6133 -132.4182  503.7770    1.0000
    1.0000    6.0000 -599.7773   36.4179  672.6130    1.0000
    1.0000    7.0000 -765.6242 -129.4290  506.7661    1.0000
    1.0000    8.0000 -802.9105 -166.7153  469.4798    1.0000
    1.0000    9.0000 -808.2077 -172.0126  464.1826    1.0000
    1.0000   10.0000 -835.6678 -199.4726  436.7225    1.0000
    2.0000    3.0000 -537.1051   99.0900  735.2852    1.0000
means = 10×2
   85.7203  133.9599
  187.3282  133.9599
   88.2381  133.9599
   35.3217  133.9599
  218.1385  133.9599
   49.3024  133.9599
  215.1493  133.9599
  252.4356  133.9599
  257.7328  133.9599
  285.1929  133.9599
```

```
stats=gplotmatrix(X1',[],group,[],'*.')
```




```
stats =
  11×11×2 graphics array.
```

```
Tbtimelm = table(X1(1,:)',X1(2,:)',X1(3,:)',X1(4,:)',X1(5,:)',X1(6,:)',X1(7,:)',X1(8,:)',X1(9,:)',X1(10,:)', group,'VariableNames',{'Asyme

lm1_cor1 = fitlm(Tbtimelm,'TYPE~Asymetry/Duration+MEANICTAL*STDICTAL/DIST_3SIGMA+DIST_Q3')
```

```
lm1_cor1 =
Linear regression model:
    TYPE ~ 1 + Asymetry + DIST_Q3 + Asymetry:Duration + DIST_3SIGMA:STDICTAL + STDICTAL*MEANICTAL + DIST_3SIGMA:STDICTAL:MEANICTAL

Estimated Coefficients:
                                    Estimate          SE         tStat     pValue
                                   ___________    _________    _______    _______

    (Intercept)                       0.43276       0.39375     1.0991    0.46997
    Asymetry                           1.3799       0.28974     4.7628    0.13175
    DIST_Q3                         -0.015116      0.010761    -1.4047    0.39385
    STDICTAL                          -2.2958         1.917    -1.1977     0.4429
    MEANICTAL                         -0.72481       0.61236    -1.1836    0.44659
    Asymetry:Duration              -0.00065061    0.00016183    -4.0204     0.1552
    DIST_3SIGMA:STDICTAL             0.040735      0.035798     1.1379    0.45899
    STDICTAL:MEANICTAL               0.50468       0.60648    0.83213    0.55817
    DIST_3SIGMA:STDICTAL:MEANICTAL   0.014092      0.019384      0.727    0.59981


Number of observations: 10, Error degrees of freedom: 1
Root Mean Squared Error: 0.0295
```

```
lm1_cor2 = fitlm(Tbtimelm,'TYPE~Asymetry/Duration+DIST_Q3/DIST_3SIGMA')
```

```
lm1_cor2 =
Linear regression model:
    TYPE ~ 1 + Asymetry + DIST_Q3 + Asymetry:Duration + DIST_Q3:DIST_3SIGMA

Estimated Coefficients:
                            Estimate          SE         tStat       pValue
                           ___________    _________    _______    __________
```

(Intercept)	-0.0086619	0.027651	-0.31326	0.76673
Asymetry	1.0311	0.03944	26.145	1.5297e-06
DIST_Q3	-0.0013648	0.0053492	-0.25515	0.80877
Asymetry:Duration	-0.00051523	4.6281e-05	-11.133	0.00010196
DIST_Q3:DIST_3SIGMA	1.6852e-05	8.1852e-05	0.20589	0.845

```
Number of observations: 10, Error degrees of freedom: 5
Root Mean Squared Error: 0.0335
```

```
Xnew = sort(X1(1:10,:));
ypred = predict(lm1_cor2,Xnew')
```

```
ypred = 10×1
    0.1247
   -0.0083
   -0.0154
   -6.1975
   -0.0100
   -0.0116
   -0.0091
   -0.0091
    0.0219
   -0.0091
```

```
%ypred = ypred - 1:10;
ypred(ypred> mean(ypred)) = -1;
ypred(ypred<= mean(ypred)) = 1
```

```
ypred = 10×1
    -1
    -1
    -1
     1
    -1
    -1
    -1
    -1
    -1
    -1
```

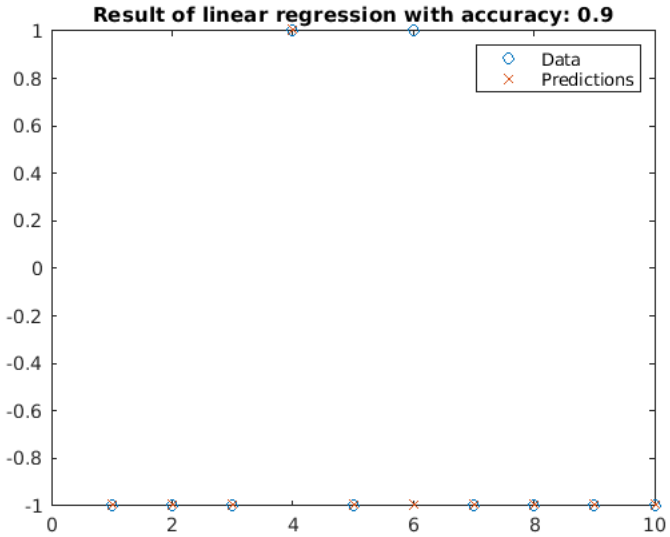
```
%y = [-1,1,1,-1,-1,1,-1,-1,-1,-1];
y
```

```
y = 1×10
    -1    -1    -1     1    -1     1    -1    -1    -1    -1
```

```
ypred == y';
accuracy = sum(ypred == y')/ length(y)
```

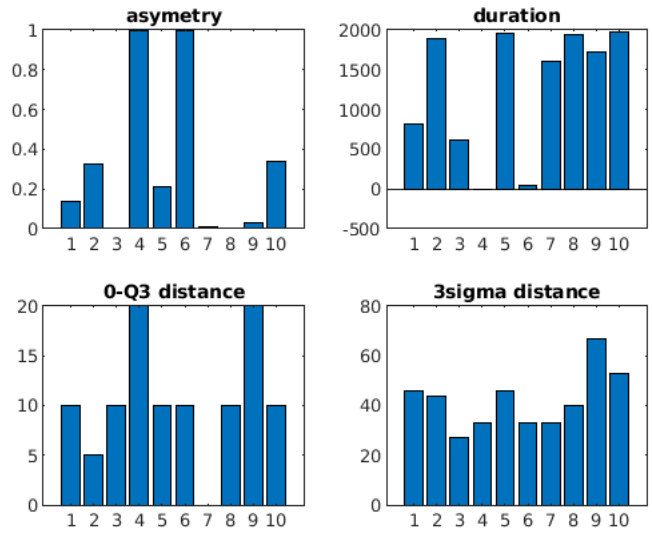
```
accuracy = 0.9000
```

```
% % Plot the original responses and the predicted responses to see how they differ.
figure,
plot(1:length(y),y,'o',1:length(y),ypred,'x')
legend('Data','Predictions')
title(['Result of linear regression with accuracy: ',num2str(accuracy)]);
```

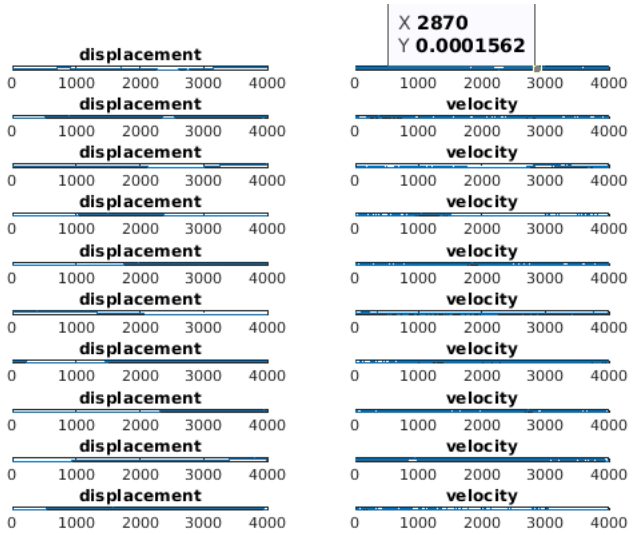



```
figure,
subplot(2,2,1)
```

```
    bar(asym);
    title('asymetry')
subplot(2,2,2)
    bar(dur);
    title('duration')
subplot(2,2,3)
    bar(QBINDIST(1: size(fire_n_interv,2)));
    title('0-Q3 distance');
subplot(2,2,4)
    bar(TrSIGMADIST(1: size(fire_n_interv,2)));
    title('3sigma distance');
```




```
 %   figure,
  %  CORRTF= [chns_rho(NBIN,:),chnsd_rho(NBIN,:),chnsth_rho(NBIN,:),chnsa_rho(NBIN,:),chnsm_rho(NBIN,:),chnss_rho(NBIN,:),chnsb_rho(NBIN,:
%    imagesc(CORRTF)
%    title('ACG of the 10 spikes interval on time and frequency domain')
%    colorbar

    figure,
    for n = 1:size(fire_n_interv, 2)
        wave = fire_n_interv(:, n);
        N = length(wave);
        if mod(N,2)==1
            v = zeros(2*N-1,1);
            v(1:2:2*N-3) = wave(2:length(wave)) - wave(1:length(wave)-1);
            v(2:2:length(v)-1) = 0.5*v(1:2:length(v)-2)+0.5*v(3:2:length(v));
            s = interp(wave, 2);
        else
            v = zeros(2*N,1);
            v(1:2:2*N-2) = wave(2:length(wave)) - wave(1:length(wave)-1);
            v = [v;v(length(v)-2)];
            v(2:2:length(v)-1) = 0.5*v(1:2:length(v)-2)+0.5*v(3:2:length(v));
            s = interp(wave, 2);
        end
        velocity(:,n) = v;
        displacement(:,n) = s;
        subplot(size(fire_n_interv, 2), 2, 2*n-1)
        plot(s)
        title('displacement')
        subplot(size(fire_n_interv, 2), 2, 2*n)
        plot(v)
        title('velocity')
    end
```




