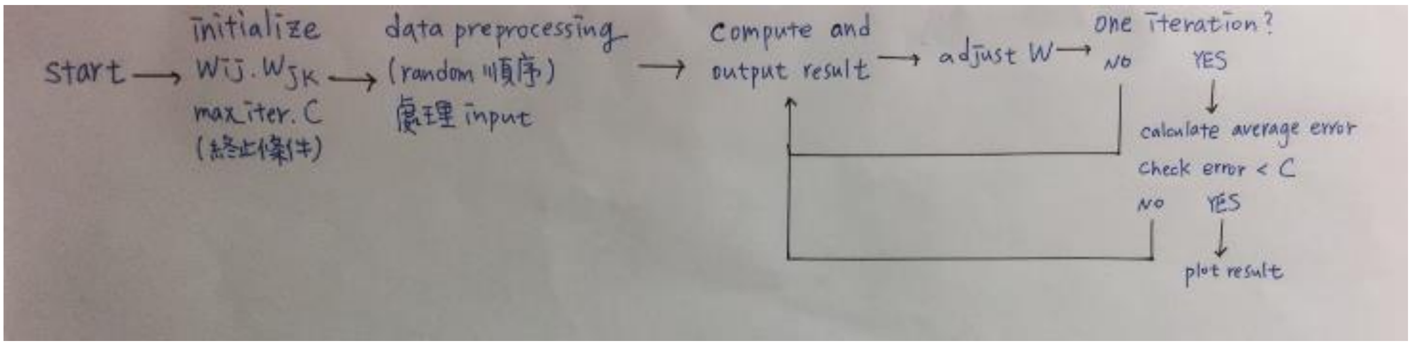
Project #2(a):　Multilayer Perceptron　　　0516222 許芳瑀

Q1:

做法:

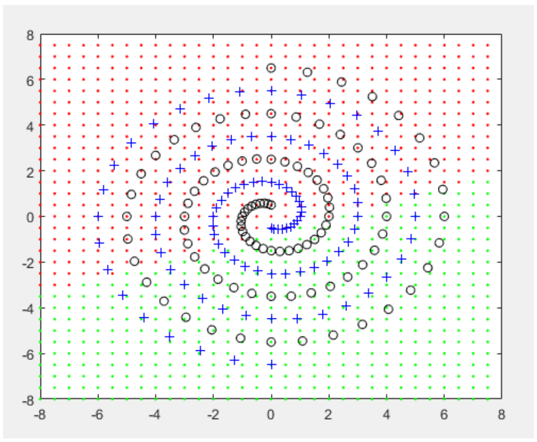
這題我使用了兩層 hidden layer　，第一層 20 個 node，第二層 10 個 node，最一開始處理資料時，我先將 x y 存到 oi(加上常數 1)，並且將資料順序 random，讓同種類的點分散，開始 train 之後，便是接受 input，其中採用的 active function 是 sigmoid function，經過跟 weight 內積之後，output 的輸出是 1 或 0(因為只有要分兩類)，然後調整 weight，一個 iteration 之後計算 error，直到我指定的最大次數或是 e 小於指定的數字。

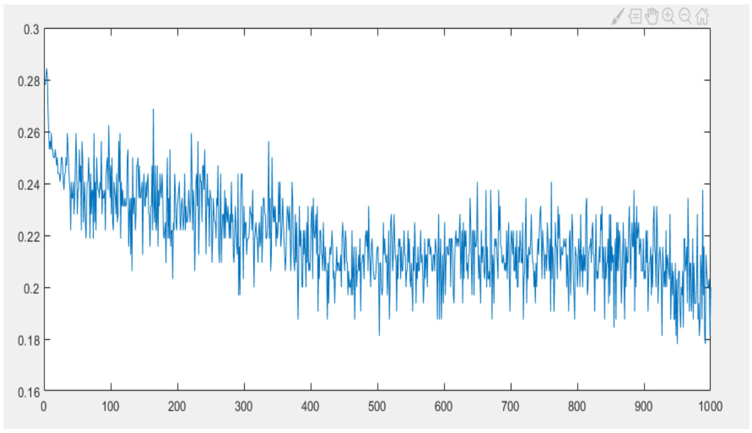
Flowchart:



結果:

decision region　　　　　　　　　　　　　average error vs. iteration





討論:

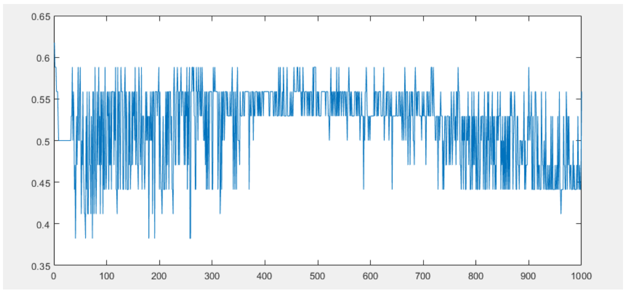
<u>How to determine the hidden node number in each problem?</u>

