# Computer Assignment 1

## CPE 261456
## (Introduction to Computational Intelligence)

**โดย**

**นายธนาคม หัสแดง**

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**เสนอ**

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## วิธีการทำงานของโปรแกรม

เริ่มต้นโปรแกรมจะต้องใส่ค่า input ที่กำหนด ได้แก่

- รูปแบบ neural เช่น [1,2] มี รูปแบบเป็น 2 hidden layer , ขนาด 1 และ 2 ตามลำดับ
- cross validation size เช่น [80,20] คือ train 80% , test 20 %
- dataset_number ได้แก่ 0 คือ cross.pat , 1 คือ flood data
- learning rate
- momentum rate
- activation funct
- epoch

โดยขั้นตอนการทำงานของโปรแกรมนั้น

1) เมื่อได้ค่าจากที่กำหนด โปรแกรม จะมา random weight ให้เส้นแต่ละเส้นที่เชื่อมต่อระหว่าง hidden node ซึ่งค่าอยู่ระหว่าง
2) เข้ากระบวนการ train โดยเริ่มทำ feedforward network ก่อนโดยแต่ละ layer ได้จากการ dot product ระหว่าง matrix output ของ layer ก่อนหน้า กับ matrix weight ทุก เส้นที่เข้า layer นั้น
3) เมื่อทำ feedforward จนครบแล้ว ทำ back propagation โดยเริ่มจาก หา error โดยนำค่าที่ควรจะเป็น ลบ ค่าที่ได้จาก output node

$$e_j(t) = d_j(t) - y_j(t)$$

4) นำ error ที่ได้ไปหา gradient จากสูตร

$$\delta_j(t) = e_j(t)\varphi_j'(v_j(t))$$

5) จากนั้นนำ gradient ไปหา gradient ใน node ก่อนหน้า เรื่อยๆ โดยใช้สูตรนี้

$$\delta_j^{(l)}(t) = \varphi_j^{(l)'}\left(v_j^{(l)}(t)\right)\sum_k \delta_k^{(l+1)}(t)w_{kj}^{(l+1)}(t)$$

6) นำ gradient ที่ได้จาก สูตรข้อที่แล้ว ไปคำนวณเพื่อปรับ weight จากสูตรนี้

$$\Delta w_{ji}^{(l)}(t) = \alpha\Delta w_{ji}^{(l)}(t-1) + \eta\delta_j^{(l)}(t)y_i^{(l-1)}(t)$$

7) จะได้ weight ใหม่ ละนำ weight ใหม่นี้ ไปวนทำซ้ำจนกว่าจะครบรอบจำนวนการ train

โดยในการทดลองจะแบ่งรูปแบบการทดลองออกเป็น 4 แบบ คือ

- ทดลองเปลี่ยนแปลงรูปแบบ และ ขนาดของ Hidden nodes
  อยู่ในช่วง 1 hidden layer , 1 - 14 hidden node
  2 hidden layer , 1 - 14 hidden node
- ทดลองเปลี่ยนแปลงค่า learning rate
  อยู่ในช่วง [0,1]
- ทดลองเปลี่ยนแปลงค่า momentum rate
  อยู่ในช่วง [0,1]
- ทดลองเปลี่ยนแปลงจำนวนรอบการtrain (#epoch)
  จำนวน = [100,250,500,1000,2000,5000,10000]

## ผลการทดลอง และ วิเคราะห์ผลการทดลอง

<u>การทดลองการ Predict ระดับน้ำที่สะพานนวรัตน์ ในอีก 7 ชั่วโมงข้างหน้า</u>

**การทดลองที่ 1** : เปลี่ยนแปลงรูปแบบ และ ขนาดของ Hidden nodes
ได้ผลออกมาดังนี้

- แบบที่มี 1 Hidden layer โดยมีจำนวน hidden node ในช่วง [1,14]

| Neural | | | learning rate | momentum rate | #epoch | avg error | min error |
|---|---|---|---|---|---|---|---|
| 8 | 1 | 1 | 0.12 | 0.07 | 1000 | 7164.8043 | 5082.60379 |
| 8 | 2 | 1 | 0.12 | 0.07 | 1000 | 1652.6775 | 965.8234 |
| 8 | 3 | 1 | 0.12 | 0.07 | 1000 | 2031.4607 | 1415.775045 |
| 8 | 4 | 1 | 0.12 | 0.07 | 1000 | 1865.2652 | 977.076397 |
| 8 | 5 | 1 | 0.12 | 0.07 | 1000 | 1985.9267 | 889.900016 |
| 8 | 6 | 1 | 0.12 | 0.07 | 1000 | 2013.6769 | 1023.431926 |
| 8 | 7 | 1 | 0.12 | 0.07 | 1000 | 1725.3579 | 841.863129 |
| 8 | 8 | 1 | 0.12 | 0.07 | 1000 | 1646.1176 | 765.831823 |
| 8 | 9 | 1 | 0.12 | 0.07 | 1000 | 1483.529 | 622.305481 |
| 8 | 10 | 1 | 0.12 | 0.07 | 1000 | 1518.4148 | 1100.5419 |
| 8 | 11 | 1 | 0.12 | 0.07 | 1000 | 1599.0754 | 866.237965 |
| 8 | 12 | 1 | 0.12 | 0.07 | 1000 | 1577.579 | 954.451523 |
| 8 | 13 | 1 | 0.12 | 0.07 | 1000 | 1587.2177 | 889.086242 |
| 8 | 14 | 1 | 0.12 | 0.07 | 1000 | 1761.6648 | 835.167171 |

- แบบที่มี 2 Hidden layers โดยมีจำนวน hidden node ในช่วง [1,14]

| Nueral | | | | learning rate | momentum rate | #epoch | avg error | min error |
|---|---|---|---|---|---|---|---|---|
| 8 | 1 | 1 | 1 | 0.12 | 0.07 | 1000 | 5516.4951 | 748.26251 |
| 8 | 1 | 2 | 1 | 0.12 | 0.07 | 1000 | 3708.5619 | 1371.029158 |
| 8 | 1 | 3 | 1 | 0.12 | 0.07 | 1000 | 3155.9771 | 760.803352 |
| 8 | 1 | 4 | 1 | 0.12 | 0.07 | 1000 | 2656.2176 | 1536.920681 |
| 8 | 1 | 5 | 1 | 0.12 | 0.07 | 1000 | 2392.8342 | 777.855455 |
| 8 | 1 | 6 | 1 | 0.12 | 0.07 | 1000 | 3366.0247 | 1561.07911 |
| 8 | 1 | 7 | 1 | 0.12 | 0.07 | 1000 | 2518.1337 | 1404.836716 |

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|---|---|---|---|---|---|---|---|---|
| 8 | 1 | 8 | 1 | 0.12 | 0.07 | 1000 | 2737.1659 | 1340.636519 |
| 8 | 1 | 9 | 1 | 0.12 | 0.07 | 1000 | 3338.8515 | 2171.40841 |
| 8 | 1 | 10 | 1 | 0.12 | 0.07 | 1000 | 3536.498 | 2387.668942 |
| 8 | 1 | 11 | 1 | 0.12 | 0.07 | 1000 | 3648.6302 | 1619.456906 |
| 8 | 1 | 12 | 1 | 0.12 | 0.07 | 1000 | 3185.9712 | 2006.314481 |
| 8 | 1 | 13 | 1 | 0.12 | 0.07 | 1000 | 3281.3899 | 833.441194 |
| 8 | 1 | 14 | 1 | 0.12 | 0.07 | 1000 | 3154.9063 | 1701.194597 |
| 8 | 2 | 1 | 1 | 0.12 | 0.07 | 1000 | 1956.6006 | 331.905532 |
| 8 | 2 | 2 | 1 | 0.12 | 0.07 | 1000 | 1057.3282 | 540.626287 |
| 8 | 2 | 3 | 1 | 0.12 | 0.07 | 1000 | 1577.91 | 581.259077 |
| 8 | 2 | 4 | 1 | 0.12 | 0.07 | 1000 | 1415.5879 | 607.984881 |
| 8 | 2 | 5 | 1 | 0.12 | 0.07 | 1000 | 2065.6567 | 939.260526 |
| 8 | 2 | 6 | 1 | 0.12 | 0.07 | 1000 | 1409.9576 | 791.087206 |
| 8 | 2 | 7 | 1 | 0.12 | 0.07 | 1000 | 1696.3733 | 916.727339 |
| 8 | 2 | 8 | 1 | 0.12 | 0.07 | 1000 | 1575.5773 | 698.286952 |
| 8 | 2 | 9 | 1 | 0.12 | 0.07 | 1000 | 1739.8666 | 862.713732 |
| 8 | 2 | 10 | 1 | 0.12 | 0.07 | 1000 | 1895.4892 | 1175.725987 |
| 8 | 2 | 11 | 1 | 0.12 | 0.07 | 1000 | 1808.4549 | 865.057561 |
| 8 | 2 | 12 | 1 | 0.12 | 0.07 | 1000 | 2193.6483 | 1156.382942 |
| 8 | 2 | 13 | 1 | 0.12 | 0.07 | 1000 | 1936.9181 | 1296.594458 |
| 8 | 2 | 14 | 1 | 0.12 | 0.07 | 1000 | 2723.2142 | 1267.92419 |
| 8 | 3 | 1 | 1 | 0.12 | 0.07 | 1000 | 949.3388 | 454.842003 |
| 8 | 3 | 2 | 1 | 0.12 | 0.07 | 1000 | 1320.1741 | 296.109474 |
| 8 | 3 | 3 | 1 | 0.12 | 0.07 | 1000 | 669.1097 | 242.489452 |
| 8 | 3 | 4 | 1 | 0.12 | 0.07 | 1000 | 743.9345 | 325.883742 |
| 8 | 3 | 5 | 1 | 0.12 | 0.07 | 1000 | 699.9933 | 421.561319 |
| 8 | 3 | 6 | 1 | 0.12 | 0.07 | 1000 | 1020.9736 | 596.238355 |
| 8 | 3 | 7 | 1 | 0.12 | 0.07 | 1000 | 851.5826 | 442.342435 |
| 8 | 3 | 8 | 1 | 0.12 | 0.07 | 1000 | 1797.1074 | 486.748268 |
| 8 | 3 | 9 | 1 | 0.12 | 0.07 | 1000 | 1272.6671 | 601.910687 |
| 8 | 3 | 10 | 1 | 0.12 | 0.07 | 1000 | 1136.7645 | 632.909929 |
| 8 | 3 | 11 | 1 | 0.12 | 0.07 | 1000 | 1276.3388 | 365.760042 |

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|---|---|---|---|---|---|---|---|---|
| 8 | 3 | 12 | 1 | 0.12 | 0.07 | 1000 | 926.9166 | 456.225739 |
| 8 | 3 | 13 | 1 | 0.12 | 0.07 | 1000 | 946.3836 | 603.125697 |
| 8 | 3 | 14 | 1 | 0.12 | 0.07 | 1000 | 1248.2746 | 515.2925 |
| 8 | 4 | 1 | 1 | 0.12 | 0.07 | 1000 | 1022.4401 | 597.503242 |
| 8 | 4 | 2 | 1 | 0.12 | 0.07 | 1000 | 573.2888 | 369.085345 |
| 8 | 4 | 3 | 1 | 0.12 | 0.07 | 1000 | 623.9521 | 334.753068 |
| 8 | 4 | 4 | 1 | 0.12 | 0.07 | 1000 | 550.9211 | 225.177503 |
| 8 | 4 | 5 | 1 | 0.12 | 0.07 | 1000 | 537.8885 | 370.719016 |
| 8 | 4 | 6 | 1 | 0.12 | 0.07 | 1000 | 851.0001 | 312.437955 |
| 8 | 4 | 7 | 1 | 0.12 | 0.07 | 1000 | 638.4713 | 354.573619 |
| 8 | 4 | 8 | 1 | 0.12 | 0.07 | 1000 | 604.0285 | 371.550281 |
| 8 | 4 | 9 | 1 | 0.12 | 0.07 | 1000 | 772.8395 | 376.826929 |
| 8 | 4 | 10 | 1 | 0.12 | 0.07 | 1000 | 523.0501 | 285.709897 |
| 8 | 4 | 11 | 1 | 0.12 | 0.07 | 1000 | 984.5883 | 404.361523 |
| 8 | 4 | 12 | 1 | 0.12 | 0.07 | 1000 | 782.9617 | 349.3292 |
| 8 | 4 | 13 | 1 | 0.12 | 0.07 | 1000 | 637.3624 | 351.443639 |
| 8 | 4 | 14 | 1 | 0.12 | 0.07 | 1000 | 767.2578 | 395.014632 |
| 8 | 5 | 1 | 1 | 0.12 | 0.07 | 1000 | 941.1699 | 198.699342 |
| 8 | 5 | 2 | 1 | 0.12 | 0.07 | 1000 | 542.1616 | 263.149648 |
| 8 | 5 | 3 | 1 | 0.12 | 0.07 | 1000 | 480.2532 | 136.25831 |
| 8 | 5 | 4 | 1 | 0.12 | 0.07 | 1000 | 466.0922 | 335.295223 |
| 8 | 5 | 5 | 1 | 0.12 | 0.07 | 1000 | 460.4622 | 369.243123 |
| 8 | 5 | 6 | 1 | 0.12 | 0.07 | 1000 | 484.1003 | 227.930761 |
| 8 | 5 | 7 | 1 | 0.12 | 0.07 | 1000 | 477.6297 | 284.867377 |
| 8 | 5 | 8 | 1 | 0.12 | 0.07 | 1000 | 522.7573 | 225.844468 |
| 8 | 5 | 9 | 1 | 0.12 | 0.07 | 1000 | 515.4249 | 266.265294 |
| 8 | 5 | 10 | 1 | 0.12 | 0.07 | 1000 | 596.2404 | 206.125958 |
| 8 | 5 | 11 | 1 | 0.12 | 0.07 | 1000 | 579.3274 | 233.703677 |
| 8 | 5 | 12 | 1 | 0.12 | 0.07 | 1000 | 656.604 | 312.020045 |
| 8 | 5 | 13 | 1 | 0.12 | 0.07 | 1000 | 910.7839 | 504.722261 |
| 8 | 5 | 14 | 1 | 0.12 | 0.07 | 1000 | 892.0943 | 370.88109 |
| 8 | 6 | 1 | 1 | 0.12 | 0.07 | 1000 | 952.7672 | 542.319465 |

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|---|---|---|---|---|---|---|---|---|
| 8 | 6 | 2 | 1 | 0.12 | 0.07 | 1000 | 451.268 | 305.261035 |
| 8 | 6 | 3 | 1 | 0.12 | 0.07 | 1000 | 361.4295 | 132.773965 |
| 8 | 6 | 4 | 1 | 0.12 | 0.07 | 1000 | 385.9407 | 210.490761 |
| 8 | 6 | 5 | 1 | 0.12 | 0.07 | 1000 | 398.1112 | 222.010584 |
| 8 | 6 | 6 | 1 | 0.12 | 0.07 | 1000 | 434.5291 | 261.772616 |
| 8 | 6 | 7 | 1 | 0.12 | 0.07 | 1000 | 403.0513 | 289.483129 |
| 8 | 6 | 8 | 1 | 0.12 | 0.07 | 1000 | 403.8919 | 177.755813 |
| 8 | 6 | 9 | 1 | 0.12 | 0.07 | 1000 | 440.3116 | 173.238439 |
| 8 | 6 | 10 | 1 | 0.12 | 0.07 | 1000 | 504.8552 | 276.593935 |
| 8 | 6 | 11 | 1 | 0.12 | 0.07 | 1000 | 532.5468 | 224.445671 |
| 8 | 6 | 12 | 1 | 0.12 | 0.07 | 1000 | 514.2662 | 255.085139 |
| 8 | 6 | 13 | 1 | 0.12 | 0.07 | 1000 | 4787.1547 | 233.959539 |
| 8 | 6 | 14 | 1 | 0.12 | 0.07 | 1000 | 11581.2328 | 284.833652 |
| 8 | 7 | 1 | 1 | 0.12 | 0.07 | 1000 | 898.3208 | 285.527342 |
| 8 | 7 | 2 | 1 | 0.12 | 0.07 | 1000 | 532.7709 | 227.344726 |
| 8 | 7 | 3 | 1 | 0.12 | 0.07 | 1000 | 397.3186 | 186.002771 |
| 8 | 7 | 4 | 1 | 0.12 | 0.07 | 1000 | 371.4991 | 200.507455 |
| 8 | 7 | 5 | 1 | 0.12 | 0.07 | 1000 | 400.0784 | 162.9456 |
| 8 | 7 | 6 | 1 | 0.12 | 0.07 | 1000 | 419.6482 | 265.717826 |
| 8 | 7 | 7 | 1 | 0.12 | 0.07 | 1000 | 399.1256 | 165.408535 |
| 8 | 7 | 8 | 1 | 0.12 | 0.07 | 1000 | 407.3365 | 186.449494 |
| 8 | 7 | 9 | 1 | 0.12 | 0.07 | 1000 | 422.2662 | 210.755374 |
| 8 | 7 | 10 | 1 | 0.12 | 0.07 | 1000 | 437.5094 | 131.230994 |
| 8 | 7 | 11 | 1 | 0.12 | 0.07 | 1000 | 417.6192 | 242.783768 |
| 8 | 7 | 12 | 1 | 0.12 | 0.07 | 1000 | 480.1298 | 376.269761 |
| 8 | 7 | 13 | 1 | 0.12 | 0.07 | 1000 | 428.1383 | 264.672303 |
| 8 | 7 | 14 | 1 | 0.12 | 0.07 | 1000 | 4450.0058 | 144.307148 |
| 8 | 8 | 1 | 1 | 0.12 | 0.07 | 1000 | 883.7643 | 389.243245 |
| 8 | 8 | 2 | 1 | 0.12 | 0.07 | 1000 | 472.9024 | 241.776887 |
| 8 | 8 | 3 | 1 | 0.12 | 0.07 | 1000 | 332.7103 | 208.521477 |
| 8 | 8 | 4 | 1 | 0.12 | 0.07 | 1000 | 373.4889 | 229.478855 |
| 8 | 8 | 5 | 1 | 0.12 | 0.07 | 1000 | 368.8708 | 103.714887 |

