Problem 2

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Single sample perceptron

Method:

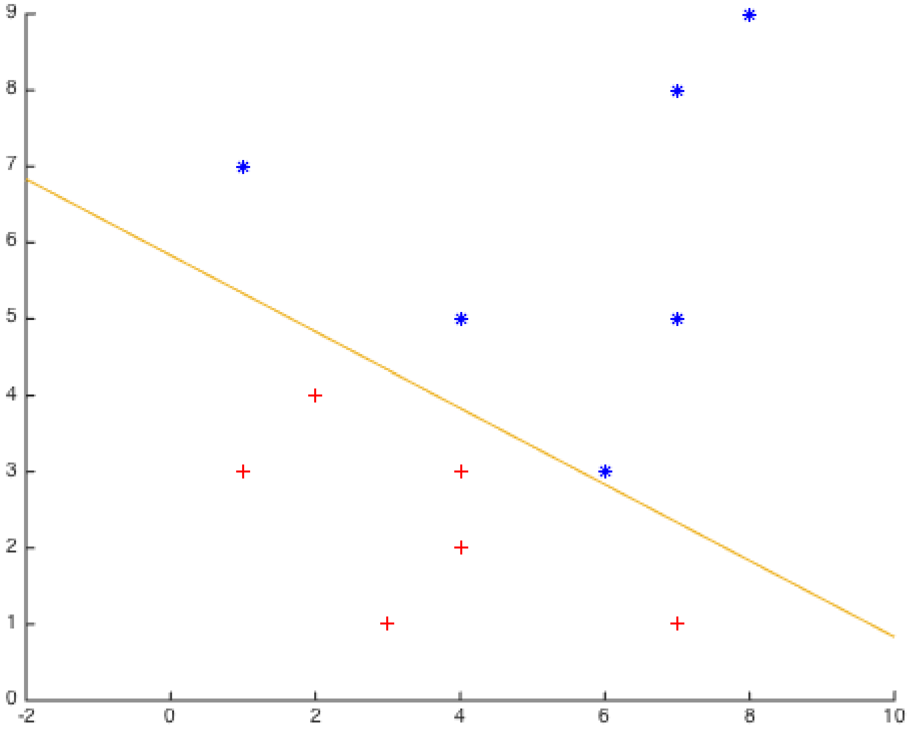
Weight vector for classification is updated each time we encounter a misclassified sample. This process is repeated over the training set until all samples are classified.

Code:

```
clear;
clc;
close all;
tic

x = [1 7; 6 3; 7 8; 8 9; 4 5; 7 5; 3 1; 4 3; 2 4; 7 1; 1 3; 4 2];
y(:, 2 : 3) = x;
y(:, 1) = 1;

% Normalization of vector spaces
y(7 : 12, :) = -y(7 : 12, :);

%Weight vector initialization
a = [1 1 1];

% Perceptron function
g = @(a, y) a * y';

figure
s = scatter(y(1 : 6, 2), y(1 : 6, 3), 25, 'b', '*');
hold on;
t = scatter(-y(7 : 12, 2),-y(7 : 12, 3), 25, 'r', '+');

k = 0;
p = -2:0.01:10;
n = size(y, 1);
while nnz((a * y') > 0) ~= n
    k = mod(k, n) + 1;
    yk = y(k, :);
    if (g(a, yk) <= 0)
```

```
        a = a + yk;
    end
end

% Exceptional Handling for a(3) = 0 (Vertical line)
if (a(3) ~= 0)
    q = (- a(2) * p - a(1))/a(3);
    plot(p, q);
else
    hx = -a(1)/a(2) * ones(1, 10);
    hy = 1 : 10;
    plot(hx, hy);
end

toc
```

```
Elapsed time is 0.126055 seconds.
```