這題花了蠻久的時間，一開始我只有用一層 layer，50 個 node，發現效果蠻差的，所以多設計一層，以及把 iteration 的次數也加高到 10000，但效果還是不好。

<u>Any experiment</u>

我只用了八成的資料 training，剩下的兩成用於 test，再每次 iteration 之後都算一次答案的正確性。

Accuracy



Code:

```
i=[0:96]
theta_i = i * pi / 16;
theta_j = i * pi / 16;
r_i = 6.5 .* (104 - i) / 104;
r_j = 6.5 .* (104 - i) / 104;
N=250;
theta1 = linspace(-180,180, N)*pi/360;
r = 8 ;
x1 = r_i .* sin(theta_i);
y1 = r_i .* cos(theta_i);
x2 = -x1;
y2 = -y1;
% set ans 0/1 class
oi = [x1.' y1.' zeros(97,1)+1 ; x2.' y2.' zeros(97,1)+1 ];
ans = [zeros(97,1) ;zeros(97,1)+1 ];
% rearrange
total=194;
train_total=160;
test_total = 34;
r = randperm(total);
oi(:,1) = oi(r,1);
oi(:,2) = oi(r,2);
ans = ans(r);

test=oi([train_total+1 :total], :);
test_ans = ans([train_total+1 :total],:);

% set initial value
num_j = 20;
num_k = 10;
wij = rand(3,20);
wjk = rand(21,10);
wkl = rand(11, 1);
i_wij = wij;
i_wjk = wjk;
i_wkl = wkl;
rate = 0.001;
C    = 0.01;
max_iter = 15000;
iter = 1;
sj = [];
sk = [];
sl = [];
oj = [];
ok = [];
ol = [];

% last result
accuracy=[];
e=[];
% regulize
oi(:,1) = (oi(:,1)-mean(oi(:,1)) ) / std(oi(:,1));
oi(:,2) = (oi(:,2)-mean(oi(:,2)) ) / std(oi(:,2));
while iter<=max_iter
    disp(iter);
    error = 0;
    for i = 1:1:train_total
        % foward
        sj = oi(i,:)*wij;
        oj = [sj 1];
        sk = oj*wjk;
        ok= [sk 1];
        sl = ok*wkl;
        ol = round(sigmf(sl,[1,0]));
        prev_wjk = wjk;
        prev_wkl = wkl;
        % update wkl
        f = sigmf(sl,[1,0]);
        for kk=1:num_k+1
            wkl(kk,1) =    wkl(kk,1) + rate * (ans(i)-ol)* f * (1-f)
* ok(kk);
        end

        % update wjk
        for jj = 1:num_j+1
            for kk = 1:num_k
                f = sigmf(sk(kk),[1,0]);
                fl = sigmf(sl,[1,0]);
                sum =    (ans(i,1) - ol ) * fl * (1-fl) *
prev_wkl(kk,1);
                wjk(jj,kk) = wjk(jj,kk) + rate*    sum *    f * (1-
f) * oj(jj);
            end
        end
```

```
% update wij
            sum=0;
            for ii = 1:3
                  for jj = 1:num_j
                        fj = sigmf(sj(jj),[1,0]);
                        for kk=1:num_k
                              fk=sigmf(sk(kk),[1 0]);
                              sum = sum + (ans(i,1) - ol)*fk*(1-fk)*wjk(jj,kk);
                        end
                        wij(ii,jj) = wij(ii,jj) + rate*    sum *    fj * (1-fj) * oi(i,ii);
                  end
            end
            error = error + (ans(i) - ol).^2/2;
      end
      e(iter) = error/train_total;
      if error < C
            break;
      end
      acc=0;
      for t=1:test_total
            sj = test(t,:)*wij;
            oj = [sj 1];

            sk = oj*wjk;
            ok= [sk 1];

            sl = ok*wkl;
            ol = round(sigmf(sl,[1,0]));
            if ol== test_ans(t)
                  acc = acc+1;
            end
      end
      acc = acc/test_total;
      accuracy(iter) = acc;
      iter = iter + 1;
end
figure(1);
plot(e);
figure(2);
plot(accuracy);
```