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| 8 | 8 | 6 | 1 | 0.12 | 0.07 | 1000 | 334.489 | 184.165355 |
| 8 | 8 | 7 | 1 | 0.12 | 0.07 | 1000 | 383.8156 | 162.078713 |
| 8 | 8 | 8 | 1 | 0.12 | 0.07 | 1000 | 364.8624 | 122.606268 |
| 8 | 8 | 9 | 1 | 0.12 | 0.07 | 1000 | 408.4629 | 209.942503 |
| 8 | 8 | 10 | 1 | 0.12 | 0.07 | 1000 | 350.2632 | 177.752726 |
| 8 | 8 | 11 | 1 | 0.12 | 0.07 | 1000 | 376.6573 | 156.222026 |
| 8 | 8 | 12 | 1 | 0.12 | 0.07 | 1000 | 513.0171 | 314.8894 |
| 8 | 8 | 13 | 1 | 0.12 | 0.07 | 1000 | 408.6436 | 223.020781 |
| 8 | 8 | 14 | 1 | 0.12 | 0.07 | 1000 | 4204.1879 | 277.875471 |
| 8 | 9 | 1 | 1 | 0.12 | 0.07 | 1000 | 907.5957 | 236.885419 |
| 8 | 9 | 2 | 1 | 0.12 | 0.07 | 1000 | 426.9488 | 171.5012 |
| 8 | 9 | 3 | 1 | 0.12 | 0.07 | 1000 | 327.1263 | 233.751323 |
| 8 | 9 | 4 | 1 | 0.12 | 0.07 | 1000 | 353.1213 | 152.509071 |
| 8 | 9 | 5 | 1 | 0.12 | 0.07 | 1000 | 350.8856 | 218.317826 |
| 8 | 9 | 6 | 1 | 0.12 | 0.07 | 1000 | 334.416 | 229.561426 |
| 8 | 9 | 7 | 1 | 0.12 | 0.07 | 1000 | 358.197 | 152.488223 |
| 8 | 9 | 8 | 1 | 0.12 | 0.07 | 1000 | 345.9645 | 196.114594 |
| 8 | 9 | 9 | 1 | 0.12 | 0.07 | 1000 | 372.5477 | 146.300465 |
| 8 | 9 | 10 | 1 | 0.12 | 0.07 | 1000 | 395.4041 | 252.889239 |
| 8 | 9 | 11 | 1 | 0.12 | 0.07 | 1000 | 4541.4758 | 207.7888 |
| 8 | 9 | 12 | 1 | 0.12 | 0.07 | 1000 | 404.5233 | 174.356077 |
| 8 | 9 | 13 | 1 | 0.12 | 0.07 | 1000 | 428.3002 | 229.433513 |
| 8 | 9 | 14 | 1 | 0.12 | 0.07 | 1000 | 4121.8224 | 258.448813 |
| 8 | 10 | 1 | 1 | 0.12 | 0.07 | 1000 | 941.9389 | 645.694103 |
| 8 | 10 | 2 | 1 | 0.12 | 0.07 | 1000 | 387.6876 | 152.747939 |
| 8 | 10 | 3 | 1 | 0.12 | 0.07 | 1000 | 369.5347 | 168.442006 |
| 8 | 10 | 4 | 1 | 0.12 | 0.07 | 1000 | 356.4045 | 205.522084 |
| 8 | 10 | 5 | 1 | 0.12 | 0.07 | 1000 | 333.8694 | 225.60259 |
| 8 | 10 | 6 | 1 | 0.12 | 0.07 | 1000 | 311.8568 | 165.207439 |
| 8 | 10 | 7 | 1 | 0.12 | 0.07 | 1000 | 323.2105 | 140.949806 |
| 8 | 10 | 8 | 1 | 0.12 | 0.07 | 1000 | 317.1925 | 153.371177 |
| 8 | 10 | 9 | 1 | 0.12 | 0.07 | 1000 | 338.6478 | 121.17429 |

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|---|---|---|---|---|---|---|---|---|
| 8 | 10 | 10 | 1 | 0.12 | 0.07 | 1000 | 337.3392 | 116.443739 |
| 8 | 10 | 11 | 1 | 0.12 | 0.07 | 1000 | 362.556 | 255.226723 |
| 8 | 10 | 12 | 1 | 0.12 | 0.07 | 1000 | 366.6477 | 187.311884 |
| 8 | 10 | 13 | 1 | 0.12 | 0.07 | 1000 | 347.4094 | 215.173768 |
| 8 | 10 | 14 | 1 | 0.12 | 0.07 | 1000 | 8696.3028 | 168.605032 |
| 8 | 11 | 1 | 1 | 0.12 | 0.07 | 1000 | 933.0619 | 181.623894 |
| 8 | 11 | 2 | 1 | 0.12 | 0.07 | 1000 | 382.6432 | 246.668103 |
| 8 | 11 | 3 | 1 | 0.12 | 0.07 | 1000 | 358.6149 | 174.407552 |
| 8 | 11 | 4 | 1 | 0.12 | 0.07 | 1000 | 324.4401 | 95.371916 |
| 8 | 11 | 5 | 1 | 0.12 | 0.07 | 1000 | 326.1993 | 94.074548 |
| 8 | 11 | 6 | 1 | 0.12 | 0.07 | 1000 | 327.7679 | 160.472474 |
| 8 | 11 | 7 | 1 | 0.12 | 0.07 | 1000 | 371.013 | 189.201642 |
| 8 | 11 | 8 | 1 | 0.12 | 0.07 | 1000 | 353.2321 | 267.749526 |
| 8 | 11 | 9 | 1 | 0.12 | 0.07 | 1000 | 376.318 | 155.396239 |
| 8 | 11 | 10 | 1 | 0.12 | 0.07 | 1000 | 372.3794 | 160.112087 |
| 8 | 11 | 11 | 1 | 0.12 | 0.07 | 1000 | 368.3131 | 226.77429 |
| 8 | 11 | 12 | 1 | 0.12 | 0.07 | 1000 | 411.2677 | 150.274029 |
| 8 | 11 | 13 | 1 | 0.12 | 0.07 | 1000 | 397.9464 | 183.059129 |
| 8 | 11 | 14 | 1 | 0.12 | 0.07 | 1000 | 5235.7427 | 217.919374 |
| 8 | 12 | 1 | 1 | 0.12 | 0.07 | 1000 | 956.513 | 472.758384 |
| 8 | 12 | 2 | 1 | 0.12 | 0.07 | 1000 | 603.9178 | 209.935858 |
| 8 | 12 | 3 | 1 | 0.12 | 0.07 | 1000 | 339.8969 | 112.78801 |
| 8 | 12 | 4 | 1 | 0.12 | 0.07 | 1000 | 321.0256 | 137.159681 |
| 8 | 12 | 5 | 1 | 0.12 | 0.07 | 1000 | 308.1273 | 147.687632 |
| 8 | 12 | 6 | 1 | 0.12 | 0.07 | 1000 | 341.6304 | 188.887484 |
| 8 | 12 | 7 | 1 | 0.12 | 0.07 | 1000 | 338.2958 | 171.697994 |
| 8 | 12 | 8 | 1 | 0.12 | 0.07 | 1000 | 360.2356 | 216.590365 |
| 8 | 12 | 9 | 1 | 0.12 | 0.07 | 1000 | 345.4566 | 122.253881 |
| 8 | 12 | 10 | 1 | 0.12 | 0.07 | 1000 | 405.1147 | 217.996806 |
| 8 | 12 | 11 | 1 | 0.12 | 0.07 | 1000 | 369.2777 | 202.677455 |
| 8 | 12 | 12 | 1 | 0.12 | 0.07 | 1000 | 5043.9227 | 147.837352 |
| 8 | 12 | 13 | 1 | 0.12 | 0.07 | 1000 | 433.9423 | 220.212065 |

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|---|---|---|---|---|---|---|---|---|
| 8 | 12 | 14 | 1 | 0.12 | 0.07 | 1000 | 7197.3368 | 149.982832 |
| 8 | 13 | 1 | 1 | 0.12 | 0.07 | 1000 | 914.6108 | 437.932335 |
| 8 | 13 | 2 | 1 | 0.12 | 0.07 | 1000 | 395.89 | 136.190629 |
| 8 | 13 | 3 | 1 | 0.12 | 0.07 | 1000 | 320.6174 | 160.338584 |
| 8 | 13 | 4 | 1 | 0.12 | 0.07 | 1000 | 336.2324 | 150.919642 |
| 8 | 13 | 5 | 1 | 0.12 | 0.07 | 1000 | 305.9969 | 119.335687 |
| 8 | 13 | 6 | 1 | 0.12 | 0.07 | 1000 | 328.9036 | 132.212545 |
| 8 | 13 | 7 | 1 | 0.12 | 0.07 | 1000 | 338.9665 | 148.343881 |
| 8 | 13 | 8 | 1 | 0.12 | 0.07 | 1000 | 343.2261 | 115.439161 |
| 8 | 13 | 9 | 1 | 0.12 | 0.07 | 1000 | 342.5435 | 122.023684 |
| 8 | 13 | 10 | 1 | 0.12 | 0.07 | 1000 | 378.361 | 204.997571 |
| 8 | 13 | 11 | 1 | 0.12 | 0.07 | 1000 | 360.0913 | 205.463119 |
| 8 | 13 | 12 | 1 | 0.12 | 0.07 | 1000 | 3967.7374 | 144.681361 |
| 8 | 13 | 13 | 1 | 0.12 | 0.07 | 1000 | 4314.594 | 208.730119 |
| 8 | 13 | 14 | 1 | 0.12 | 0.07 | 1000 | 340.3364 | 198.808458 |
| 8 | 14 | 1 | 1 | 0.12 | 0.07 | 1000 | 928.4872 | 463.328235 |
| 8 | 14 | 2 | 1 | 0.12 | 0.07 | 1000 | 363.5879 | 210.564494 |
| 8 | 14 | 3 | 1 | 0.12 | 0.07 | 1000 | 338.729 | 158.965135 |
| 8 | 14 | 4 | 1 | 0.12 | 0.07 | 1000 | 344.9195 | 190.446419 |
| 8 | 14 | 5 | 1 | 0.12 | 0.07 | 1000 | 317.8834 | 135.407745 |
| 8 | 14 | 6 | 1 | 0.12 | 0.07 | 1000 | 388.7381 | 152.854126 |
| 8 | 14 | 7 | 1 | 0.12 | 0.07 | 1000 | 304.3679 | 139.9853 |
| 8 | 14 | 8 | 1 | 0.12 | 0.07 | 1000 | 354.4205 | 188.808513 |
| 8 | 14 | 9 | 1 | 0.12 | 0.07 | 1000 | 340.786 | 205.925 |
| 8 | 14 | 10 | 1 | 0.12 | 0.07 | 1000 | 359.6813 | 235.904797 |
| 8 | 14 | 11 | 1 | 0.12 | 0.07 | 1000 | 342.0143 | 104.739203 |
| 8 | 14 | 12 | 1 | 0.12 | 0.07 | 1000 | 363.639 | 137.280545 |
| 8 | 14 | 13 | 1 | 0.12 | 0.07 | 1000 | 4275.7731 | 236.76819 |
| 8 | 14 | 14 | 1 | 0.12 | 0.07 | 1000 | 4075.1118 | 122.936671 |

* ข้อมูลในตารางเป็นข้อมูลที่ผ่านการ cross validation ทั้งหมดแล้ว แต่นำมาเพียงค่าเฉลี่ย และ ค่าน้อยสุดเท่านั้น

- แบบที่ 3 : นำรูปแบบ (Neural) ที่ได้ sum average error น้อยที่สุด [8-10-6-1] มาแสดง cross validation

```
------------------------------- Variable --------------------------------

Datafile : Flood data set
Neural name : 8-10-6-1
Learning rate : 0.12
Momentum rate : 0.07
Activaion Function : sigmoid
Cross validation : [90 : 10]
#Epoch : 1000
```

```
------------------------------- Round : 0 --------------------------------
Desired Output          |       Predict                 |       Error
--------------------------------------------------------------------------
405                     |       370.77320091            |       34.23
208                     |       225.92039829            |       -17.92
377                     |       354.87588910            |       22.12
290                     |       284.39025817            |       5.61
156                     |       161.57561649            |       -5.58
297                     |       276.07609583            |       20.92
404                     |       383.88675319            |       20.11
486                     |       476.48785124            |       9.51
213                     |       226.36173719            |       -13.36
315                     |       307.83524630            |       7.16
489                     |       476.16481451            |       12.84
323                     |       307.75773914            |       15.24
410                     |       389.51897714            |       20.48
410                     |       359.33131820            |       50.67
472                     |       478.17342950            |       -6.17
308                     |       296.25959142            |       11.74
255                     |       243.66167612            |       11.34
286                     |       271.56372012            |       14.44
331                     |       332.05725203            |       -1.06
397                     |       384.19954496            |       12.8
153                     |       159.66848790            |       -6.67
447                     |       435.64802127            |       11.35
467                     |       455.50291710            |       11.5
340                     |       259.72064613            |       80.28
462                     |       451.26188606            |       10.74
153                     |       160.21327249            |       -7.21
251                     |       261.08606972            |       -10.09
262                     |       263.64635918            |       -1.65
471                     |       460.25641010            |       10.74
454                     |       430.90011982            |       23.1
237                     |       189.52913617            |       47.47
--------------------------------------------------------------------------
                Mean Square Error = 554.632529
==========================================================================
```

```
-------------------------------- Round : 1 --------------------------------
Desired Output          |       Predict                 |       Error
---------------------------------------------------------------------------
215                     |       228.98409188            |       -13.98
450                     |       446.11696959            |       3.88
471                     |       471.90381168            |       -0.9
296                     |       311.49531402            |       -15.5
471                     |       471.37209202            |       -0.37
488                     |       481.66848519            |       6.33
333                     |       349.58084233            |       -16.58
245                     |       251.07747021            |       -6.08
478                     |       483.98731045            |       -5.99
339                     |       359.19262037            |       -20.19
294                     |       323.40437618            |       -29.4
328                     |       357.20813008            |       -29.21
160                     |       172.42720033            |       -12.43
448                     |       457.01687486            |       -9.02
315                     |       334.94992034            |       -19.95
444                     |       451.84862072            |       -7.85
218                     |       224.45434965            |       -6.45
325                     |       354.10878800            |       -29.11
154                     |       171.57136357            |       -17.57
234                     |       238.67517069            |       -4.68
153                     |       171.40442765            |       -18.4
450                     |       457.59452855            |       -7.59
232                     |       237.08346048            |       -5.08
351                     |       371.60974961            |       -20.61
215                     |       228.51354484            |       -13.51
436                     |       445.46973834            |       -9.47
490                     |       482.69673255            |       7.3
325                     |       366.80425759            |       -41.8
455                     |       460.18813801            |       -5.19
390                     |       408.45891537            |       -18.46
217                     |       225.42741211            |       -8.43
---------------------------------------------------------------------------
                Mean Square Error = 265.744068
===========================================================================
```

```
-------------------------------- Round : 2 --------------------------------
Desired Output          |       Predict                 |       Error
--------------------------------------------------------------------------------
211                     |       226.14259472            |       -15.14
420                     |       391.98462884            |       28.02
168                     |       165.26558125            |       2.73
424                     |       395.82616749            |       28.17
253                     |       262.17024301            |       -9.17
259                     |       210.38167494            |       48.62
490                     |       478.95571533            |       11.04
361                     |       348.12869709            |       12.87
238                     |       240.77170501            |       -2.77
468                     |       458.92566109            |       9.07
433                     |       406.58786966            |       26.41
302                     |       290.34255934            |       11.66
328                     |       338.60322832            |       -10.6
245                     |       237.22900762            |       7.77
382                     |       368.88801453            |       13.11
259                     |       264.73058743            |       -5.73
294                     |       280.35255991            |       13.65
290                     |       284.31128929            |       5.69
153                     |       161.32162645            |       -8.32
417                     |       380.85579797            |       36.14
209                     |       223.46103010            |       -14.46
215                     |       221.99040391            |       -6.99
214                     |       223.64871443            |       -9.65
276                     |       268.29772166            |       7.7
230                     |       228.28270389            |       1.72
230                     |       227.82848814            |       2.17
233                     |       228.73783863            |       4.26
459                     |       449.63967366            |       9.36
208                     |       222.66216934            |       -14.66
303                     |       299.24598873            |       3.75
470                     |       479.25460445            |       -9.25
--------------------------------------------------------------------------------
                Mean Square Error = 267.226545
================================================================================
```

```
-------------------------------- Round : 3 --------------------------------
Desired Output          |       Predict                 |       Error
-------------------------------------------------------------------------------
447                     |       468.68076296           |       -21.68
457                     |       457.97216990           |       -0.97
239                     |       251.93900213           |       -12.94
433                     |       444.18249896           |       -11.18
155                     |       168.05403183           |       -13.05
427                     |       439.47069292           |       -12.47
236                     |       248.87352017           |       -12.87
345                     |       369.72978414           |       -24.73
350                     |       282.15440064           |       67.85
333                     |       354.85097285           |       -21.85
305                     |       320.69511101           |       -15.7
164                     |       169.28962084           |       -5.29
209                     |       232.69736478           |       -23.7
156                     |       168.12814167           |       -12.13
268                     |       285.54232668           |       -17.54
435                     |       450.66254425           |       -15.66
291                     |       312.66642827           |       -21.67
314                     |       317.34512388           |       -3.35
412                     |       408.56117091           |       3.44
253                     |       279.68946082           |       -26.69
475                     |       477.88165829           |       -2.88
460                     |       462.50703226           |       -2.51
311                     |       334.97536589           |       -23.98
467                     |       469.79983648           |       -2.8
172                     |       170.83290655           |       1.17
483                     |       482.50070510           |       0.5
390                     |       378.35610572           |       11.64
256                     |       280.53536668           |       -24.54
315                     |       321.73085887           |       -6.73
322                     |       355.44401609           |       -33.44
468                     |       480.24641752           |       -12.25
-------------------------------------------------------------------------------
                Mean Square Error = 398.033252
===============================================================================
```

```
-------------------------------- Round : 4 --------------------------------
Desired Output          |       Predict                 |       Error
-------------------------------------------------------------------------------
329                     |       348.41337602            |       -19.41
481                     |       478.61106347            |       2.39
322                     |       324.11290221            |       -2.11
431                     |       444.55509279            |       -13.56
317                     |       341.18001776            |       -24.18
247                     |       259.73835512            |       -12.74
216                     |       229.71455631            |       -13.71
188                     |       170.95052571            |       17.05
470                     |       471.72912050            |       -1.73
430                     |       440.22675868            |       -10.23
422                     |       433.93376919            |       -11.93
465                     |       475.62397935            |       -10.62
214                     |       233.84881578            |       -19.85
344                     |       366.02408998            |       -22.02
156                     |       166.57189155            |       -10.57
475                     |       482.92090837            |       -7.92
311                     |       328.08159066            |       -17.08
470                     |       471.44687717            |       -1.45
416                     |       429.47882542            |       -13.48
490                     |       481.75224433            |       8.25
240                     |       239.51746647            |       0.48
296                     |       321.77782505            |       -25.78
465                     |       467.97131157            |       -2.97
360                     |       300.91885773            |       59.08
486                     |       479.78818213            |       6.21
247                     |       259.45629700            |       -11.46
294                     |       309.90887571            |       -15.91
337                     |       362.43037925            |       -25.43
156                     |       166.24011300            |       -10.24
231                     |       239.76061639            |       -8.76
215                     |       230.63364406            |       -15.63
-------------------------------------------------------------------------------
                Mean Square Error = 303.737113
===============================================================================
```

```
-------------------------------- Round : 5 --------------------------------
Desired Output          |       Predict                 |       Error
-------------------------------------------------------------------------------
310                     |       330.03919811            |       -20.04
210                     |       232.95772613            |       -22.96
251                     |       278.80484344            |       -26.8
290                     |       269.26328213            |       20.74
353                     |       376.37832045            |       -23.38
398                     |       388.53508968            |       9.46
250                     |       277.17509554            |       -27.18
444                     |       453.66323451            |       -9.66
243                     |       241.04421382            |       1.96
274                     |       285.76933349            |       -11.77
481                     |       483.09017439            |       -2.09
468                     |       475.95539565            |       -7.96
335                     |       354.60879674            |       -19.61
305                     |       323.14429198            |       -18.14
291                     |       308.38134144            |       -17.38
271                     |       284.97642608            |       -13.98
247                     |       256.91537714            |       -9.92
214                     |       231.68589431            |       -17.69
210                     |       232.22859138            |       -22.23
464                     |       474.73242620            |       -10.73
470                     |       471.36850700            |       -1.37
300                     |       256.73865847            |       43.26
208                     |       230.59960243            |       -22.6
471                     |       472.41882704            |       -1.42
303                     |       326.15358888            |       -23.15
221                     |       224.17414403            |       -3.17
315                     |       339.09241983            |       -24.09
246                     |       253.02941639            |       -7.03
314                     |       260.12356406            |       53.88
328                     |       264.71605459            |       63.28
260                     |       255.74767475            |       4.25
-------------------------------------------------------------------------------
                Mean Square Error = 531.434852
===============================================================================
```

```
-------------------------------- Round : 6 --------------------------------
Desired Output          |       Predict                 |       Error
--------------------------------------------------------------------------
393                     |       413.72995345            |       -20.73
209                     |       228.71601890            |       -19.72
465                     |       463.27160876            |       1.73
246                     |       197.59508937            |       48.4
288                     |       308.84763476            |       -20.85
292                     |       302.29439218            |       -10.29
250                     |       248.23501389            |       1.76
270                     |       254.72753858            |       15.27
232                     |       230.88275510            |       1.12
153                     |       168.34414320            |       -15.34
280                     |       292.95595743            |       -12.96
293                     |       320.57223646            |       -27.57
230                     |       226.86181810            |       3.14
232                     |       237.59154057            |       -5.59
420                     |       419.59771119            |       0.4
333                     |       361.25564334            |       -28.26
390                     |       410.09888580            |       -20.1
288                     |       309.38539561            |       -21.39
490                     |       482.16653718            |       7.83
307                     |       332.17486805            |       -25.17
469                     |       469.45149737            |       -0.45
234                     |       236.87079527            |       -2.87
192                     |       175.24605705            |       16.75
319                     |       342.51457298            |       -23.51
265                     |       285.81082968            |       -20.81
381                     |       402.39257530            |       -21.39
240                     |       237.09942603            |       2.9
485                     |       482.41509841            |       2.58
327                     |       346.36250049            |       -19.36
238                     |       233.41025022            |       4.59
470                     |       476.53029713            |       -6.53
--------------------------------------------------------------------------
                Mean Square Error = 312.511232
==========================================================================
```

```
-------------------------------- Round : 7 --------------------------------
Desired Output          |       Predict                 |       Error
-------------------------------------------------------------------------------
236                     |       227.37716568            |       8.62
209                     |       222.04322552            |       -13.04
490                     |       477.93702590            |       12.06
280                     |       240.20086389            |       39.8
341                     |       335.48320546            |       5.52
401                     |       389.62146283            |       11.38
437                     |       421.31962711            |       15.68
178                     |       167.25501467            |       10.74
308                     |       302.49406377            |       5.51
308                     |       292.91227544            |       15.09
330                     |       311.69518742            |       18.3
440                     |       425.78608362            |       14.21
356                     |       344.31438057            |       11.69
466                     |       454.20385818            |       11.8
376                     |       364.80097243            |       11.2
212                     |       222.93145456            |       -10.93
284                     |       272.11436832            |       11.89
428                     |       398.68557271            |       29.31
235                     |       227.92313160            |       7.08
319                     |       315.51569066            |       3.48
327                     |       304.57794348            |       22.42
307                     |       300.43819775            |       6.56
427                     |       404.76849831            |       22.23
288                     |       274.42242414            |       13.58
242                     |       228.50995991            |       13.49
362                     |       350.75499448            |       11.25
305                     |       300.64447443            |       4.36
405                     |       381.26388950            |       23.74
231                     |       226.24299838            |       4.76
374                     |       357.00310989            |       17.0
313                     |       309.23954573            |       3.76
-------------------------------------------------------------------------------
                Mean Square Error = 235.954742
===============================================================================
```

```
-------------------------------- Round : 8 --------------------------------
Desired Output          |       Predict                 |       Error
-------------------------------------------------------------------------------
368                     |       356.99992931            |       11.0
247                     |       246.11107987            |       0.89
451                     |       448.91854573            |       2.08
470                     |       461.71956217            |       8.28
489                     |       477.41487696            |       11.59
298                     |       300.85854784            |       -2.86
225                     |       218.55662009            |       6.44
370                     |       353.09921397            |       16.9
211                     |       226.05706632            |       -15.06
340                     |       329.15200912            |       10.85
490                     |       478.31523191            |       11.68
441                     |       428.39896731            |       12.6
438                     |       413.36672946            |       24.63
380                     |       341.26404345            |       38.74
460                     |       463.15259791            |       -3.15
456                     |       458.68883546            |       -2.69
322                     |       319.56751590            |       2.43
153                     |       161.07589421            |       -8.08
300                     |       302.29249982            |       -2.29
209                     |       223.60697429            |       -14.61
251                     |       261.98237726            |       -9.98
413                     |       372.52882951            |       40.47
326                     |       311.62982086            |       14.37
396                     |       381.44811208            |       14.55
288                     |       244.11343515            |       43.89
349                     |       339.97671631            |       9.02
457                     |       447.20982239            |       9.79
360                     |       349.70512038            |       10.29
320                     |       325.56761348            |       -5.57
224                     |       181.20663205            |       42.79
445                     |       421.14555707            |       23.85
-------------------------------------------------------------------------------
                Mean Square Error = 339.171619
===============================================================================
```

```
------------------------------- Round : 9 --------------------------------
Desired Output          |       Predict                 |       Error
--------------------------------------------------------------------------
303                     |       316.71937285            |       -13.72
207                     |       181.93088810            |       25.07
240                     |       248.84069049            |       -8.84
412                     |       428.82178350            |       -16.82
165                     |       168.64905526            |       -3.65
294                     |       318.80293082            |       -24.8
153                     |       165.58830019            |       -12.59
245                     |       243.31922992            |       1.68
390                     |       387.22893962            |       2.77
309                     |       331.07810301            |       -22.08
490                     |       481.35231587            |       8.65
357                     |       380.94991190            |       -23.95
241                     |       239.31787434            |       1.68
370                     |       334.37013702            |       35.63
484                     |       479.01192651            |       4.99
328                     |       364.05797839            |       -36.06
249                     |       264.96735890            |       -15.97
153                     |       165.44680601            |       -12.45
234                     |       244.13943222            |       -10.14
270                     |       231.34661892            |       38.65
300                     |       312.62371835            |       -12.62
469                     |       470.96571651            |       -1.97
317                     |       346.00724989            |       -29.01
244                     |       245.18538894            |       -1.19
365                     |       385.33855420            |       -20.34
490                     |       481.60742481            |       8.39
213                     |       233.31654134            |       -20.32
235                     |       234.89906399            |       0.1
385                     |       406.43065065            |       -21.43
488                     |       480.09228757            |       7.91
306                     |       320.60658281            |       -14.61
--------------------------------------------------------------------------
                Mean Square Error = 333.992703
==========================================================================

********  Mean Square Error Average : 354.2439  *********
```