Single sample perceptron with margin

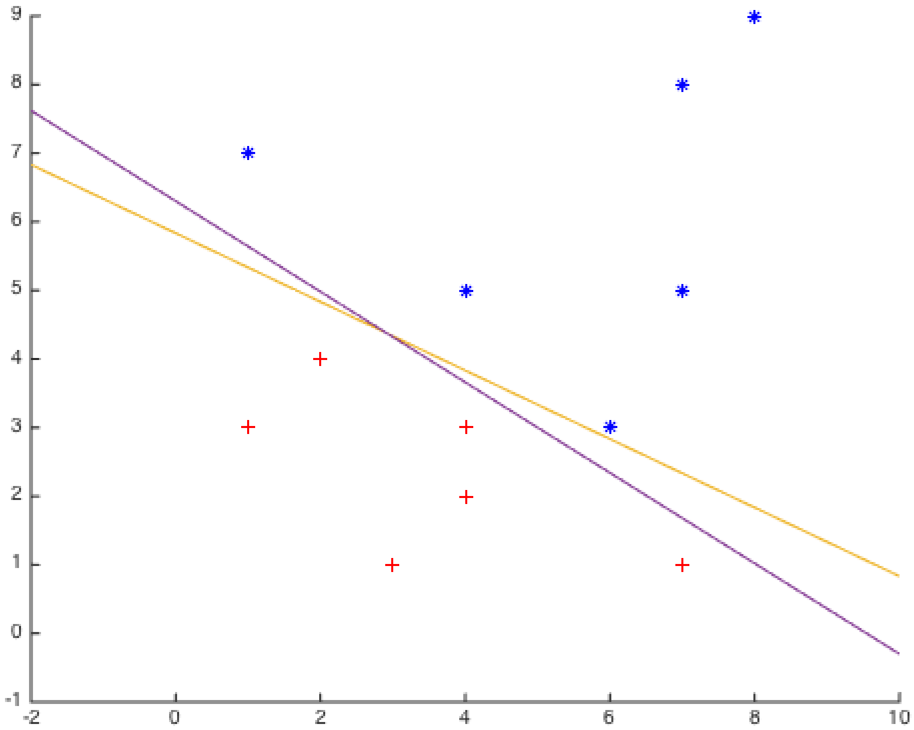
Method:

Single sample rule is followed along with margin 'b' make sure that points are not too close to decision boundry.

Code:

```
tic

x = [1 7; 6 3; 7 8; 8 9; 4 5; 7 5; 3 1; 4 3; 2 4; 7 1; 1 3; 4 2];
y(:, 2 : 3) = x;
y(:, 1) = 1;

% Normalization of vector spaces
y(7 : 12, :) = -y(7 : 12, :);

%Weight vector initialization
a = [1 1 1];

% Margin
b = -100;

% Perceptron function
g = @(a, y) a * y' + b;

%figure
%s = scatter(y(1 : 6, 2), y(1 : 6, 3), 25, 'b', '*');
%hold on;
%t = scatter(-y(7 : 12, 2),-y(7 : 12, 3), 25, 'r', '+');

k = 0;
p = -2:0.01:10;
n = size(y, 1);
while nnz(g(a, y) > 0) ~= n
    k = mod(k, n) + 1;
    yk = y(k, :);
    if (g(a, yk) <= 0)
        a = a + yk;
    end

end

% Exceptional Handling for a(3) = 0 (Vertical line)
if (a(3) ~= 0)
    q = (- a(2) * p - a(1))/a(3);
    plot(p, q);
else
    hx = -a(1)/a(2) * ones(1, 10);
    hy = 1 : 10;
    plot(hx, hy);
end

toc
```

```
Elapsed time is 0.642617 seconds.
```



Relaxation algorithm with margin

Method:

Following perceptron criterion function Jp is chosen:

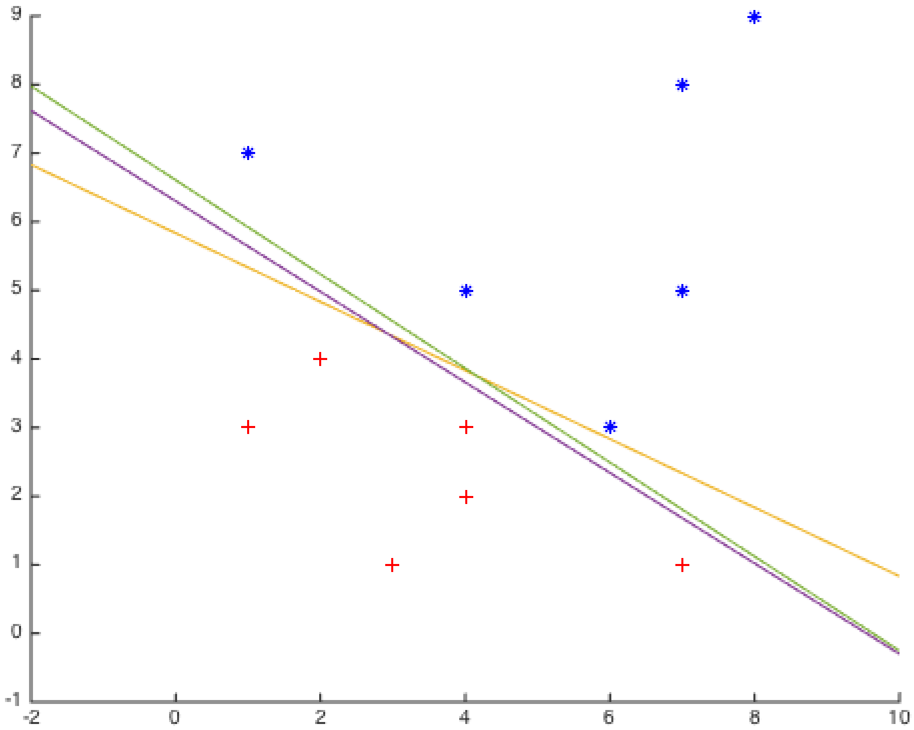
$$J_r(a) = \frac{1}{2}\sum_{y\in\mathcal{Y}} \frac{(a^t y - b)^2}{\|y\|^2}$$

Its gradient is more continuous and smooth. Since longest sample vector can dominate the perceptron criterion function, hence normalization is done.

```
tic
x = [1 7; 6 3; 7 8; 8 9; 4 5; 7 5; 3 1; 4 3; 2 4; 7 1; 1 3; 4 2];
y(:, 2 : 3) = x;
y(:, 1) = 1;

% Normalization of vector spaces
y(7 : 12, :) = -y(7 : 12, :);

%Weight vector initialization
a = [1 1 1];

%Margin
b = 100;
```

```
% Perceptron function
g = @(a, y) a * y' - b;

%figure
%s = scatter(y(1 : 6, 2), y(1 : 6, 3), 25, 'b', '*');
%hold on;
%t = scatter(-y(7 : 12, 2),-y(7 : 12, 3), 25, 'r', '+');

k = 0;
p = -2:0.01:10;
n = size(y, 1);

eta = 2.1;
while nnz(g(a, y) > 0) ~= n
    k = mod(k, n) + 1;
    yk = y(k, :);
    if (g(a, yk) <= 0)
       a = a - ((eta * g(a, yk))/(norm(yk)^2)) * yk;
    end
end

% Exceptional Handling for a(3) = 0 (Vertical line)
if (a(3) ~= 0)
    q = (- a(2) * p - a(1))/a(3);
    plot(p, q);
else
    hx = -a(1)/a(2) * ones(1, 10);
    hy = 1 : 10;
    plot(hx, hy);
end

toc
```

```
Elapsed time is 0.027720 seconds.
```



