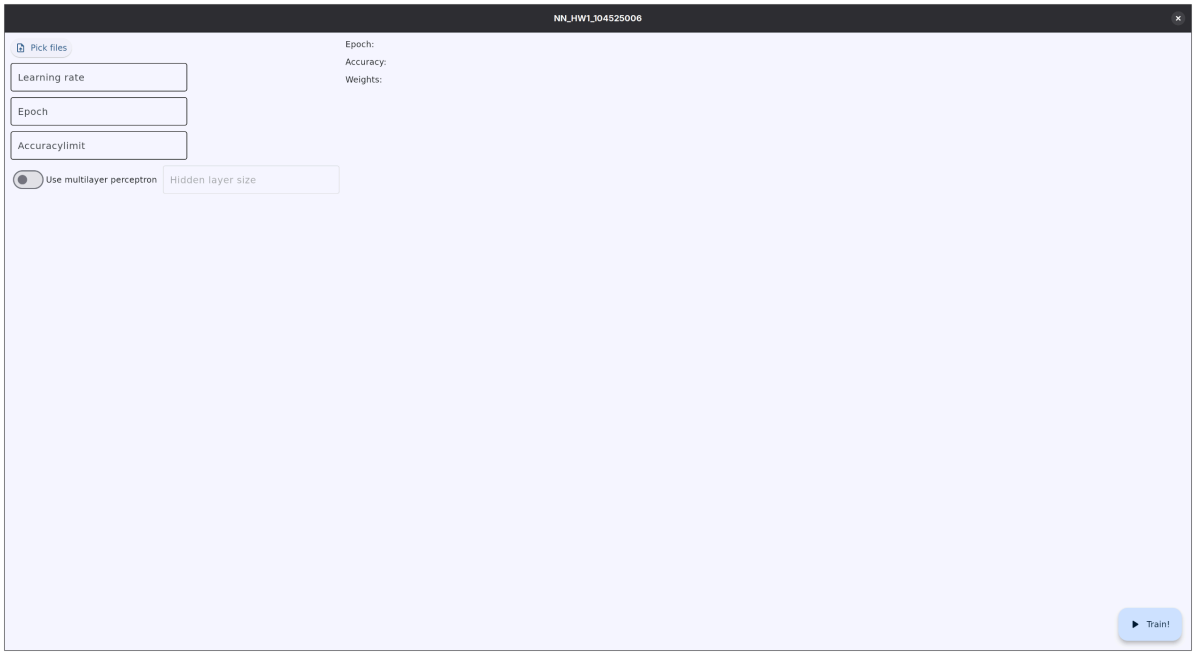
一 加分題完成功能

- [x] 三維資料圖形顯示介面
- [x] 能夠處理多維資料(四維以上)
- [ ] 數字辨識
- [ ] 可辨識兩群以上的資料

二 程式執行說明 (GUI 功能說明)



- 左側顯示可調整參數
  - 選擇 Data(選中後在右側顯示檔名)
  - 學習率
  - 執行 Epoch 數
  - 準確率限制(達到設定值後停止訓練)
  - 選擇是否使用多層感知機
    - 設定隱藏層大小
- 右側顯示訓練結果
  - 訓練的 Epoch 數
  - Test 資料的準確率
  - 鍵結值
- 右下方為訓練按鈕, 若為 2 或 3 維資料, 會將結果圖彈出顯示

三 程式碼簡介

三.1 單層感知機

```
for row in train_data:
  input = np.array([-1, *row[:-1]])
  if weight @ input < 0 and row[-1] == 1:
    weight = weight + learning_rate * input
  elif weight @ input > 0 and row[-1] == 0:
    weight = weight - learning_rate * input
```

計算網路輸出值: $y(n) = \varphi[w^T(n)x(n)]$

$\varphi(v) = \begin{cases} +1 \text{ if } v \geq 0 \\ -1 \text{ if } v < 0 \end{cases}$

調整鍵結值向量: $w(n+1) = \begin{cases} w(n) \text{ if 分類正確} \\ w(n) + \eta x(n) \text{ if } y(n) < 0 \\ w(n) - \eta x(n) \text{ if } y(n) \geq 0 \end{cases}$

三.2 多層感知機

三.2.a 前饋

```
y = [row[:-1]]
  for weight in weights:
    y.append(lib.sigmoid(weight @ [-1, *y[-1]]))
```

計算網路輸出值: $y(n) = \varphi[w^T(n)x(n)]$

$\varphi(v) = \begin{cases} +1 \text{ if } v \geq 0 \\ -1 \text{ if } v < 0 \end{cases}$