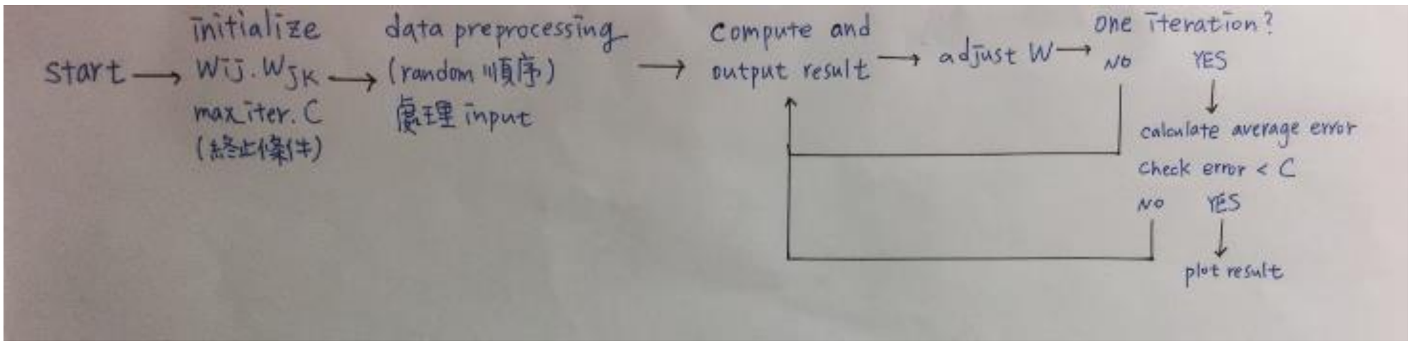
```
%  畫圖
for ix=-16:16
      for iy=-16:16
dx=0.5*(ix-1);
            dy=0.5*(iy-1);
            oi=[dx dy 1];

            sj = oi*wij;
            oj = [sj 1];
            sk = oj*wjk;
            ok= [sk 1];
            sl = ok*wkl;
            ol = round(sigmf(sl,[1,0]));

            if ol==1
                  figure(3);
                  axis([-8 8 -8 8]);
                  plot(dx,dy,
'g .',x1,y1,'ko',x2,y2,'b+');
                  hold on;
            elseif ol==0
                  figure(3);
                  axis([-8 8 -8 8]);
                  plot(dx,dy,
'r .',x1,y1,'ko',x2,y2,'b+');
                  hold on;
            end
      end
end
```

Q2:

做法:

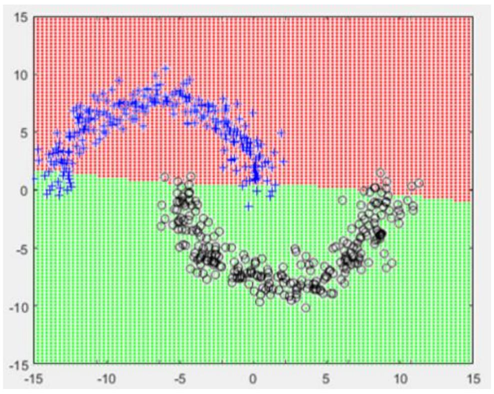
這題我使用了一層 hidden layer、四個 node，最一開始處理資料時，我先將 x y 存到 oi(加上常數 1)，並且將資料順序 random，讓同種類的點分散，開始 train 之後，便是接受 input，其中採用的 active function 是 sigmoid function，經過跟 weight 內積之後，output 的輸出是 1 或 0(因為只有要分兩類)，然後調整 weight，一個 iteration 之後計算 error，直到我指定的最大次數或是 e 小於指定的數字。

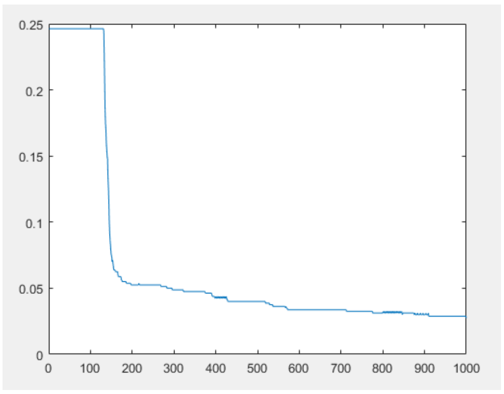
Flowchart:



結果:

decision region　　　　　　　　　　average error vs. iteration





討論:

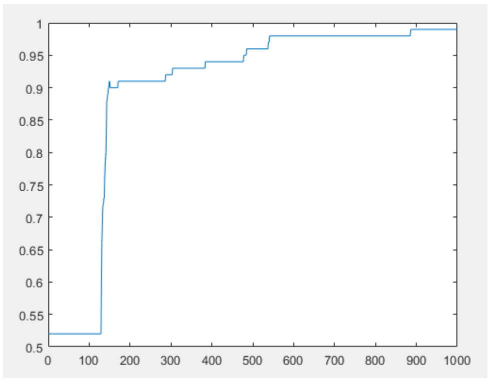
<u>How to determine the hidden node number in each problem?</u>

