```
%David Melanson
clf reset; clearvars; clc
pausetime = 0;
pauseflag = 0;
maxw = 10;
minw = 0;
%Problem definition - bipolar AND function

%define three 4 element input vectors -- one element in a vector for each
%state
P = [
    1 1 -1 -1;          %X1
    1 -1 1 -1;          %X2
    1 1 1 1             %Bias
    ];

%each row is one input set
%each column is one set of training data for network
%define 4 1-element output vectors
%  Ni01 Ni02 Ni03 Ni04
T = [1  -1   -1   -1];

%Initialize network
%=====================================================
[R, Q] = size(P); [S, Q] = size(T);
W0 = zeros(S, R);
B0 = ones(S, 1);
fprintf('R =%2i Q =%2i S =%2i\n', R, Q, S);

% Plot original values
%=====================================================
disp(['pause for ', num2str(pausetime), 'sec']);
pause(pausetime);
figure(1);
hintonw(W0, maxw, minw);
title('Original Weights W(i,j)');

% TRAIN THE NETWORK
%=====================================================
% TRAINING PARAMETERS
disp_freq = 1;
max_epoch = 4;
% lr = 0.1;
% dr = lr/3;
% lp Learning Parameter
% lr Learning Rate
% dr Decay Rate
lr = 1;
lp.lr = lr;
lp.dr = 0;

W = W0;
B = B0;

for epoch = 1:max_epoch
    for q = 1:Q
        % PRESENTATION PHASE
        A = T(:, q);
        % LEARNING PHASE
```

```
        dW = learnhd(W, P(:, q), [], [], A, [], [], [], [], [], lp, []);
        fprintf("\npause\n");
        W = W +dW;
        fprintf('input = %2i W = %2i %2i %2i', epoch, W)
        if pauseflag == 1
            pause(pausetime)
            figure(1)
        end
    end
    % DISPLAY PROGRESS
    if rem(epoch, disp_freq) == 0
        pause(pausetime)
        hintonw(W, maxw, minw)
        title('Weights W(i,j)');
    end
end

% PLOT FINAL VALUES
hintonw(W, maxw, minw);
title('Final Weights W(i,j)');
pause(pausetime);

% SUMMARIZE RESULTS
%=================================================
fprintf("\nWith inputs of \n%2i %2i %2i\n%2i %2i %2i\n%2i %2i %2i\n%2i %2i %2i\n", P);
disp("")
fprintf("The network applies weights of %2i %2i %2i.\n", W)
A_nonbin = hardlims(W*P);
A_bin = hardlim(W*P);
disp('The network responds with binary outputs')
disp(A_bin)
disp('Thus the network succesfully replicated an AND gate.')

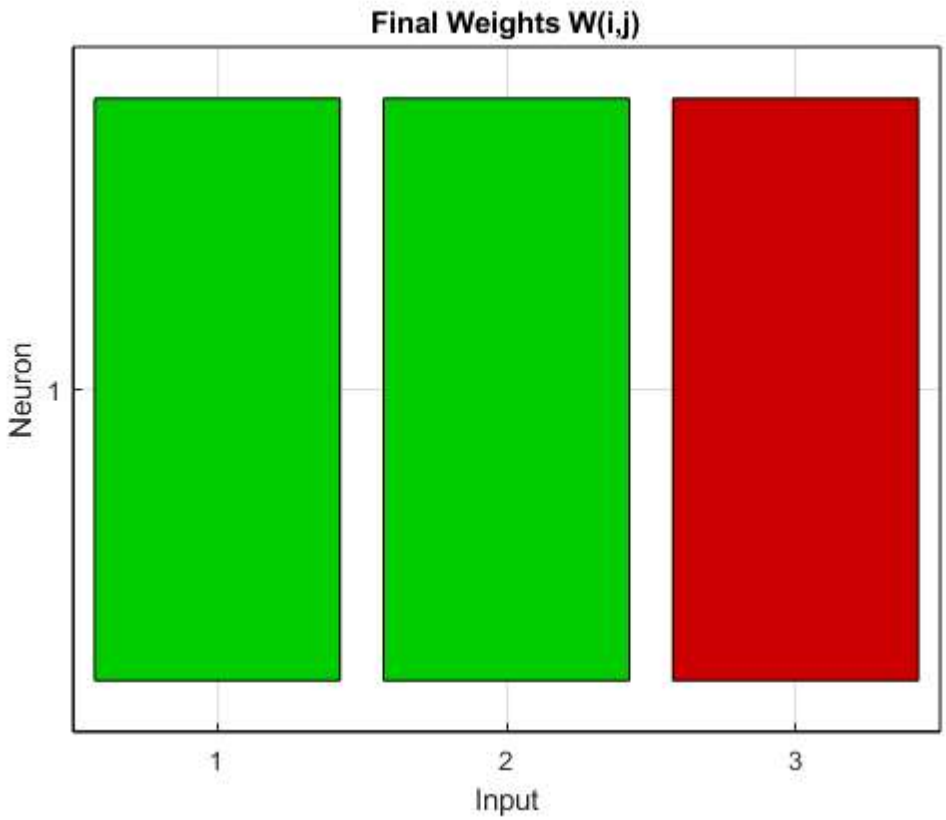
%input, target, and output are necessary for submission of HW
```

```
R = 3 Q = 4 S = 1
pause for 0sec

pause
input =  1 W =  1  1  1
pause
input =  1 W =  0  2  0
pause
input =  1 W =  1  1 -1
pause
input =  1 W =  2  2 -2
pause
input =  2 W =  3  3 -1
pause
input =  2 W =  2  4 -2
pause
input =  2 W =  3  3 -3
pause
input =  2 W =  4  4 -4
pause
input =  3 W =  5  5 -3
pause
input =  3 W =  4  6 -4
pause
```

```
input =  3 W =  5  5 -5
pause
input =  3 W =  6  6 -6
pause
input =  4 W =  7  7 -5
pause
input =  4 W =  6  8 -6
pause
input =  4 W =  7  7 -7
pause
input =  4 W =  8  8 -8
With inputs of
 1  1  1
 1 -1  1
-1  1  1
-1 -1  1
The network applies weights of  8  8 -8.
The network responds with binary outputs
     1     0     0     0

Thus the network succesfully replicated an AND gate.
```