```
%manovacluster(ictal_n_interv)
% legend('Input Data','Filtered Data')
%
% plot(interval,MEAy_ch(bin*(n-1)+1:bin*(n-1)+1+length(interval)-1),'r');
% hold on
% plot(interval,MEA_t(bin*(n-1)+1:bin*(n-1)+1+length(interval)-1),'b');
% title(['raw data v.s filtered data on channel', num2str(ch),' ', num2str(n_interv), 'th ictal interval : ', num2str(n),' s to ', num2str
% legend('Input Data','Filtered Data')
% ictal_n_interv = ictal_n_interv(:, 1:2:size(ictal_n_interv,2));
type = ["interictal","ictal", "ictal", "interictal",  "interictal"];
group = [0,1,1,0,0];
y = [-1,1,1,-1,-1];
%[Asym, Dur, ypred, lml_cor3] = ictalclassify(ictal_n_interv, fs, asym, dur, type, group, y, ch)

% ictal, inter-ictal
ictal_n_interv = zeros(60000,5);
for i = 1:size(ictals, 1)
    ictal_n_interv(1:length((floor(ictals(i,1))-1)*bin+1: (floor(ictals(i,2))+1)*bin),i) = MEA_t((floor(ictals(i,1))-1)*bin+1: (floor(icta
end
EEG = ictal_n_interv(1:10:size(ictal_n_interv, 1), :);
%L = size(ictal_n_interv, 2);
%seglen = bin;
%M = ceil(size(ictal_n_interv, 1)/bin);
%a = 0.1;
%FF = RD_STFT(EEG, fs, M, L, seglen, a);%overlap 0.5
[yupper,ylower] = envelope(EEG);
[M, N] = size(EEG);
SE = zeros(M, N);
SEH = SE;
for i = 1:N
    %empirical mode decompose
    figure(2*i-1),
    title('IMF')
   [imftemp,residualtemp,info] = emd(EEG(:,i),'MaxNumIMF',10, 'Display',0)%hide table
   imf(1:size(imftemp,1), 1:size(imftemp,2), i) = imftemp;
   residualtemp(1:size(residualtemp,1), 1:size(residualtemp,2), i) = residualtemp;
%   figure, have to plot by mysef somehow
%   plot(imf)
    subplot(size(imftemp,2), 1, 1)
    plot(imf(:,1,i))
    ylabel('IMF1')
    subplot(size(imftemp,2), 1, 2)
    plot(imf(:,2,i))
    ylabel('IMF2')
    subplot(size(imftemp,2), 1, 3)
    plot(imf(:,3,i))
    ylabel('IMF3')
    subplot(size(imftemp,2), 1, 4)
    plot(imf(:,4,i))
    ylabel('IMF4')
    subplot(size(imftemp,2), 1, 5)
    plot(imf(:,5,i))
    ylabel('IMF5')
    subplot(size(imftemp,2), 1, 6)
    plot(imf(:,6,i))
```

```
    ylabel('IMF6')

   figure(2*i),
   [hs,f,t,imfinsf(1:size(imf,1),1:size(imf,2,i),i),imfinse(1:size(imf,1),1:size(imf,2,i),i)] = hht(imf(:, :, i), fs)
   subplot(1, 2, 1)
   mesh(seconds(t),f,hs,'EdgeColor','none','FaceColor','interp')
   xlabel('Time')
   ylabel('Frequency')
   zlabel('Instantaneous Energy')

   subplot(1, 2, 2)
   mesh(imfinse(1:size(imf,1),1:size(imf,2,i),i),imfinse(1:size(imf,1),1:size(imf,2,i),i))
   xlabel('IMFs')
   ylabel('Instantaneous Frequency')
   zlabel('Instantaneous Energy')

   mdl = fit([1: size(yupper,1)]', 0.5*(yupper(:,i)+ylower(:,i)), 'poly3', 'Normalize','on', 'Robust','Bisquare');
   h(:,i) = EEG(:, i)- mdl(1:M);
   k = 1;
   hk(:,k) = abs(h(:,i) - mean(h(:,i) , 1));
%   [~,~,~,Hk,~]= hht(hk(:,k), fs)
   SD = abs(hk(:,k) - abs(hk(:,k)  - mean(hk(:,k) , 1))).^2./abs(hk(:,k) - mean(hk(:,k) , 1)).^2;
   while  sum(SD > mean(SD))>0.001*i*M & k < size(imf,2) -1
       hk(:,k+1)  = abs(hk(:,k) - mean(hk(:,k) , 1));
       dif= imf(:,k)-hk(:,k+1);
       SD = SD + abs(hk(:,k) - abs(hk(:,k+1)  - mean(hk(:,k+1), 1))).^2./abs(hk(:,k+1) - mean(hk(:,k+1) , 1)).^2;
       k = k+1;
   end
   if k >1
       SE(:,i) = sum(hk./repmat(sum(hk,2),[1, size(hk,2)]).*log(hk./repmat(sum(hk,2),[1,size(hk,2)])),2);
%       SEH(:,i) = sum(Hk./repmat(sum(Hk,2),[1, size(Hk,2)]).*log(Hk./repmat(sum(Hk,2),[1,size(Hk,2)])),2);
   else
       SE(:,i) = hk/sum(hk).*log(hk/sum(hk))+(1-hk/sum(hk)).*log(1-hk/sum(hk));
%       SEH(:,i) = Hk/sum(Hk).*log(Hk/sum(Hk))+(1-Hk/sum(Hk)).*log(1-Hk/sum(Hk));
   end
   clear hk Hk SD mdl hs
end
```

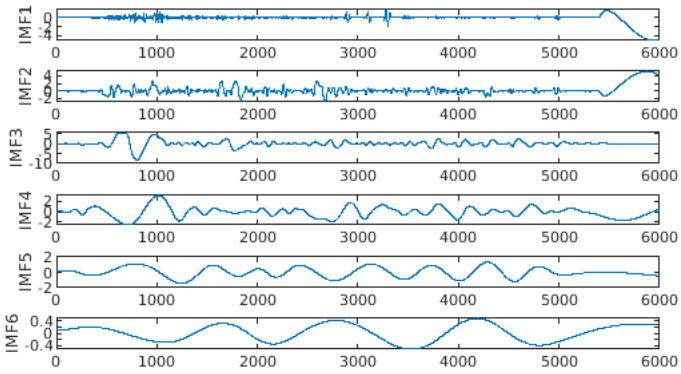
imftemp = 6000×8

0.0038	0.0599	-0.0690	-0.0181	0.1351	0.0974	0.0802	-0.1158
-0.0041	0.0667	-0.0717	-0.0147	0.1355	0.0976	0.0799	-0.1157
0.0057	0.0610	-0.0741	-0.0113	0.1360	0.0978	0.0795	-0.1156
-0.0082	0.0494	-0.0762	-0.0079	0.1365	0.0981	0.0792	-0.1155
0.0010	0.0399	-0.0779	-0.0044	0.1370	0.0983	0.0788	-0.1154
0.0087	0.0319	-0.0792	-0.0010	0.1375	0.0985	0.0785	-0.1152
0.0126	0.0226	-0.0801	0.0025	0.1380	0.0988	0.0782	-0.1151
-0.0123	0.0102	-0.0806	0.0060	0.1386	0.0990	0.0778	-0.1150
0.0033	-0.0049	-0.0806	0.0095	0.1392	0.0992	0.0775	-0.1149
0.0106	-0.0199	-0.0802	0.0130	0.1398	0.0995	0.0771	-0.1148

residualtemp = 6000×1

0.3331
0.3331
0.3331
0.3331
0.3331
0.3331
0.3331
0.3331
0.3331
0.3332

```
info = struct with fields:
                NumIMF: [8×1 double]
            NumExtrema: [8×1 double]
       NumZerocrossing: [8×1 double]
             NumSifting: [8×1 double]
    MeanEnvelopeEnergy: [8×1 double]
     RelativeTolerance: [8×1 double]
```




```
hs =
    (2,1)       1.6437
    (4,1)       0.0139
   (94,1)       0.0630
    (1,2)      55.6337
    (2,2)       0.0135
   (48,2)       0.0126
    (1,3)      54.5122
    (2,3)       0.0105
    (1,4)      42.5356
    (2,4)       0.0472
    (1,5)      83.5280
    (1,6)      69.6910
    (1,7)      35.9780
    (1,8)      31.6938
    (1,9)      60.7349
f = 101×1
     0
    10
    20
    30
    40
    50
    60
    70
    80
    90


t = 6000×1
         0
    0.0005
    0.0010
    0.0015
    0.0020
    0.0025
    0.0030
    0.0035
    0.0040
    0.0045


imfinsf = 6000×8
   -0.2917   -0.9684   -5.9542  935.1286   14.2498  -30.1620  -12.3376   32.3132
    0.0649   -0.3591   -4.2153  470.8839    7.1406  -15.2670   -5.5912   16.6374
   -0.1154    0.2363   -2.8048   15.1493    3.9299   -8.1592   -1.3357    6.2420
   -0.0979    0.3427   -2.3325   14.2244    3.9394   -8.1752   -1.3471    6.2049
    0.4418    0.3601   -1.6559    5.2232    3.0437   -6.2155   -0.4093    4.0721
    0.3231    0.3762   -1.1833    4.8937    3.0542   -6.2262   -0.4182    4.0496
   -0.6038    0.5636   -0.6111    3.6327    2.6197   -5.2648   -0.0026    3.1239
   -0.2501    0.7465   -0.1335    3.4795    2.6312   -5.2728   -0.0100    3.1078
    0.7018    0.8907    0.4061    3.0638    2.3736   -4.6881    0.2250    2.5883
   -0.0375    0.8447    0.8857    2.9756    2.3858   -4.6944    0.2186    2.5758


imfinse = 6000×8
```

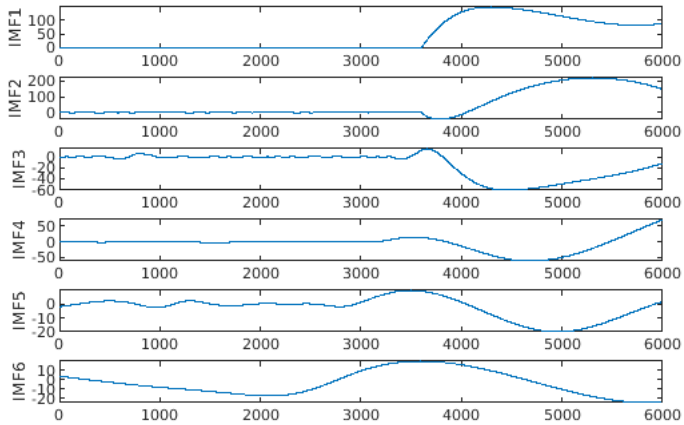
```
  108.3735   97.5587    0.1376    0.0630    1.6437    0.1599    0.0374    0.0139
   54.8148   53.6426    0.1232    0.0126    0.8189    0.0853    0.0315    0.0135
   54.7164   53.6753    0.1224    0.0105    0.8234    0.0851    0.0317    0.0135
   40.8999   41.9080    0.1183    0.0472    0.6142    0.0659    0.0300    0.0134
   41.0326   41.8207    0.1185    0.0435    0.6177    0.0658    0.0301    0.0133
   33.6675   35.4267    0.1169    0.0755    0.5080    0.0556    0.0292    0.0133
   33.4866   35.3828    0.1178    0.0711    0.5109    0.0555    0.0293    0.0133
   28.7544   31.1436    0.1172    0.0972    0.4397    0.0489    0.0286    0.0132
   28.9746   31.0653    0.1185    0.0924    0.4423    0.0488    0.0288    0.0132
   25.3454   27.8700    0.1186    0.1139    0.3910    0.0440    0.0283    0.0132
```