因為這題的分布看起來沒有很複雜，所以我決定用一層 layer 就好，然後一開始選擇了三個 node，發現結果蠻普通的，所以改用四個 node。

<u>Any experiment</u>

我只用了八成的資料 training，剩下的兩成用於 test，再每次 iteration 之後都算一次答案的正確性，發現結果達到了大於九成的準確率。

Accuracy



<u>如何決定初始的 weight</u>

一開始我的 weight 都是用 random 決定，後來發現這樣有可能會產生很極端的結果，所以我就挑了一次

最好的結果，並改用那次初始的 weight。

Code:

```
clear;
N=250;
theta1 = linspace(-180,180, N)*pi/360;
r = 8 ;
x1 = -5 + r*sin(theta1)+randn(1,N);
y1 = r*cos(theta1)+randn(1,N);
x2 = 5 + r*sin(theta1)+randn(1,N);
y2 = -r*cos(theta1)+randn(1,N);

% set ans 0/1 class
oi = [x1.' y1.' zeros(250,1)+1 ; x2.' y2.' zeros(250,1)+1 ];
ans = [zeros(250,1) ;zeros(250,1)+1 ];
% rearrange
total=500;
train_total=400;
test_total = 100;
r = randperm(total);
oi(:,1) = oi(r,1);
oi(:,2) = oi(r,2);
ans = ans(r);

test=oi([train_total+1 :total], :);
test_ans = ans([train_total+1 :total],:);

% set initial value
wij =
[0.749120729449102,0.127013893617675,0.113789807451064,0.492415695453145;0.147735486618356,0.91692135212
5118,0.960227492817496,0.361313401952203;0.00288774509561229,0.672121707253300,0.119383120967445,0.47000
0490547994];
wjk =[0.0587797688209679;0.330011701173118;0.264520477657796;0.245917666364952;0.947676359396337];

rate = 0.0001;
C    = 0.0025;
max_iter = 1000;
iter = 1;
sj = [];
sk = [];
oj = [];
ok = [];
% last result
accuracy=[];
e=[];
```

```
while iter<=max_iter
    error = 0;
    for i = 1:1:train_total
        % foward
        sj = oi(i,:)*wij;
        oj = [sigmf(sj,[1,0]) 1];
        sk = oj*wjk;
        ok= round(sigmf(sk,[1,0]));
        prev_wjk = wjk;
        % update w2
        f = sigmf(sk,[1,0]);
        for j=1:5
            wjk(j,1) =    wjk(j,1) + rate * (ans(i)-ok)* f * (1-f) * oj(j);
        end
        % update w1
        for ii = 1:3
            for jj = 1:4
                f = sigmf(sj(jj),[1,0]);
                fk = sigmf(sk,[1,0]);
                sum =    (ans(i,1) - ok ) * fk * (1-fk) * prev_wjk(jj,1);
                wij(ii,jj) = wij(ii,jj) + rate*    sum * f * (1-f) *prev_wjk(jj) * f * (1-f) * oi(i,ii);
            end
        end
        error = error + (ans(i) - ok).^2/2;
    end
    e(iter) = error/train_total;

    if error < C
        break;
    end
    acc=0;
    for t=1:test_total
        sj = test(t,:)*wij;
        oj = [sigmf(sj,[1,0]) 1];
        sk = oj*wjk;
        ok= round(sigmf(sk,[1,0]));
        prev_wjk = wjk;
        if ok== test_ans(t)
            acc = acc+1;
        end
    end
    acc = acc/test_total;
    accuracy(iter) = acc;
    iter = iter + 1;
```

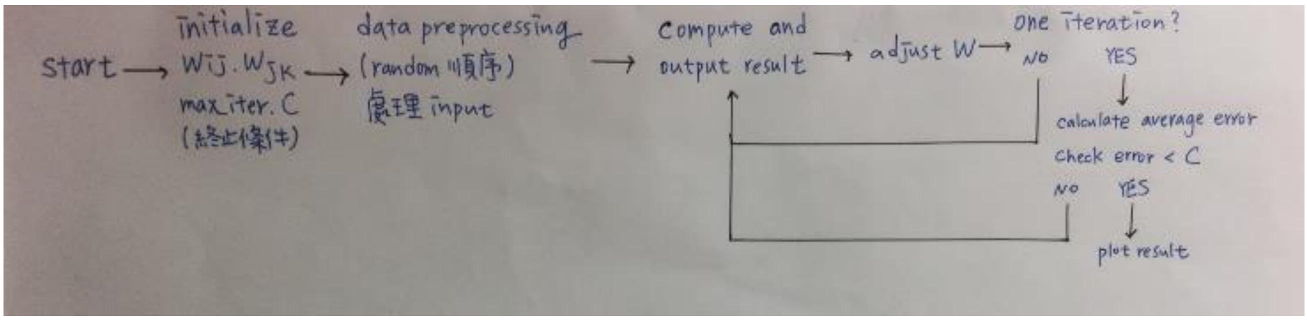
```
end
figure(1);
plot(e);
figure(2);
plot(accuracy);
for ix=-50:50
    for iy=-50:50
        dx=0.3*(ix-1);
        dy=0.3*(iy-1);
        oi=[dx dy 1];
        sj = oi*wij;
        oj = sigmf(sj,[1,0]);
        oj = [oj 1];
        sk = oj*wjk;
        ok= round(sigmf(sk,[1,0]));
        if ok==1
            figure(3);
            axis([-15 15 -15 15]);
            plot(dx,dy, 'g .');
            hold on;
        elseif ok==0
            figure(3);
            axis([-15 15 -15 15]);
            plot(dx,dy, 'r .');
            hold on;
        end
    end
end
```

