

Computer Assignment 4
CPE 261456 (Introduction to Computational Intelligence)

โดย

นายธนาคม หัสแดง
รหัสนักศึกษา 590610624

เสนอ
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ลักษณะการทำงานของระบบ :

เริ่มต้นด้วยการรับ Input มาโดยจะเป็นไฟล์ excel จะเก็บเฉพาะข้อมูลใน column ที่ 3 6 8 10 11 12 13 14 ไว้เป็นข้อมูลในการ train และ เก็บ column ที่ 5 ไว้เป็น desire output โดยหลักการของโปรแกรมเริ่มจากการกำหนดค่า $c1$ $c2$ และ W เสียก่อน โดนปกติ $c1+c2 < 4$ และ $W < 1$ โดยหลังจากนั้นกำหนด ขนาดของ iterations และ particles โดยหลังจากนี้จะทำการแยก cross validation โดยแบ่งข้อมูลออกเป็น test 10% และ train 90% โดยหลังจากได้ข้อมูลมาแล้วจะเริ่มกำหนด structure ของ MLP และเริ่มกำหนดของ Search space โดยจะกำหนด ให้มีการสุ่มค่าตำแหน่งของ g_best และ กำหนดให้ค่า g_best เริ่มต้นเป็น infinity โดยเมื่อกำหนดค่าเริ่มต้นเสร็จแล้วจะ มาตั้งค่าในส่วนของ Particle โดยแต่ละ Particle นั้นจะถูกสุ่ม position โดย position ในที่นี้ จะนำไปใช้เป็น weight ของ MLP ในขั้นตอนต่อไป โดยจะสุ่มให้อยู่ในช่วงของ -1 ถึง 1 และตั้งค่า p_best ให้เป็น infinity โดยทำแบบี้จนครบตามจำนวน Particle หลังจากนั้นจะเริ่มทำการ train โดยจะนำค่า Position ของ Particle แต่ละตัวเข้าไปหาค่า fitness โดยจะเป็นการเข้าสู่ model ของ MLP โดย output จะออกมาเป็นค่า และวัดผลโดยการนำ Desire_output ไปลบกับ ค่าที่ได้ แล้วนำมา absolute บวกกันแล้วหารด้วยจำนวนทั้งหมด โดยถ้าค่า fitness ที่ได้ของ particle นั้นน้อยกว่า p_best ก็จะกำหนดให้ตำแหน่งนั้นเป็น p_best และ ค่า fitness ของ p_best เท่ากันกับ position ของ particle นั้นด้วย โดยจะทำเช่นเดียวกันกับกรณีของ $gbest$ โดยเมื่อทำทั้ง 2 กรณีเสร็จแล้วจะเริ่มทำการเคลื่อนย้าย position โดย จะนำค่า W ก่อนหน้านี้มาคูณกับค่า Velocity ที่กำหนดไว้ให้เป็น ศูนย์ก่อนหน้า และนำไปบวกกับ ผลคูณของ $c1$ กับ ผลลบระหว่าง $pbest$ กับค่า position ของ particle นั้น และ $c2$ กับ ผลลบระหว่าง g_best กับ ค่า position ของ particle นั้น โดยเมื่อได้ค่า Velocity มาแล้วจะนำค่านั้นไป บวกเพิ่มจาก position เดิม และทำการ update ค่า position และ velocity จากเดิมด้วย ทำแบบนี้ไปจนครบตามจำนวน iterations โดยในผลสุดท้ายจะได้ค่า บอกตำแหน่งที่ทำให้ได้ค่า fitness ที่ดีที่สุด และ ตำแหน่ง iteration ที่ดีที่สุดด้วย

Simulator :