**วิเคราะห์ ผลการทดลองที่ 1 :**

จากผลการทดลอง จะเห็นได้ว่าเมื่อมีจำนวนของ hidden layer มากขึ้น จะทำให้ค่าเฉลี่ย error ที่น้อยที่สุด น้อยลง ซึ่งเป็นผลดี แต่ในทางกลับกัน ค่าเฉลี่ย error ที่มากที่สุดก็ากขึ้นด้วยเช่นกัน แต่ในด้านการเพิ่มจำนวน node นั้น จะเห็นได้ว่า เมื่อเพิ่ม node มา ณ นำรวนหนึ่งจะทำให้ได้ ผล ค่าเฉลี่ย error ดีที่สุด และเมื่อเลยจำนวนนั้นไป ก็จะทำให้ ค่าเฉลี่ย error กลับมา เพิ่มขึ้นเหมือนเดิม ทำให้ไม่สามารถ ระบุได้ว่า โครงข่ายที่มีจำนวน hidden node และ hidden layer มากกว่า จะทำให้ได้ผลที่ดีกว่า

**การทดลองที่ 2 :** ทดลองปรับเปลี่ยนค่า learning rate
ได้ผลออกมาดังนี้

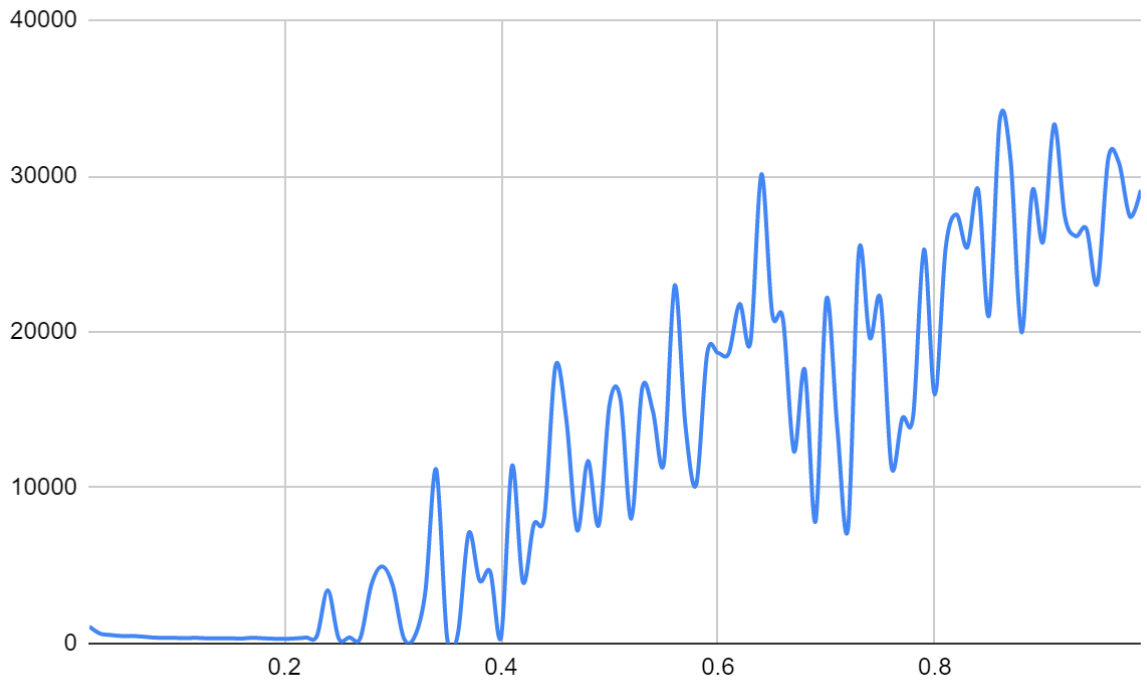
| Neural | | | | learning rate | momentum rate | #epoch | avg error | min error |
|---|---|---|---|---|---|---|---|---|
| 8 | 10 | 6 | 1 | 0.01 | 0.07 | 1000 | 1088.2838 | 656.271535 |
| 8 | 10 | 6 | 1 | 0.02 | 0.07 | 1000 | 635.2292 | 430.302574 |
| 8 | 10 | 6 | 1 | 0.03 | 0.07 | 1000 | 542.74 | 270.381681 |
| 8 | 10 | 6 | 1 | 0.04 | 0.07 | 1000 | 478.7582 | 149.082584 |
| 8 | 10 | 6 | 1 | 0.05 | 0.07 | 1000 | 484.7064 | 265.421706 |
| 8 | 10 | 6 | 1 | 0.06 | 0.07 | 1000 | 435.6343 | 295.178552 |
| 8 | 10 | 6 | 1 | 0.07 | 0.07 | 1000 | 377.9354 | 189.861503 |
| 8 | 10 | 6 | 1 | 0.08 | 0.07 | 1000 | 358.4872 | 222.197171 |
| 8 | 10 | 6 | 1 | 0.09 | 0.07 | 1000 | 356.9589 | 152.670406 |
| 8 | 10 | 6 | 1 | 0.1 | 0.07 | 1000 | 352.9311 | 125.20439 |
| 8 | 10 | 6 | 1 | 0.11 | 0.07 | 1000 | 358.1204 | 198.785526 |
| 8 | 10 | 6 | 1 | 0.12 | 0.07 | 1000 | 327.3557 | 216.388581 |
| 8 | 10 | 6 | 1 | 0.13 | 0.07 | 1000 | 335.1534 | 170.452629 |
| 8 | 10 | 6 | 1 | 0.14 | 0.07 | 1000 | 336.9682 | 109.6899 |
| 8 | 10 | 6 | 1 | 0.15 | 0.07 | 1000 | 315.2094 | 200.870584 |
| 8 | 10 | 6 | 1 | 0.16 | 0.07 | 1000 | 366.516 | 163.31709 |
| 8 | 10 | 6 | 1 | 0.17 | 0.07 | 1000 | 336.8556 | 125.6643 |
| 8 | 10 | 6 | 1 | 0.18 | 0.07 | 1000 | 306.1344 | 168.4127 |
| 8 | 10 | 6 | 1 | 0.19 | 0.07 | 1000 | 292.607 | 140.367326 |
| 8 | 10 | 6 | 1 | 0.2 | 0.07 | 1000 | 328.1722 | 202.265074 |
| 8 | 10 | 6 | 1 | 0.21 | 0.07 | 1000 | 382.1865 | 146.035561 |
| 8 | 10 | 6 | 1 | 0.22 | 0.07 | 1000 | 489.3023 | 218.883432 |
| 8 | 10 | 6 | 1 | 0.23 | 0.07 | 1000 | 3418.3531 | 135.207203 |
| 8 | 10 | 6 | 1 | 0.24 | 0.07 | 1000 | 336.7429 | 139.443052 |
| 8 | 10 | 6 | 1 | 0.25 | 0.07 | 1000 | 393.7602 | 201.724974 |
| 8 | 10 | 6 | 1 | 0.26 | 0.07 | 1000 | 348.8319 | 136.937929 |
| 8 | 10 | 6 | 1 | 0.27 | 0.07 | 1000 | 3715.0814 | 186.353461 |
| 8 | 10 | 6 | 1 | 0.28 | 0.07 | 1000 | 4946.1013 | 270.093848 |
| 8 | 10 | 6 | 1 | 0.29 | 0.07 | 1000 | 3706.2845 | 136.177481 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8 | 10 | 6 | 1 | 0.3 | 0.07 | 1000 | 368.8305 | 155.565803 |
| 8 | 10 | 6 | 1 | 0.31 | 0.07 | 1000 | 425.1009 | 206.309555 |
| 8 | 10 | 6 | 1 | 0.32 | 0.07 | 1000 | 3329.0156 | 199.069268 |
| 8 | 10 | 6 | 1 | 0.33 | 0.07 | 1000 | 11178.4446 | 188.688074 |
| 8 | 10 | 6 | 1 | 0.34 | 0.07 | 1000 | 411.4788 | 100.266287 |
| 8 | 10 | 6 | 1 | 0.35 | 0.07 | 1000 | 603.6889 | 96.480868 |
| 8 | 10 | 6 | 1 | 0.36 | 0.07 | 1000 | 7088.769 | 139.345184 |
| 8 | 10 | 6 | 1 | 0.37 | 0.07 | 1000 | 4043.8564 | 210.701171 |
| 8 | 10 | 6 | 1 | 0.38 | 0.07 | 1000 | 4588.3563 | 126.938132 |
| 8 | 10 | 6 | 1 | 0.39 | 0.07 | 1000 | 439.9288 | 179.633542 |
| 8 | 10 | 6 | 1 | 0.4 | 0.07 | 1000 | 11403.7181 | 134.583748 |
| 8 | 10 | 6 | 1 | 0.41 | 0.07 | 1000 | 3948.249 | 269.049284 |
| 8 | 10 | 6 | 1 | 0.42 | 0.07 | 1000 | 7618.9512 | 166.008703 |
| 8 | 10 | 6 | 1 | 0.43 | 0.07 | 1000 | 8280.4785 | 220.653226 |
| 8 | 10 | 6 | 1 | 0.44 | 0.07 | 1000 | 17787.6101 | 232.491948 |
| 8 | 10 | 6 | 1 | 0.45 | 0.07 | 1000 | 14429.4743 | 280.196919 |
| 8 | 10 | 6 | 1 | 0.46 | 0.07 | 1000 | 7276.0209 | 332.711526 |
| 8 | 10 | 6 | 1 | 0.47 | 0.07 | 1000 | 11721.7104 | 194.968513 |
| 8 | 10 | 6 | 1 | 0.48 | 0.07 | 1000 | 7596.1607 | 366.856165 |
| 8 | 10 | 6 | 1 | 0.49 | 0.07 | 1000 | 15374.2064 | 240.555645 |
| 8 | 10 | 6 | 1 | 0.5 | 0.07 | 1000 | 15684.3007 | 375.325829 |
| 8 | 10 | 6 | 1 | 0.51 | 0.07 | 1000 | 8013.5618 | 106.775997 |
| 8 | 10 | 6 | 1 | 0.52 | 0.07 | 1000 | 16373.0858 | 322.478526 |
| 8 | 10 | 6 | 1 | 0.53 | 0.07 | 1000 | 14892.878 | 271.055935 |
| 8 | 10 | 6 | 1 | 0.54 | 0.07 | 1000 | 11570.4866 | 244.303603 |
| 8 | 10 | 6 | 1 | 0.55 | 0.07 | 1000 | 22985.0154 | 281.465797 |
| 8 | 10 | 6 | 1 | 0.56 | 0.07 | 1000 | 13946.7056 | 272.55549 |
| 8 | 10 | 6 | 1 | 0.57 | 0.07 | 1000 | 10211.7795 | 385.571652 |
| 8 | 10 | 6 | 1 | 0.58 | 0.07 | 1000 | 18606.3792 | 387.265197 |
| 8 | 10 | 6 | 1 | 0.59 | 0.07 | 1000 | 18649.6331 | 316.278494 |
| 8 | 10 | 6 | 1 | 0.6 | 0.07 | 1000 | 18638.11 | 423.496306 |
| 8 | 10 | 6 | 1 | 0.61 | 0.07 | 1000 | 21792.8739 | 298.6313 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8 | 10 | 6 | 1 | 0.62 | 0.07 | 1000 | 19347.3982 | 474.642061 |
| 8 | 10 | 6 | 1 | 0.63 | 0.07 | 1000 | 30116.0812 | 310.680829 |
| 8 | 10 | 6 | 1 | 0.64 | 0.07 | 1000 | 21187.0564 | 249.949835 |
| 8 | 10 | 6 | 1 | 0.65 | 0.07 | 1000 | 20806.031 | 662.498523 |
| 8 | 10 | 6 | 1 | 0.66 | 0.07 | 1000 | 12342.4332 | 533.440358 |
| 8 | 10 | 6 | 1 | 0.67 | 0.07 | 1000 | 17574.0337 | 702.399165 |
| 8 | 10 | 6 | 1 | 0.68 | 0.07 | 1000 | 7835.9091 | 376.934626 |
| 8 | 10 | 6 | 1 | 0.69 | 0.07 | 1000 | 22101.9256 | 911.575458 |
| 8 | 10 | 6 | 1 | 0.7 | 0.07 | 1000 | 13905.63 | 405.544342 |
| 8 | 10 | 6 | 1 | 0.71 | 0.07 | 1000 | 7413.2925 | 277.54161 |
| 8 | 10 | 6 | 1 | 0.72 | 0.07 | 1000 | 25194.8564 | 559.229645 |
| 8 | 10 | 6 | 1 | 0.73 | 0.07 | 1000 | 19621.8791 | 393.824355 |
| 8 | 10 | 6 | 1 | 0.74 | 0.07 | 1000 | 22068.3688 | 289.733668 |
| 8 | 10 | 6 | 1 | 0.75 | 0.07 | 1000 | 11343.4747 | 651.34461 |
| 8 | 10 | 6 | 1 | 0.76 | 0.07 | 1000 | 14451.2518 | 637.2289 |
| 8 | 10 | 6 | 1 | 0.77 | 0.07 | 1000 | 14569.2544 | 511.788361 |
| 8 | 10 | 6 | 1 | 0.78 | 0.07 | 1000 | 25289.4024 | 486.361013 |
| 8 | 10 | 6 | 1 | 0.79 | 0.07 | 1000 | 15977.0739 | 702.987181 |
| 8 | 10 | 6 | 1 | 0.8 | 0.07 | 1000 | 25348.8293 | 890.604871 |
| 8 | 10 | 6 | 1 | 0.81 | 0.07 | 1000 | 27542.3081 | 935.180494 |
| 8 | 10 | 6 | 1 | 0.82 | 0.07 | 1000 | 25424.6877 | 884.477945 |
| 8 | 10 | 6 | 1 | 0.83 | 0.07 | 1000 | 29141.7123 | 907.877545 |
| 8 | 10 | 6 | 1 | 0.84 | 0.07 | 1000 | 21053.6292 | 345.081577 |
| 8 | 10 | 6 | 1 | 0.85 | 0.07 | 1000 | 33604.7665 | 857.729335 |
| 8 | 10 | 6 | 1 | 0.86 | 0.07 | 1000 | 31009.273 | 1554.961126 |
| 8 | 10 | 6 | 1 | 0.87 | 0.07 | 1000 | 19982.7678 | 376.776565 |
| 8 | 10 | 6 | 1 | 0.88 | 0.07 | 1000 | 29053.4125 | 1300.4717 |
| 8 | 10 | 6 | 1 | 0.89 | 0.07 | 1000 | 25794.1247 | 935.764703 |
| 8 | 10 | 6 | 1 | 0.9 | 0.07 | 1000 | 33318.3047 | 1221.756939 |
| 8 | 10 | 6 | 1 | 0.91 | 0.07 | 1000 | 27406.4285 | 1773.661271 |
| 8 | 10 | 6 | 1 | 0.92 | 0.07 | 1000 | 26150.9604 | 915.542977 |
| 8 | 10 | 6 | 1 | 0.93 | 0.07 | 1000 | 26601.6468 | 1581.962455 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8 | 10 | 6 | 1 | 0.94 | 0.07 | 1000 | 23113.1403 | 711.210516 |
| 8 | 10 | 6 | 1 | 0.95 | 0.07 | 1000 | 31108.9688 | 13672.02911 |
| 8 | 10 | 6 | 1 | 0.96 | 0.07 | 1000 | 30826.1995 | 902.732945 |
| 8 | 10 | 6 | 1 | 0.97 | 0.07 | 1000 | 27408.1697 | 647.39191 |
| 8 | 10 | 6 | 1 | 0.98 | 0.07 | 1000 | 29109.3576 | 1469.210365 |
| 8 | 10 | 6 | 1 | 0.99 | 0.07 | 1000 | 31108.8764 | 1835.908368 |

