```
%Ahmad Malik
%ECE302
%Project 4: Detection
clc;
clear;
close all;
```

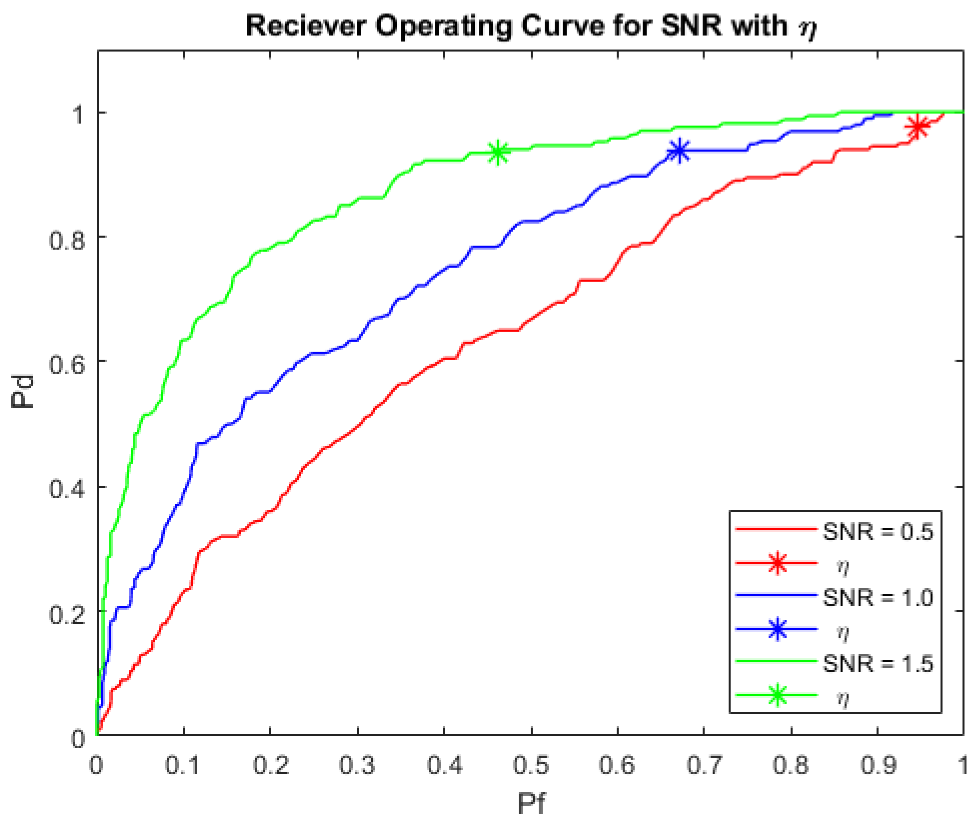
Question 1

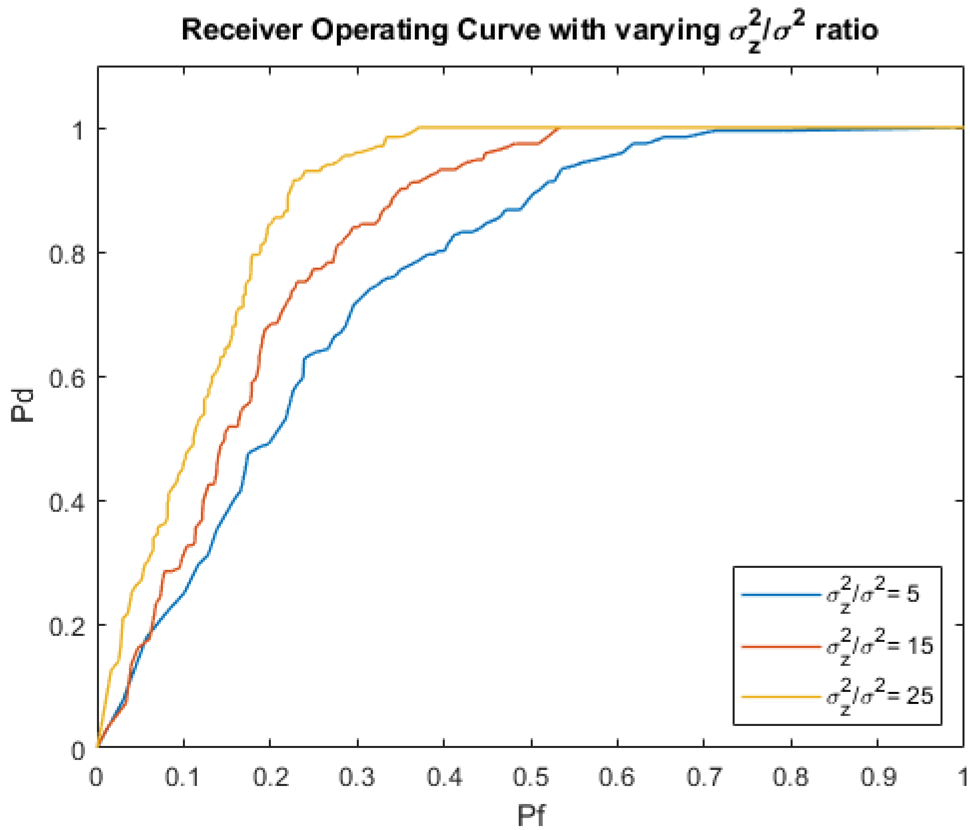
```
fprintf('Question 1 \n\n');

%a
p0 = 0.8; %prob target is not present
p1 = 0.2; %prob target is present
A_const = 1; %A = 1 when present=
N = 1000; %  num of iterations
var = 1; %Variance of X
sigmax = sqrt(var);

%Random A vector where A=1 20% of the time and A=0 80% of the time
A = double(~logical((randi(5, N, 1))-1));
%Random X vector, gaussian
X = normrnd(0, sigmax, [N, 1]);
Y = A + X;

%MAP rule
%Computing Threshold
threshold = (A_const / 2) + ((sigmax^2 / A_const) * log(p0 /
 p1)); %equation 8.37
%Computing Experimental Error Relative to Threshold
Exp_Error = sum((Y > threshold) ~= A) / N;
%Computing Theoretical Error using cdf curves;
Theo_Error = p0 * (1 - normcdf(threshold, 0, sigmax)) + p1 *
 normcdf(threshold, A_const, sigmax);

fprintf('a)\nTheoretical Error: %0.4f \nExperimental Error: %0.4f\n',
 Theo_Error,Exp_Error);

%b and C)

fprintf('c) \n');
SNR = [0.5, 1, 1.5]; %Testing SNR
threshold_test = linspace(-10, 10, 1000); %threshold testing
pf = zeros(1000, 3);
Pd = zeros(1000, 3);