- กำหนด Cross validation train 90 % , Test 10%
- $c1 = 1.2$
- $c2 = 1.4$
- $W = (1/2*(c1+c2)-1)+0.3$
- $n_iterations = 10$
- $n_particles = 10$
- $structure = [8,15,1]$

```
----- # Round 0 -----
iteration : #1
----> pbest : [17.87372985]
----> pbest : [17.78525689]
----> pbest : [18.28568152]
----> pbest : [18.02354381]
----> pbest : [17.99631829]
----> pbest : [17.71439598]
----> pbest : [17.90514954]
----> pbest : [18.18850479]
----> pbest : [18.41260694]
----> pbest : [17.95330838]
-----> gbest : 17.71439598208045
iteration : #2
----> pbest : [17.71922416]
----> pbest : [17.76584212]
----> pbest : [18.0972294]
----> pbest : [17.6857842]
----> pbest : [17.84975013]
----> pbest : [17.71439598]
----> pbest : [17.85507597]
----> pbest : [17.91081197]
----> pbest : [17.70710475]
----> pbest : [17.91958755]
-----> gbest : 17.685784201468355
iteration : #3
----> pbest : [17.66079267]
----> pbest : [17.76584212]
----> pbest : [17.65235174]
----> pbest : [17.66582928]
```

```
----> pbest : [17.6716502]
----> pbest : [17.7022003]
----> pbest : [17.69209105]
----> pbest : [17.73301249]
----> pbest : [17.66452288]
----> pbest : [17.67161174]
-----> gbest : 17.652351741317407
iteration : #4
----> pbest : [17.65704659]
----> pbest : [17.65508232]
----> pbest : [17.65235174]
----> pbest : [17.65555719]
----> pbest : [17.64839764]
----> pbest : [17.6698456]
----> pbest : [17.66870886]
----> pbest : [17.65173047]
----> pbest : [17.64874836]
----> pbest : [17.67117804]
-----> gbest : 17.648397644222946
iteration : #5
----> pbest : [17.64575979]
----> pbest : [17.64587166]
----> pbest : [17.64956693]
----> pbest : [17.64902171]
----> pbest : [17.64473673]
----> pbest : [17.64545855]
----> pbest : [17.64611356]
----> pbest : [17.64624743]
----> pbest : [17.64563356]
----> pbest : [17.6451349]
-----> gbest : 17.644736730637224
iteration : #6
----> pbest : [17.64403443]
----> pbest : [17.64400727]
----> pbest : [17.64956693]
----> pbest : [17.64657364]
----> pbest : [17.64360379]
----> pbest : [17.64255145]
----> pbest : [17.64361413]
----> pbest : [17.64341344]
----> pbest : [17.64563356]
----> pbest : [17.6430403]
-----> gbest : 17.64255145151561
iteration : #7
```

```
----> pbest : [17.64316803]
----> pbest : [17.64194799]
----> pbest : [17.64829042]
----> pbest : [17.6434217]
----> pbest : [17.64245646]
----> pbest : [17.64183359]
----> pbest : [17.64260912]
----> pbest : [17.64176144]
----> pbest : [17.64422051]
----> pbest : [17.6430403]
-----> gbest : 17.641761439150297
iteration : #8
----> pbest : [17.64202732]
----> pbest : [17.64140059]
----> pbest : [17.6443326]
----> pbest : [17.6434217]
----> pbest : [17.64245646]
----> pbest : [17.64155795]
----> pbest : [17.64260912]
c:\users\thanakom_hatsadeang\appdata\local\programs\python\python37\lib\site-
packages\ipykernel_launcher.py:39: RuntimeWarning: overflow encountered in ex
p
----> pbest : [17.64176144]
----> pbest : [17.64173741]
----> pbest : [17.6430403]
-----> gbest : 17.641400589351786
iteration : #9
----> pbest : [17.64202732]
----> pbest : [17.64140059]
----> pbest : [17.64430148]
----> pbest : [17.6414339]
----> pbest : [17.64181215]
----> pbest : [17.64155795]
----> pbest : [17.64148083]
----> pbest : [17.64176144]
----> pbest : [17.64120651]
----> pbest : [17.64226463]
-----> gbest : 17.641206505120014
iteration : #10
----> pbest : [17.64202732]
----> pbest : [17.64123435]
----> pbest : [17.6410828]
----> pbest : [17.64115859]
----> pbest : [17.64181215]
```

```

----> pbest : [17.64124548]
----> pbest : [17.64140727]
----> pbest : [17.64145729]
----> pbest : [17.64106528]
----> pbest : [17.64160773]
-----> gbest : 17.641065275129634
The best solution is: [[-2.63379499  4.41547364  1.09323919 -1.39342584  1.2
516736  3.45462124
-3.84950606  2.83257691  1.95573361  3.16776531 -3.40870592 -5.62595074
 3.5275277 -1.74886371 -0.06203647  2.82671741 -2.28651437 -1.94030776
-1.55350529  2.02549334  0.42593572 -5.65348397 -2.69590908  0.60129575
 4.36172909 -1.97180065  2.90071355 -0.51711266 -1.95431334  2.1454045
 0.14745931 -2.0294582  3.77607001  1.98545712 -1.52084159 -3.81550369
-2.99949312  5.1150206  5.22230829  3.36591555  0.3757154 -2.5594551
-3.75391704  2.92170092  5.3218712  1.37628417 -3.40898742  3.77691157
-1.24445348  3.15673897  2.0154715  3.3138115  1.53069582 -2.08443204
 2.98291604 -0.01258459  1.55299585 -1.28286416 -1.30921481 -1.04059739
-1.1617546 -4.5801254 -2.44440504 -0.4120206  3.18935471 -6.244058
-3.02414564  1.77243127 -3.00093476 -2.47779402 -2.18408898 -2.5374266
 2.41115901  0.9494781 -4.109809  2.96304368  4.39405555  0.26137937
 2.27104818 -4.26266937  3.4739103 -3.18925167 -4.6094642 -0.97718225
-1.09066222 -0.7087531 -2.0247777  3.35415823 -1.1522508  5.12185009
 3.07065417 -2.23504426 -1.15447182  1.68546217  5.16677018  0.55037713
-1.02871064 -2.61768632  4.23027449 -2.28216193 -0.96425729 -0.28792228
-2.87142473  2.78074684  1.38872991  2.5966237 -0.84255795  4.29812674
-3.40510535 -1.41737691 -1.05317343 -2.45888545 -2.2301019  0.91137502
 2.81779071 -2.23597284 -1.91987901 -1.75023219 -4.10245547  2.24535106
 1.37449094  2.41245322 -3.11298021  4.86525952  2.32805658  1.49452794
 2.27532278  0.79583596  1.03848767  6.41650449 -1.87852061 -3.56082913
-1.23971473 -0.35949699  2.60873132]] in n_iterations: 10
----- # Round 1 -----
iteration : #1
----> pbest : [18.35199675]
----> pbest : [18.30429306]
----> pbest : [18.14305788]
----> pbest : [17.86680083]
----> pbest : [18.43146923]
----> pbest : [17.81411658]
----> pbest : [18.27198574]
----> pbest : [18.35054127]
----> pbest : [18.38533743]
----> pbest : [18.11466311]
-----> gbest : 17.814116581912558
iteration : #2