Q3:

做法:

這題我使用了一層 hidden layer、五個 node，最一開始處理資料時，我先將 x y 存到 oi(加上常數 1)，並且將資料順序 random，讓同種類的點分散，開始 train 之後，便是接受 input，其中採用的 active function 是 sigmoid function，經過跟 weight 內積之後，output 的輸出是四個數值，哪一個數值為 1 就是哪一類(其他數值為 0)，然後調整 weight，一個 iteration 之後計算 error，直到我指定的最大次數或是 e 小於指定的數字。

Flowchart:



討論:

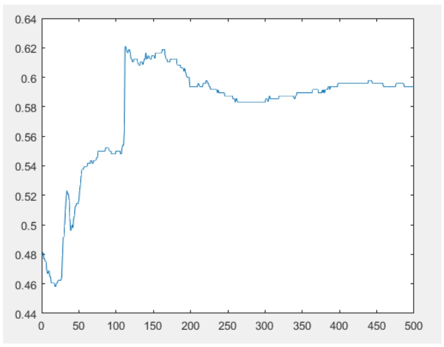
<u>How to determine the hidden node number in each problem?</u>

因為這題的分布看起來沒有很複雜，所以我決定用一層 layer 就好，然後一開始選擇了三個 node，發現結果蠻普通的，所以改用五個 node。

<u>Any experiment</u>

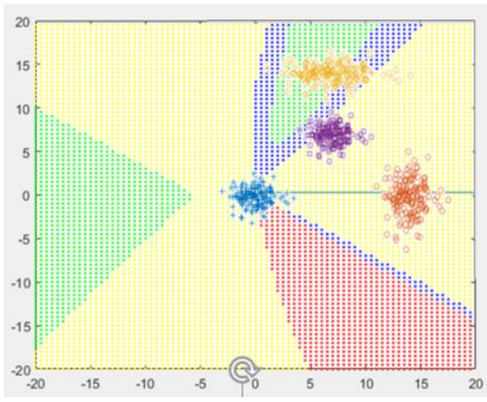
我只用了八成的資料 training，剩下的兩成用於 test，再每次 iteration 之後都算一次答案的正確性。

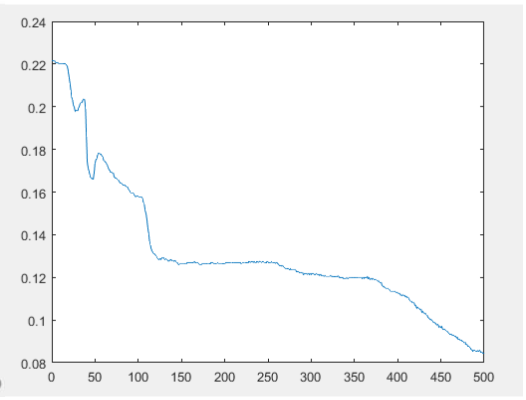
accuracy



結果:

decision region　　　　　　average error vs. iteration

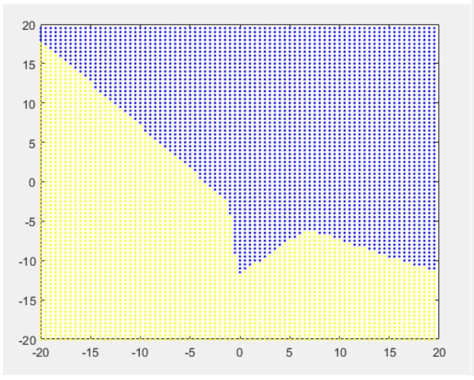


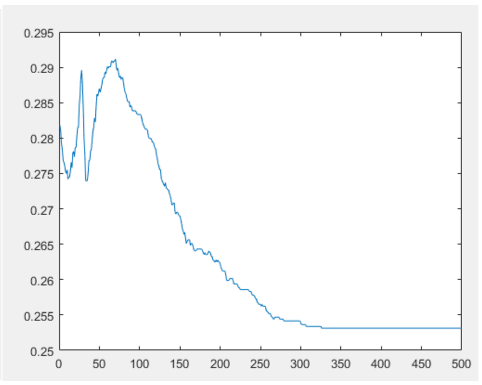


(b) 將 activation function 改為 ReLu function

將 active function 改成 ReLu 之後，我試過很多其他微調(像是 rate 之類)，發現效果都很差，可能這題並沒有很適合 ReLu funcion 當作 active function。