for i = 1:3
    A_const = var * SNR(i);
    A = A_const* double(~logical((randi(5, N, 1))-1)); %Randomly
 occuring A vector scaled by SNR
    Y = A + X;
    %MAP Rule: C01 = 10*C10
```

```
    threshold = (A_const / 2) + ((sigmax^2 / A_const) * log(p0 /
 (p1*10))); %computing threshold
    fprintf('Threshold value for SNR(%0.1f)if missing target is 10
 times worse: %0.4f \n',SNR(i),threshold); %part c
    for x = 1:1000
        %Finding value that minimizes the conditional risk
        F10(i) = sum((Y > threshold) & (A ~= A_const)) / sum((A ==
 0));
        D10(i) = sum((Y > threshold) & (A == A_const)) / sum((A ==
 A_const));
        %computing false positive probability Pf & true positive
 probability Pd
        Pf(x,i) = sum((Y > threshold_test(x)) & (A ~= A_const)) /
 sum((A == 0));
        Pd(x,i) = sum((Y > threshold_test(x)) & (A == A_const)) /
 sum((A == A_const));
    end
end
%Plotting ROC with their associated SNR values and the point where the
 conditional risk is minimized (part c)
figure;
set(groot,'defaultLineMarkerSize',10);
plot(Pf(:,1), Pd(:,1), '-r', F10(1), D10(1), '-r*',...
     Pf(:,2), Pd(:,2), '-b', F10(2), D10(2), '-b*',...