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```
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%state
P = [
    -1 1 1 1;          %X1
    -1 1 -1 1;          %X2
    1 1 1 1             %Bias
    ];

%each row is one input set
%each column is one set of training data for network
%define 4 1-element output vectors
%  Ni01 Ni02 Ni03 Ni04
T = [-1 1 1 1];

%Initialize network
%=====================================================
[R, Q] = size(P); [S, Q] = size(T);
W0 = zeros(S, R);
B0 = ones(S, 1);
fprintf('R =%2i Q =%2i S =%2i\n', R, Q, S);

% Plot original values
%=====================================================
disp(['pause for ', num2str(pausetime), 'sec']);
pause(pausetime);
figure(1);
hintonw(W0, maxw, minw);
title('Original Weights W(i,j)');

% TRAIN THE NETWORK
%=====================================================
% TRAINING PARAMETERS
disp_freq = 1;
max_epoch = 4;
% lr = 0.1;
% dr = lr/3;
% lp Learning Parameter
% lr Learning Rate
% dr Decay Rate
lr = 1;
lp.lr = lr;
lp.dr = 0;

W = W0;
B = B0;

for epoch = 1:max_epoch
    for q = 1:Q
        % PRESENTATION PHASE
        A = T(:, q);
        % LEARNING PHASE
```

```
        dW = learnhd(W, P(:, q), [], [], A, [], [], [], [], [], lp, []);
        fprintf("\npause\n");
        W = W +dW;
        fprintf('input = %2i W = %2i %2i %2i', epoch, W)
        if pauseflag == 1
            pause(pausetime)
            figure(1)
        end
    end
    % DISPLAY PROGRESS
    if rem(epoch, disp_freq) == 0
        pause(pausetime)
        hintonw(W, maxw, minw)
        title('Weights W(i,j)');
    end
end

% PLOT FINAL VALUES
hintonw(W, maxw, minw);
title('Final Weights W(i,j)');
pause(pausetime);