```
Warni  : Iteration limit reached for robust fitting.
```

```
imftemp = 6000×7
    0.0091   -0.0577    0.0516    0.3431   -1.8846    3.5323  -31.7043
    0.0079   -0.0615    0.0444    0.3326   -1.8747    3.5205  -31.6806
   -0.0065   -0.0671    0.0368    0.3219   -1.8647    3.5088  -31.6569
   -0.0042   -0.0728    0.0288    0.3110   -1.8547    3.4970  -31.6332
   -0.0011   -0.0772    0.0205    0.3000   -1.8447    3.4852  -31.6095
    0.0051   -0.0789    0.0117    0.2889   -1.8348    3.4734  -31.5857
   -0.0074   -0.0769    0.0026    0.2775   -1.8248    3.4616  -31.5619
    0.0092   -0.0708   -0.0067    0.2661   -1.8148    3.4498  -31.5381
    0.0154   -0.0609   -0.0163    0.2544   -1.8048    3.4380  -31.5143
    0.0068   -0.0484   -0.0261    0.2426   -1.7948    3.4261  -31.4905
```

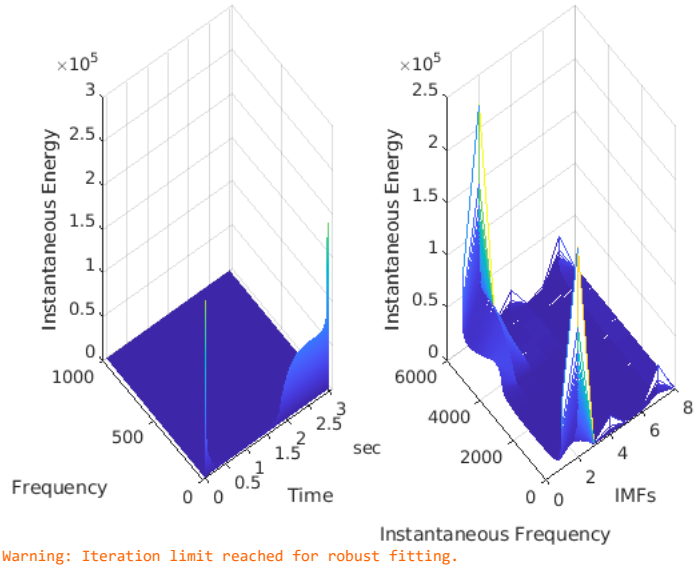
```
residualtemp = 6000×1
   29.6575
   29.6401
   29.6227
   29.6052
   29.5878
   29.5703
   29.5528
   29.5353
   29.5178
   29.5003
```

```
info = struct with fields:
                NumIMF: [7×1 double]
            NumExtrema: [7×1 double]
       NumZerocrossing: [7×1 double]
            NumSifting: [7×1 double]
    MeanEnvelopeEnergy: [7×1 double]
     RelativeTolerance: [7×1 double]
```




```
hs =
   1.0e+05 *

   (1,1)       2.0695
   (9,1)       0.0001
   (1,2)       1.6473
   (5,2)       0.0003
   (1,3)       1.6457
   (1,4)       1.0437
   (1,5)       1.0421
   (1,6)       1.1966
   (1,7)       0.0132
   (1,8)       0.0115
   (1,9)       0.2985
   (1,10)      0.2724
   (1,11)      0.2727
f = 101×1
```

```
     0
    10
    20
    30
    40
    50
    60
    70
    80
    90


t = 6000×1
         0
    0.0005
    0.0010
    0.0015
    0.0020
    0.0025
    0.0030
    0.0035
    0.0040
    0.0045


imfinsf =
imfinsf(:,:,1) =

   -0.2917   -0.9684   -5.9542  935.1286   14.2498  -30.1620  -12.3376   32.3132
    0.0649   -0.3591   -4.2153  470.8839    7.1406  -15.2670   -5.5912   16.6374
   -0.1154    0.2363   -2.8048   15.1493    3.9299   -8.1592   -1.3357    6.2420
   -0.0979    0.3427   -2.3325   14.2244    3.9394   -8.1752   -1.3471    6.2049
    0.4418    0.3601   -1.6559    5.2232    3.0437   -6.2155   -0.4093    4.0721
    0.3231    0.3762   -1.1833    4.8937    3.0542   -6.2262   -0.4182    4.0496
   -0.6038    0.5636   -0.6111    3.6327    2.6197   -5.2648   -0.0026    3.1239
   -0.2501    0.7465   -0.1335    3.4795    2.6312   -5.2728   -0.0100    3.1078
    0.7018    0.8907    0.4061    3.0638    2.3736   -4.6881    0.2250    2.5883
   -0.0375    0.8447    0.8857    2.9756    2.3858   -4.6944    0.2186    2.5758
   -0.6900    0.7425    1.4082    2.7866    2.2167   -4.2952    0.3697    2.2422
   -0.3545    0.5728    1.8870    2.7282    2.2296   -4.3002    0.3640    2.2320
    0.3813    0.3895    2.3970    2.6234    2.1119   -4.0068    0.4691    1.9991
imfinse =
imfinse(:,:,1) =

  108.3735   97.5587    0.1376    0.0630    1.6437    0.1599    0.0374    0.0139
   54.8148   53.6426    0.1232    0.0126    0.8189    0.0853    0.0315    0.0135
   54.7164   53.6753    0.1224    0.0105    0.8234    0.0851    0.0317    0.0135
   40.8999   41.9080    0.1183    0.0472    0.6142    0.0659    0.0300    0.0134
   41.0326   41.8207    0.1185    0.0435    0.6177    0.0658    0.0301    0.0133
   33.6675   35.4267    0.1169    0.0755    0.5080    0.0556    0.0292    0.0133
   33.4866   35.3828    0.1178    0.0711    0.5109    0.0555    0.0293    0.0133
   28.7544   31.1436    0.1172    0.0972    0.4397    0.0489    0.0286    0.0132
   28.9746   31.0653    0.1185    0.0924    0.4423    0.0488    0.0288    0.0132
   25.3454   27.8700    0.1186    0.1139    0.3910    0.0440    0.0283    0.0132
   25.3020   27.7133    0.1200    0.1088    0.3933    0.0440    0.0284    0.0132
   22.6906   25.1595    0.1204    0.1267    0.3540    0.0404    0.0280    0.0131
   22.8345   24.9768    0.1218    0.1213    0.3561    0.0403    0.0281    0.0131
```

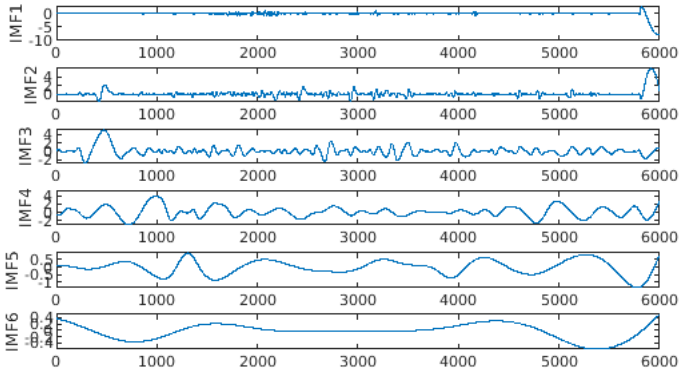



```
Warning: Iteration limit reached for robust fitting.
imftemp = 6000×8
```

```
    0.0016    0.0083    0.2023   -0.7360    0.1076    0.3672   -0.2039    0.1368
    0.0086    0.0069    0.2079   -0.7383    0.1080    0.3664   -0.2041    0.1367
    0.0053    0.0028    0.2146   -0.7405    0.1084    0.3656   -0.2042    0.1365
   -0.0052   -0.0033    0.2221   -0.7425    0.1089    0.3648   -0.2043    0.1364
   -0.0071   -0.0100    0.2303   -0.7444    0.1092    0.3640   -0.2044    0.1363
    0.0065   -0.0156    0.2391   -0.7461    0.1096    0.3632   -0.2045    0.1362
    0.0006   -0.0181    0.2482   -0.7476    0.1100    0.3624   -0.2046    0.1361
   -0.0055   -0.0163    0.2572   -0.7489    0.1103    0.3615   -0.2047    0.1360
   -0.0020   -0.0091    0.2660   -0.7499    0.1106    0.3607   -0.2048    0.1359
    0.0065    0.0016    0.2744   -0.7507    0.1110    0.3599   -0.2049    0.1358
```

```
residualtemp = 6000×1
    0.0464
    0.0464
    0.0465
    0.0466
    0.0466
    0.0467
    0.0468
    0.0468
    0.0469
    0.0470
```