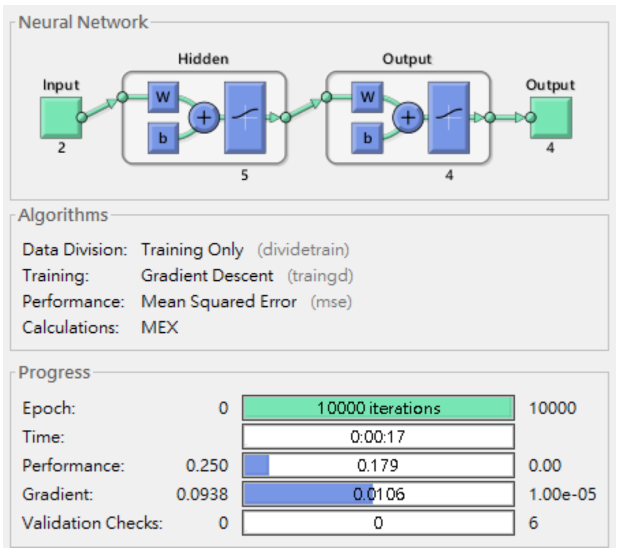
decision region　　　　　　average error vs. iteration





(c) 利用 MATLAB 的 neural networks 的 toolbox

比較:用函式很快就跑出結果了，但是 perfoemance 和 gradient 都沒有表現的很好，我也試了其他 train function，發現用其他的效果會比 gradient decent 好很多，像試 trainscg 之類的



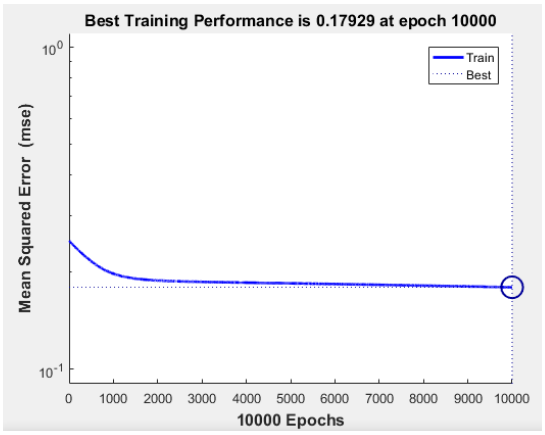
Neural Network

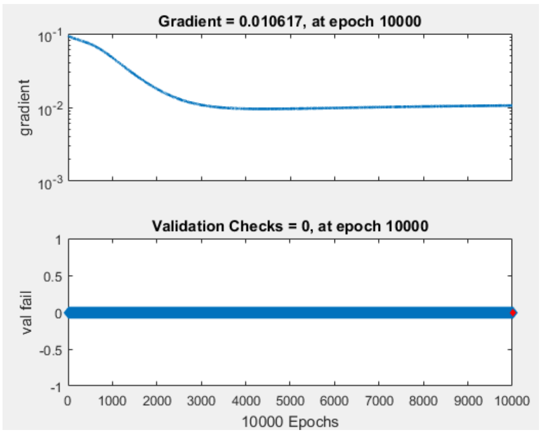
Algorithms

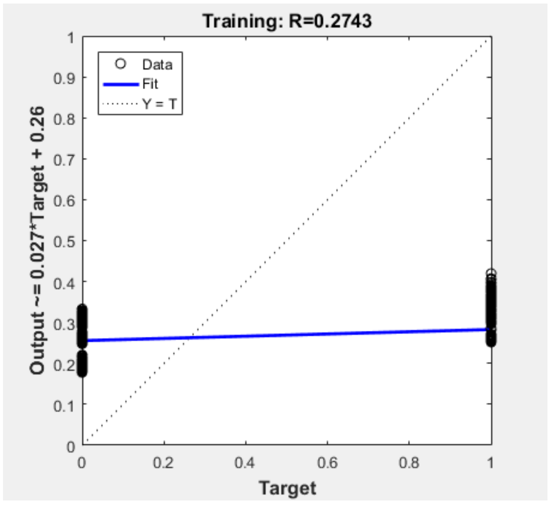
Data Division: Training Only (dividetrain)
Training: Gradient Descent (traingd)
Performance: Mean Squared Error (mse)
Calculations: MEX

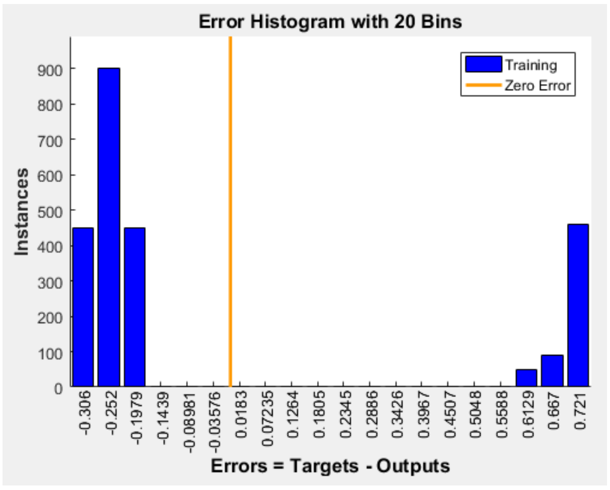
Progress

Epoch:	0	10000 iterations	10000
Time:		0:00:17	
Performance:	0.250	0.179	0.00
Gradient:	0.0938	0.0106	1.00e-05
Validation Checks:	0	0	6