三.2.b 倒傳遞

```
def delta_final(prediction, output):
  return (output - prediction) * prediction * (1 - prediction)
```

$\delta_j = e_j(n)\varphi'\big(v_j(n)\big) = \big(d_{j(n)} - O_j(n)\big)O_{j(n)}\big(1 - O_j(n)\big)$

```
for layer in range(len(layer_size)-2, 0, -1):
  delta = [y[layer] * (1 - y[layer]) * (weights[layer].T[1:] @ delta[0]), *delta]
```

$\delta_{j(n)} = \varphi'\big(v_{j(n)}\big)\sum_k \delta_k(n)w_{kj}(n) = y_j(n)\big(1 - y_j(n)\big)\sum_k \delta_{k(n)}w_{kj}(n)$

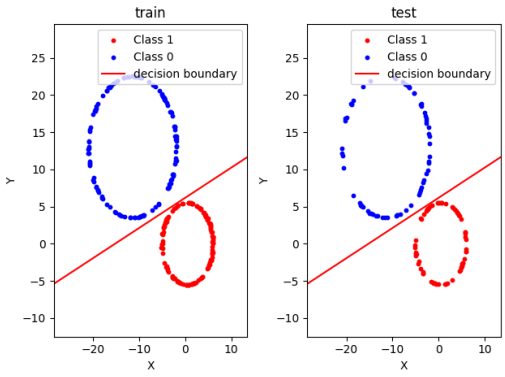
三.2.c 調整鍵結值

```
for layer in range(len(weights)):
  weights[layer] += learning_rate * np.outer(delta[layer], [-1, *y[layer]])
```

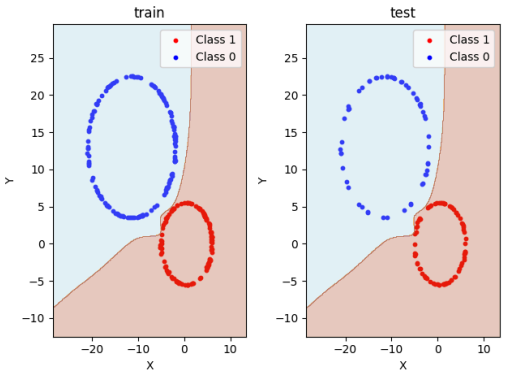
$w_{ji} = w_{ji} + \Delta w_{ji} = w_{ji} + \eta \times \delta_j(n) \times y_i(n)$

四 實驗結果

四.1 基本題



2cring



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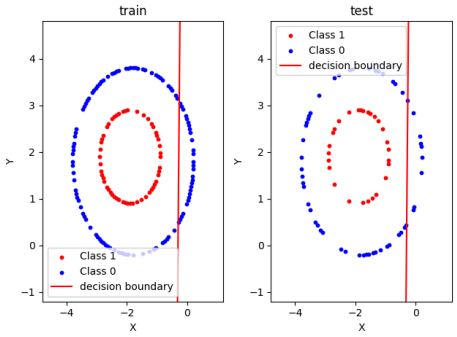

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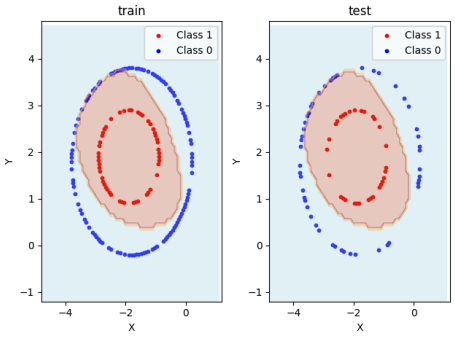

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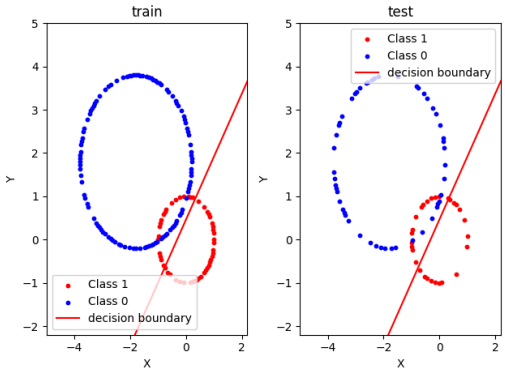