```
info = struct with fields:
               NumIMF: [8×1 double]
           NumExtrema: [8×1 double]
       NumZerocrossing: [8×1 double]
            NumSifting: [8×1 double]
    MeanEnvelopeEnergy: [8×1 double]
     RelativeTolerance: [8×1 double]
```

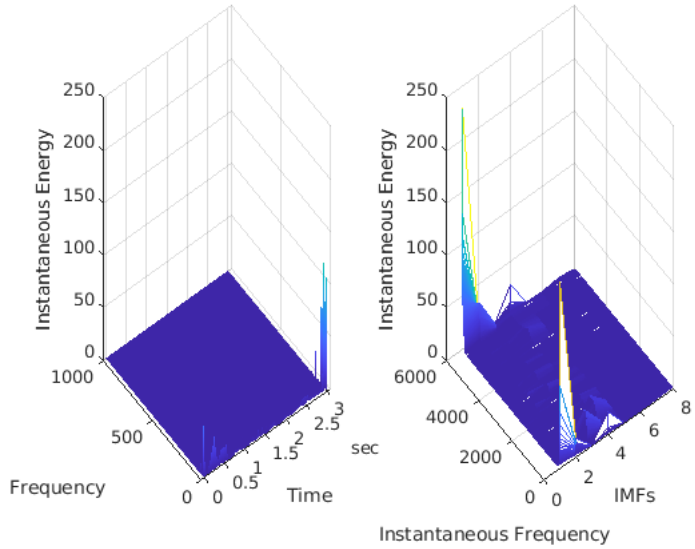



```
hs =
   (1,1)     196.2203
   (3,1)       1.0558
   (5,1)      21.3020
   (1,2)      92.7568
   (2,2)       0.5029
   (3,2)       6.0220
   (1,3)      14.0415
   (2,3)       6.2784
   (1,4)      12.5105
   (2,4)       3.3683
   (1,5)      66.4167
   (2,5)       3.5108
   (1,6)      53.1234
   (2,6)       2.2448
   (1,7)      10.4910
f = 101×1
     0
    10
    20
    30
    40
    50
    60
    70
    80
    90
```

```
t = 6000×1
```

```
         0
    0.0005
    0.0010
    0.0015
    0.0020
    0.0025
    0.0030
    0.0035
    0.0040
    0.0045
```

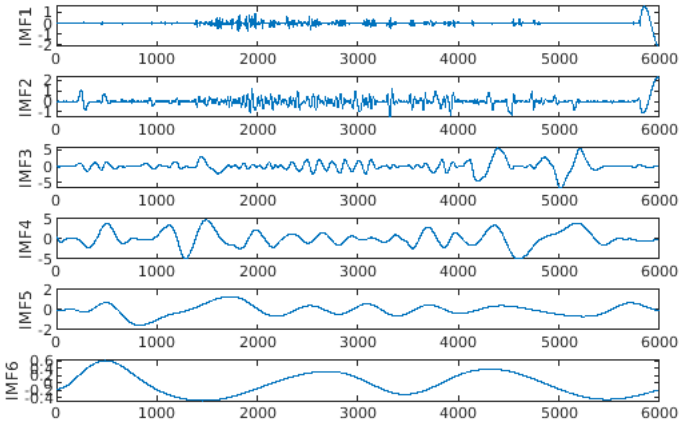
```
imfinsf =
imfinsf(:,:,1) =

   -0.2917   -0.9684   -5.9542  935.1286   14.2498  -30.1620  -12.3376   32.3132
    0.0649   -0.3591   -4.2153  470.8839    7.1406  -15.2670   -5.5912   16.6374
   -0.1154    0.2363   -2.8048   15.1493    3.9299   -8.1592   -1.3357    6.2420
   -0.0979    0.3427   -2.3325   14.2244    3.9394   -8.1752   -1.3471    6.2049
    0.4418    0.3601   -1.6559    5.2232    3.0437   -6.2155   -0.4093    4.0721
    0.3231    0.3762   -1.1833    4.8937    3.0542   -6.2262   -0.4182    4.0496
   -0.6038    0.5636   -0.6111    3.6327    2.6197   -5.2648   -0.0026    3.1239
   -0.2501    0.7465   -0.1335    3.4795    2.6312   -5.2728   -0.0100    3.1078
    0.7018    0.8907    0.4061    3.0638    2.3736   -4.6881    0.2250    2.5883
   -0.0375    0.8447    0.8857    2.9756    2.3858   -4.6944    0.2186    2.5758
   -0.6900    0.7425    1.4082    2.7866    2.2167   -4.2952    0.3697    2.2422
   -0.3545    0.5728    1.8870    2.7282    2.2296   -4.3002    0.3640    2.2320
    0.3813    0.3895    2.3970    2.6234    2.1119   -4.0068    0.4691    1.9991
imfinse =
imfinse(:,:,1) =

  108.3735   97.5587    0.1376    0.0630    1.6437    0.1599    0.0374    0.0139
   54.8148   53.6426    0.1232    0.0126    0.8189    0.0853    0.0315    0.0135
   54.7164   53.6753    0.1224    0.0105    0.8234    0.0851    0.0317    0.0135
   40.8999   41.9080    0.1183    0.0472    0.6142    0.0659    0.0300    0.0134
   41.0326   41.8207    0.1185    0.0435    0.6177    0.0658    0.0301    0.0133
   33.6675   35.4267    0.1169    0.0755    0.5080    0.0556    0.0292    0.0133
   33.4866   35.3828    0.1178    0.0711    0.5109    0.0555    0.0293    0.0133
   28.7544   31.1436    0.1172    0.0972    0.4397    0.0489    0.0286    0.0132
   28.9746   31.0653    0.1185    0.0924    0.4423    0.0488    0.0288    0.0132
   25.3454   27.8700    0.1186    0.1139    0.3910    0.0440    0.0283    0.0132
   25.3020   27.7133    0.1200    0.1088    0.3933    0.0440    0.0284    0.0132
   22.6906   25.1595    0.1204    0.1267    0.3540    0.0404    0.0280    0.0131
   22.8345   24.9768    0.1218    0.1213    0.3561    0.0403    0.0281    0.0131
```




```
Warning: Iteration limit reached for robust fitting.
imftemp = 6000×7

    0.0136    0.0063    0.0179    0.4434   -0.0764   -0.1668   -0.2188
   -0.0109    0.0028    0.0043    0.4307   -0.0788   -0.1668   -0.2185
   -0.0195   -0.0010   -0.0109    0.4150   -0.0812   -0.1668   -0.2182
   -0.0184   -0.0032   -0.0271    0.3966   -0.0835   -0.1667   -0.2179
   -0.0080   -0.0034   -0.0435    0.3755   -0.0857   -0.1667   -0.2176
    0.0159   -0.0016   -0.0597    0.3521   -0.0878   -0.1666   -0.2173
   -0.0006    0.0012   -0.0749    0.3263   -0.0899   -0.1666   -0.2170
   -0.0152    0.0025   -0.0889    0.2985   -0.0919   -0.1665   -0.2167
   -0.0011    0.0002   -0.1013    0.2686   -0.0939   -0.1664   -0.2163
    0.0142   -0.0046   -0.1121    0.2370   -0.0958   -0.1662   -0.2160


residualtemp = 6000×1
```

```
    0.2483
    0.2484
    0.2484
    0.2484
    0.2484
    0.2484
    0.2484
    0.2484
    0.2484
    0.2484
```

```
info = struct with fields:
               NumIMF: [7×1 double]
            NumExtrema: [7×1 double]
      NumZerocrossing: [7×1 double]
            NumSifting: [7×1 double]
    MeanEnvelopeEnergy: [7×1 double]
     RelativeTolerance: [7×1 double]
```

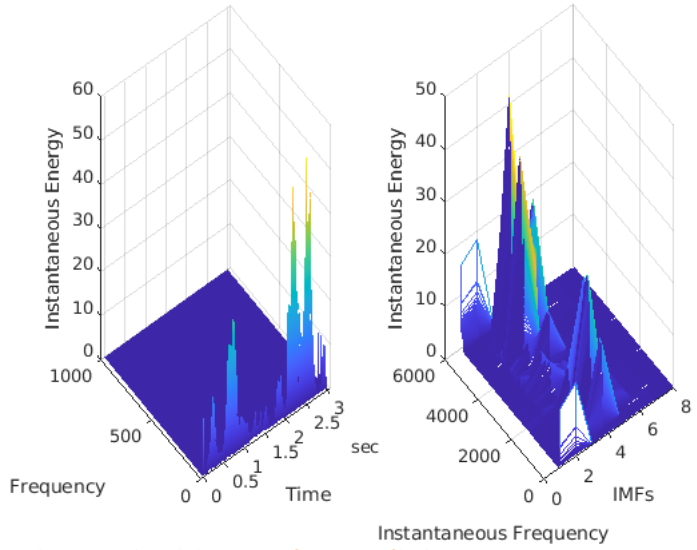



```
hs =
   (1,1)      14.3841
  (14,1)       0.6349
   (1,2)       5.8398
   (2,2)       0.1007
   (8,2)       0.2571
   (1,3)       5.8794
   (2,3)       0.1131
   (6,3)       0.2273
   (1,4)       6.4098
   (2,4)       0.0700
   (6,4)       0.1642
   (1,5)       2.6633
   (3,5)       0.0766
   (6,5)       0.1439
   (1,6)       1.8681
f = 101×1
     0
    10
    20
    30
    40
    50
    60
    70
    80
    90
```

```
t = 6000×1
         0
    0.0005
    0.0010
    0.0015
    0.0020
    0.0025
    0.0030
    0.0035
    0.0040
    0.0045
```

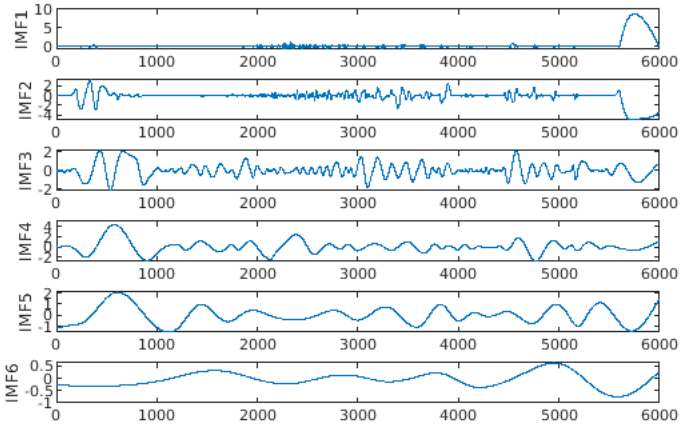
```
imfinsf =
```