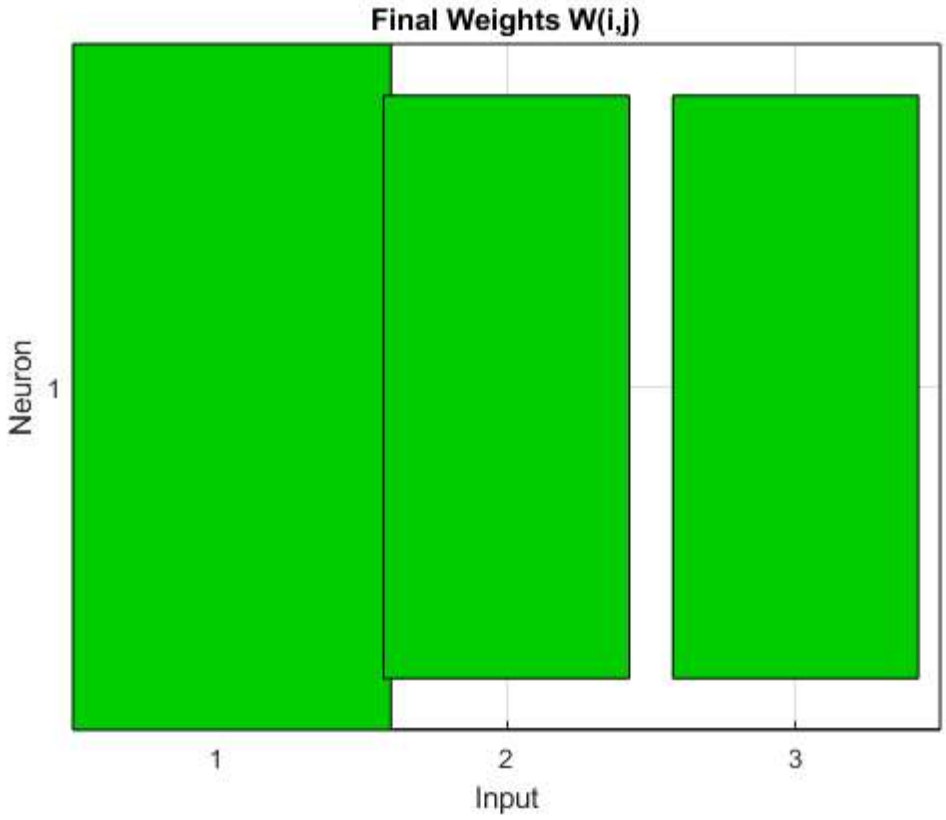
% SUMMARIZE RESULTS
%=================================================
fprintf("\nWith inputs of \n%2i %2i %2i\n%2i %2i %2i\n%2i %2i %2i\n%2i %2i %2i\n", P);
disp("")
fprintf("The network applies weights of %2i %2i %2i.\n", W)
A_nonbin = hardlims(W*P);
A_bin = hardlim(W*P);
disp('The network responds with binary outputs')
disp(A_bin)
disp('Thus the network succesfully replicated an OR gate.')
```

```
R = 3 Q = 4 S = 1
pause for 0sec

pause
input =  1 W =  1  1 -1
pause
input =  1 W =  2  2  0
pause
input =  1 W =  3  1  1
pause
input =  1 W =  4  2  2
pause
input =  2 W =  5  3  1
pause
input =  2 W =  6  4  2
pause
input =  2 W =  7  3  3
pause
input =  2 W =  8  4  4
pause
input =  3 W =  9  5  3
pause
input =  3 W = 10  6  4
pause
input =  3 W = 11  5  5
pause
```

```
input =  3 W = 12  6  6
pause
input =  4 W = 13  7  5
pause
input =  4 W = 14  8  6
pause
input =  4 W = 15  7  7
pause
input =  4 W = 16  8  8
With inputs of
-1 -1  1
 1  1  1
 1 -1  1
 1  1  1
The network applies weights of 16  8  8.
The network responds with binary outputs
     0     1     1     1