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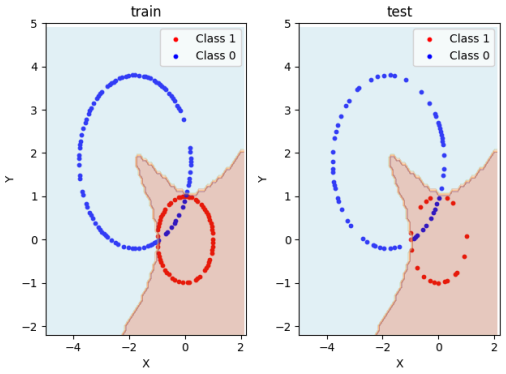

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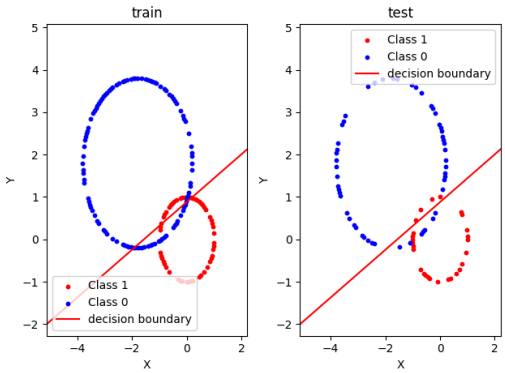

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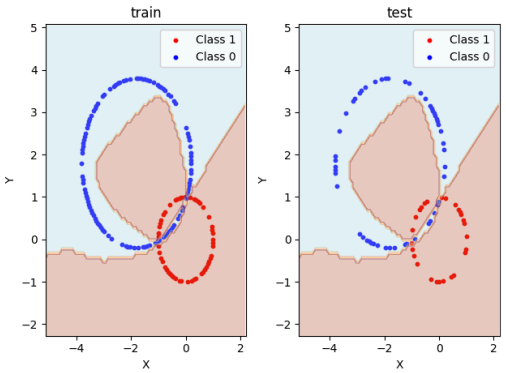

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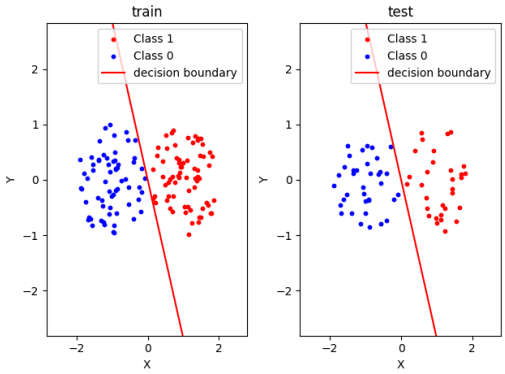

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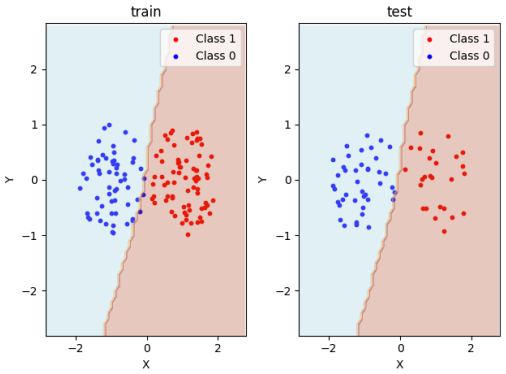

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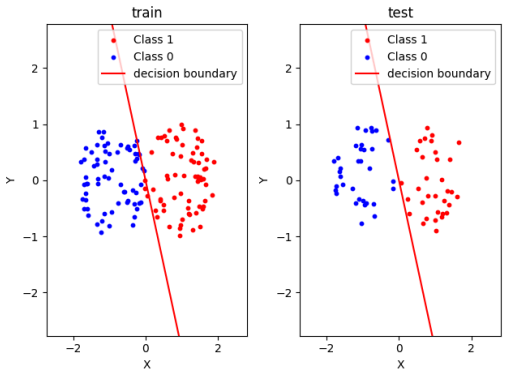

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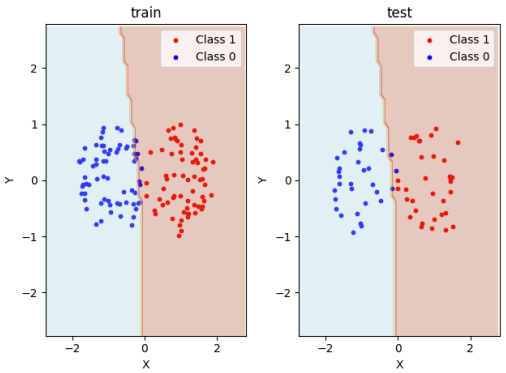