```

```
----> pbest : [18.2410586]
----> pbest : [18.11442077]
----> pbest : [17.98412747]
----> pbest : [17.80004536]
----> pbest : [17.95945493]
----> pbest : [17.81411658]
----> pbest : [17.8590371]
----> pbest : [18.17710564]
----> pbest : [18.04385001]
----> pbest : [17.9607119]
-----> gbest : 17.800045360635593
iteration : #3
----> pbest : [17.80664032]
----> pbest : [17.87232868]
----> pbest : [17.98412747]
----> pbest : [17.68869128]
----> pbest : [17.81003416]
----> pbest : [17.809062]
----> pbest : [17.85747241]
----> pbest : [17.7364525]
----> pbest : [17.81676895]
----> pbest : [17.87200701]
-----> gbest : 17.68869128440882
iteration : #4
----> pbest : [17.66352223]
----> pbest : [17.74619159]
----> pbest : [17.98412747]
----> pbest : [17.65973817]
----> pbest : [17.65829774]
----> pbest : [17.6695602]
----> pbest : [17.84026533]
----> pbest : [17.65573752]
----> pbest : [17.70009492]
----> pbest : [17.86803684]
-----> gbest : 17.655737523346204
iteration : #5
----> pbest : [17.64670922]
----> pbest : [17.67760134]
----> pbest : [17.67290793]
----> pbest : [17.65296151]
----> pbest : [17.64408031]
----> pbest : [17.6476024]
----> pbest : [17.68878542]
----> pbest : [17.64732568]
```

```
----> pbest : [17.6602345]
----> pbest : [17.69576731]
-----> gbest : 17.644080310374452
iteration : #6
----> pbest : [17.64282507]
----> pbest : [17.64274781]
----> pbest : [17.64216164]
----> pbest : [17.64358125]
----> pbest : [17.64217978]
----> pbest : [17.64210101]
----> pbest : [17.64267345]
----> pbest : [17.64379784]
----> pbest : [17.64350644]
----> pbest : [17.65670241]
-----> gbest : 17.64210100663585
iteration : #7
----> pbest : [17.64162179]
----> pbest : [17.6412452]
----> pbest : [17.64118338]
----> pbest : [17.64166928]
----> pbest : [17.64165845]
----> pbest : [17.64132482]
----> pbest : [17.64146483]
----> pbest : [17.64162221]
----> pbest : [17.64142529]
----> pbest : [17.64118173]
-----> gbest : 17.64118173251054
iteration : #8
----> pbest : [17.64142719]
----> pbest : [17.64110487]
----> pbest : [17.64098674]
----> pbest : [17.64109253]
----> pbest : [17.64122496]
----> pbest : [17.64108313]
----> pbest : [17.64146483]
----> pbest : [17.64140796]
----> pbest : [17.64108056]
----> pbest : [17.64101158]
-----> gbest : 17.6409867366102
iteration : #9
----> pbest : [17.64095709]
----> pbest : [17.64102156]
----> pbest : [17.64095872]
----> pbest : [17.64094527]
```



```

----> pbest : [17.64092847]
----> pbest : [17.64094711]
----> pbest : [17.64095704]
----> pbest : [17.64100635]
----> pbest : [17.64093484]
----> pbest : [17.6409557]
-----> gbest : 17.64092847178121
iteration : #10
----> pbest : [17.64090504]
----> pbest : [17.64092352]
----> pbest : [17.64094801]
----> pbest : [17.64090667]
----> pbest : [17.64090205]
----> pbest : [17.64090764]
----> pbest : [17.64091388]
----> pbest : [17.64090815]
----> pbest : [17.64091104]
----> pbest : [17.64091611]
-----> gbest : 17.640902048391098
The best solution is: [[ -6.4832832  -6.13795358  5.77562425  -1.81230608
3.43818348
-2.81348287  1.44800808 -0.35487679 -3.75918006 -4.4809281
-8.06711436  2.81589757  5.52988555  3.57274885 -1.30511484
-3.5833661 -8.08235703 -1.01645491  4.7738605 -5.08111708
 5.06468466 -8.52123356 -6.42239713 -4.60395169  5.13094222
-3.45237075 -2.57619171  0.62359813 -1.29557636 -0.12002319
-2.71776339 -3.24382329  4.43697651 -5.35547353  0.43479757
-4.08781594 -1.73519392 -4.55096914 -0.14607504 -3.12990028
-1.40230376  1.92986004 -8.78151925  4.98455877  8.0666585
-2.55619555 -3.93934025  9.25332477 -5.71662169 -6.74344745
 5.6834302 -1.62213739  1.21263985 -2.62249906 -2.69569074
-10.18657436 -2.7782835 -0.56424775 -6.81244173  1.91524741
-1.2501333  6.5039129 -1.43979866  0.40667867 -7.52327266
 4.50953745  2.02390338  2.37657363 -6.60540392  3.29948125
-2.57527844 -3.5686056  1.66312583  5.26412896  6.82569448
 2.37815236 -5.44021601  0.9044605 -8.75065334  6.46688993
 1.52083226  3.01053112 -6.11685766  1.92894559 -1.99590236
-2.72921994  3.94101445  6.2938213  2.20861301 -9.56718068
-3.31227187  0.02094668  1.45755295  0.05659061 -1.05766387
-0.31582863 -3.97222107  2.63756785 -1.33714712  4.76183094
-2.21958918  0.16048024  0.99339238 -1.94654356 -2.36177409
-4.69580358 -5.29754253  7.35187378  4.12000168  0.86692489
-1.98767515  0.51740554  9.42315433  4.32491494 -7.15205794
 6.29424883  0.81006031 -3.54305674 -0.96876022  7.6283188