```
imfinsf(:,:,1) =

   -0.2917   -0.9684   -5.9542  935.1286   14.2498  -30.1620  -12.3376   32.3132
    0.0649   -0.3591   -4.2153  470.8839    7.1406  -15.2670   -5.5912   16.6374
   -0.1154    0.2363   -2.8048   15.1493    3.9299   -8.1592   -1.3357    6.2420
   -0.0979    0.3427   -2.3325   14.2244    3.9394   -8.1752   -1.3471    6.2049
    0.4418    0.3601   -1.6559    5.2232    3.0437   -6.2155   -0.4093    4.0721
    0.3231    0.3762   -1.1833    4.8937    3.0542   -6.2262   -0.4182    4.0496
   -0.6038    0.5636   -0.6111    3.6327    2.6197   -5.2648   -0.0026    3.1239
   -0.2501    0.7465   -0.1335    3.4795    2.6312   -5.2728   -0.0100    3.1078
    0.7018    0.8907    0.4061    3.0638    2.3736   -4.6881    0.2250    2.5883
   -0.0375    0.8447    0.8857    2.9756    2.3858   -4.6944    0.2186    2.5758
   -0.6900    0.7425    1.4082    2.7866    2.2167   -4.2952    0.3697    2.2422
   -0.3545    0.5728    1.8870    2.7282    2.2296   -4.3002    0.3640    2.2320
imfinse =
imfinse(:,:,1) =

  108.3735   97.5587    0.1376    0.0630    1.6437    0.1599    0.0374    0.0139
   54.8148   53.6426    0.1232    0.0126    0.8189    0.0853    0.0315    0.0135
   54.7164   53.6753    0.1224    0.0105    0.8234    0.0851    0.0317    0.0135
   40.8999   41.9080    0.1183    0.0472    0.6142    0.0659    0.0300    0.0134
   41.0326   41.8207    0.1185    0.0435    0.6177    0.0658    0.0301    0.0133
   33.6675   35.4267    0.1169    0.0755    0.5080    0.0556    0.0292    0.0133
   33.4866   35.3828    0.1178    0.0711    0.5109    0.0555    0.0293    0.0133
   28.7544   31.1436    0.1172    0.0972    0.4397    0.0489    0.0286    0.0132
   28.9746   31.0653    0.1185    0.0924    0.4423    0.0488    0.0288    0.0132
   25.3454   27.8700    0.1186    0.1139    0.3910    0.0440    0.0283    0.0132
   25.3020   27.7133    0.1200    0.1088    0.3933    0.0440    0.0284    0.0132
   22.6906   25.1595    0.1204    0.1267    0.3540    0.0404    0.0280    0.0131
   22.8345   24.9768    0.1218    0.1213    0.3561    0.0403    0.0281    0.0131
```



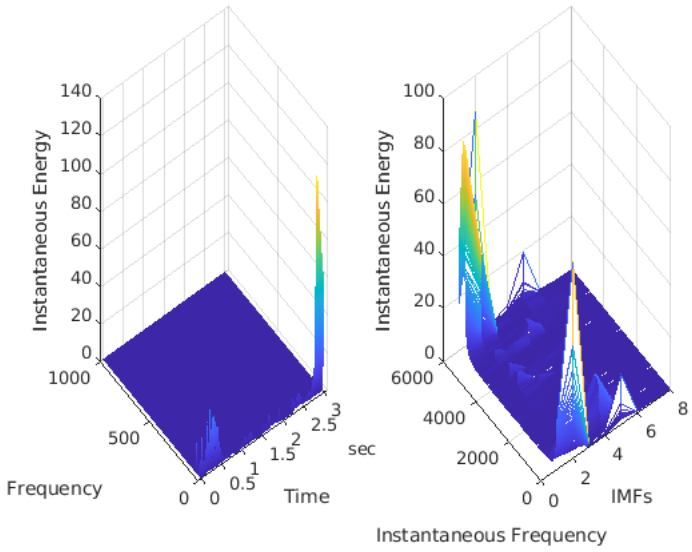

```
Warning: Iteration limit reached for robust fitting.
imftemp = 6000×7
   -0.0038    0.0162    0.0078    0.1259   -1.1782   -0.2587   -0.3710
    0.0049    0.0118    0.0065    0.1141   -1.1777   -0.2590   -0.3706
    0.0081    0.0072    0.0047    0.1015   -1.1772   -0.2593   -0.3702
    0.0050    0.0037    0.0025    0.0883   -1.1767   -0.2596   -0.3698
   -0.0068    0.0020    0.0001    0.0745   -1.1761   -0.2600   -0.3694
    0.0056    0.0020   -0.0023    0.0604   -1.1754   -0.2603   -0.3690
    0.0031    0.0017   -0.0046    0.0459   -1.1747   -0.2606   -0.3686
   -0.0027    0.0006   -0.0067    0.0312   -1.1740   -0.2609   -0.3682
    0.0021   -0.0008   -0.0084    0.0165   -1.1733   -0.2612   -0.3677
   -0.0025    0.0003   -0.0096    0.0018   -1.1725   -0.2615   -0.3673


residualtemp = 6000×1
    0.0915
    0.0915
    0.0916
    0.0916
    0.0916
    0.0916
    0.0916
    0.0916
    0.0916
    0.0917


info = struct with fields:
                NumIMF: [7×1 double]
            NumExtrema: [7×1 double]
       NumZerocrossing: [7×1 double]
            NumSifting: [7×1 double]
```

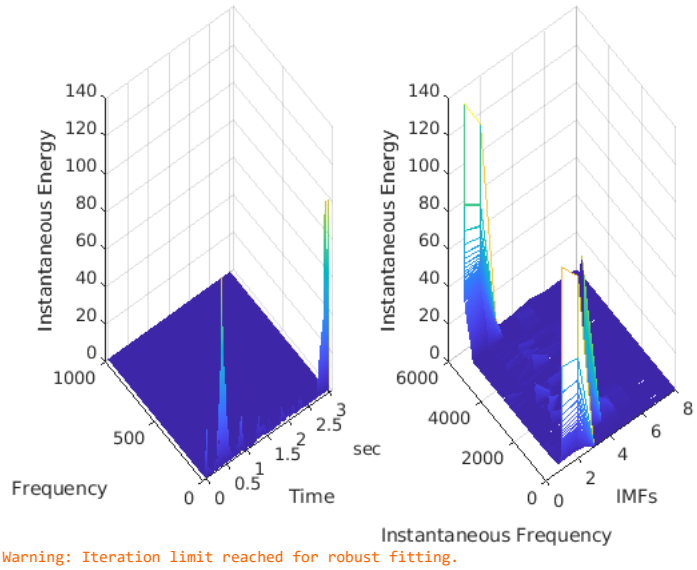
```
    MeanEnvelopeEnergy: [7×1 double]
     RelativeTolerance: [7×1 double]
```




```
hs =
   (3,1)       0.1428
   (6,1)      19.9568
   (2,2)       0.1395
   (3,2)       8.1306
   (1,3)       1.2616
   (2,3)       8.2222
   (1,4)      17.9677
   (2,4)       5.6050
   (1,5)       0.8352
   (2,5)       5.6634
   (1,6)       0.6201
   (2,6)       4.4010
   (1,7)      17.0073
   (2,7)       4.2330
   (1,8)      16.6329
f = 101×1
     0
    10
    20
    30
    40
    50
    60
    70
    80
    90


t = 6000×1
         0
    0.0005
    0.0010
    0.0015
    0.0020
    0.0025
    0.0030
    0.0035
    0.0040
    0.0045


imfinsf =
imfinsf(:,:,1) =

   -0.2917   -0.9684   -5.9542  935.1286   14.2498  -30.1620  -12.3376   32.3132
    0.0649   -0.3591   -4.2153  470.8839    7.1406  -15.2670   -5.5912   16.6374
   -0.1154    0.2363   -2.8048   15.1493    3.9299   -8.1592   -1.3357    6.2420
   -0.0979    0.3427   -2.3325   14.2244    3.9394   -8.1752   -1.3471    6.2049
    0.4418    0.3601   -1.6559    5.2232    3.0437   -6.2155   -0.4093    4.0721
    0.3231    0.3762   -1.1833    4.8937    3.0542   -6.2262   -0.4182    4.0496
   -0.6038    0.5636   -0.6111    3.6327    2.6197   -5.2648   -0.0026    3.1239
   -0.2501    0.7465   -0.1335    3.4795    2.6312   -5.2728   -0.0100    3.1078
    0.7018    0.8907    0.4061    3.0638    2.3736   -4.6881    0.2250    2.5883
   -0.0375    0.8447    0.8857    2.9756    2.3858   -4.6944    0.2186    2.5758
   -0.6900    0.7425    1.4082    2.7866    2.2167   -4.2952    0.3697    2.2422
   -0.3545    0.5728    1.8870    2.7282    2.2296   -4.3002    0.3640    2.2320
    0.3813    0.3895    2.3970    2.6234    2.1119   -4.0068    0.4691    1.9991
imfinse =
imfinse(:,:,1) =
```