**วิเคราะห์ ผลการทดลองที่ 2 :**




จากกราฟจะเห็นว่า เมื่อมีการเพิ่ม learning rate มา ณ จำนวนหนึ่งจะทำให้ได้ค่าเฉลี่ย error น้อยที่สุด และเมื่อเลย ไปก็จะทำให้ค่าเฉลี่ย error กลับมามากเหมือนเดิม จึงสรุปได้ว่า ไม่ควรปรับ learning rate ให้มากเกิน หรือ น้อยจนเกินไป เพราะอาจทำให้ได้ ค่าที่ผิดพลาดมากขึ้น

**การทดลองที่ 3** : ทดลองปรับเปลี่ยนค่า momentum rate
ได้ผลออกมาดังนี้

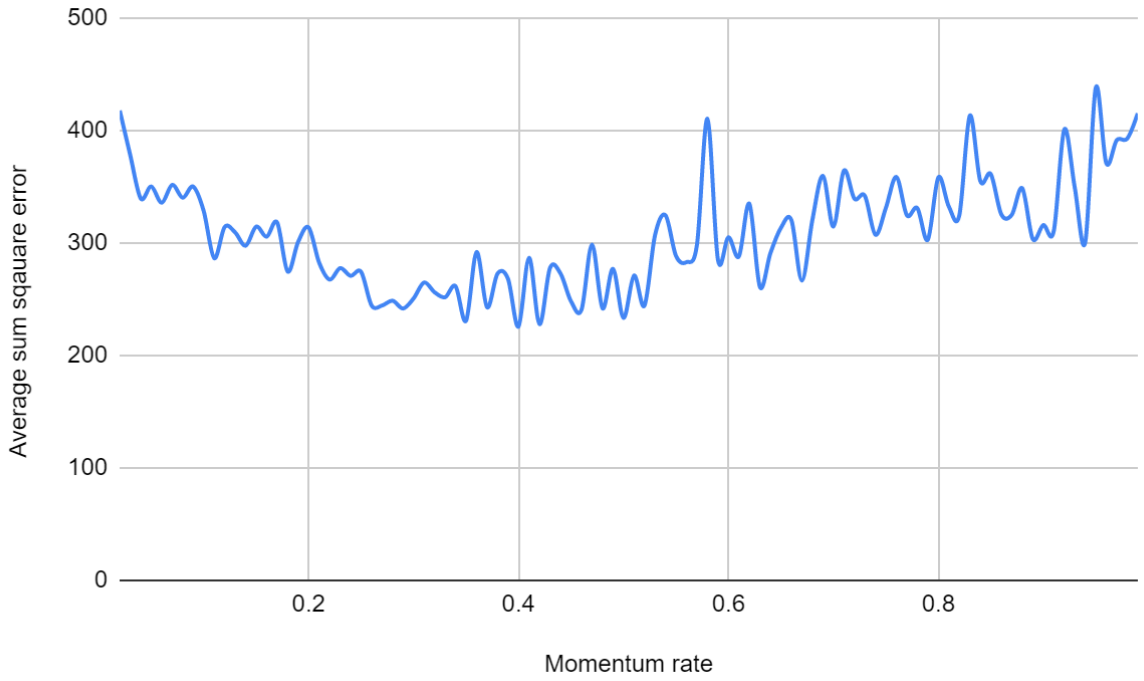
| Neural | | | | learning rate | momentum rate | #epoch | avg error | min error |
|---|---|---|---|---|---|---|---|---|
| 8 | 10 | 6 | 1 | 0.12 | 0.01 | 1000 | 417.9439 | 205.995071 |
| 8 | 10 | 6 | 1 | 0.12 | 0.02 | 1000 | 378.2068 | 161.236206 |
| 8 | 10 | 6 | 1 | 0.12 | 0.03 | 1000 | 339.7103 | 135.283165 |
| 8 | 10 | 6 | 1 | 0.12 | 0.04 | 1000 | 350.3838 | 141.217977 |
| 8 | 10 | 6 | 1 | 0.12 | 0.05 | 1000 | 335.9183 | 213.591506 |
| 8 | 10 | 6 | 1 | 0.12 | 0.06 | 1000 | 351.836 | 200.585913 |
| 8 | 10 | 6 | 1 | 0.12 | 0.07 | 1000 | 340.4021 | 216.091952 |
| 8 | 10 | 6 | 1 | 0.12 | 0.08 | 1000 | 350.2639 | 169.31669 |
| 8 | 10 | 6 | 1 | 0.12 | 0.09 | 1000 | 328.4914 | 188.838555 |
| 8 | 10 | 6 | 1 | 0.12 | 0.1 | 1000 | 286.6255 | 115.998045 |
| 8 | 10 | 6 | 1 | 0.12 | 0.11 | 1000 | 314.3821 | 124.896926 |
| 8 | 10 | 6 | 1 | 0.12 | 0.12 | 1000 | 309.4609 | 168.393377 |
| 8 | 10 | 6 | 1 | 0.12 | 0.13 | 1000 | 297.6905 | 167.701845 |
| 8 | 10 | 6 | 1 | 0.12 | 0.14 | 1000 | 314.6435 | 122.545223 |
| 8 | 10 | 6 | 1 | 0.12 | 0.15 | 1000 | 305.7064 | 147.6504 |
| 8 | 10 | 6 | 1 | 0.12 | 0.16 | 1000 | 318.3457 | 164.839935 |
| 8 | 10 | 6 | 1 | 0.12 | 0.17 | 1000 | 274.7055 | 135.547297 |
| 8 | 10 | 6 | 1 | 0.12 | 0.18 | 1000 | 301.1172 | 180.52441 |
| 8 | 10 | 6 | 1 | 0.12 | 0.19 | 1000 | 313.8709 | 231.539387 |
| 8 | 10 | 6 | 1 | 0.12 | 0.2 | 1000 | 282.6256 | 135.247055 |
| 8 | 10 | 6 | 1 | 0.12 | 0.21 | 1000 | 267.5511 | 103.939352 |
| 8 | 10 | 6 | 1 | 0.12 | 0.22 | 1000 | 277.7556 | 166.224555 |
| 8 | 10 | 6 | 1 | 0.12 | 0.23 | 1000 | 270.8673 | 131.595719 |
| 8 | 10 | 6 | 1 | 0.12 | 0.24 | 1000 | 274.3726 | 108.1973 |
| 8 | 10 | 6 | 1 | 0.12 | 0.25 | 1000 | 244.408 | 57.033835 |
| 8 | 10 | 6 | 1 | 0.12 | 0.26 | 1000 | 244.5223 | 90.533845 |
| 8 | 10 | 6 | 1 | 0.12 | 0.27 | 1000 | 248.7649 | 100.172394 |
| 8 | 10 | 6 | 1 | 0.12 | 0.28 | 1000 | 241.8185 | 143.093087 |
| 8 | 10 | 6 | 1 | 0.12 | 0.29 | 1000 | 250.8404 | 83.313342 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8 | 10 | 6 | 1 | 0.12 | 0.3 | 1000 | 264.9354 | 141.858942 |
| 8 | 10 | 6 | 1 | 0.12 | 0.31 | 1000 | 256.2628 | 108.215955 |
| 8 | 10 | 6 | 1 | 0.12 | 0.32 | 1000 | 251.8611 | 122.858168 |
| 8 | 10 | 6 | 1 | 0.12 | 0.33 | 1000 | 261.6185 | 98.050455 |
| 8 | 10 | 6 | 1 | 0.12 | 0.34 | 1000 | 230.9231 | 66.918216 |
| 8 | 10 | 6 | 1 | 0.12 | 0.35 | 1000 | 291.9732 | 70.516168 |
| 8 | 10 | 6 | 1 | 0.12 | 0.36 | 1000 | 242.9574 | 121.111035 |
| 8 | 10 | 6 | 1 | 0.12 | 0.37 | 1000 | 272.9097 | 115.517913 |
| 8 | 10 | 6 | 1 | 0.12 | 0.38 | 1000 | 268.0814 | 75.964245 |
| 8 | 10 | 6 | 1 | 0.12 | 0.39 | 1000 | 225.7939 | 57.409168 |
| 8 | 10 | 6 | 1 | 0.12 | 0.4 | 1000 | 286.9338 | 88.879606 |
| 8 | 10 | 6 | 1 | 0.12 | 0.41 | 1000 | 227.9588 | 76.359065 |
| 8 | 10 | 6 | 1 | 0.12 | 0.42 | 1000 | 277.9418 | 90.379874 |
| 8 | 10 | 6 | 1 | 0.12 | 0.43 | 1000 | 272.9327 | 179.196681 |
| 8 | 10 | 6 | 1 | 0.12 | 0.44 | 1000 | 248.2151 | 77.5047 |
| 8 | 10 | 6 | 1 | 0.12 | 0.45 | 1000 | 240.8145 | 98.547923 |
| 8 | 10 | 6 | 1 | 0.12 | 0.46 | 1000 | 298.7145 | 125.49951 |
| 8 | 10 | 6 | 1 | 0.12 | 0.47 | 1000 | 241.9852 | 75.871674 |
| 8 | 10 | 6 | 1 | 0.12 | 0.48 | 1000 | 277.0441 | 100.6098 |
| 8 | 10 | 6 | 1 | 0.12 | 0.49 | 1000 | 233.4685 | 67.591568 |
| 8 | 10 | 6 | 1 | 0.12 | 0.5 | 1000 | 271.1003 | 113.390977 |
| 8 | 10 | 6 | 1 | 0.12 | 0.51 | 1000 | 244.4433 | 60.044035 |
| 8 | 10 | 6 | 1 | 0.12 | 0.52 | 1000 | 306.9308 | 139.677368 |
| 8 | 10 | 6 | 1 | 0.12 | 0.53 | 1000 | 324.7371 | 177.724258 |
| 8 | 10 | 6 | 1 | 0.12 | 0.54 | 1000 | 288.6314 | 120.378452 |
| 8 | 10 | 6 | 1 | 0.12 | 0.55 | 1000 | 283.0301 | 103.825732 |
| 8 | 10 | 6 | 1 | 0.12 | 0.56 | 1000 | 298.4787 | 111.966871 |
| 8 | 10 | 6 | 1 | 0.12 | 0.57 | 1000 | 410.5639 | 125.106003 |
| 8 | 10 | 6 | 1 | 0.12 | 0.58 | 1000 | 285.2626 | 75.500906 |
| 8 | 10 | 6 | 1 | 0.12 | 0.59 | 1000 | 305.1473 | 105.956816 |
| 8 | 10 | 6 | 1 | 0.12 | 0.6 | 1000 | 288.2339 | 148.326826 |
| 8 | 10 | 6 | 1 | 0.12 | 0.61 | 1000 | 334.8939 | 106.676174 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8 | 10 | 6 | 1 | 0.12 | 0.62 | 1000 | 261.0405 | 71.771729 |
| 8 | 10 | 6 | 1 | 0.12 | 0.63 | 1000 | 291.0575 | 120.026939 |
| 8 | 10 | 6 | 1 | 0.12 | 0.64 | 1000 | 313.5467 | 135.924952 |
| 8 | 10 | 6 | 1 | 0.12 | 0.65 | 1000 | 320.4432 | 157.553981 |
| 8 | 10 | 6 | 1 | 0.12 | 0.66 | 1000 | 266.6498 | 128.407371 |
| 8 | 10 | 6 | 1 | 0.12 | 0.67 | 1000 | 320.7064 | 83.519784 |
| 8 | 10 | 6 | 1 | 0.12 | 0.68 | 1000 | 359.8212 | 188.157623 |
| 8 | 10 | 6 | 1 | 0.12 | 0.69 | 1000 | 314.745 | 141.81001 |
| 8 | 10 | 6 | 1 | 0.12 | 0.7 | 1000 | 364.4573 | 236.529803 |
| 8 | 10 | 6 | 1 | 0.12 | 0.71 | 1000 | 339.5914 | 111.882461 |
| 8 | 10 | 6 | 1 | 0.12 | 0.72 | 1000 | 342.0262 | 90.495371 |
| 8 | 10 | 6 | 1 | 0.12 | 0.73 | 1000 | 307.4924 | 176.960981 |
| 8 | 10 | 6 | 1 | 0.12 | 0.74 | 1000 | 331.3283 | 136.097974 |
| 8 | 10 | 6 | 1 | 0.12 | 0.75 | 1000 | 358.8389 | 163.814877 |
| 8 | 10 | 6 | 1 | 0.12 | 0.76 | 1000 | 324.7596 | 113.049413 |
| 8 | 10 | 6 | 1 | 0.12 | 0.77 | 1000 | 331.1051 | 169.858442 |
| 8 | 10 | 6 | 1 | 0.12 | 0.78 | 1000 | 303.0437 | 77.657235 |
| 8 | 10 | 6 | 1 | 0.12 | 0.79 | 1000 | 358.4213 | 128.666629 |
| 8 | 10 | 6 | 1 | 0.12 | 0.8 | 1000 | 332.5498 | 133.259755 |
| 8 | 10 | 6 | 1 | 0.12 | 0.81 | 1000 | 324.6445 | 86.191961 |
| 8 | 10 | 6 | 1 | 0.12 | 0.82 | 1000 | 413.3361 | 131.414068 |
| 8 | 10 | 6 | 1 | 0.12 | 0.83 | 1000 | 355.2569 | 99.861055 |
| 8 | 10 | 6 | 1 | 0.12 | 0.84 | 1000 | 361.4424 | 104.592626 |
| 8 | 10 | 6 | 1 | 0.12 | 0.85 | 1000 | 325.5952 | 204.343487 |
| 8 | 10 | 6 | 1 | 0.12 | 0.86 | 1000 | 325.1699 | 119.204777 |
| 8 | 10 | 6 | 1 | 0.12 | 0.87 | 1000 | 348.7668 | 205.618613 |
| 8 | 10 | 6 | 1 | 0.12 | 0.88 | 1000 | 303.6299 | 64.499326 |
| 8 | 10 | 6 | 1 | 0.12 | 0.89 | 1000 | 316.0362 | 67.739561 |
| 8 | 10 | 6 | 1 | 0.12 | 0.9 | 1000 | 310.7712 | 166.940948 |
| 8 | 10 | 6 | 1 | 0.12 | 0.91 | 1000 | 401.0397 | 170.68859 |
| 8 | 10 | 6 | 1 | 0.12 | 0.92 | 1000 | 349.3447 | 117.633819 |
| 8 | 10 | 6 | 1 | 0.12 | 0.93 | 1000 | 300.8867 | 121.677177 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8 | 10 | 6 | 1 | 0.12 | 0.94 | 1000 | 438.2552 | 129.18911 |
| 8 | 10 | 6 | 1 | 0.12 | 0.95 | 1000 | 371.1347 | 185.277539 |
| 8 | 10 | 6 | 1 | 0.12 | 0.96 | 1000 | 391.6313 | 104.172406 |
| 8 | 10 | 6 | 1 | 0.12 | 0.97 | 1000 | 392.9988 | 229.046977 |
| 8 | 10 | 6 | 1 | 0.12 | 0.98 | 1000 | 415.4817 | 200.936603 |
| 8 | 10 | 6 | 1 | 0.12 | 0.99 | 1000 | 493.9534 | 247.560665 |

**วิเคราะห์ ผลการทดลองที่ 3 :**

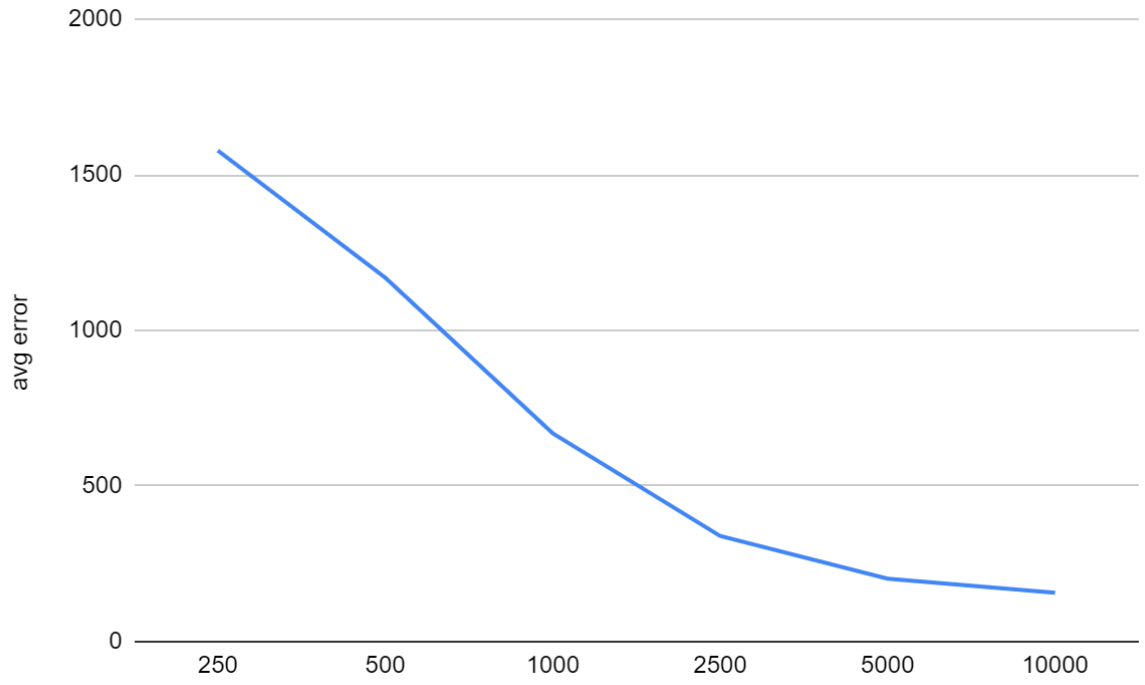



จากกราฟจะเห็นว่า ณ ตอนที่ momentum rate น้อย จะทำให้ได้ค่าเฉลีย error มาก แต่เมื่อเพิ่มมาถึงช่วง 0.2 - 0.4 จะเห็นว่า ค่าเฉลี่ยนั้น น้อยลง แต่เมื่อเลยช่วงไป ก็จะกลับมามากเหมือนเดิม ดังนั้น จึงควรปรับค่า momentum ให้อยู่ในช่วงที่ไม่มากหรือไม่น้อยจนเกินไป