```

```
4.07416055 -0.52127003 7.28197393 2.33909108 -3.75195152
-2.37500505 2.37152793 -0.84229141 1.17273928 -1.51996242
1.55854485 3.25059543 -0.57048417 3.50051605 4.85788501]] in n_it
erations: 10
```

```
----- # Round 2 -----
```

```
iteration : #1
```

```
----> pbest : [18.25225474]
----> pbest : [18.31198194]
----> pbest : [18.01175112]
----> pbest : [17.95237556]
----> pbest : [18.05842628]
----> pbest : [17.67567514]
----> pbest : [18.39995328]
----> pbest : [18.36607755]
----> pbest : [17.95109123]
----> pbest : [17.7778561]
-----> gbest : 17.675675138372295
```

```
iteration : #2
```

```
----> pbest : [17.66024856]
----> pbest : [17.73165339]
----> pbest : [17.67633262]
----> pbest : [17.74027669]
----> pbest : [17.70427507]
----> pbest : [17.67567514]
----> pbest : [18.39506874]
----> pbest : [18.26141616]
----> pbest : [17.89738557]
----> pbest : [17.6757008]
-----> gbest : 17.660248560080923
```

```
iteration : #3
```

```
----> pbest : [17.64434123]
----> pbest : [17.6541126]
----> pbest : [17.6445339]
----> pbest : [17.65110414]
----> pbest : [17.64862939]
----> pbest : [17.65958265]
----> pbest : [17.65656304]
----> pbest : [17.69933134]
----> pbest : [17.64708335]
----> pbest : [17.6757008]
-----> gbest : 17.644341232771954
```

```
iteration : #4
```

```
----> pbest : [17.64232361]
----> pbest : [17.64329963]
```

```
----> pbest : [17.64165485]
----> pbest : [17.64314547]
----> pbest : [17.6423806]
----> pbest : [17.64583471]
----> pbest : [17.64174258]
----> pbest : [17.64409519]
----> pbest : [17.6412186]
----> pbest : [17.66905561]
-----> gbest : 17.64121859927813
iteration : #5
----> pbest : [17.64232361]
----> pbest : [17.64105313]
----> pbest : [17.64115667]
----> pbest : [17.64103376]
----> pbest : [17.6423806]
----> pbest : [17.6410047]
----> pbest : [17.6414395]
----> pbest : [17.64409519]
----> pbest : [17.64102525]
----> pbest : [17.64132615]
-----> gbest : 17.641004696680973
iteration : #6
----> pbest : [17.64102056]
----> pbest : [17.64096837]
----> pbest : [17.64115667]
----> pbest : [17.64095988]
----> pbest : [17.64099793]
----> pbest : [17.64093325]
----> pbest : [17.64096783]
----> pbest : [17.64102526]
----> pbest : [17.64095717]
----> pbest : [17.64097397]
-----> gbest : 17.64093324628174
iteration : #7
----> pbest : [17.64094137]
----> pbest : [17.64091736]
----> pbest : [17.640919]
----> pbest : [17.64091902]
----> pbest : [17.64098246]
----> pbest : [17.64091496]
----> pbest : [17.64096783]
----> pbest : [17.64094019]
----> pbest : [17.6409181]
----> pbest : [17.64091371]
```

```

-----> gbest : 17.64091371187333
iteration : #8
----> pbest : [17.64091165]
----> pbest : [17.640903]
----> pbest : [17.64090028]
----> pbest : [17.64090605]
----> pbest : [17.64090394]
----> pbest : [17.64090713]
----> pbest : [17.6409273]
----> pbest : [17.64090349]
----> pbest : [17.64090389]
----> pbest : [17.64090208]
-----> gbest : 17.640900275292193
iteration : #9
----> pbest : [17.64090276]
----> pbest : [17.64089307]
----> pbest : [17.64089298]
----> pbest : [17.64090142]
----> pbest : [17.64089568]
----> pbest : [17.64090094]
----> pbest : [17.6408986]
----> pbest : [17.64089538]
----> pbest : [17.64089314]
----> pbest : [17.64089769]
-----> gbest : 17.640892982780997
iteration : #10
----> pbest : [17.64089271]
----> pbest : [17.64089274]
----> pbest : [17.64089275]
----> pbest : [17.64089274]
----> pbest : [17.64089312]
----> pbest : [17.64089299]
----> pbest : [17.64089447]
----> pbest : [17.64089269]
----> pbest : [17.64089276]
----> pbest : [17.64089283]
-----> gbest : 17.640892694795113
The best solution is: [[ -4.63424663  0.05263513  7.72144275 -0.5358549
4.01117288
    2.70113193  4.96432799  1.02976066  4.51808367  1.53644242
    1.30466726 -9.34720186 -2.28282943  5.56220394  0.7850163
   -2.67309587  2.84865864 -4.85635167  3.50303932 -1.42217711
    8.18875597  3.04389467 -4.68142164 -2.36519979  0.45459447
   -2.08496628  1.67193473 -2.25278753 -6.12612109 -1.16600895