討論

Code:

```
clear;
% set data1
mu = [0;0];
sigma = [1 0; 0 1];
rng default    % For reproducibility
r = mvnrnd(mu,sigma,150);
temp = zeros(150,1)+1;
oi = [r,temp];
% set data2
mu = [14;0];
sigma = [1 0; 0 4];
rng default    % For reproducibility
r = mvnrnd(mu,sigma,150);
oi = [ oi ;r temp];
% set data3
mu = [7;14];
sigma = [4 0; 0 1];
rng default    % For reproducibility
r = mvnrnd(mu,sigma,150);
oi = [ oi ;r temp];
% set data4
mu = [7;7];
sigma = [1 0; 0 1];
rng default    % For reproducibility
r = mvnrnd(mu,sigma,150);
oi = [ oi ;r temp];
% set ans
ans = [zeros(150,1)+1 ;zeros(150,1)+2 ;zeros(150,1)+3; zeros(150,1)+4];
% rearrange
total=600;
train_total=total*0.8;
test_total = total*0.2;
r = randperm(total);
oi(:,1) = oi(r,1);
oi(:,2) = oi(r,2);
ans = ans(r);
t=[1:total];
final_ans = zeros(600,4);
for i=1:600
        final_ans(i,ans(i)) = 1;
```

```
end
test=oi([train_total+1 :total], :);
test_ans = final_ans([train_total+1 :total],:);

% set initial value

wij = rand(3,5).*2-1;
wjk = rand(6,4).*2-1;
i_wij=wij;
i_wjk=wjk;

rate = 0.0001;
C    = 0.005;
max_iter = 500;
iter = 1;
sj = [];
sk = [];
oj = zeros(600,6);
ok = [];
% last result
accuracy=[];
e=[];
% regulize
oi(:,1) = (oi(:,1)-mean(oi(:,1)) ) / std(oi(:,1));
oi(:,2) = (oi(:,2)-mean(oi(:,2)) ) / std(oi(:,2));
while iter<=max_iter
        error = 0;
        for i = 1:1:train_total
                % foward
                sj = oi(i,:)*wij;
                oj = [sigmf(sj,[1,0]) 1];
                sk = oj*wjk;
                ok= round(sigmf(sk,[1,0]));
                prev_wjk = wjk;
                % update w2
                for k=1:4
                        f = sigmf(sk(k),[1,0]);
                        for j=1:6
                                wjk(j,k) =    wjk(j,k) + rate * (final_ans(i,k)-ok(k))* f * (1-f) * oj(j);
                        end
                end
                % update w1
                for ii = 1:3
                        for jj = 1:5
```

```
                    f = sigmf(sj(jj),[1,0]);
                    sum=0;
                    for kk=1:4
                        fk = sigmf(sk(kk),[1,0]);
                        sum = sum + (final_ans(i,k) - ok(k) ) * fk * (1-fk) * prev_wjk(jj,kk);
                    end
                    wij(ii,jj) = wij(ii,jj) + rate*    sum * f * (1-f) * oi(i,ii);
                end
            end
            for tt=1:4
                error = error + (final_ans(i,tt) - ok(tt)).^2/8;
            end

        end
        e(iter) = error/train_total;

          if error < C
              break;
          end
        acc=0;
        for t=1:test_total
            sj = test(t,:)*wij;
            oj = [sigmf(sj,[1,0]) 1];
            sk = oj*wjk;
            ok= round(sigmf(sk,[1,0]));
            prev_wjk = wjk;
            for temp=1:4
                if ok(temp) == test_ans(t,temp)
                    acc = acc+1;
                end
            end
        end
        acc = acc/test_total/4;
        accuracy(iter) = acc;
        iter = iter + 1;
end
figure(1);
plot(e);
figure(2);
plot(accuracy);
for ix=-40:40 %% ±q-15~15
        for iy=-40:40
            dx=0.5*(ix-1);
            dy=0.5*(iy-1);
            input=[dx dy 1];
            sj = input*wij;
            oj = sigmf(sj,[1,0]);
            oj = [oj 1];
            sk = oj*wjk;
            ok= round(sigmf(sk,[1,0]));
            figure(3);
            if ok(1)==1
                axis([-20 20 -20 20]);
                plot(dx,dy, 'g .');
                hold on;
            end
            if ok(2)==1
                axis([-20 20 -20 20]);
                plot(dx,dy, 'r .');
                hold on;
             end
             if ok(3)==1
                axis([-20 20 -20 20]);
                plot(dx,dy, 'b .');
                hold on;
             end
            if ok(4)==1
                axis([-20 20 -20 20]);
                plot(dx,dy, 'y .');
                hold on;
            end

        end
end




%%% relu
wij = rand(3,5)*2-1;
wjk = rand(6,4)*2-1;