```
  108.3735   97.5587    0.1376    0.0630    1.6437    0.1599    0.0374    0.0139
   54.8148   53.6426    0.1232    0.0126    0.8189    0.0853    0.0315    0.0135
   54.7164   53.6753    0.1224    0.0105    0.8234    0.0851    0.0317    0.0135
   40.8999   41.9080    0.1183    0.0472    0.6142    0.0659    0.0300    0.0134
   41.0326   41.8207    0.1185    0.0435    0.6177    0.0658    0.0301    0.0133
   33.6675   35.4267    0.1169    0.0755    0.5080    0.0556    0.0292    0.0133
   33.4866   35.3828    0.1178    0.0711    0.5109    0.0555    0.0293    0.0133
   28.7544   31.1436    0.1172    0.0972    0.4397    0.0489    0.0286    0.0132
   28.9746   31.0653    0.1185    0.0924    0.4423    0.0488    0.0288    0.0132
   25.3454   27.8700    0.1186    0.1139    0.3910    0.0440    0.0283    0.0132
   25.3020   27.7133    0.1200    0.1088    0.3933    0.0440    0.0284    0.0132
   22.6906   25.1595    0.1204    0.1267    0.3540    0.0404    0.0280    0.0131
   22.8345   24.9768    0.1218    0.1213    0.3561    0.0403    0.0281    0.0131
```



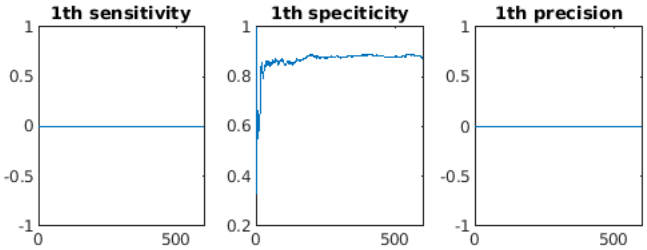


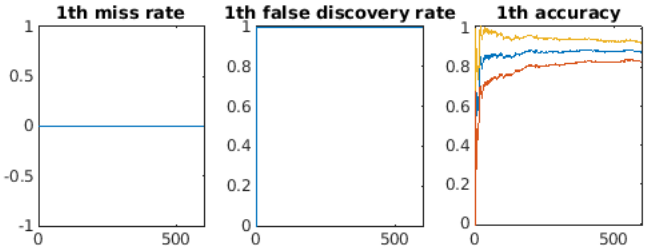
Warning: Iteration limit reached for robust fitting.

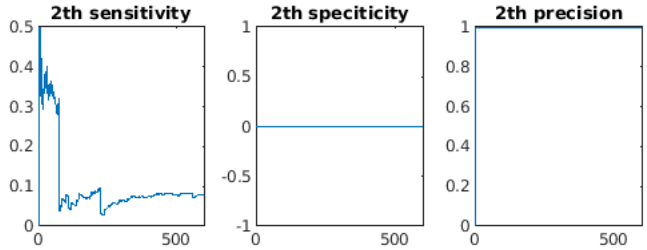
```
difE = SE-mean(imfinse,2);
```

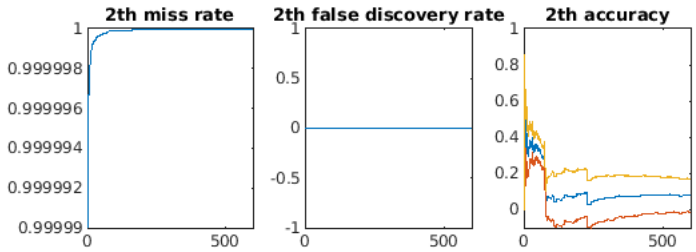
```
%hmmm of ictal type
% logistic regression with regulation
eta0 = 0.1;
%threshold1 = 80;
%threshold2 = 120;
%fn = 0:bin-1;
%f = 1.0*double(fn)/double(bin-1);
%t = -0.5:1/bin:0.5;  % Time vector
%L = length(t)-1;      % Signal length
%X = 1/(4*sqrt(2*pi*0.01))*(exp(-t(1:L).^2/(2*0.01)));
%fX = fft(MEA_ch(1: bin: Pnts)).*X;
%ni = find(MEA_ch > threshold);
LC = [zeros(size(L,1),1), ones(size(L,1),1), ones(size(L,1),1), zeros(size(L,1),1), zeros(size(L,1),1)];

ypred = zeros(1, N);
% Mu = ze(length(ctx), 1);
% Eta = zeros(idN, idN);
```

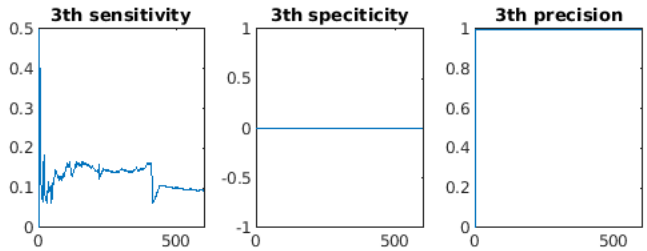
```
% Kse = zeros(idN, idN);
    for k = 1:N
%    k = 1;
%    for k =
%    1:length(ctx)
%    for k = 1:7
%    for k = 59:length(ctx)
%for k = 54:length(ctx);
        SEtemp = SE(:,k);
%        SEtemp = (SEtemp - mean(SEtemp))/std(SEtemp);
        SEtemp_ = [SEtemp(length(SEtemp)); SEtemp(1:(length(SEtemp)-1))];
        difSE = SEtemp-SEtemp_;
        Utemp = -log(SEtemp);
        EKtemp = mean(imfinse(:,:,k),2);
        Y = y(k);
        steps = 50;
        sl = 100;

        while steps >0
            if steps == 50
                m0 = 2*EKtemp./(difSE+0.0001);
            end
            s = 0;

            while s < sl
                m = m0((s+1):(s+length(EKtemp)*10/sl));
                [lpdf0,glpdf0] = normalDistGrad(m,mean(m),std(m));
         %       logpdf = @(X)normalDistGrad(X,mean(X),std(X));
                m = m+eta0/2*glpdf0./lpdf0;
                glpdf = glpdf0 + eta0*m;
                lpdf = lpdf0 + eta0*mean(m);
                M(:, s*sl/length(EKtemp)+1) = m+eta0/2*glpdf./lpdf;
                [Lpdf(s*sl/length(EKtemp)+1),Glpdf(:, s*sl/length(EKtemp)+1)] = normalDistGrad(lpdf,mean(lpdf),std(lpdf));
                s = s + length(EKtemp)/sl;
            end
            m_ = m0;
            difm = M-m_(1:length(EKtemp)*10/sl);
            lbd =  Lpdf  - 0.5*difm.*M+log(M)- repmat(lpdf0-glpdf0(1:length(EKtemp)*10/sl) + EKtemp(1:length(EKtemp)*10/sl), 1, size(difm,
%configuration: min(exp(real(lbd)), 1) 1,
            if sum(sum(min(exp(real(lbd)), 1))< 0.5*length(exp(real(lbd))))~=0
                m = M(:,sum(min(exp(real(lbd)), 1))< 0.5*length(exp(real(lbd))));
                glpdf = Glpdf(:, sum(min(exp(real(lbd)), 1))< 0.5*length(exp(real(lbd))));
            end
            steps = steps -1;
        end
        L(:, k) = glpdf;
         %according to definition: likelihood r = d/(1-d),(y = 1|x)/(y = 0|x)
        for i = 1: size(L, 1)
        %sensitivity, speciticity, precision, miss rate, false discovery rate
            TPR(i,k) = sum(abs(L(1:i,k))>mean(abs(L(1:i,k))) & LC(1:i,k)==1)/(sum(LC(1:i,k)==1)+0.00001);
            TNR(i,k) = sum(abs(L(1:i,k))<=mean(abs(L(1:i,k))) & LC(1:i,k)==0)/(sum(LC(1:i,k)==0)+0.00001);
            PPV(i,k) = sum(abs(L(1:i,k))>mean(abs(L(1:i,k))) & LC(1:i,k)==1)/(sum(abs(L(1:i,k))> mean(abs(L(1:i,k))))+0.00001);
            FNR(i,k) = sum(abs(L(1:i,k))<=mean(abs(L(1:i,k))) & LC(1:i,k)==1)/(sum(abs(L(1:i,k))<=mean(abs(L(1:i,k))) & LC(1:i,k)==1)+ sum
            FDR(i,k) = sum(abs(L(1:i,k))>mean(abs(L(1:i,k))) & LC(1:i,k)==0)/(sum(abs(L(1:i,k))>mean(abs(L(1:i,k))))+0.00001);
            ACC(i,k) = (sum(abs(L(1:i,k))>mean(abs(L(1:i,k))) & LC(1:i,k)==1)+sum(abs(L(1:i,k))<=mean(abs(L(1:i,k))) & LC(1:i,k)==0))/i;
            STDACC(i,k) = std(ACC(1:i,k));
            STDACC(isnan(STDACC)) = 0;
        end
        figure,
        subplot(2, 3, 1)
        plot(TPR(:,k))
        title([num2str(k),'th sensitivity'])
        subplot(2, 3, 2)
        plot(TNR(:,k))
        title([num2str(k),'th speciticity'])
        subplot(2, 3, 3)
        plot(PPV(:,k))
        title([num2str(k),'th precision'])
        subplot(2, 3, 4)
        plot(FNR(:,k))
        title([num2str(k),'th miss rate'])
        subplot(2, 3, 5)
        plot(FDR(:,k))
        title([num2str(k),'th false discovery rate'])
        subplot(2, 3, 6)
        plot([ACC(:,k), ACC(:,k)-STDACC(:,k), ACC(:,k)+STDACC(:,k)])
        title([num2str(k),'th accuracy'])
        clear glpdf lbd difm Lpdf Glpdf M m m_ m0
    end
```

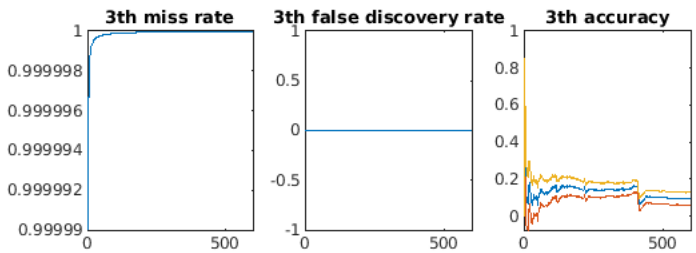

1th sensitivity
1th speciticity
1th precision

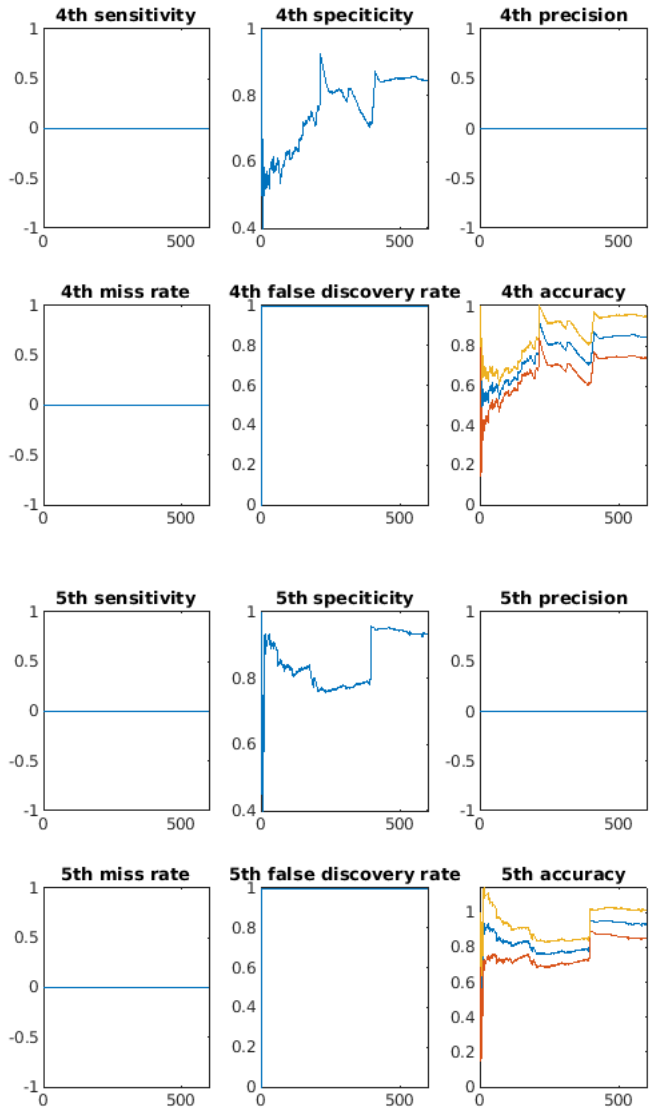

1th miss rate
1th false discovery rate
1th accuracy


2th sensitivity
2th speciticity
2th precision


2th miss rate
2th false discovery rate
2th accuracy


3th sensitivity
3th speciticity
3th precision


3th miss rate
3th false discovery rate
3th accuracy