**การทดลองที่ 4 :** ทดลองปรับจำนวนรอบการ train ของ neural network
ได้ผลออกมาดังนี้

| Neural | | | | learning rate | momentum rate | #epoch | avg error | min error |
|---|---|---|---|---|---|---|---|---|
| 8 | 10 | 6 | 1 | 0.12 | 0.07 | 100 | 1577.9041 | 1197.087468 |
| 8 | 10 | 6 | 1 | 0.12 | 0.07 | 250 | 1169.5606 | 813.187245 |
| 8 | 10 | 6 | 1 | 0.12 | 0.07 | 500 | 669.2213 | 236.051923 |
| 8 | 10 | 6 | 1 | 0.12 | 0.07 | 1000 | 339.831 | 195.642913 |
| 8 | 10 | 6 | 1 | 0.12 | 0.07 | 2500 | 202.0886 | 105.891355 |
| 8 | 10 | 6 | 1 | 0.12 | 0.07 | 5000 | 157.0216 | 67.772248 |
| 8 | 10 | 6 | 1 | 0.12 | 0.07 | 10000 | 124.3311 | 28.719516 |

**วิเคราะห์ ผลการทดลองที่ 4 :**




จากกราฟจะเห็นว่าเมื่อเราเพิ่มจำนวนรอบของการ train จะทำให้ค่าเฉลี่ย error ค่อยๆน้อยลง นั่นจึงสรุปได้ว่า ยิ่งจำนวนรวบการ train มากขึ้นก็ยิ่งทำให้โปรแกรมทำงานได้ถูกต้องมากยิ่งขึ้น

**ทดลองกับ cross.pat**

**การทดลองที่ 1 :** เปลี่ยนแปลงรูปแบบ และ ขนาดของ Hidden nodes
ได้ผลออกมาดังนี้

- แบบที่มี 1 Hidden layer โดยมีจำนวน hidden node ในช่วง [1,14]

| Neural | | | learning rate | momentum rate | #epoch | avg accuracy | max accuracy |
|---|---|---|---|---|---|---|---|
| 2 | 1 | 2 | 0.12 | 0.07 | 1000 | 0.615 | 0.7 |
| 2 | 2 | 2 | 0.12 | 0.07 | 1000 | 0.77 | 0.9 |
| 2 | 3 | 2 | 0.12 | 0.07 | 1000 | 0.735 | 0.8 |
| 2 | 4 | 2 | 0.12 | 0.07 | 1000 | 0.715 | 0.85 |
| 2 | 5 | 2 | 0.12 | 0.07 | 1000 | 0.77 | 0.9 |
| 2 | 6 | 2 | 0.12 | 0.07 | 1000 | 0.775 | 0.95 |
| 2 | 7 | 2 | 0.12 | 0.07 | 1000 | 0.73 | 0.85 |
| 2 | 8 | 2 | 0.12 | 0.07 | 1000 | 0.785 | 1 |
| 2 | 9 | 2 | 0.12 | 0.07 | 1000 | 0.8 | 0.9 |
| 2 | 10 | 2 | 0.12 | 0.07 | 1000 | 0.755 | 0.9 |
| 2 | 11 | 2 | 0.12 | 0.07 | 1000 | 0.765 | 0.85 |
| 2 | 12 | 2 | 0.12 | 0.07 | 1000 | 0.845 | 0.95 |
| 2 | 13 | 2 | 0.12 | 0.07 | 1000 | 0.75 | 0.9 |
| 2 | 14 | 2 | 0.12 | 0.07 | 1000 | 0.5 | 0.55 |

- แบบที่มี 2 Hidden layers โดยมีจำนวน hidden node ในช่วง [1,14]

| Neural | | | | learning rate | momentum rate | #epoch | avg accuracy | max accuracy |
|---|---|---|---|---|---|---|---|---|
| 2 | 1 | 1 | 2 | 0.12 | 0.07 | 1000 | 0.44 | 0.5 |
| 2 | 1 | 2 | 2 | 0.12 | 0.07 | 1000 | 0.56 | 0.7 |
| 2 | 1 | 3 | 2 | 0.12 | 0.07 | 1000 | 0.645 | 0.85 |
| 2 | 1 | 4 | 2 | 0.12 | 0.07 | 1000 | 0.595 | 0.75 |
| 2 | 1 | 5 | 2 | 0.12 | 0.07 | 1000 | 0.65 | 0.8 |
| 2 | 1 | 6 | 2 | 0.12 | 0.07 | 1000 | 0.645 | 0.8 |
| 2 | 1 | 7 | 2 | 0.12 | 0.07 | 1000 | 0.615 | 0.75 |
| 2 | 1 | 8 | 2 | 0.12 | 0.07 | 1000 | 0.635 | 0.8 |
| 2 | 1 | 9 | 2 | 0.12 | 0.07 | 1000 | 0.62 | 0.75 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 1 | 10 | 2 | 0.12 | 0.07 | 1000 | 0.625 | 0.8 |
| 2 | 1 | 11 | 2 | 0.12 | 0.07 | 1000 | 0.615 | 0.7 |
| 2 | 1 | 12 | 2 | 0.12 | 0.07 | 1000 | 0.615 | 0.7 |
| 2 | 1 | 13 | 2 | 0.12 | 0.07 | 1000 | 0.675 | 0.85 |
| 2 | 1 | 14 | 2 | 0.12 | 0.07 | 1000 | 0.615 | 0.75 |
| 2 | 2 | 1 | 2 | 0.12 | 0.07 | 1000 | 0.45 | 0.5 |
| 2 | 2 | 2 | 2 | 0.12 | 0.07 | 1000 | 0.705 | 0.85 |
| 2 | 2 | 3 | 2 | 0.12 | 0.07 | 1000 | 0.79 | 0.9 |
| 2 | 2 | 4 | 2 | 0.12 | 0.07 | 1000 | 0.73 | 0.95 |
| 2 | 2 | 5 | 2 | 0.12 | 0.07 | 1000 | 0.74 | 0.9 |
| 2 | 2 | 6 | 2 | 0.12 | 0.07 | 1000 | 0.775 | 0.85 |
| 2 | 2 | 7 | 2 | 0.12 | 0.07 | 1000 | 0.775 | 0.85 |
| 2 | 2 | 8 | 2 | 0.12 | 0.07 | 1000 | 0.76 | 0.85 |
| 2 | 2 | 9 | 2 | 0.12 | 0.07 | 1000 | 0.785 | 0.95 |
| 2 | 2 | 10 | 2 | 0.12 | 0.07 | 1000 | 0.74 | 0.85 |
| 2 | 2 | 11 | 2 | 0.12 | 0.07 | 1000 | 0.74 | 0.85 |
| 2 | 2 | 12 | 2 | 0.12 | 0.07 | 1000 | 0.68 | 0.85 |
| 2 | 2 | 13 | 2 | 0.12 | 0.07 | 1000 | 0.73 | 0.9 |
| 2 | 2 | 14 | 2 | 0.12 | 0.07 | 1000 | 0.725 | 0.9 |
| 2 | 3 | 1 | 2 | 0.12 | 0.07 | 1000 | 0.42 | 0.5 |
| 2 | 3 | 2 | 2 | 0.12 | 0.07 | 1000 | 0.75 | 0.85 |
| 2 | 3 | 3 | 2 | 0.12 | 0.07 | 1000 | 0.76 | 0.9 |
| 2 | 3 | 4 | 2 | 0.12 | 0.07 | 1000 | 0.805 | 0.95 |
| 2 | 3 | 5 | 2 | 0.12 | 0.07 | 1000 | 0.775 | 0.9 |
| 2 | 3 | 6 | 2 | 0.12 | 0.07 | 1000 | 0.8 | 0.9 |
| 2 | 3 | 7 | 2 | 0.12 | 0.07 | 1000 | 0.795 | 0.9 |
| 2 | 3 | 8 | 2 | 0.12 | 0.07 | 1000 | 0.755 | 0.9 |
| 2 | 3 | 9 | 2 | 0.12 | 0.07 | 1000 | 0.77 | 0.9 |
| 2 | 3 | 10 | 2 | 0.12 | 0.07 | 1000 | 0.785 | 1 |
| 2 | 3 | 11 | 2 | 0.12 | 0.07 | 1000 | 0.75 | 0.95 |
| 2 | 3 | 12 | 2 | 0.12 | 0.07 | 1000 | 0.75 | 0.8 |
| 2 | 3 | 13 | 2 | 0.12 | 0.07 | 1000 | 0.735 | 0.85 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 3 | 14 | 2 | 0.12 | 0.07 | 1000 | 0.735 | 0.85 |
| 2 | 4 | 1 | 2 | 0.12 | 0.07 | 1000 | 0.38 | 0.5 |
| 2 | 4 | 2 | 2 | 0.12 | 0.07 | 1000 | 0.76 | 0.85 |
| 2 | 4 | 3 | 2 | 0.12 | 0.07 | 1000 | 0.755 | 0.95 |
| 2 | 4 | 4 | 2 | 0.12 | 0.07 | 1000 | 0.735 | 0.95 |
| 2 | 4 | 5 | 2 | 0.12 | 0.07 | 1000 | 0.77 | 0.95 |
| 2 | 4 | 6 | 2 | 0.12 | 0.07 | 1000 | 0.85 | 1 |
| 2 | 4 | 7 | 2 | 0.12 | 0.07 | 1000 | 0.765 | 0.9 |
| 2 | 4 | 8 | 2 | 0.12 | 0.07 | 1000 | 0.81 | 0.95 |
| 2 | 4 | 9 | 2 | 0.12 | 0.07 | 1000 | 0.785 | 0.9 |
| 2 | 4 | 10 | 2 | 0.12 | 0.07 | 1000 | 0.78 | 0.95 |
| 2 | 4 | 11 | 2 | 0.12 | 0.07 | 1000 | 0.785 | 0.9 |
| 2 | 4 | 12 | 2 | 0.12 | 0.07 | 1000 | 0.775 | 0.95 |
| 2 | 4 | 13 | 2 | 0.12 | 0.07 | 1000 | 0.74 | 0.85 |
| 2 | 4 | 14 | 2 | 0.12 | 0.07 | 1000 | 0.785 | 0.9 |
| 2 | 5 | 1 | 2 | 0.12 | 0.07 | 1000 | 0.4 | 0.5 |
| 2 | 5 | 2 | 2 | 0.12 | 0.07 | 1000 | 0.755 | 0.9 |
| 2 | 5 | 3 | 2 | 0.12 | 0.07 | 1000 | 0.785 | 0.9 |
| 2 | 5 | 4 | 2 | 0.12 | 0.07 | 1000 | 0.805 | 1 |
| 2 | 5 | 5 | 2 | 0.12 | 0.07 | 1000 | 0.825 | 0.95 |
| 2 | 5 | 6 | 2 | 0.12 | 0.07 | 1000 | 0.82 | 0.95 |
| 2 | 5 | 7 | 2 | 0.12 | 0.07 | 1000 | 0.805 | 0.95 |
| 2 | 5 | 8 | 2 | 0.12 | 0.07 | 1000 | 0.745 | 0.9 |
| 2 | 5 | 9 | 2 | 0.12 | 0.07 | 1000 | 0.825 | 0.9 |
| 2 | 5 | 10 | 2 | 0.12 | 0.07 | 1000 | 0.765 | 0.9 |
| 2 | 5 | 11 | 2 | 0.12 | 0.07 | 1000 | 0.83 | 0.95 |
| 2 | 5 | 12 | 2 | 0.12 | 0.07 | 1000 | 0.765 | 0.9 |
| 2 | 5 | 13 | 2 | 0.12 | 0.07 | 1000 | 0.805 | 0.95 |
| 2 | 5 | 14 | 2 | 0.12 | 0.07 | 1000 | 0.775 | 0.9 |
| 2 | 6 | 1 | 2 | 0.12 | 0.07 | 1000 | 0.45 | 0.5 |
| 2 | 6 | 2 | 2 | 0.12 | 0.07 | 1000 | 0.75 | 0.9 |
| 2 | 6 | 3 | 2 | 0.12 | 0.07 | 1000 | 0.81 | 0.95 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 6 | 4 | 2 | 0.12 | 0.07 | 1000 | 0.83 | 0.95 |
| 2 | 6 | 5 | 2 | 0.12 | 0.07 | 1000 | 0.805 | 0.95 |
| 2 | 6 | 6 | 2 | 0.12 | 0.07 | 1000 | 0.77 | 0.9 |
| 2 | 6 | 7 | 2 | 0.12 | 0.07 | 1000 | 0.855 | 1 |
| 2 | 6 | 8 | 2 | 0.12 | 0.07 | 1000 | 0.805 | 0.95 |
| 2 | 6 | 9 | 2 | 0.12 | 0.07 | 1000 | 0.745 | 0.9 |
| 2 | 6 | 10 | 2 | 0.12 | 0.07 | 1000 | 0.79 | 1 |
| 2 | 6 | 11 | 2 | 0.12 | 0.07 | 1000 | 0.795 | 0.95 |
| 2 | 6 | 12 | 2 | 0.12 | 0.07 | 1000 | 0.83 | 0.95 |
| 2 | 6 | 13 | 2 | 0.12 | 0.07 | 1000 | 0.82 | 1 |
| 2 | 6 | 14 | 2 | 0.12 | 0.07 | 1000 | 0.795 | 0.9 |
| 2 | 7 | 1 | 2 | 0.12 | 0.07 | 1000 | 0.42 | 0.5 |
| 2 | 7 | 2 | 2 | 0.12 | 0.07 | 1000 | 0.75 | 0.85 |
| 2 | 7 | 3 | 2 | 0.12 | 0.07 | 1000 | 0.82 | 0.9 |
| 2 | 7 | 4 | 2 | 0.12 | 0.07 | 1000 | 0.785 | 0.9 |
| 2 | 7 | 5 | 2 | 0.12 | 0.07 | 1000 | 0.8 | 1 |
| 2 | 7 | 6 | 2 | 0.12 | 0.07 | 1000 | 0.885 | 0.95 |
| 2 | 7 | 7 | 2 | 0.12 | 0.07 | 1000 | 0.82 | 0.95 |
| 2 | 7 | 8 | 2 | 0.12 | 0.07 | 1000 | 0.78 | 1 |
| 2 | 7 | 9 | 2 | 0.12 | 0.07 | 1000 | 0.78 | 0.95 |
| 2 | 7 | 10 | 2 | 0.12 | 0.07 | 1000 | 0.81 | 0.95 |
| 2 | 7 | 11 | 2 | 0.12 | 0.07 | 1000 | 0.755 | 0.95 |
| 2 | 7 | 12 | 2 | 0.12 | 0.07 | 1000 | 0.83 | 0.95 |
| 2 | 7 | 13 | 2 | 0.12 | 0.07 | 1000 | 0.76 | 0.9 |
| 2 | 7 | 14 | 2 | 0.12 | 0.07 | 1000 | 0.845 | 0.95 |
| 2 | 8 | 1 | 2 | 0.12 | 0.07 | 1000 | 0.42 | 0.5 |
| 2 | 8 | 2 | 2 | 0.12 | 0.07 | 1000 | 0.765 | 0.9 |
| 2 | 8 | 3 | 2 | 0.12 | 0.07 | 1000 | 0.815 | 1 |
| 2 | 8 | 4 | 2 | 0.12 | 0.07 | 1000 | 0.825 | 0.95 |
| 2 | 8 | 5 | 2 | 0.12 | 0.07 | 1000 | 0.8 | 0.95 |
| 2 | 8 | 6 | 2 | 0.12 | 0.07 | 1000 | 0.835 | 1 |
| 2 | 8 | 7 | 2 | 0.12 | 0.07 | 1000 | 0.8 | 0.95 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 8 | 8 | 2 | 0.12 | 0.07 | 1000 | 0.805 | 1 |
| 2 | 8 | 9 | 2 | 0.12 | 0.07 | 1000 | 0.83 | 0.95 |
| 2 | 8 | 10 | 2 | 0.12 | 0.07 | 1000 | 0.77 | 0.9 |
| 2 | 8 | 11 | 2 | 0.12 | 0.07 | 1000 | 0.835 | 1 |
| 2 | 8 | 12 | 2 | 0.12 | 0.07 | 1000 | 0.805 | 0.95 |
| 2 | 8 | 13 | 2 | 0.12 | 0.07 | 1000 | 0.825 | 0.9 |
| 2 | 8 | 14 | 2 | 0.12 | 0.07 | 1000 | 0.8 | 0.9 |
| 2 | 9 | 1 | 2 | 0.12 | 0.07 | 1000 | 0.41 | 0.5 |
| 2 | 9 | 2 | 2 | 0.12 | 0.07 | 1000 | 0.78 | 0.85 |
| 2 | 9 | 3 | 2 | 0.12 | 0.07 | 1000 | 0.835 | 0.95 |
| 2 | 9 | 4 | 2 | 0.12 | 0.07 | 1000 | 0.85 | 0.95 |
| 2 | 9 | 5 | 2 | 0.12 | 0.07 | 1000 | 0.78 | 1 |
| 2 | 9 | 6 | 2 | 0.12 | 0.07 | 1000 | 0.815 | 0.95 |
| 2 | 9 | 7 | 2 | 0.12 | 0.07 | 1000 | 0.795 | 0.95 |
| 2 | 9 | 8 | 2 | 0.12 | 0.07 | 1000 | 0.845 | 0.95 |
| 2 | 9 | 9 | 2 | 0.12 | 0.07 | 1000 | 0.82 | 1 |
| 2 | 9 | 10 | 2 | 0.12 | 0.07 | 1000 | 0.785 | 0.95 |
| 2 | 9 | 11 | 2 | 0.12 | 0.07 | 1000 | 0.805 | 0.9 |
| 2 | 9 | 12 | 2 | 0.12 | 0.07 | 1000 | 0.84 | 1 |
| 2 | 9 | 13 | 2 | 0.12 | 0.07 | 1000 | 0.795 | 0.95 |
| 2 | 9 | 14 | 2 | 0.12 | 0.07 | 1000 | 0.81 | 0.95 |
| 2 | 10 | 1 | 2 | 0.12 | 0.07 | 1000 | 0.41 | 0.5 |
| 2 | 10 | 2 | 2 | 0.12 | 0.07 | 1000 | 0.76 | 0.9 |
| 2 | 10 | 3 | 2 | 0.12 | 0.07 | 1000 | 0.76 | 0.8 |
| 2 | 10 | 4 | 2 | 0.12 | 0.07 | 1000 | 0.82 | 0.95 |
| 2 | 10 | 5 | 2 | 0.12 | 0.07 | 1000 | 0.825 | 0.9 |
| 2 | 10 | 6 | 2 | 0.12 | 0.07 | 1000 | 0.83 | 0.9 |
| 2 | 10 | 7 | 2 | 0.12 | 0.07 | 1000 | 0.84 | 0.95 |
| 2 | 10 | 8 | 2 | 0.12 | 0.07 | 1000 | 0.83 | 1 |
| 2 | 10 | 9 | 2 | 0.12 | 0.07 | 1000 | 0.835 | 0.95 |
| 2 | 10 | 10 | 2 | 0.12 | 0.07 | 1000 | 0.785 | 0.95 |
| 2 | 10 | 11 | 2 | 0.12 | 0.07 | 1000 | 0.87 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 10 | 12 | 2 | 0.12 | 0.07 | 1000 | 0.785 | 0.95 |
| 2 | 10 | 13 | 2 | 0.12 | 0.07 | 1000 | 0.83 | 0.95 |
| 2 | 10 | 14 | 2 | 0.12 | 0.07 | 1000 | 0.78 | 0.9 |
| 2 | 11 | 1 | 2 | 0.12 | 0.07 | 1000 | 0.39 | 0.45 |
| 2 | 11 | 2 | 2 | 0.12 | 0.07 | 1000 | 0.73 | 0.9 |
| 2 | 11 | 3 | 2 | 0.12 | 0.07 | 1000 | 0.795 | 1 |
| 2 | 11 | 4 | 2 | 0.12 | 0.07 | 1000 | 0.89 | 0.95 |
| 2 | 11 | 5 | 2 | 0.12 | 0.07 | 1000 | 0.82 | 0.95 |
| 2 | 11 | 6 | 2 | 0.12 | 0.07 | 1000 | 0.85 | 1 |
| 2 | 11 | 7 | 2 | 0.12 | 0.07 | 1000 | 0.8 | 1 |
| 2 | 11 | 8 | 2 | 0.12 | 0.07 | 1000 | 0.825 | 1 |
| 2 | 11 | 9 | 2 | 0.12 | 0.07 | 1000 | 0.85 | 1 |
| 2 | 11 | 10 | 2 | 0.12 | 0.07 | 1000 | 0.835 | 0.9 |
| 2 | 11 | 11 | 2 | 0.12 | 0.07 | 1000 | 0.825 | 1 |
| 2 | 11 | 12 | 2 | 0.12 | 0.07 | 1000 | 0.835 | 0.9 |
| 2 | 11 | 13 | 2 | 0.12 | 0.07 | 1000 | 0.825 | 0.95 |
| 2 | 11 | 14 | 2 | 0.12 | 0.07 | 1000 | 0.83 | 0.9 |
| 2 | 12 | 1 | 2 | 0.12 | 0.07 | 1000 | 0.42 | 0.5 |
| 2 | 12 | 2 | 2 | 0.12 | 0.07 | 1000 | 0.72 | 0.85 |
| 2 | 12 | 3 | 2 | 0.12 | 0.07 | 1000 | 0.86 | 0.95 |
| 2 | 12 | 4 | 2 | 0.12 | 0.07 | 1000 | 0.82 | 0.95 |
| 2 | 12 | 5 | 2 | 0.12 | 0.07 | 1000 | 0.825 | 0.95 |
| 2 | 12 | 6 | 2 | 0.12 | 0.07 | 1000 | 0.815 | 1 |
| 2 | 12 | 7 | 2 | 0.12 | 0.07 | 1000 | 0.9 | 1 |
| 2 | 12 | 8 | 2 | 0.12 | 0.07 | 1000 | 0.85 | 1 |
| 2 | 12 | 9 | 2 | 0.12 | 0.07 | 1000 | 0.855 | 0.95 |
| 2 | 12 | 10 | 2 | 0.12 | 0.07 | 1000 | 0.86 | 1 |
| 2 | 12 | 11 | 2 | 0.12 | 0.07 | 1000 | 0.885 | 1 |
| 2 | 12 | 12 | 2 | 0.12 | 0.07 | 1000 | 0.89 | 1 |
| 2 | 12 | 13 | 2 | 0.12 | 0.07 | 1000 | 0.84 | 1 |
| 2 | 12 | 14 | 2 | 0.12 | 0.07 | 1000 | 0.865 | 0.95 |
| 2 | 13 | 1 | 2 | 0.12 | 0.07 | 1000 | 0.38 | 0.5 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 13 | 2 | 2 | 0.12 | 0.07 | 1000 | 0.75 | 0.9 |
| 2 | 13 | 3 | 2 | 0.12 | 0.07 | 1000 | 0.84 | 1 |
| 2 | 13 | 4 | 2 | 0.12 | 0.07 | 1000 | 0.86 | 0.95 |
| 2 | 13 | 5 | 2 | 0.12 | 0.07 | 1000 | 0.86 | 1 |
| 2 | 13 | 6 | 2 | 0.12 | 0.07 | 1000 | 0.76 | 0.85 |
| 2 | 13 | 7 | 2 | 0.12 | 0.07 | 1000 | 0.84 | 1 |
| 2 | 13 | 8 | 2 | 0.12 | 0.07 | 1000 | 0.855 | 0.95 |
| 2 | 13 | 9 | 2 | 0.12 | 0.07 | 1000 | 0.87 | 1 |
| 2 | 13 | 10 | 2 | 0.12 | 0.07 | 1000 | 0.835 | 1 |
| 2 | 13 | 11 | 2 | 0.12 | 0.07 | 1000 | 0.865 | 0.95 |
| 2 | 13 | 12 | 2 | 0.12 | 0.07 | 1000 | 0.88 | 1 |
| 2 | 13 | 13 | 2 | 0.12 | 0.07 | 1000 | 0.815 | 1 |
| 2 | 13 | 14 | 2 | 0.12 | 0.07 | 1000 | 0.885 | 1 |
| 2 | 14 | 1 | 2 | 0.12 | 0.07 | 1000 | 0.43 | 0.5 |
| 2 | 14 | 2 | 2 | 0.12 | 0.07 | 1000 | 0.74 | 0.95 |
| 2 | 14 | 3 | 2 | 0.12 | 0.07 | 1000 | 0.845 | 0.95 |
| 2 | 14 | 4 | 2 | 0.12 | 0.07 | 1000 | 0.82 | 0.95 |
| 2 | 14 | 5 | 2 | 0.12 | 0.07 | 1000 | 0.86 | 1 |
| 2 | 14 | 6 | 2 | 0.12 | 0.07 | 1000 | 0.875 | 1 |
| 2 | 14 | 7 | 2 | 0.12 | 0.07 | 1000 | 0.845 | 0.95 |
| 2 | 14 | 8 | 2 | 0.12 | 0.07 | 1000 | 0.855 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.07 | 1000 | 0.915 | 1 |
| 2 | 14 | 10 | 2 | 0.12 | 0.07 | 1000 | 0.845 | 0.95 |
| 2 | 14 | 11 | 2 | 0.12 | 0.07 | 1000 | 0.845 | 0.95 |
| 2 | 14 | 12 | 2 | 0.12 | 0.07 | 1000 | 0.855 | 0.95 |
| 2 | 14 | 13 | 2 | 0.12 | 0.07 | 1000 | 0.855 | 1 |
| 2 | 14 | 14 | 2 | 0.12 | 0.07 | 1000 | 0.905 | 1 |