     Pf(:,3), Pd(:,3), '-g', F10(3), D10(3), '-g*', 'linewidth', 1);
 xlabel('Pf');
 ylabel('Pd');
 title('Reciever Operating Curve for SNR with \eta')
 legend("SNR = 0.5", "  \eta  ","SNR = 1.0", "  \eta  ","SNR = 1.5", "
  \eta  ", 'Location', 'southeast');
 xlim([0 1.0]);
 ylim([0 1.1]);

%e)
%sigma and var of X and Z
var_x = 1;
var_z = 25;
sigma_x = sqrt(var_x);
sigma_z = sqrt(var_z);

%Generating New Model
A = double(~logical((randi(5, N, 1))-1));
X = normrnd(0, sigma_x, [N, 1]);
Z = normrnd(0, sigma_z, [N, 1]);
Y = A + (X .* A) + (Z .* (~A));

%Theoretical Error
%Finding Threshold
threshold  = 2 * ((sigma_x^2 * sigma_z^2) / (sigma_z^2 - sigma_x^2)) *
 log((p1 * sigma_z) / (p0 * sigma_x));
%Finding probability of false detection using p01 and p10
p01 = 2 * (1 - normcdf(threshold, 0, sigma_x));
p10 = normcdf(threshold, 0, sigma_z) - normcdf(-threshold, 0,
 sigma_z);
```

```
theo_error = p10 * p0 + p01 * p1;

%experimental probability of error
%If Y has any imaginary components, target is present, otherwise it is
 not
exp_error = sum((imag(Y) ~= 0) ~= (A == 1)) / N;
fprintf('\ne)\nTheoretical Probability of Error: %.3f\n', theo_error);
fprintf('Experimental Probability of Error: %.3f\n', exp_error);

%Generating data for ROC plot with varying var_z/varz_x ratio
var_z = [5, 15, 25];
sigma_z = sqrt(var_z);
%var_z/varz_x ratio
ratio = zeros(3, 1, N);
n = linspace(-5,3,N);
pf = zeros(3, 1, N);
pd = zeros(3, 1, N);

for i = 1:3
    A = double(~logical((randi(5, N, 1))-1));
    X = normrnd(0, sigma_x, [N, 1]);
    Z = normrnd(0, sigma_z(i), [N, 1]);
    %New Model
    Y = A + (X .* A) + (Z .* (~A));
    %Computing ROC values
    pf(i,:,:) = sum(and((p1 * (1/sqrt(var_x *2*pi)) * exp(-((Y -
 A_const).^2) / (2 * var_x))) >= ...
     (p0*(1/sqrt(var_z(i)*2*pi)) * exp(-((Y-A_const).^2)/
(2*var_z(i))))*n, ~A))/sum(~A);
    pd(i,:,:) = sum(and((p1 * (1/sqrt(var_x *2*pi)) * exp(-((Y -
 A_const).^2) / (2 * var_x))) >= ...
     (p0*(1/sqrt(var_z(i)*2*pi)) * exp(-((Y-A_const).^2)/
(2*var_z(i))))*n, A))/sum(A);
    %var_z/varz_x ratio
    ratio(i) = var_z(i) / var_x;
end

%ROC Plot
figure;
plot(reshape(pf(1, :, :), [1,N]), reshape(pd(1, :, :), [1,N]),...
     reshape(pf(2, :, :), [1,N]), reshape(pd(2, :, :), [1,N]),...
     reshape(pf(3, :, :), [1,N]), reshape(pd(3, :, :),
 [1,N]),'linewidth', 1);
xlabel('Pf')
ylabel('Pd')
title('Receiver Operating Curve with varying \sigma_z^2/\sigma^2
 ratio')
xlim([0 1.0]);
ylim([0 1.1]);
legend(['\sigma_z^2/\sigma^2= ',num2str(ratio(1))],['\sigma_z^2/
\sigma^2= ',num2str(ratio(2))],...