i_wij=wij;
i_wjk=wjk;
rate = 0.0001;
iter=1;
temp2=[];
while iter<=max_iter
    error = 0;
    for i = 1:1:train_total
```

```
        % foward
        sj = oi(i,:)*wij;
        oj = [max(sj,0) 1];
        sk = oj*wjk;
        temp2(i,:) = sk;
        ok= max(sk,0) > 0;
        prev_wjk = wjk;
        % update w2
        for k=1:4
            f=1;
                if max(sj(k),0)==0
                    f=0;
                end
            for j=1:6
                wjk(j,k) =    wjk(j,k) + rate * (final_ans(i,k)-ok(k))* f * (1-f) * oj(j);
            end
        end
        % update w1
        for ii = 1:3
            for jj = 1:5
                f=1;
                if max(sj(jj),0)==0
                    f=0;
                end
                sum=0;
                for kk=1:4
                    fk=1;
                    if max(sk(kk),0)==0
                        fk=0;
                    end
                    sum = sum + (final_ans(i,k) - ok(k) ) * fk     * prev_wjk(jj,kk);
                end
                wij(ii,jj) = wij(ii,jj) + rate*    sum     * f     * oi(i,ii);
            end
        end
        for tt=1:4
            error = error + (final_ans(i,tt) - ok(tt)).^2/8;
        end

    end
    e(iter) = error/train_total;

     if error < C
         break;
```

```
          end
        acc=0;
        for t=1:test_total
                sj = test(t,:)*wij;
                oj = [max(sj,0) 1];
                sk = oj*wjk;
                ok= max(sk,0)>0;
                prev_wjk = wjk;
                for temp=1:4
                        if ok(temp) == test_ans(t,temp)
                                acc = acc+1;
                        end
                end
        end
        acc = acc/test_total/4;
        accuracy(iter) = acc;
        iter = iter + 1;
end
figure(4);
plot(e);
figure(5);
plot(accuracy);
for ix=-40:40 %% ±q-15~15
        for iy=-40:40
                dx=0.5*(ix-1);
                dy=0.5*(iy-1);
                oi=[dx dy 1];
                sj = oi*wij;
                oj = [max(sj,0) 1];
                sk = oj*wjk;
                ok= max(sk,0)>0;
                figure(6);
                if ok(1)==1
                        axis([-20 20 -20 20]);
                        plot(dx,dy, 'g .');
                        hold on;
                end
                if ok(2)==1
                        axis([-20 20 -20 20]);
                        plot(dx,dy, 'r .');
                        hold on;
                  end
                  if ok(3)==1
                        axis([-20 20 -20 20]);
                        plot(dx,dy, 'b .');
                        hold on;
                  end
                if ok(4)==1
                        axis([-20 20 -20 20]);
                        plot(dx,dy, 'y .');
                        hold on;
                end

        end
end



% use toolbox
clear;
% set data1
mu = [0;0];
sigma = [1 0; 0 1];
rng default    % For reproducibility
r = mvnrnd(mu,sigma,150);
oi = [r];
% set data2
mu = [14;0];
sigma = [1 0; 0 4];
rng default    % For reproducibility
r = mvnrnd(mu,sigma,150);
oi = [ oi ;r];
% set data3
mu = [7;14];
sigma = [4 0; 0 1];
rng default    % For reproducibility
r = mvnrnd(mu,sigma,150);
oi = [ oi ;r];
% set data4
mu = [7;7];
sigma = [1 0; 0 1];
rng default    % For reproducibility
r = mvnrnd(mu,sigma,150);
oi = [ oi ;r ];
% set ans
ans = [zeros(150,1)+1 ;zeros(150,1)+2 ;zeros(150,1)+3; zeros(150,1)+4];
% rearrange
total=600;
train_total=total*0.8;
```

```
test_total = total*0.2;
r = randperm(total);
oi(:,1) = oi(r,1);
oi(:,2) = oi(r,2);
ans = ans(r);
t=[1:total];
final_ans = zeros(600,4);
for i=1:600
        final_ans(i,ans(i)) = 1;
end
test=oi([train_total+1 :total], :);
test_ans = final_ans([train_total+1 :total],:);

net = feedforwardnet(5);
net.layers{2}.size = 4;
net.inputs{1}.size=2;
net.layers{1}.transferFcn = 'logsig';
net.layers{2}.transferFcn = 'logsig';
net.divideFcn = 'dividetrain';
net.trainFcn='traingd';
net=train(net,oi.',final_ans.');
```