```

```

-1.83059511 -0.88509075 -3.78575205 1.49289677 6.14229457
 2.13498075 5.38058332 2.9611055 -3.4276075 -2.33471235
-1.07229509 -0.35280585 2.44792662 3.47325528 -3.02529493
 8.13606856 3.64802913 -9.36376223 -1.98891858 -1.2274446
 2.79112827 -1.53206037 6.22678002 4.98185753 3.86054294
-6.90885883 1.34572518 2.82128504 2.63897507 -3.24745738
-0.89370242 -0.30107164 -8.43388391 3.6022006 -2.52245821
-1.82105822 5.76421064 -2.01042121 -8.38762675 -1.80461842
-1.56565523 5.88278101 3.36822296 1.38077021 10.28235147
-0.92989366 8.15572754 4.35220785 0.88014995 6.18920103
-5.62377551 1.44539229 6.07148998 8.46682685 3.13867726
-5.82008698 -0.02857518 -2.80719076 -2.9229637 -2.21739196
-0.89997537 3.52969218 -1.13000142 -3.63444706 7.32533979
-1.53106574 8.19689741 -2.00961025 9.27150474 5.62749498
 2.85552192 -0.67957798 -1.19125386 -0.58698169 9.67680898
-0.52313814 -0.0392246 -3.52310099 -11.34566014 -6.66249311
 2.00552575 -2.28340628 -5.2901275 -0.96143622 -0.13623074
-3.48589321 -6.15302685 3.27825264 -0.98279112 5.71570668
 2.79299079 -2.16040965 0.5508858 4.8424178 4.09346629
 9.28574662 -1.79299835 -4.72179976 4.81886082 8.73513489
 4.2536257 -0.33572419 4.43073325 6.16019589 -5.52158759]] in n_it
erations: 10
----- # Round 3 -----
iteration : #1
----> pbest : [18.29456256]
----> pbest : [18.09534698]
----> pbest : [18.08905448]
----> pbest : [17.80441022]
----> pbest : [18.03078746]
----> pbest : [18.2447666]
----> pbest : [18.4427416]
----> pbest : [18.16837847]
----> pbest : [18.00891403]
----> pbest : [18.04697555]
-----> gbest : 17.80441021861099
iteration : #2
----> pbest : [18.09971989]
----> pbest : [17.77347621]
----> pbest : [18.02498381]
----> pbest : [17.80441022]
----> pbest : [17.8117068]
----> pbest : [18.16334338]
----> pbest : [17.76015186]
----> pbest : [17.74573408]