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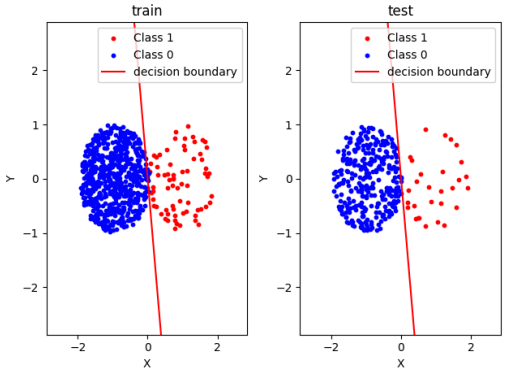

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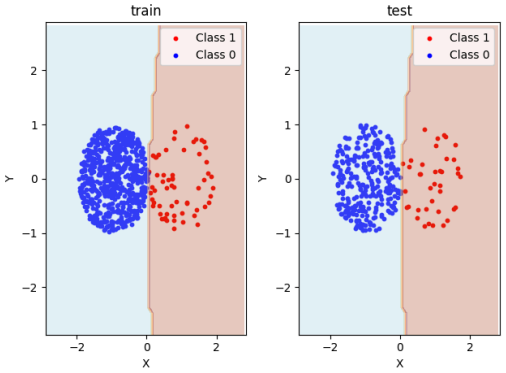

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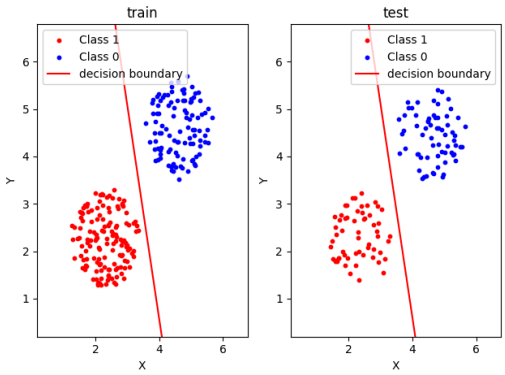

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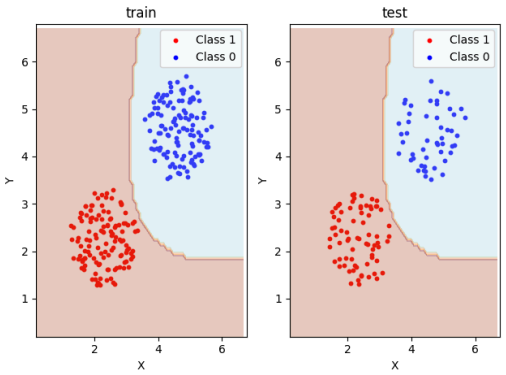

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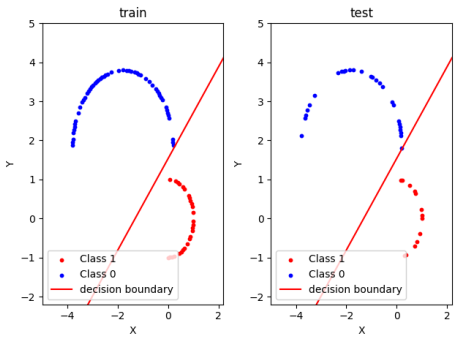

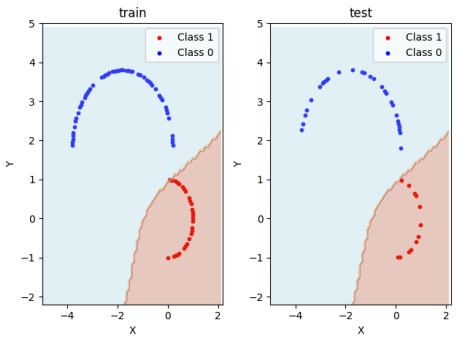

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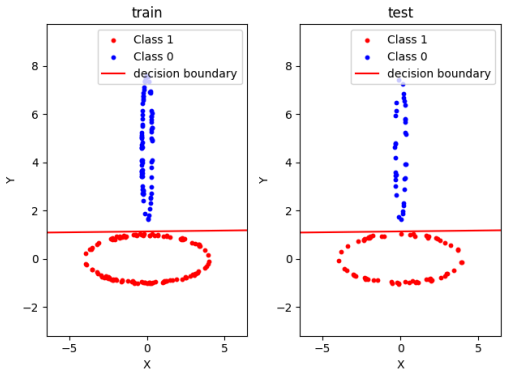