* ข้อมูลในตารางเป็นข้อมูลที่ผ่านการ cross validation ทั้งหมดแล้ว แต่นำมาเพียงค่าเฉลี่ย และ ค่าน้อยสุดเท่านั้น

- แบบที่ 3 : นำรูปแบบ (Neural) ที่ได้ sum average error น้อยที่สุด [2-14-9-2] มาแสดง cross validation

```
------------------- Variable --------------------

Datafile : cross.pat
Neural name : 2-14-9-2
Learning rate : 0.12
Momentum rate : 0.07
Activaion Function : sigmoid
Cross validation : [90 : 10]
#Epoch : 1000
```

```
----------------- Round : 0 -----------------
 Desired Output          |       Predict
 ------------------------------------------------
 1                       |       1
 0                       |       0
 0                       |       1
 1                       |       1
 1                       |       1
 0                       |       0
 0                       |       0
 1                       |       0
 1                       |       1
 0                       |       1
 1                       |       1
 1                       |       1
 0                       |       1
 0                       |       0
 0                       |       0
 1                       |       1
 1                       |       1
 0                       |       0
 0                       |       0
 1                       |       1
 ------------------------------------------------
```

```
                Confusion Matrix
  ---------------------------------------------
 |                       |                     |
 |                       |                     |
 |          11           |          1          |        12
 |                       |                     |
 |                       |                     |
  ---------------------------------------------
 |                       |                     |
 |                       |                     |
 |          2            |          6          |        8
 |                       |                     |
 |                       |                     |
  ---------------------------------------------
            13                      7                20

 Accuracy : 0.85
```

```
                Confusion Matrix
 ---------------------------------------------
|                       |                     |
|                       |                     |
|          6            |          0          |         6
|                       |                     |
|                       |                     |
 ---------------------------------------------
|                       |                     |
|                       |                     |
|          1            |          13         |         14
|                       |                     |
|                       |                     |
 ---------------------------------------------
           7                        13                20

Accuracy : 0.95
```

```
 ----------------- Round : 3 -----------------
Desired Output          |       Predict
 ------------------------------------------------
0                       |       0
1                       |       1
0                       |       0
1                       |       1
0                       |       0
1                       |       1
0                       |       1
0                       |       0
0                       |       0
0                       |       0
1                       |       1
0                       |       0
1                       |       1
0                       |       0
1                       |       0
1                       |       1
0                       |       0
1                       |       1
0                       |       0
0                       |       0
 ------------------------------------------------
```

```
                Confusion Matrix
 ---------------------------------------------
|                       |                     |
|                       |                     |
|          11           |          1          |         12
|                       |                     |
|                       |                     |
 ---------------------------------------------
|                       |                     |
|                       |                     |
|          1            |          7          |         8
|                       |                     |
|                       |                     |
 ---------------------------------------------
           12                       8                 20

Accuracy : 0.9
```

```
----------------- Round : 4 -----------------
Desired Output          |       Predict
-------------------------------------------------
0                       |       1
0                       |       0
0                       |       1
1                       |       0
1                       |       1
0                       |       1
0                       |       0
0                       |       0
0                       |       0
1                       |       1
0                       |       0
0                       |       0
1                       |       1
1                       |       1
0                       |       0
0                       |       0
0                       |       0
0                       |       0
1                       |       0
0                       |       0
-------------------------------------------------
```

```
                Confusion Matrix
 ---------------------------------------------
|                       |                     |
|                       |                     |
|          11           |          3          |        14
|                       |                     |
|                       |                     |
 ---------------------------------------------
|                       |                     |
|                       |                     |
|          2            |          4          |        6
|                       |                     |
|                       |                     |
 ---------------------------------------------
           13                       7                20

Accuracy : 0.75
```

```
----------------- Round : 5 -----------------
Desired Output          |       Predict
-------------------------------------------------
0                       |       1
0                       |       0
1                       |       1
1                       |       1
1                       |       1
1                       |       1
1                       |       1
0                       |       0
0                       |       0
0                       |       0
1                       |       1
1                       |       1
0                       |       0
1                       |       0
1                       |       1
1                       |       1
1                       |       1
0                       |       0
0                       |       1
0                       |       0
-------------------------------------------------
```

Confusion Matrix

| | | |
|---|---|---|
| 7 | 2 | 9 |
| 1 | 10 | 11 |
| 8 | 12 | 20 |

Accuracy : 0.85

```
----------------- Round : 6 -----------------
Desired Output          |       Predict
-------------------------------------------------
1                       |       1
1                       |       1
0                       |       0
1                       |       1
0                       |       0
0                       |       0
1                       |       1
1                       |       1
1                       |       1
1                       |       1
1                       |       1
0                       |       0
0                       |       0
0                       |       0
0                       |       0
0                       |       0
1                       |       1
0                       |       0
0                       |       0
1                       |       1
-------------------------------------------------
```

```
                Confusion Matrix
  ---------------------------------------------
 |                       |                     |
 |                       |                     |
 |          10           |          0          |        10
 |                       |                     |
 |                       |                     |
  ---------------------------------------------
 |                       |                     |
 |                       |                     |
 |          0            |          10         |        10
 |                       |                     |
 |                       |                     |
  ---------------------------------------------
            10                      10                20

Accuracy : 1.0
```

```
---------- Round : 7 ----------
Desired Output          |       Predict
-----------------------------------------------
1                       |       0
1                       |       1
1                       |       1
0                       |       0
0                       |       0
1                       |       1
0                       |       0
0                       |       0
1                       |       1
1                       |       1
1                       |       1
1                       |       1
1                       |       1
1                       |       1
1                       |       1
0                       |       0
1                       |       0
1                       |       1
1                       |       1
1                       |       1
-----------------------------------------------
```

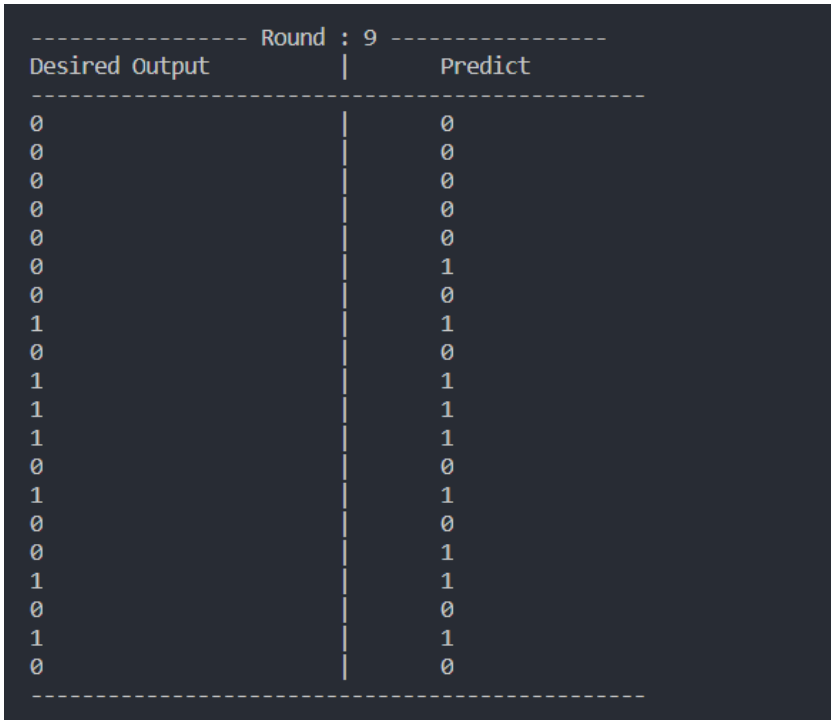
```
                Confusion Matrix
  ---------------------------------------------
 |                       |                     |
 |                       |                     |
 |          5            |          0          |        5
 |                       |                     |
 |                       |                     |
  ---------------------------------------------
 |                       |                     |
 |                       |                     |
 |          2            |          13         |        15
 |                       |                     |
 |                       |                     |
  ---------------------------------------------
            7                       13                20

 Accuracy : 0.9
```

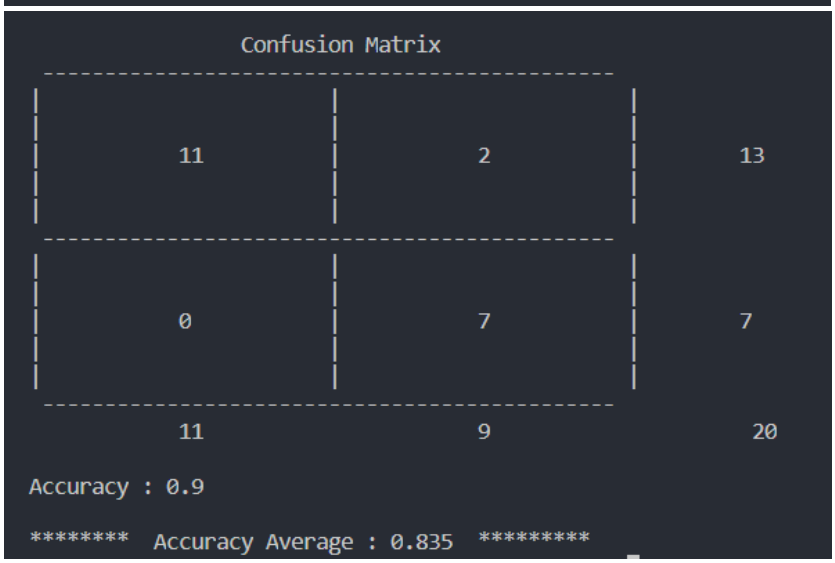
```
---------- Round : 8 ----------
Desired Output          |       Predict
-------------------------------------------------
1                       |       1
0                       |       0
1                       |       1
0                       |       0
1                       |       0
1                       |       0
1                       |       0
0                       |       0
1                       |       1
0                       |       0
1                       |       1
1                       |       1
0                       |       0
0                       |       0
0                       |       0
1                       |       1
0                       |       0
0                       |       0
0                       |       0
1                       |       1
-------------------------------------------------
```

```
                Confusion Matrix
 ---------------------------------------------
|                       |                     |
|                       |                     |
|          10           |          0          |        10
|                       |                     |
|                       |                     |
 ---------------------------------------------
|                       |                     |
|                       |                     |
|          3            |          7          |        10
|                       |                     |
|                       |                     |
 ---------------------------------------------
           13                       7                  20

Accuracy : 0.85
```



```
---------- Round : 9 ----------
Desired Output          |       Predict
-----------------------------------------------
0                       |       0
0                       |       0
0                       |       0
0                       |       0
0                       |       0
0                       |       1
0                       |       0
1                       |       1
0                       |       0
1                       |       1
1                       |       1
1                       |       1
0                       |       0
1                       |       1
0                       |       0
0                       |       1
1                       |       1
0                       |       0
1                       |       1
0                       |       0
-----------------------------------------------
```



```
                Confusion Matrix
 ---------------------------------------------
|                       |                     |
|                       |                     |
|          11           |          2          |        13
|                       |                     |
|                       |                     |
 ---------------------------------------------
|                       |                     |
|                       |                     |
|          0            |          7          |        7
|                       |                     |
|                       |                     |
 ---------------------------------------------
           11                       9                 20

Accuracy : 0.9

********  Accuracy Average : 0.835  *********
```

**วิเคราะห์ ผลการทดลองที่ 1 :**

จากผลการทดลอง จะเห็นได้ว่าเมื่อเพิ่มจำนวน hidden layers ทำให้ได้ ค่าเฉลี่ย accuracy ที่มากที่สุด เป็น 1 ซึ่งเป็นผลที่ดีมาก แต่ในทางกลับกันก็มีค่า accuracy ที่ได้ 0.4 เช่นกัน ซึ่งเป็นค่าที่น้อยกว่า กรณีที่เป็น 1 hidden layer เสียอีก จึงทำให้สรุปได้ว่า การเพิ่ม hidden layer นั้นมีผลต่อ accuracy แต่การเพิ่มเท่าไหร่นั้น ก็ต้องมาพิจารณาจากหลายๆปัจจัย(learning rate, mometum rate) ซึ่งไม่ใช่ว่า ยิ่ง hidden node เยอะยิ่งดี แต่อาจจะ ยิ่งแย่ลงก็ได้