```

```
----> pbest : [17.74574133]
----> pbest : [17.75719472]
-----> gbest : 17.745734080967264
iteration : #3
----> pbest : [17.71940703]
----> pbest : [17.67087011]
----> pbest : [17.71038339]
----> pbest : [17.77834588]
----> pbest : [17.71447508]
----> pbest : [17.68707682]
----> pbest : [17.66581255]
----> pbest : [17.69057438]
----> pbest : [17.65844058]
----> pbest : [17.6634368]
-----> gbest : 17.658440583022827
iteration : #4
----> pbest : [17.66506421]
----> pbest : [17.64964556]
----> pbest : [17.64634686]
----> pbest : [17.66704474]
----> pbest : [17.65315294]
----> pbest : [17.65163379]
----> pbest : [17.64961277]
----> pbest : [17.64908426]
----> pbest : [17.64783264]
----> pbest : [17.65351025]
-----> gbest : 17.646346860634168
iteration : #5
----> pbest : [17.64880269]
----> pbest : [17.64494895]
----> pbest : [17.64390871]
----> pbest : [17.64352986]
----> pbest : [17.64541476]
----> pbest : [17.64621533]
----> pbest : [17.64457867]
----> pbest : [17.64671314]
----> pbest : [17.64490608]
----> pbest : [17.64666405]
-----> gbest : 17.643529857239535
iteration : #6
----> pbest : [17.6433181]
----> pbest : [17.64316292]
----> pbest : [17.64324583]
----> pbest : [17.64233442]
```

```
----> pbest : [17.64242488]
----> pbest : [17.64331363]
----> pbest : [17.64165116]
----> pbest : [17.64671314]
----> pbest : [17.64297992]
----> pbest : [17.64133584]
-----> gbest : 17.64133584378164
iteration : #7
----> pbest : [17.64098258]
----> pbest : [17.64259201]
----> pbest : [17.64281253]
----> pbest : [17.64099785]
----> pbest : [17.64177348]
----> pbest : [17.64117246]
----> pbest : [17.64128859]
----> pbest : [17.6411671]
----> pbest : [17.64101472]
----> pbest : [17.64098865]
-----> gbest : 17.640982578514574
iteration : #8
----> pbest : [17.6409605]
----> pbest : [17.64096129]
----> pbest : [17.64099179]
----> pbest : [17.64099785]
----> pbest : [17.64094499]
----> pbest : [17.64107564]
----> pbest : [17.64107877]
----> pbest : [17.64109953]
----> pbest : [17.64096798]
----> pbest : [17.64095076]
-----> gbest : 17.640944985108085
iteration : #9
----> pbest : [17.64093045]
----> pbest : [17.6409141]
----> pbest : [17.64096275]
----> pbest : [17.64098357]
----> pbest : [17.64093709]
----> pbest : [17.64093272]
----> pbest : [17.64094314]
----> pbest : [17.64093603]
----> pbest : [17.64093756]
----> pbest : [17.64093122]
-----> gbest : 17.640914103223167
iteration : #10
```

```

----> pbest : [17.64091004]
----> pbest : [17.64090329]
----> pbest : [17.64093582]
----> pbest : [17.64090485]
----> pbest : [17.64091003]
----> pbest : [17.64090199]
----> pbest : [17.64090731]
----> pbest : [17.64090232]
----> pbest : [17.64090923]
----> pbest : [17.64091659]
-----> gbest : 17.640901993375405
The best solution is: [[ -2.12943868 -3.53771998 -6.94670445 8.07053471
9.15331
4.37419104 4.31474045 2.42697501 -0.29611292 3.78813626
-0.10496676 -5.13782716 3.93512864 -1.08734151 1.8615294
-4.27221334 2.13965082 0.08831879 -0.57989229 5.57475099
-2.41673389 -6.62989587 -0.02007773 9.50753616 0.78407123
1.19614905 -2.31241076 -4.79343439 -5.38992451 1.33392123
7.7640855 3.5866218 -3.23381578 -4.12679276 -4.44238962
9.49485299 -1.03952372 -1.34748516 -1.73383422 1.53985222
0.78269456 1.39707127 0.65274521 -7.00374611 3.63796105
1.09203792 3.68562928 4.93456545 0.69801604 7.33196372
-2.34188527 6.72066387 -7.60452497 -2.56858503 1.07443698
7.83001796 -1.14966917 0.11035113 -2.85408117 0.52710844
-1.11330329 4.30351794 -6.54441977 -1.91105018 -7.86964705
3.97204715 -8.00863984 0.34643928 -2.76266107 -7.92512162
1.04613744 -3.91972636 2.17453507 9.08663646 0.44126859
-10.40930873 9.03340328 -2.53421608 0.23287832 -2.6431044
3.46477903 2.99611337 -3.02385826 -6.15412787 -5.48776042
1.0998009 5.73389503 1.73704659 -4.56793956 -4.1923089
-2.61381484 3.48866175 -5.31756191 -4.9793671 7.01358128
0.8289558 0.45943245 -3.76325545 -4.62790193 0.11394144
-7.87091768 -5.69016611 -5.77460477 -5.66458612 0.28168829
-4.6429753 7.52224782 1.67797191 -1.22458394 6.49857575
-2.74675755 4.29099472 -5.94756553 4.91923719 3.11569549
4.39679803 -1.96141965 -1.63253577 -1.92936703 -1.00751864
-4.68250989 0.0891407 8.72646566 3.67390169 8.12595894
-1.8248233 -6.24961178 4.33415049 0.2754839 5.98993164
4.85758669 -4.38947878 5.0947316 2.83842961 -7.37896986]] in n_it
erations: 10
----- # Round 4 -----
iteration : #1
----> pbest : [18.24765454]
----> pbest : [18.02358012]