Widrow-Hoff or Least Mean Squared (LMS) Rule

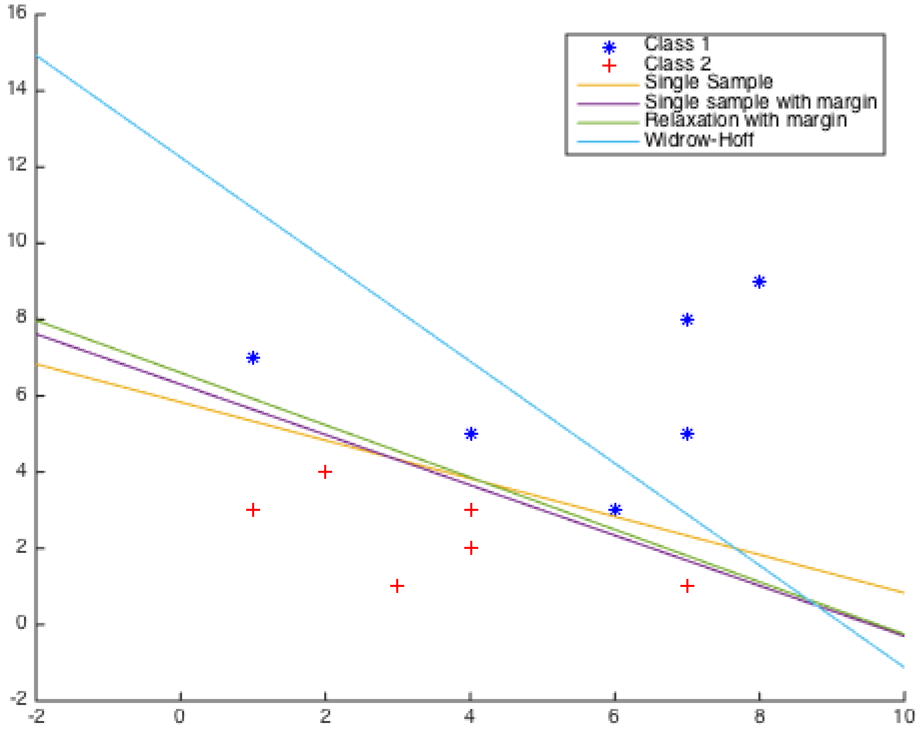
Method:

In this procedure, we consider all data samples rather than misclassified ones. Margin vector 'b' is taken. This procedure might not yield a seperating hyperplance but a reasonable one.

Code:

```
tic

x = [1 7; 6 3; 7 8; 8 9; 4 5; 7 5; 3 1; 4 3; 2 4; 7 1; 1 3; 4 2];
y(:, 2 : 3) = x;
y(:, 1) = 1;

% Normalization of vector spaces
y(7 : 12, :) = -y(7 : 12, :);

%Weight vector initialization
a = [1 1 1];

%Margin
b = 10;
```

```
% Perceptron function
g = @(a, y) a * y' - b;
rownorm = @(x,p) sum(abs(x).^p,2).^(1/p);

%figure
%s = scatter(y(1 : 6, 2), y(1 : 6, 3), 25, 'b', '*');
%hold on;
%t = scatter(-y(7 : 12, 2),-y(7 : 12, 3), 25, 'r', '+');

k = 0;
p = -2:0.01:10;
n = size(y, 1);

theta = 1 * ones(12, 1);
eta = 0.5;
count = 1;
while nnz(rownorm(((eta/count) * repmat(g(a, y)', 1, 3) .* y), 2) < theta) ~= n
    k = mod(k, n) + 1;
    yk = y(k, :);
    a = a - ((eta/count) * g(a, yk)) * yk;
    count = count + 1;
end

% Exceptional Handling for a(3) = 0 (Vertical line)
if (a(3) ~= 0)
    q = (- a(2) * p - a(1))/a(3);
    plot(p, q);
else
    hx = -a(1)/a(2) * ones(1, 10);
    hy = 1 : 10;
    plot(hx, hy);
end

toc

legend({'Class 1','Class 2', 'Single Sample', 'Single sample with margin', 'Relaxa

hold off

Elapsed time is 1.646746 seconds.
```



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