```
ypred(mean(abs(L), 1)>mean(mean(abs(L),1))) = 1;
ypred(mean(abs(L), 1)<=mean(mean(abs(L),1))) = -1;
accuracy = (sum(ypred == y))./length(y)
```

```
accuracy = 0.8000
```

```
%
[h, p] = ttest(ypred , y)
```

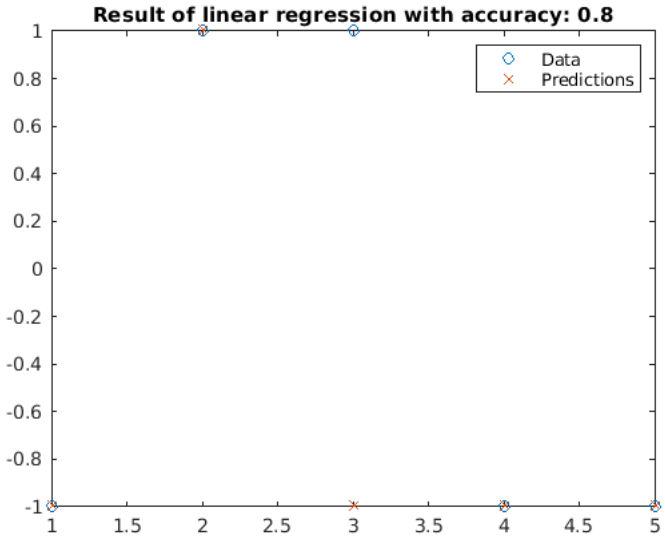
```
h = 0
p = 0.3739
```

```
 %discrete U-test

pcd = y/max(y);
yc = ones(1,length(pcd))./(1+exp(-pcd));
yc1 = ones(1,length(pcd))./(1+exp(-pcd-log(1)));

pred = ypred/max(ypred);
ycpred = ones(1,length(pred))./(1+exp(-pred));
ycpred1 = ones(1,length(pred))./(1+exp(-pred-log(1)));

[h, p] = ttest(yc, ycpred)% h = 1, significantly different
```

```
h = 0
p = 0.3739
```

```
figure,
plot(1:length(y),y,'o',1:length(y),ypred,'x')
```

```
legend('Data','Predictions')
title(['Result of linear regression with accuracy: ',num2str(accuracy)]);
```



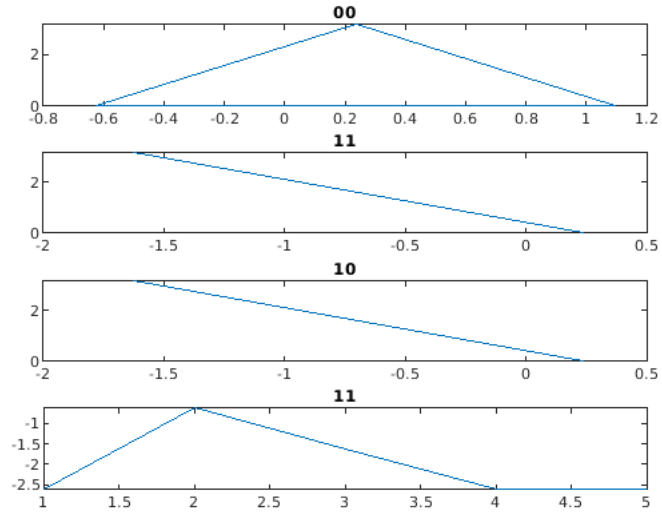

```
%F0
 fa_ac = (yc+pcd).*(ycpred+pred);
 %F01
 fa_ac1 = (yc1+pcd).*(yc1-pcd*log(1));
 %F10
 f1a1_ac = (ycpred-pred*log(1)).*(ycpred+pred);
 %F1
 f1a1_ac1 = (yc-pcd*log(1)).*(ycpred-pred*log(1));

  % fk = (gam(1) - pad(1:4).*log(1.1)).*(gam(2) - pacd(1:4).*log(1.1));
F0 = [mean(fa_ac(:)), mean(fa_ac1(:))];
F1 = [mean(f1a1_ac(1)), mean(f1a1_ac1(1))];


nH = sum([ttest(F0(1),F1(1))==0 ,ttest(F0(2),F1(1))==0 ,ttest(F0(1),F1(2))==0 ,ttest(F0(2),F1(2))==0]);
phi =  3/4+0.5*nH/4;
psi = 0.5+0.5*(3/4-1/4);

phi_ = mean(F0(:))-mean(F1(:))+0.5
```

```
phi_ = 1.0897
```

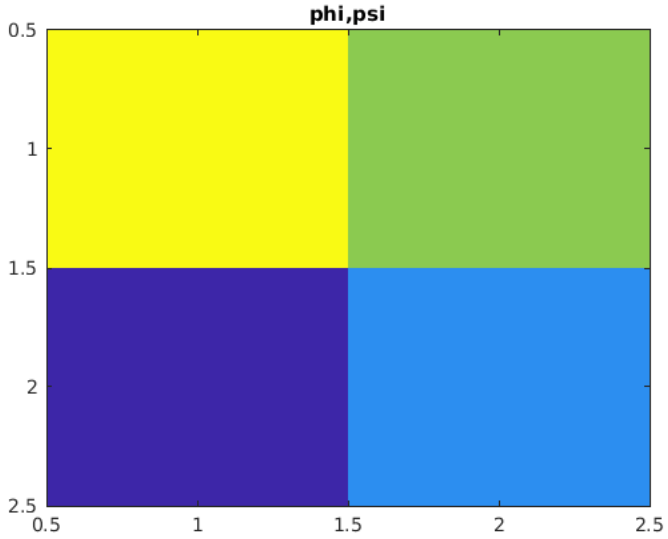
```
psi_ = max(F0(:)-F1(:))
```

```
psi_ = 0.8635
```

```
figure,
subplot(4,1,1)
plot(log(fa_ac));
title('00');
subplot(4,1,2)
plot(log(fa_ac1));
title('11');
subplot(4,1,3)
plot(log(f1a1_ac));
title('10');
subplot(4,1,4)
plot(log(f1a1_ac1));
title('11');
```




```
figure,
imagesc([F0;F1])
title('phi,psi')
```




```
%manovacluster(ictal_n_interv)
%% fast ripple and ripple
% legend('Input Data','Filtered Data')
%
% plot(interval,MEAy_ch(bin*(n-1)+1:bin*(n-1)+1+length(interval)-1),'r');
% hold on
% plot(interval,MEA_t(bin*(n-1)+1:bin*(n-1)+1+length(interval)-1),'b');
% title(['raw data v.s filtered data on channel', num2str(ch),' ', num2str(n_interv), 'th ictal interval : ', num2str(n),' s to ', num2str
% legend('Input Data','Filtered Data')
% ictal_n_interv = ictal_n_interv(:, 1:2:size(ictal_n_interv,2));
type = ["interictal","ictal", "ictal", "interictal",  "interictal"];
group = [0,1,1,0,0];
y = [-1,1,1,-1,-1];
%[Asym, Dur, ypred, lml_cor3] = ictalclassify(ictal_n_interv, fs, asym, dur, type, group, y, ch)

% ictal, inter-ictal
ictal_n_interv = chf_bin_h(:);
for i = 1:size(ictals, 1)
    ictal_n_interv(1:length((floor(ictals(i,1))-1)*bin+1: (floor(ictals(i,2))+1)*bin),i) = MEA_t((floor(ictals(i,1))-1)*bin+1: (floor(icta
end
EEG = ictal_n_interv(1:10:size(ictal_n_interv, 1), :);
%L = size(ictal_n_interv, 2);
%seglen = bin;
%M = ceil(size(ictal_n_interv, 1)/bin);
%a = 0.1;
%FF = RD_STFT(EEG, fs, M, L, seglen, a);%overlap 0.5
```

```
[yupper,ylower] = envelope(EEG);
[M, N] = size(EEG);
SE = zeros(M, N);
SEH = SE;

for i = 1:N
   mdl = fit([1: size(yupper,1)]', 0.5*(yupper(:,i)+ylower(:,i)), 'poly3', 'Normalize','on', 'Robust','Bisquare');
   h(:,i) = EEG(:, i)- mdl(1:M);
   k = 1;
   hk(:,k) = abs(h(:,i) - mean(h(:,i) , 1));
   Hk(:,k) = real(hilbert(hk(:,k)));
   SD = abs(hk(:,k) - abs(hk(:,k)  - mean(hk(:,k) , 1))).^2./abs(hk(:,k) - mean(hk(:,k) , 1)).^2;
   while  sum(SD > mean(SD))>0.001*i*M & k < M
       hk(:,k+1)  = abs(hk(:,k) - mean(hk(:,k) , 1));
       Hk(:,k+1) = real(hilbert(hk(:,k)));
       SD = SD + abs(hk(:,k) - abs(hk(:,k+1)  - mean(hk(:,k+1) , 1))).^2./abs(hk(:,k+1) - mean(hk(:,k+1) , 1)).^2;
       k = k+1;
   end
   if k >1
       SE(:,i) = sum(hk./repmat(sum(hk,2),[1, size(hk,2)]).*log(hk./repmat(sum(hk,2),[1,size(hk,2)])),2);
       SEH(:,i) = sum(Hk./repmat(sum(Hk,2),[1, size(Hk,2)]).*log(Hk./repmat(sum(Hk,2),[1,size(Hk,2)])),2);
   else
       SE(:,i) = hk/sum(hk).*log(hk/sum(hk))+(1-hk/sum(hk)).*log(1-hk/sum(hk));
       SEH(:,i) = Hk/sum(Hk).*log(Hk/sum(Hk))+(1-Hk/sum(Hk)).*log(1-Hk/sum(Hk));
   end
   clear hk Hk SD mdl
end
```