```



```
----> pbest : [17.94153171]
----> pbest : [17.85026351]
----> pbest : [18.23054479]
----> pbest : [18.16579144]
----> pbest : [18.00561497]
----> pbest : [17.77067474]
----> pbest : [18.41483695]
----> pbest : [18.03352657]
-----> gbest : 17.770674744683635
iteration : #2
----> pbest : [18.20455048]
----> pbest : [17.76186159]
----> pbest : [17.91388773]
----> pbest : [17.77325159]
----> pbest : [17.90510409]
----> pbest : [17.76817987]
----> pbest : [17.75371165]
----> pbest : [17.77067474]
----> pbest : [17.82815786]
----> pbest : [18.03178765]
-----> gbest : 17.75371165271309
iteration : #3
----> pbest : [18.16694428]
----> pbest : [17.76186159]
----> pbest : [17.80938898]
----> pbest : [17.77325159]
----> pbest : [17.70026931]
----> pbest : [17.73138172]
----> pbest : [17.70698065]
----> pbest : [17.76856085]
----> pbest : [17.70714732]
----> pbest : [17.7333175]
-----> gbest : 17.700269310141742
iteration : #4
----> pbest : [18.01067493]
----> pbest : [17.72369492]
----> pbest : [17.70345506]
----> pbest : [17.70012307]
----> pbest : [17.65933633]
----> pbest : [17.68077478]
----> pbest : [17.69602717]
----> pbest : [17.6936119]
----> pbest : [17.67673297]
----> pbest : [17.67237205]
```

```
-----> gbest : 17.65933632524989
iteration : #5
----> pbest : [17.71407529]
----> pbest : [17.67538864]
----> pbest : [17.65424235]
----> pbest : [17.66449263]
----> pbest : [17.65045399]
----> pbest : [17.66196614]
----> pbest : [17.65550392]
----> pbest : [17.66383874]
----> pbest : [17.65613397]
----> pbest : [17.64999521]
-----> gbest : 17.649995214067932
iteration : #6
----> pbest : [17.64507993]
----> pbest : [17.65399454]
----> pbest : [17.64487084]
----> pbest : [17.6478314]
----> pbest : [17.64732109]
----> pbest : [17.653914]
----> pbest : [17.65550392]
----> pbest : [17.64779334]
----> pbest : [17.64986833]
----> pbest : [17.64747307]
-----> gbest : 17.644870836118436
iteration : #7
----> pbest : [17.64206977]
----> pbest : [17.64374756]
----> pbest : [17.64331665]
----> pbest : [17.64432206]
----> pbest : [17.6449244]
----> pbest : [17.6460392]
----> pbest : [17.64415779]
----> pbest : [17.64455327]
----> pbest : [17.64641426]
----> pbest : [17.64396854]
-----> gbest : 17.642069771457184
iteration : #8
----> pbest : [17.6415885]
----> pbest : [17.64178621]
----> pbest : [17.64237702]
----> pbest : [17.64267948]
----> pbest : [17.64240538]
----> pbest : [17.64327011]
```

```
----> pbest : [17.64415779]
----> pbest : [17.64168825]
----> pbest : [17.64295624]
----> pbest : [17.64132213]
-----> gbest : 17.641322125203498
```