       ['\sigma_z^2/\sigma^2=
 ',num2str(ratio(3))], 'Location', 'southeast');
```

```
Question 1

a)
Theoretical Error: 0.1862
Experimental Error: 0.1900
c)
Threshold value for SNR(0.5)if missing target is 10 times worse:
 -1.5826
Threshold value for SNR(1.0)if missing target is 10 times worse:
 -0.4163
Threshold value for SNR(1.5)if missing target is 10 times worse:
 0.1391

e)
Theoretical Probability of Error: 0.188
Experimental Probability of Error: 0.183
```





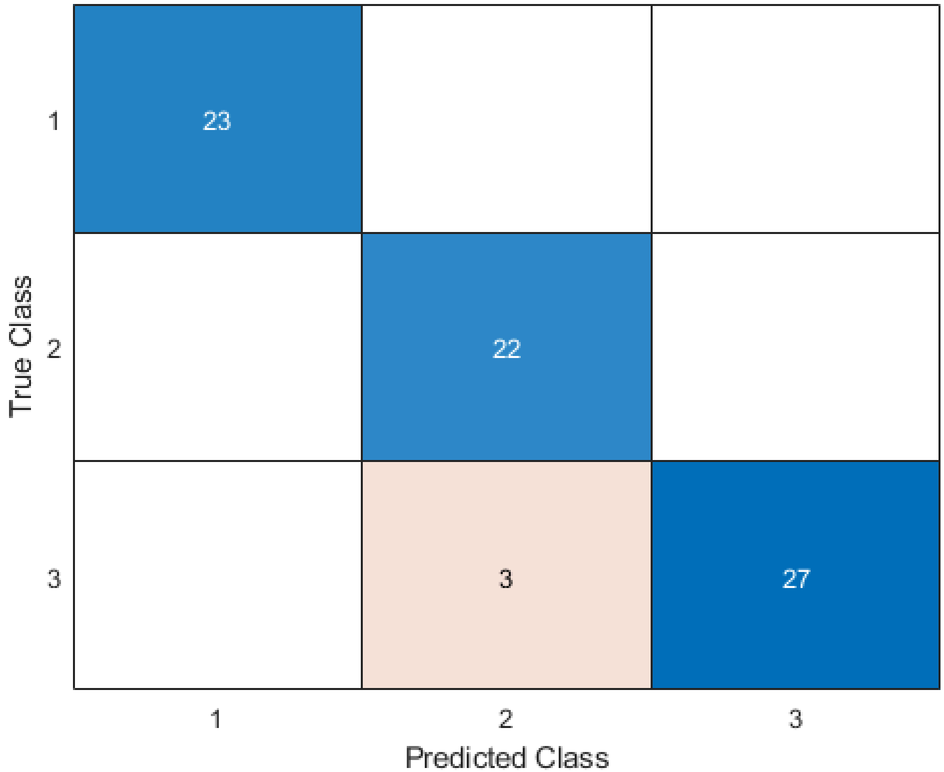
Question 2

```
data = load('Iris.mat');
numOfSamples = size(data.features, 1);
half = numOfSamples/2;

% shuffle data to keep training random
shuffled = randperm(size(data.features, 1));
shuffled_features = data.features(shuffled, :);
shuffled_labels = data.labels(shuffled, :);

%training
train_features = shuffled_features(1:half, :);
train_labels = shuffled_labels(1:half);

%testing
test_features = shuffled_features(half+1:numOfSamples, :);
test_labels = shuffled_labels(half+1:numOfSamples);

%Categorizing
Cat1 = train_features(train_labels == 1, :);
Cat2 = train_features(train_labels == 2, :);
Cat3 = train_features(train_labels == 3, :);

%calculating mean
```

```
m1 = [mean(Cat1(:, 1)), mean(Cat1(:, 2)), mean(Cat1(:, 3)),
 mean(Cat1(:, 4))];
m2 = [mean(Cat2(:, 1)), mean(Cat2(:, 2)), mean(Cat2(:, 3)),
 mean(Cat2(:, 4))];
m3 = [mean(Cat3(:, 1)), mean(Cat3(:, 2)), mean(Cat3(:, 3)),
 mean(Cat3(:, 4))];

%variances
cov1 = cov(Cat1);
cov2 = cov(Cat2);
cov3 = cov(Cat3);

%Calculating likelihood
likelihood = [mvnpdf(test_features, m1, cov1),mvnpdf(test_features,
 m2, cov2),mvnpdf(test_features, m3, cov3)];
%the maximum
[~, output] = max(likelihood, [], 2);

%calculating error
error = 1- mean(output == test_labels);
fprintf('\n\nQuestion 2 \n\nTotal Probability of Error: %0.4f',
 error);

%Confusion Matrix
figure;
confusionchart(confusionmat(test_labels, output));
```

Question 2

Total Probability of Error: 0.0400



Published with MATLAB® R2020a