Thus the network succesfully replicated an OR gate.
```



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clf reset; clearvars; clc
pausetime = 0;
pauseflag = 0;
maxw = 10;
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%Problem definition - bipolar AND function

%define three 4 element input vectors -- one element in a vector for each
%state
P = [
    -1 -1 1 1;          %X1
    -1 1 -1 1;          %X2
    1 1 1 1             %Bias
    ];

%each row is one input set
%each column is one set of training data for network
%define 4 1-element output vectors
%  Ni01 Ni02 Ni03 Ni04
T = [1 1 1 -1];

%Initialize network
%=====================================================
[R, Q] = size(P); [S, Q] = size(T);
W0 = zeros(S, R);
B0 = ones(S, 1);
fprintf('R =%2i Q =%2i S =%2i\n', R, Q, S);

% Plot original values
%=====================================================
disp(['pause for ', num2str(pausetime), 'sec']);
pause(pausetime);
figure(1);
hintonw(W0, maxw, minw);
title('Original Weights W(i,j)');

% TRAIN THE NETWORK
%=====================================================
% TRAINING PARAMETERS
disp_freq = 1;
max_epoch = 4;
% lr = 0.1;
% dr = lr/3;
% lp Learning Parameter
% lr Learning Rate
% dr Decay Rate
lr = 1;
lp.lr = lr;
lp.dr = 0;

W = W0;
B = B0;

for epoch = 1:max_epoch
    for q = 1:Q
        % PRESENTATION PHASE
        A = T(:, q);
        % LEARNING PHASE
```

```
        dW = learnhd(W, P(:, q), [], [], A, [], [], [], [], [], lp, []);
        fprintf("\npause\n");
        W = W +dW;
        fprintf('input = %2i W = %2i %2i %2i', epoch, W)
        if pauseflag == 1
            pause(pausetime)
            figure(1)
        end
    end
    % DISPLAY PROGRESS
    if rem(epoch, disp_freq) == 0
        pause(pausetime)
        hintonw(W, maxw, minw)
        title('Weights W(i,j)');
    end
end

% PLOT FINAL VALUES
hintonw(W, maxw, minw);
title('Final Weights W(i,j)');
pause(pausetime);

% SUMMARIZE RESULTS
%=================================================
fprintf("\nWith inputs of \n%2i %2i %2i\n%2i %2i %2i\n%2i %2i %2i\n%2i %2i %2i\n", P);
disp("")
fprintf("The network applies weights of %2i %2i %2i.\n", W)
A_nonbin = hardlims(W*P);
A_bin = hardlim(W*P);
disp('The network responds with binary outputs')
disp(A_bin)
disp('Thus the network succesfully replicated a NAND gate.')

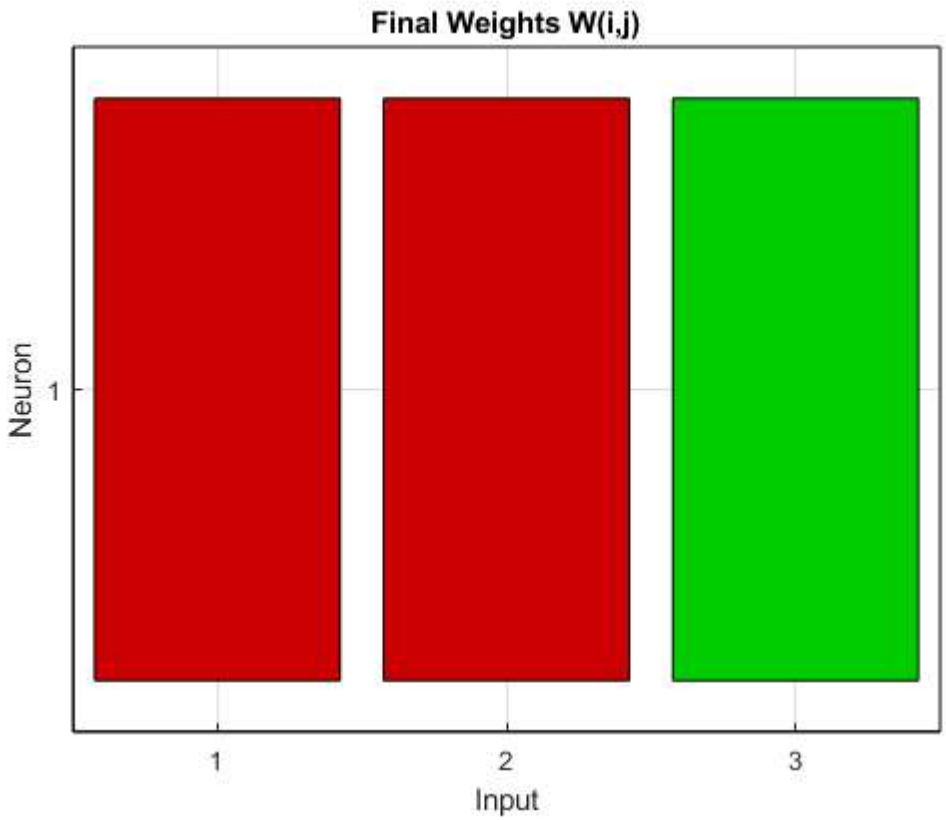
%input, target, and output are necessary for submission of HW
```

```
R = 3 Q = 4 S = 1
pause for 0sec

pause
input =  1 W = -1 -1  1
pause
input =  1 W = -2  0  2
pause
input =  1 W = -1 -1  3
pause
input =  1 W = -2 -2  2
pause
input =  2 W = -3 -3  3
pause
input =  2 W = -4 -2  4
pause
input =  2 W = -3 -3  5
pause
input =  2 W = -4 -4  4
pause
input =  3 W = -5 -5  5
pause
input =  3 W = -6 -4  6
pause
```

```
input =  3 W = -5 -5  7
pause
input =  3 W = -6 -6  6
pause
input =  4 W = -7 -7  7
pause
input =  4 W = -8 -6  8
pause
input =  4 W = -7 -7  9
pause
input =  4 W = -8 -8  8
With inputs of
-1 -1  1
-1  1  1
 1 -1  1
 1  1  1
The network applies weights of -8 -8  8.
The network responds with binary outputs
     1     1     1     0

Thus the network succesfully replicated a NAND gate.
```



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