**การทดลองที่ 2 :** ทดลองปรับเปลี่ยนค่า learning rate
ได้ผลออกมาดังนี้

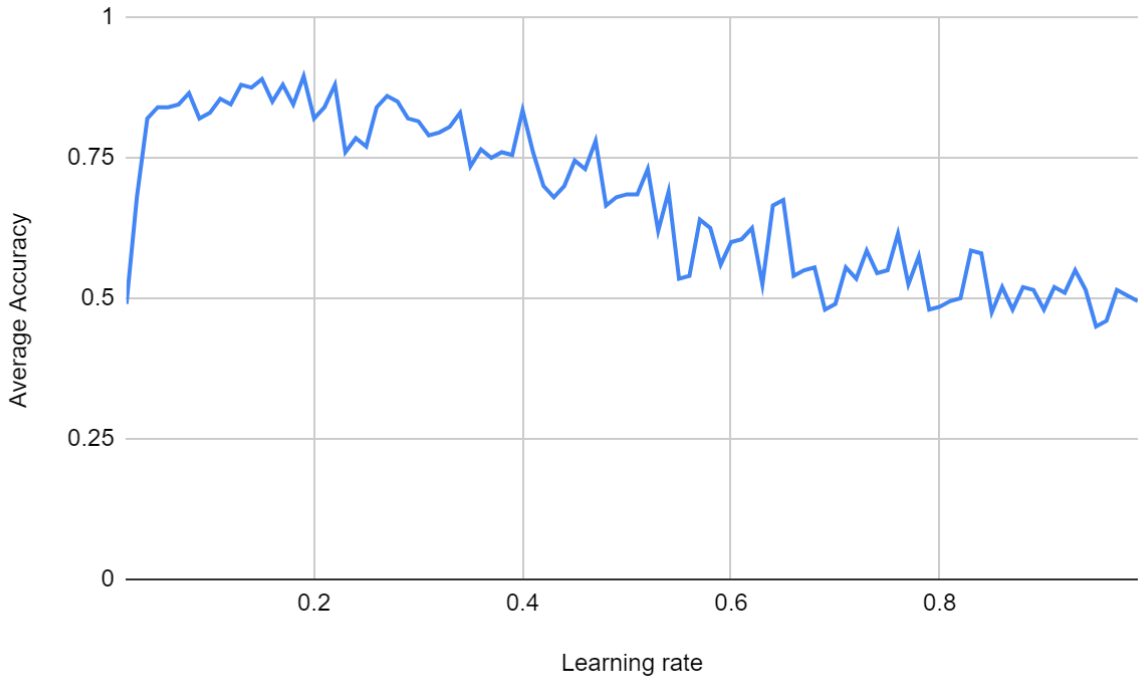
| Neural | | | | learning rate | momentum rate | #epoch | avg accuracy | max accuracy |
|---|---|---|---|---|---|---|---|---|
| 2 | 14 | 9 | 2 | 0.01 | 0.07 | 1000 | 0.49 | 0.65 |
| 2 | 14 | 9 | 2 | 0.02 | 0.07 | 1000 | 0.68 | 0.9 |
| 2 | 14 | 9 | 2 | 0.03 | 0.07 | 1000 | 0.82 | 0.95 |
| 2 | 14 | 9 | 2 | 0.04 | 0.07 | 1000 | 0.84 | 0.95 |
| 2 | 14 | 9 | 2 | 0.05 | 0.07 | 1000 | 0.84 | 0.95 |
| 2 | 14 | 9 | 2 | 0.06 | 0.07 | 1000 | 0.845 | 1 |
| 2 | 14 | 9 | 2 | 0.07 | 0.07 | 1000 | 0.865 | 0.95 |
| 2 | 14 | 9 | 2 | 0.08 | 0.07 | 1000 | 0.82 | 0.9 |
| 2 | 14 | 9 | 2 | 0.09 | 0.07 | 1000 | 0.83 | 1 |
| 2 | 14 | 9 | 2 | 0.1 | 0.07 | 1000 | 0.855 | 0.95 |
| 2 | 14 | 9 | 2 | 0.11 | 0.07 | 1000 | 0.845 | 0.9 |
| 2 | 14 | 9 | 2 | 0.12 | 0.07 | 1000 | 0.88 | 1 |
| 2 | 14 | 9 | 2 | 0.13 | 0.07 | 1000 | 0.875 | 1 |
| 2 | 14 | 9 | 2 | 0.14 | 0.07 | 1000 | 0.89 | 1 |
| 2 | 14 | 9 | 2 | 0.15 | 0.07 | 1000 | 0.85 | 1 |
| 2 | 14 | 9 | 2 | 0.16 | 0.07 | 1000 | 0.88 | 0.95 |
| 2 | 14 | 9 | 2 | 0.17 | 0.07 | 1000 | 0.845 | 1 |
| 2 | 14 | 9 | 2 | 0.18 | 0.07 | 1000 | 0.895 | 1 |
| 2 | 14 | 9 | 2 | 0.19 | 0.07 | 1000 | 0.82 | 1 |
| 2 | 14 | 9 | 2 | 0.2 | 0.07 | 1000 | 0.84 | 1 |
| 2 | 14 | 9 | 2 | 0.21 | 0.07 | 1000 | 0.88 | 0.95 |
| 2 | 14 | 9 | 2 | 0.22 | 0.07 | 1000 | 0.76 | 0.85 |
| 2 | 14 | 9 | 2 | 0.23 | 0.07 | 1000 | 0.785 | 0.85 |
| 2 | 14 | 9 | 2 | 0.24 | 0.07 | 1000 | 0.77 | 0.85 |
| 2 | 14 | 9 | 2 | 0.25 | 0.07 | 1000 | 0.84 | 1 |
| 2 | 14 | 9 | 2 | 0.26 | 0.07 | 1000 | 0.86 | 1 |
| 2 | 14 | 9 | 2 | 0.27 | 0.07 | 1000 | 0.85 | 0.95 |
| 2 | 14 | 9 | 2 | 0.28 | 0.07 | 1000 | 0.82 | 0.95 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 14 | 9 | 2 | 0.29 | 0.07 | 1000 | 0.815 | 0.95 |
| 2 | 14 | 9 | 2 | 0.3 | 0.07 | 1000 | 0.79 | 0.9 |
| 2 | 14 | 9 | 2 | 0.31 | 0.07 | 1000 | 0.795 | 0.9 |
| 2 | 14 | 9 | 2 | 0.32 | 0.07 | 1000 | 0.805 | 0.85 |
| 2 | 14 | 9 | 2 | 0.33 | 0.07 | 1000 | 0.83 | 0.9 |
| 2 | 14 | 9 | 2 | 0.34 | 0.07 | 1000 | 0.735 | 0.9 |
| 2 | 14 | 9 | 2 | 0.35 | 0.07 | 1000 | 0.765 | 0.95 |
| 2 | 14 | 9 | 2 | 0.36 | 0.07 | 1000 | 0.75 | 0.95 |
| 2 | 14 | 9 | 2 | 0.37 | 0.07 | 1000 | 0.76 | 0.9 |
| 2 | 14 | 9 | 2 | 0.38 | 0.07 | 1000 | 0.755 | 0.95 |
| 2 | 14 | 9 | 2 | 0.39 | 0.07 | 1000 | 0.835 | 0.95 |
| 2 | 14 | 9 | 2 | 0.4 | 0.07 | 1000 | 0.76 | 0.85 |
| 2 | 14 | 9 | 2 | 0.41 | 0.07 | 1000 | 0.7 | 0.9 |
| 2 | 14 | 9 | 2 | 0.42 | 0.07 | 1000 | 0.68 | 0.95 |
| 2 | 14 | 9 | 2 | 0.43 | 0.07 | 1000 | 0.7 | 0.95 |
| 2 | 14 | 9 | 2 | 0.44 | 0.07 | 1000 | 0.745 | 0.95 |
| 2 | 14 | 9 | 2 | 0.45 | 0.07 | 1000 | 0.73 | 0.9 |
| 2 | 14 | 9 | 2 | 0.46 | 0.07 | 1000 | 0.78 | 1 |
| 2 | 14 | 9 | 2 | 0.47 | 0.07 | 1000 | 0.665 | 0.9 |
| 2 | 14 | 9 | 2 | 0.48 | 0.07 | 1000 | 0.68 | 0.95 |
| 2 | 14 | 9 | 2 | 0.49 | 0.07 | 1000 | 0.685 | 0.85 |
| 2 | 14 | 9 | 2 | 0.5 | 0.07 | 1000 | 0.685 | 0.95 |
| 2 | 14 | 9 | 2 | 0.51 | 0.07 | 1000 | 0.73 | 0.95 |
| 2 | 14 | 9 | 2 | 0.52 | 0.07 | 1000 | 0.62 | 0.95 |
| 2 | 14 | 9 | 2 | 0.53 | 0.07 | 1000 | 0.69 | 0.95 |
| 2 | 14 | 9 | 2 | 0.54 | 0.07 | 1000 | 0.535 | 0.65 |
| 2 | 14 | 9 | 2 | 0.55 | 0.07 | 1000 | 0.54 | 0.8 |
| 2 | 14 | 9 | 2 | 0.56 | 0.07 | 1000 | 0.64 | 0.85 |
| 2 | 14 | 9 | 2 | 0.57 | 0.07 | 1000 | 0.625 | 0.9 |
| 2 | 14 | 9 | 2 | 0.58 | 0.07 | 1000 | 0.56 | 0.8 |
| 2 | 14 | 9 | 2 | 0.59 | 0.07 | 1000 | 0.6 | 0.85 |
| 2 | 14 | 9 | 2 | 0.6 | 0.07 | 1000 | 0.605 | 0.85 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 14 | 9 | 2 | 0.61 | 0.07 | 1000 | 0.625 | 0.8 |
| 2 | 14 | 9 | 2 | 0.62 | 0.07 | 1000 | 0.525 | 0.75 |
| 2 | 14 | 9 | 2 | 0.63 | 0.07 | 1000 | 0.665 | 0.95 |
| 2 | 14 | 9 | 2 | 0.64 | 0.07 | 1000 | 0.675 | 0.8 |
| 2 | 14 | 9 | 2 | 0.65 | 0.07 | 1000 | 0.54 | 0.65 |
| 2 | 14 | 9 | 2 | 0.66 | 0.07 | 1000 | 0.55 | 0.8 |
| 2 | 14 | 9 | 2 | 0.67 | 0.07 | 1000 | 0.555 | 0.75 |
| 2 | 14 | 9 | 2 | 0.68 | 0.07 | 1000 | 0.48 | 0.7 |
| 2 | 14 | 9 | 2 | 0.69 | 0.07 | 1000 | 0.49 | 0.65 |
| 2 | 14 | 9 | 2 | 0.7 | 0.07 | 1000 | 0.555 | 0.9 |
| 2 | 14 | 9 | 2 | 0.71 | 0.07 | 1000 | 0.535 | 0.7 |
| 2 | 14 | 9 | 2 | 0.72 | 0.07 | 1000 | 0.585 | 0.75 |
| 2 | 14 | 9 | 2 | 0.73 | 0.07 | 1000 | 0.545 | 0.75 |
| 2 | 14 | 9 | 2 | 0.74 | 0.07 | 1000 | 0.55 | 0.7 |
| 2 | 14 | 9 | 2 | 0.75 | 0.07 | 1000 | 0.615 | 0.8 |
| 2 | 14 | 9 | 2 | 0.76 | 0.07 | 1000 | 0.525 | 0.8 |
| 2 | 14 | 9 | 2 | 0.77 | 0.07 | 1000 | 0.575 | 0.7 |
| 2 | 14 | 9 | 2 | 0.78 | 0.07 | 1000 | 0.48 | 0.65 |
| 2 | 14 | 9 | 2 | 0.79 | 0.07 | 1000 | 0.485 | 0.75 |
| 2 | 14 | 9 | 2 | 0.8 | 0.07 | 1000 | 0.495 | 0.65 |
| 2 | 14 | 9 | 2 | 0.81 | 0.07 | 1000 | 0.5 | 0.65 |
| 2 | 14 | 9 | 2 | 0.82 | 0.07 | 1000 | 0.585 | 0.75 |
| 2 | 14 | 9 | 2 | 0.83 | 0.07 | 1000 | 0.58 | 0.8 |
| 2 | 14 | 9 | 2 | 0.84 | 0.07 | 1000 | 0.475 | 0.65 |
| 2 | 14 | 9 | 2 | 0.85 | 0.07 | 1000 | 0.52 | 0.8 |
| 2 | 14 | 9 | 2 | 0.86 | 0.07 | 1000 | 0.48 | 0.65 |
| 2 | 14 | 9 | 2 | 0.87 | 0.07 | 1000 | 0.52 | 0.8 |
| 2 | 14 | 9 | 2 | 0.88 | 0.07 | 1000 | 0.515 | 0.65 |
| 2 | 14 | 9 | 2 | 0.89 | 0.07 | 1000 | 0.48 | 0.7 |
| 2 | 14 | 9 | 2 | 0.9 | 0.07 | 1000 | 0.52 | 0.7 |
| 2 | 14 | 9 | 2 | 0.91 | 0.07 | 1000 | 0.51 | 0.9 |
| 2 | 14 | 9 | 2 | 0.92 | 0.07 | 1000 | 0.55 | 0.75 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 14 | 9 | 2 | 0.93 | 0.07 | 1000 | 0.515 | 0.75 |
| 2 | 14 | 9 | 2 | 0.94 | 0.07 | 1000 | 0.45 | 0.6 |
| 2 | 14 | 9 | 2 | 0.95 | 0.07 | 1000 | 0.46 | 0.6 |
| 2 | 14 | 9 | 2 | 0.96 | 0.07 | 1000 | 0.515 | 0.8 |
| 2 | 14 | 9 | 2 | 0.97 | 0.07 | 1000 | 0.505 | 0.6 |
| 2 | 14 | 9 | 2 | 0.98 | 0.07 | 1000 | 0.495 | 0.65 |
| 2 | 14 | 9 | 2 | 0.99 | 0.07 | 1000 | 0.5 | 0.6 |

**วิเคราะห์ ผลการทดลองที่ 2 :**




จากกราฟ เมื่อพิจารการเพิ่ม learning rate จากตอนแรกที่ learning rate น้อยมากๆ จะทำให้ได้ accuracy น้อมาก โดยประมาณ 0.5 แต่เมื่อเพิ่มมาได้จำนวนหนึ่ง ทำให้ได้ค่า accuracy ที่สูงมาก แต่เมื่อเพิ่มไปอีกกลับทำให้ได้ accuracy ที่ต่ำลง ซึ่งมีผลเหมือนกันกับ ข้อมูลการทดลองที่ 1 ซึ่งจะสรุปได้ว่า ต้องทำการเพิ่ม learning rate ให้ไม่มาก หรือ น้อย จนเกินไป จะทำให้ได้ accuracy ที่ดีที่สุด

**การทดลองที่ 3** : ทดลองปรับเปลี่ยนค่า momentum rate
ได้ผลออกมาดังนี้

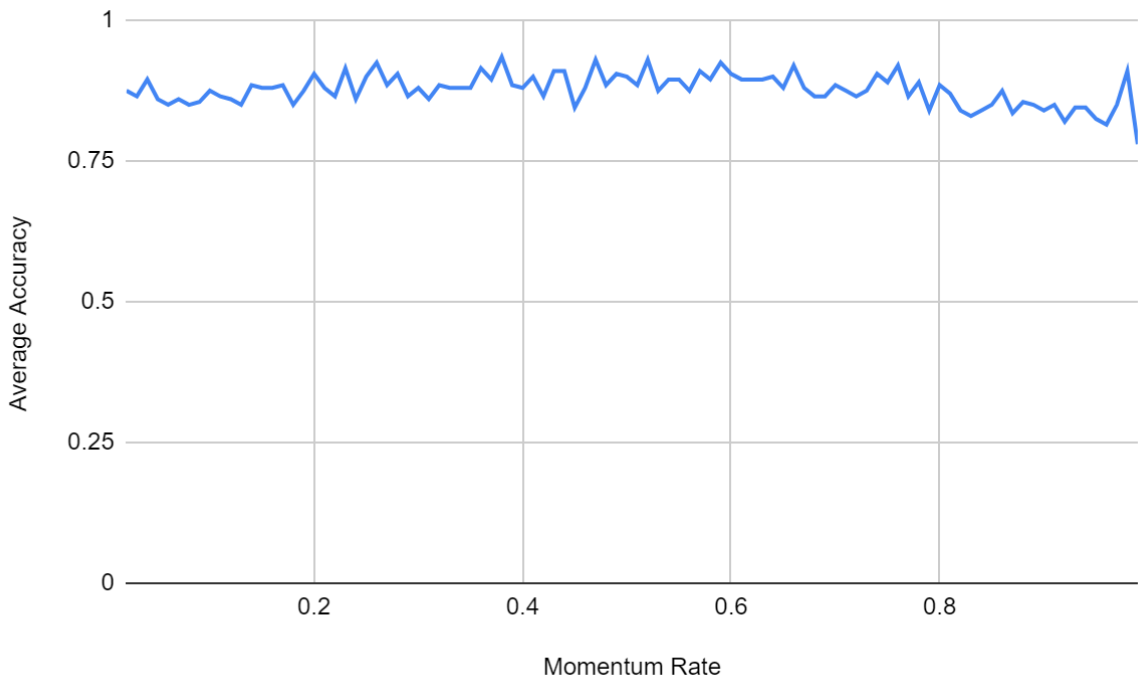
| Neural | | | | learning rate | momentum rate | #epoch | avg accuracy | max accuracy |
|---|---|---|---|---|---|---|---|---|
| 2 | 14 | 9 | 2 | 0.12 | 0.01 | 1000 | 0.875 | 0.9 |
| 2 | 14 | 9 | 2 | 0.12 | 0.02 | 1000 | 0.865 | 0.9 |
| 2 | 14 | 9 | 2 | 0.12 | 0.03 | 1000 | 0.895 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.04 | 1000 | 0.86 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.05 | 1000 | 0.85 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.06 | 1000 | 0.86 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.07 | 1000 | 0.85 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.08 | 1000 | 0.855 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.09 | 1000 | 0.875 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.1 | 1000 | 0.865 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.11 | 1000 | 0.86 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.12 | 1000 | 0.85 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.13 | 1000 | 0.885 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.14 | 1000 | 0.88 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.15 | 1000 | 0.88 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.16 | 1000 | 0.885 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.17 | 1000 | 0.85 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.18 | 1000 | 0.875 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.19 | 1000 | 0.905 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.2 | 1000 | 0.88 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.21 | 1000 | 0.865 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.22 | 1000 | 0.915 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.23 | 1000 | 0.86 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.24 | 1000 | 0.9 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.25 | 1000 | 0.925 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.26 | 1000 | 0.885 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.27 | 1000 | 0.905 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.28 | 1000 | 0.865 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.29 | 1000 | 0.88 | 0.95 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 14 | 9 | 2 | 0.12 | 0.3 | 1000 | 0.86 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.31 | 1000 | 0.885 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.32 | 1000 | 0.88 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.33 | 1000 | 0.88 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.34 | 1000 | 0.88 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.35 | 1000 | 0.915 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.36 | 1000 | 0.895 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.37 | 1000 | 0.935 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.38 | 1000 | 0.885 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.39 | 1000 | 0.88 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.4 | 1000 | 0.9 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.41 | 1000 | 0.865 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.42 | 1000 | 0.91 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.43 | 1000 | 0.91 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.44 | 1000 | 0.845 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.45 | 1000 | 0.88 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.46 | 1000 | 0.93 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.47 | 1000 | 0.885 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.48 | 1000 | 0.905 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.49 | 1000 | 0.9 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.5 | 1000 | 0.885 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.51 | 1000 | 0.93 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.52 | 1000 | 0.875 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.53 | 1000 | 0.895 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.54 | 1000 | 0.895 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.55 | 1000 | 0.875 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.56 | 1000 | 0.91 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.57 | 1000 | 0.895 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.58 | 1000 | 0.925 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.59 | 1000 | 0.905 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.6 | 1000 | 0.895 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.61 | 1000 | 0.895 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 14 | 9 | 2 | 0.12 | 0.62 | 1000 | 0.895 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.63 | 1000 | 0.9 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.64 | 1000 | 0.88 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.65 | 1000 | 0.92 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.66 | 1000 | 0.88 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.67 | 1000 | 0.865 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.68 | 1000 | 0.865 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.69 | 1000 | 0.885 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.7 | 1000 | 0.875 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.71 | 1000 | 0.865 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.72 | 1000 | 0.875 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.73 | 1000 | 0.905 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.74 | 1000 | 0.89 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.75 | 1000 | 0.92 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.76 | 1000 | 0.865 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.77 | 1000 | 0.89 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.78 | 1000 | 0.84 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.79 | 1000 | 0.885 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.8 | 1000 | 0.87 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.81 | 1000 | 0.84 | 0.9 |
| 2 | 14 | 9 | 2 | 0.12 | 0.82 | 1000 | 0.83 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.83 | 1000 | 0.84 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.84 | 1000 | 0.85 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.85 | 1000 | 0.875 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.86 | 1000 | 0.835 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.87 | 1000 | 0.855 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.88 | 1000 | 0.85 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.89 | 1000 | 0.84 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.9 | 1000 | 0.85 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.91 | 1000 | 0.82 | 0.9 |
| 2 | 14 | 9 | 2 | 0.12 | 0.92 | 1000 | 0.845 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.93 | 1000 | 0.845 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 14 | 9 | 2 | 0.12 | 0.94 | 1000 | 0.825 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.95 | 1000 | 0.815 | 0.9 |
| 2 | 14 | 9 | 2 | 0.12 | 0.96 | 1000 | 0.85 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.97 | 1000 | 0.91 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.98 | 1000 | 0.78 | 0.9 |
| 2 | 14 | 9 | 2 | 0.12 | 0.99 | 1000 | 0.85 | 0.95 |