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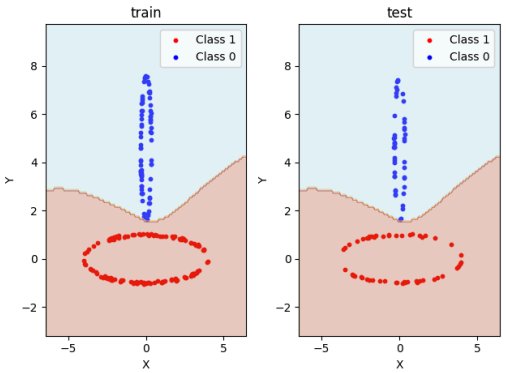
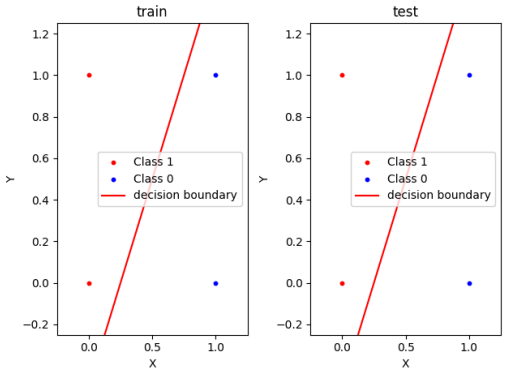
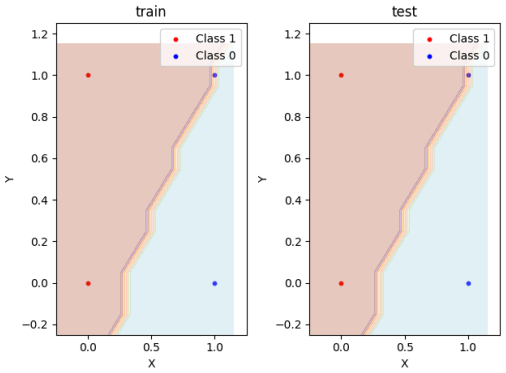


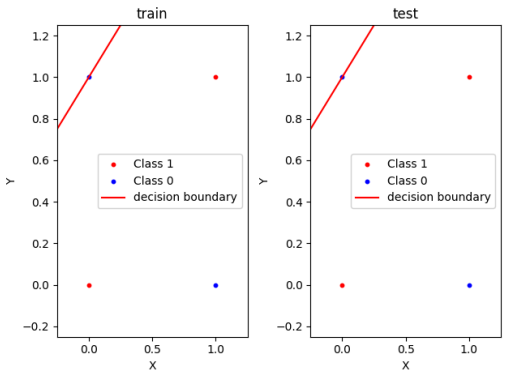
2ring



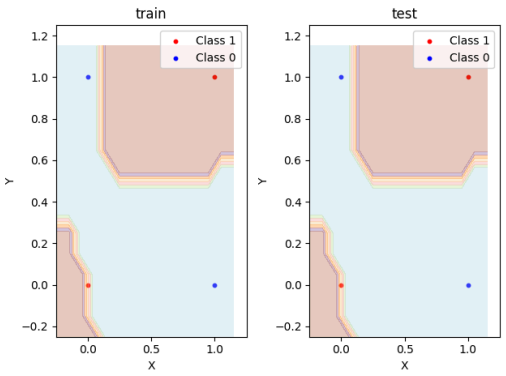
2ring (mlp)



perceptron1



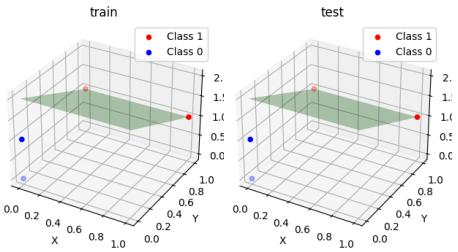
perceptron1 (mlp)



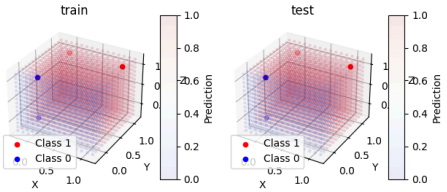
perceptron2

perceptron2 (mlp)

四.2 加分題



perceptron3



perceptron3 (mlp)

五 實驗結果分析及討論

1. 訓練次數過小容易造成未擬和, 訓練次數過大容易造成過擬和
   - 就結果而論應該選 Test 準確率最高的情況
   - 就實際考量(初始值為隨機情況下), 在 Train Data 的準確率上升變得非常緩慢時就可以考慮停止訓練
2. 多層感知機
   - 隱藏層設成 2, 3 時效果比只有一層好很多, 超過 3 層提升不明顯且時間花費巨大
   - 隱藏層越往輸出靠近每層神經元數目漸漸減少似乎有較好效果