```
%hmmm of ripple and fast ripple
% logistic regression with regulation
eps0 = 0.01;
w = ones(M, 1)/M;
lmd = w;
%threshold1 = 80;
%threshold2 = 120;
Pnts = size(ictal_n_interv, 1);

bin = 2000;
%fn = 0:bin-1;
%f = 1.0*double(fn)/double(bin-1);
%t = -0.5:1/bin:0.5;  % Time vector
%L = length(t)-1;      % Signal length
%X = 1/(4*sqrt(2*pi*0.01))*(exp(-t(1:L).^2/(2*0.01)));
%fX = fft(MEA_ch(1: bin: Pnts)).*X;
%ni = find(MEA_ch > threshold);
steps = 50;
L = repmat(-100,[M, 1]);
l = zeros(M, N);
ypred = zeros(1, N);
W = zeros(M, N);
B = zeros(M, N);
% Mu = ze(length(ctx), 1);
% Eta = zeros(idN, idN);
% Kse = zeros(idN, idN);
    for k = 1:N
%    k = 1;
%    for k =
%    1:length(ctx)
%    for k = 1:7
%    for k = 59:length(ctx)
%for k = 54:length(ctx);
        SEtemp = SE(:,k);
        SEtemp = (SEtemp - mean(SEtemp))/std(SEtemp);
        Y = y(k);
        while steps >0
            Test = normpdf(SEtemp, mean(SEtemp), std(SEtemp));
            b = gampdf(SEtemp, 0.2, 2);
%             b = ones(length(F_(:, k)),1)./(1 + exp(-F_(:, k) - sigma.*F_hat));
            w = w/(sum(w)+0.000001);
%             wd = 1+exp(-F_);
%             wd(isinf(wd)) = 10000;
%             w = w + mu*F_hat.*wd.^2./(exp(-F_(:, k)).*F_+0.00001);
%             b = b + mu*F_hat.*wd.^2./(exp(-F_(:, k)-sigma.*F_hat).*F_+0.00001);
            K =  abs(SEtemp);
            l(1:length(K), k) = log(1 + exp(-Y.* w(1:length(K)).* SEtemp(:))) + lmd(1:length(K)).*w(1:length(K)).^2/2 + 2*K.*b.* SEtemp./(
            cond = log(1 + exp(-Y.* w(1:length(K)).* SEtemp)) + lmd(1:length(K)).*w(1:length(K)).^2/2 + 2*K.*b.* SEtemp./(eps0*(1:length(K
            if sum(isnan(cond))~= length(cond) & sum(cond==0)~= length(cond)
                W(1:length(K),k) = -Y.*SEtemp./(1 + exp(-Y.* w(1:length(K)).* SEtemp));
            end
```

```
            if (sum(isnan(cond))== length(cond) | sum(cond==0)== length(cond))
                k = k+1;
                steps = 50;
                break;
            end
            w = W(:, k);
            L = log(1 + exp(-Y.* w(1:length(K)).* SEtemp)) + lmd.*w(1:length(K)).^2/2 + 2.*K.*b(1:length(K)).* SEtemp./(eps0*(1:length(K))
            steps = steps -1;
            if steps == 0
                l(isnan(l(:,k)),k) = 0.5*l(isnan(l(:,k)),max(k-1,1))+0.5*l(isnan(l(:,k)),min(k+1,N));
                l(sum(isnan(l(:,k)))==size(l,1),k) = 0.5*l(sum(isnan(l(:,k)))==size(l,1),max(k-1,1))+0.5*l(sum(isnan(l(:,k)))==size(l,1),m
                ypred(1,k) = mean(l(l(:,k)~=0,k));
                k = k+1;
                steps = 50;
                break;
            end
%             if k > length(ctx)
%                 break
%             end
        end
    end
    ypred
 ypred(ypred>mean(ypred)) = 1;
 ypred(ypred<=mean(ypred)) = -1;
 accuracy = (sum(ypred == y))./length(y)
 %
 [h, p] = ttest(ypred , y)

  %discrete U-test

 pcd = y/max(y);
 yc = ones(1,length(pcd))./(1+exp(-pcd));
 yc1 = ones(1,length(pcd))./(1+exp(-pcd-log(1)));

 pred = ypred/max(ypred);
 ycpred = ones(1,length(pred))./(1+exp(-pred));
 ycpred1 = ones(1,length(pred))./(1+exp(-pred-log(1)));

 [h, p] = ttest(yc, ycpred)% h = 1, significantly different

figure,
plot(1:length(y),y,'o',1:length(y),ypred,'x')
legend('Data','Predictions')
title(['Result of linear regression with accuracy: ',num2str(accuracy)]);


%F0
 fa_ac = (yc+pcd).*(ycpred+pred);
 %F01
 fa_ac1 = (yc1+pcd).*(yc1-pcd*log(1));
 %F10
 f1a1_ac = (ycpred-pred*log(1)).*(ycpred+pred);
 %F1
 f1a1_ac1 = (yc-pcd*log(1)).*(ycpred-pred*log(1));

  % fk = (gam(1) - pad(1:4).*log(1.1)).*(gam(2) - pacd(1:4).*log(1.1));
F0 = [mean(fa_ac(:)), mean(fa_ac1(:))];
F1 = [mean(f1a1_ac(1)), mean(f1a1_ac1(1))];


nH = sum([ttest(F0(1),F1(1))==0 ,ttest(F0(2),F1(1))==0 ,ttest(F0(1),F1(2))==0 ,ttest(F0(2),F1(2))==0]);
phi =  3/4+0.5*nH/4;
psi = 0.5+0.5*(3/4-1/4);

phi_ = mean(F0(:))-mean(F1(:))+0.5
psi_ = max(F0(:)-F1(:))

figure,
subplot(4,1,1)
plot(log(fa_ac));
title('00');
subplot(4,1,2)
plot(log(fa_ac1));
title('11');
subplot(4,1,3)
plot(log(f1a1_ac));
title('10');
subplot(4,1,4)
plot(log(f1a1_ac1));
title('11');
figure,
```

```
imagesc([F0;F1])
title('phi,psi')
```

```
eps0 = 0.01;
wt = ones(M, 1)/M;
lmdt = wt;
%threshold1 = 80;
%threshold2 = 120;
%fn = 0:bin-1;
%f = 1.0*double(fn)/double(bin-1);
%t = -0.5:1/bin:0.5;  % Time vector
%L = length(t)-1;      % Signal length
%X = 1/(4*sqrt(2*pi*0.01))*(exp(-t(1:L).^2/(2*0.01)));
%fX = fft(MEA_ch(1: bin: Pnts)).*X;
%ni = find(MEA_ch > threshold);
steps = 50;
Lt = repmat(-100,[M, 1]);
ltt = zeros(M, N);
ypredt = zeros(1, N);
Wt = zeros(M, N);
Bt = zeros(M, N);
F_t= zeros(M, N);
Testt = normpdf(SEtemp, mean(SEtemp), std(SEtemp));
clear SEtemp ;
SEtempt = Testt;
% Mu = ze(length(ctx), 1);
% Eta = zeros(idN, idN);
% Kse = zeros(idN, idN);
    for k = 1:N
%    k = 1;
%    for k =
%    1:length(ctx)
%    for k = 1:7
%    for k = 59:length(ctx)
%for k = 54:length(ctx);
        Yt = y(k);
        SEtempt = SE(:,k);
        SEtempt = (SEtemp - mean(SEtemp))/std(SEtemp);
        while steps >0

            b = gampdf(SEtemp, 0.2, 2);
%             b = ones(length(F_(:, k)),1)./(1 + exp(-F_(:, k) - sigma.*F_hat));
            w = w/(sum(w)+0.000001);
%             wd = 1+exp(-F_);
%             wd(isinf(wd)) = 10000;
%             w = w + mu*F_hat.*wd.^2./(exp(-F_(:, k)).*F_+0.00001);
%             b = b + mu*F_hat.*wd.^2./(exp(-F_(:, k)-sigma.*F_hat).*F_+0.00001);
            K =  abs(SEtemp);
            l(1:length(K), k) = log(1 + exp(-Y.* w(1:length(K)).* SEtemp(:))) + lmd(1:length(K)).*w(1:length(K)).^2/2 + 2*K.*b.* SEtemp./(
            cond = log(1 + exp(-Y.* w(1:length(K)).* SEtemp)) + lmd(1:length(K)).*w(1:length(K)).^2/2 + 2*K.*b.* SEtemp./(eps0*(1:length(K
            if sum(isnan(cond))~= length(cond) & sum(cond==0)~= length(cond)
                W(1:length(K),k) = -Y.*SEtemp./(1 + exp(-Y.* w(1:length(K)).* SEtemp));
            end

            if (sum(isnan(cond))== length(cond) | sum(cond==0)== length(cond))
                k = k+1;
                steps = 50;
                break;
            end
            w = W(:, k);
            L = log(1 + exp(-Y.* w(1:length(K)).* SEtemp)) + lmd.*w(1:length(K)).^2/2 + 2.*K.*b(1:length(K)).* SEtemp./(eps0*(1:length(K))
            steps = steps -1;
            if steps == 0
                l(isnan(l(:,k)),k) = 0.5*l(isnan(l(:,k)),max(k-1,1))+0.5*l(isnan(l(:,k)),min(k+1,N));
                l(sum(isnan(l(:,k)))==size(l,1),k) = 0.5*l(sum(isnan(l(:,k)))==size(l,1),max(k-1,1))+0.5*l(sum(isnan(l(:,k)))==size(l,1),m
                ypred(1,k) = mean(l(l(:,k)~=0,k));
                k = k+1;
                steps = 50;
                break;
            end
%             if k > length(ctx)
%                 break
%             end
        end
    end
    ypred
```