**วิเคราะห์ ผลการทดลองที่ 3 :**

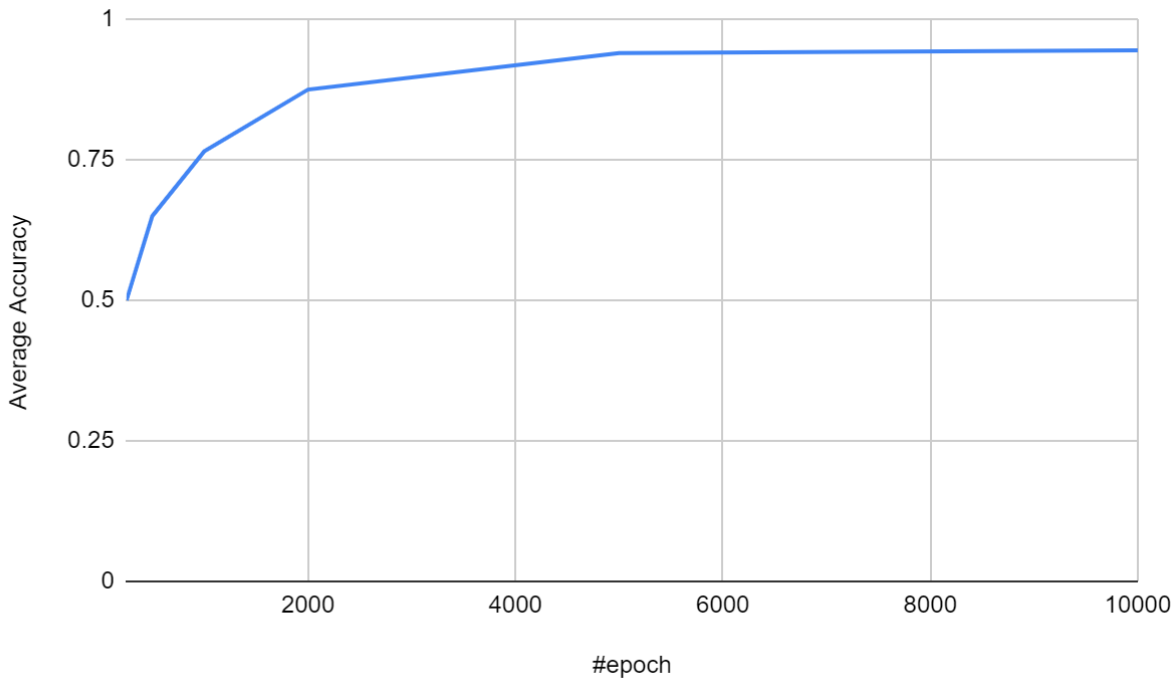



จากกราฟจะเห็นว่า accuracy ที่ได้นั้น ในช่วงแรกที่ momentum น้อยๆนั้น จะทำให้ได้ accuracy ที่ ต่ำกว่า ช่วงกลางที่มี momentum เยอะกว่า และในอีกด้านก็เช่นกัน ในช่วงที่ momentum มากๆนั้นก็น้อยกว่า momentum ในช่วงกลางเช่นกัน ถึงแม้ว่า จะเป็นจำนวน accuracy ที่ต่างกันไม่มากนักแต่การได้ ผล accuracy ที่ดีขึ้นก็เป็นเรื่องที่ดี จึงสรุปได้ว่า ไม่ควรปรับ momentum rate ให้มากหรือน้อยเกินไป ซึ่งอาจทำให้ได้ accuracy ที่น้อยลง

**ผลการทดลองที่ 4 :** ทดลองปรับจำนวนรอบการ train ของ neural network
ได้ผลออกมาดังนี้

| Nueral | | | | learning rate | momentum rate | #epoch | avg accuracy | max accuracy |
|---|---|---|---|---|---|---|---|---|
| 2 | 14 | 9 | 2 | 0.12 | 0.07 | 100 | 0.5 | 0.65 |
| 2 | 14 | 9 | 2 | 0.12 | 0.07 | 250 | 0.65 | 0.9 |
| 2 | 14 | 9 | 2 | 0.12 | 0.07 | 500 | 0.765 | 0.95 |
| 2 | 14 | 9 | 2 | 0.12 | 0.07 | 1000 | 0.875 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.07 | 2000 | 0.94 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.07 | 5000 | 0.945 | 1 |
| 2 | 14 | 9 | 2 | 0.12 | 0.07 | 10000 | 0.945 | 1 |

**วิเคราะห์ ผลการทดลองที่ 4 :**




จากกราฟ จะเห็นได้ว่า เมื่อเพิ่มจำนวนรอบการ train ขึ้น จะยิ่งทำให้ได้ accuracy ที่ดีขึ้น

## Code :

```
#!/usr/bin/env python
# coding: utf-8

import numpy as np

def load_txt(path):
    f=open(path, "r")
    if(path[-3:] == 'txt'):
        contents =f.readlines()

        dataset = np.zeros((len(contents)-2,len(contents[2].split('\t'))-1))
        label = np.zeros((len(contents)-2))

        for i in range(len(contents)-2):
            x = contents[i+2].split("\t")
            for j in range(len(x)):
                if j != len(x) - 1 :
                    dataset[i][j] = float(x[j])
                else :
                    label[i] = float(x[j][:-1])
    else :
        contents =f.readlines()
        n_data = int(len(contents)/3)
        dataset = np.zeros((n_data,2))
        label = np.zeros((n_data,2))
        j = 0
        count = 0
        for i in range(len(contents)):
            if(j == 1):
                dataset[count][0] = float(contents[i].split()[0])
                dataset[count][1] = float(contents[i].split()[1])
            if(j == 2):
                label[count][0] = int(contents[i].split()[0])
                label[count][1] = int(contents[i].split()[1])
                count = count + 1
                j = -1
            j += 1

    return dataset,label
```

```
def norm(data_r):
    data = data_r.copy()
    if data.ndim != 1:
        maxx = [0]*len(data[0])
        minn = [9999]*len(data[0])

        for i in range(len(data[0])):
            for j in range(len(data)):
                if(data[j][i] > maxx[i]):
                    maxx[i] = data[j][i]
                if(data[j][i] < minn[i]):
                    minn[i] = data[j][i]

        for i in range(len(data[0])):
            for j in range(len(data)):
                data[j][i] = (data[j][i]-minn[i])/(maxx[i]-minn[i])
    else :
        maxx = 0
        minn = 0
        for j in range(len(data)):
            if(data[j] > maxx):
                maxx = data[j]
            if(data[j] < minn):
                minn = data[j]
        for j in range(len(data)):
            data[j] = (data[j]-minn)/(maxx-minn)
    return data,maxx,minn

def convert_norm(pred,mx,mn):
    return pred*(mx - mn) + mn

import numpy as np
class NN :

    def __init__(self,shape,nueral_shape,acti_funct):
        shape[1:1] = nueral_shape
        self.shape = shape
        self.act_func = acti_funct
        self.weights = self.init_weights(self.shape)
        self.outputs = None
        self.deltas = None
        self.del_old_weights = None
```

```
        def init_old_weights(self,network_shape):
            weight_arrays = []
            for i in range(0, len(network_shape) - 1):
                cur_idx = i
                next_idx = i + 1
                weight_array = np.zeros((network_shape[next_idx], network_shape[cur_idx]))
                weight_arrays.append(weight_array)

            return weight_arrays

        def init_weights(self,network_shape):
            weight_arrays = []
            for i in range(0, len(network_shape) - 1):
                cur_idx = i
                next_idx = i + 1
                weight_array = 2*np.random.rand(network_shape[next_idx],
network_shape[cur_idx]) - 1
                weight_arrays.append(weight_array)

            return weight_arrays


        def predict(self,sample):

            current_input =  (sample.copy()).T
            outputs = []
            for network_weight in self.weights:
                current_output_temp = np.dot(network_weight, current_input)
                current_output = self.acti_funct(current_output_temp)
                outputs.append(current_output)
                current_input = current_output

            if(self.shape[-1] == 1) :
                return current_output.T
            else :
                tp = None
                fp = None
                for i in range(len(outputs[-1])):
                    if( i == 0) :
                        tp = outputs[-1][i]
                    else :
```

```
            fp = outputs[-1][i]
            tp = np.vstack((tp, fp)).T
        return np.argmax(tp, axis=1)

def train(self,sample, d_out, training_rate,momentum_rate,epoch,show=True):
    sample_T = (sample.copy()).T
    d_out_T = (d_out.copy()).T
    for i in range(epoch):
        self.FW_NN(sample_T)
        self.BW_NN(d_out_T)
        self.update_weights(sample_T,learning_rate,momentum_rate,i)
        sqe = self.sum_sqaure_error(self.predict(sample),d_out_T)
        if(show and i % 10 == 0):
            print('Epoch : #'+str(i)+',  Sum Square Error : '+str(sqe))
        if sqe < np.finfo(np.float32).eps :
            break

def FW_NN(self,input):

    current_input = input
    outputs = []
    for w in self.weights:
        current_output_tmp = np.dot(w, current_input)
        current_output = self.acti_funct(current_output_tmp)
        outputs.append(current_output)
        current_input = current_output
    self.outputs = outputs

def BW_NN(self,d_out):

    deltas = []
    O_error = d_out - self.outputs[len(self.outputs)-1]
    O_delta = O_error *self.derivertive_acti_funct(self.outputs[len(self.outputs)-1])
    deltas.append(O_delta)

    cur_delta = O_delta
    back_idx = len(self.outputs) - 2

    for w in self.weights[::-1][:-1]:
        hidd_error = np.dot(w.T, cur_delta)
        hidd_delta = hidd_error * self.derivertive_acti_funct(self.outputs[back_idx])
        deltas.append(hidd_delta)
```

```
                cur_delta = hidd_delta
                back_idx -= 1

            self.deltas = deltas

        def update_weights(self,sample,learning_rate,momentum_rate,count):
            index_current_weight = len(self.weights) - 1
            current_dels = []
            for d in self.deltas:
                sample_used = None
                if index_current_weight - 1 < 0:
                    sample_used = sample
                else:
                    sample_used = self.outputs[index_current_weight - 1]

                current_delta = learning_rate*np.dot(d, sample_used.T)

                if(count == 0) :
                    self.weights[index_current_weight] +=  current_delta
                else :
                    self.weights[index_current_weight] +=
momentum_rate*self.del_old_weights[index_current_weight]+ current_delta
                index_current_weight -= 1
                current_dels.insert(0, current_delta)

            self.del_old_weights = current_dels

        def acti_funct(self,v):
            if self.act_func == 'sigmoid' :
                return 1 / (1 + np.exp(-v))
            if self.act_func == 'tanh' :
                return np.tanh(v)
            if self.act_func == 'linear' :
                return v
            return v

        def derivertive_acti_funct(self,v):
            if self.act_func == 'sigmoid' :
                return v * (1 - v)
            if self.act_func == 'tanh' :
                return 1 - (v ** 2)
            if self.act_func == 'linear' :
```

```
                return 1
            return v


        def sum_sqaure_error(self,pred,real):
            real_m = real.copy()
            sums = 0
            if(real.ndim > 1) :
                tp = None
                fp = None
                for i in range(len(real_m)):
                    if( i == 0) :
                        tp = real_m[i]
                    else :
                        fp = real_m[i]
                        tp = np.vstack((tp, fp)).T
                real_m = np.argmax(tp, axis=1)
            for i in range(len(pred)):
                sums = sums + np.square(pred[i]-real_m[i])
            return sums/2

        def conf_matrix(self,pred,true,is_norm=False,confuse=True):
            true_m = np.zeros(len(true))
            if(true.ndim > 1) :
                for i in range(len(true)):
                    true_m[i] = np.argmax(true[i], axis=0)
            if(is_norm):
                sqr_error = 0
                print('Desired Output\t\t|\tPredict\t\t\t|\tError')
                print('------------------------------------------------------------------------------')
                for i in range(len(true)):
                    error = round(true[i] - round(pred[i][0],8),2)
                    print(str(int(true[i]))+'\t\t\t|\t'+str(format(round(pred[i][0],8),
'.8f'))+'\t\t|\t'+str(error))
                    sqr_error = sqr_error + (error * error)
                print('------------------------------------------------------------------------------')
                print('\t\t Mean Square Error = '+str(round(sqr_error/len(true),6)))

print('==============================================================
==============')
                return round(sqr_error/len(true),6)
            else :
```

```
            print('Desired Output\t\t|\tPredict\t\t\t')
            print('------------------------------------------------')
            for i in range(len(true)):
                print(str(int(true_m[i]))+'\t\t\t|\t'+str(pred[i]))
            print('------------------------------------------------')
        if(confuse):
            print('\n\t\t Confusion Matrix')
            TP = 0
            FN = 0
            FP = 0
            TN = 0
            for i in range(len(true)):
                if((pred[i] == 0) and ( true_m[i] == 0)):
                    TN = TN + 1
                elif((pred[i] == 1) and ( true_m[i] == 1)):
                    TP = TP + 1
                elif((pred[i] == 1) and ( true_m[i] == 0)):
                    FP = FP + 1
                else :
                    FN = FN + 1

            print(' ------------------------------------------------ ')
            for i in range(8):
                print('|\t\t\t|\t\t\t|')
                if(i == 1):
                    print('|\t    '+str(TN)+'\t\t|\t    '+str(FP)+'\t\t|\t '+str(FP+TN))
                if(i == 3):
                    print(' ------------------------------------------------')
                if(i == 5):
                    print('|\t    '+str(FN)+'\t\t|\t    '+str(TP)+'\t\t|\t '+str(FN+TP))
            print(' ------------------------------------------------')
            print(' \t    '+str(TN+FN)+'\t\t\t    '+str(FP+TP)+'\t\t\t  '+str(TN+FP+FN+TP))
            print('')
            print('Accuracy : '+str((TN+TP)/(TN+FP+FN+TP)))
            return((TN+TP)/(TN+FP+FN+TP))

    def load_data(name,cross):
        is_norm = False
        if(name  == 1):
            dataset,label = load_txt("./Flood_dataset.txt")
            dataset,mx_dataset,mn_dataset = norm(dataset)
            label,mx_label,mn_label = norm(label)
```

```
            is_norm = True
            max_min = [mx_dataset,mn_dataset,mx_label,mn_label]
        else :
            dataset,label = load_txt("./cross.pat")
        n_sample = np.arange(len(dataset))
        np.random.shuffle(n_sample)
        if(is_norm) :
            return dataset,label,n_sample,max_min
        else :
            return dataset,label,n_sample


    def
MLP(Neural,learning_rate,momentum_rate,activation,epoch,cross_valda_train_test,data_num) :
        if(data_num == 0):
            print('-------------------- Variable --------------------\n')
            dataset,label,n_sample = load_data(data_num,cross_valda_train_test)
            data_name = 'cross.pat'
        else :
            print('\n-------------------------------- Variable --------------------------------\n')
            dataset,label,n_sample,max_min = load_data(data_num,cross_valda_train_test)
            data_name = 'Flood data set'
        n_test_per_round = int(len(dataset)*cross_valda_train_test[1]/100)
        print('Datafile : ' +str(data_name),end='\n')
        print('Neural name : '+str(len(dataset[0]))+'-',end='')
        for i in range(len(Neural)):
            print(str(Neural[i])+'-',end='')
        print(label.ndim,end='\n')
        print('Learning rate : '+str(learning_rate),end='\n')
        print('Momentum rate : '+str(momentum_rate),end='\n')
        print('Activaion Function : ' +str(activation),end='\n')
        print('Cross validation : ['+str(cross_valda_train_test[0])+' :
'+str(cross_valda_train_test[1])+']',end='\n')
        print('#Epoch : '+str(epoch),end='\n')
        error_avg = []
        acc_avg = []
        for i in range(10):
            test_data = n_sample[i*n_test_per_round:i*n_test_per_round+n_test_per_round]
            train_data = list(set(n_sample) - set(test_data))
            nn = NN([len(dataset[0]),label.ndim],Neural,activation)

nn.train(dataset[train_data],label[train_data],learning_rate,momentum_rate,epoch,False)
```

```
                pred = nn.predict(dataset[test_data])
                if(data_num == 1):
                    print('\n------------------------------- Round : '+str(i)+' -------------------------------')
                    pred = convert_norm(pred,max_min[2],max_min[3])
                    test_label = convert_norm(label[test_data],max_min[2],max_min[3])
                    error_avg.append(nn.conf_matrix(pred,test_label,is_norm=True,confuse=False))
                else :
                    print('\n----------------- Round : '+str(i)+' -----------------')

acc_avg.append(nn.conf_matrix(pred,label[test_data],is_norm=False,confuse=True))
            if(data_num == 1):
                print('\n********  Mean Square Error Average : ' +
str(round(np.sum(error_avg)/len(error_avg),4))+'  *********')
            else :
                print('\n********  Accuracy Average : ' +
str(round(np.sum(acc_avg)/len(acc_avg),4))+'  *********')


        Neural = [10,6]
        cross_valda_train_test = [90,10] # train 90 , test 10
        data_num = 1 # 0 = cross.pat , 1 = flood data set
        learning_rate = 0.12
        momentum_rate = 0.07
        activation = 'sigmoid'
        epoch = 1000
        MLP(Neural,learning_rate,momentum_rate,activation,epoch,cross_valda_train_test,data
_num)
```