iteration : #9

```
----> pbest : [17.64115667]
----> pbest : [17.64129897]
----> pbest : [17.64149377]
----> pbest : [17.64148049]
----> pbest : [17.64122973]
----> pbest : [17.64212321]
----> pbest : [17.6412796]
----> pbest : [17.64124836]
----> pbest : [17.6419695]
----> pbest : [17.64132213]
-----> gbest : 17.64115666983991
```

iteration : #10

```
----> pbest : [17.64115667]
----> pbest : [17.641258]
----> pbest : [17.64137385]
----> pbest : [17.64122918]
----> pbest : [17.64119994]
----> pbest : [17.64177552]
----> pbest : [17.6412796]
----> pbest : [17.64124836]
----> pbest : [17.64159943]
----> pbest : [17.64132213]
-----> gbest : 17.64115666983991
```

The best solution is: $[-3.92824339e+00 \ -2.99123390e+00 \ -1.97796951e+00 \ -4.52116857e-01$

-3.54546234e+00	1.55706631e-02	2.13506527e+00	3.04750285e-01
2.98114930e+00	-4.04173510e+00	-6.35817694e-01	2.53196227e+00
1.35981054e+00	-2.92412951e-01	8.45461893e-01	1.23922120e+00
3.88884622e-03	1.07435466e+00	-9.29150452e-01	-1.71039302e+00
-4.85633584e+00	1.13144535e+00	2.04182045e+00	-2.70269319e+00
-1.91649106e+00	-2.03348626e-01	4.37151680e+00	-3.13671780e+00
2.21773580e+00	4.12764335e+00	-3.29514174e+00	2.03090965e+00
-8.75515319e-01	6.93890639e-01	-3.81276737e+00	-2.61697001e+00
3.36086732e+00	4.13135537e+00	3.31883413e+00	-5.29518845e-01
2.78870218e+00	1.23598775e+00	1.25795502e+00	6.75869945e-01
2.22083869e+00	-2.16450850e+00	1.01165450e+00	1.31472057e+00
-4.95315289e-01	-2.30498205e-01	4.47038027e-01	-1.52048808e+00
1.70029259e+00	1.14781871e+00	-9.77098981e-01	6.94207370e-01

```

-1.94588830e+00  4.17659720e+00  2.29741823e+00  4.41746086e+00
 3.62587527e+00 -1.35505748e+00  3.14505667e+00 -3.95276045e+00
-1.44317119e+00 -2.09117074e+00 -4.20047635e-01  2.57179232e+00
 3.44115219e+00  7.13900816e-01  4.13479427e+00  2.83224744e+00
-1.25546412e+00 -1.87644365e+00  3.10037727e+00 -1.87058706e+00
 2.60379528e-01 -1.78322983e+00  1.04479556e+00  4.82362243e-01
-9.87425214e-01  1.61115372e+00  9.54930276e-01  1.68115062e+00
-2.50130609e+00  2.02435348e+00 -2.70911115e+00 -1.67054381e+00
-2.77256925e+00 -1.78292608e+00  4.68925891e-01  1.73928324e-01
-6.33985687e-01  2.40020145e+00  3.14550715e+00 -1.54334200e+00
-3.72445116e+00  1.83591577e+00  3.21075032e+00  3.37441222e+00
 3.78713076e+00 -5.51687135e-01  3.11319148e+00  3.59698269e+00
 9.95559483e-01 -4.46491146e+00 -3.10364549e+00 -4.15327102e-01
 2.08320614e+00 -1.95226172e+00  2.17043519e+00 -4.08875204e+00
 3.00370351e-01 -3.89386186e+00 -2.41271767e+00  2.83654400e+00
 2.43326003e+00 -4.12516313e-01 -2.56796736e+00  1.79234534e+00
 2.49034276e+00  5.20198784e-01  2.95017351e-01  2.09678194e+00
 2.25868621e+00 -4.53762434e+00  2.98059054e+00  3.44148580e+00
 3.96845666e-01  1.84832133e-01 -2.56926946e-01  1.67897563e+00
 3.21055335e-01  2.78129412e-01  2.08260914e+00]] in n_iterations: 10
----- # Round 5 -----
iteration : #1
----> pbest : [18.29657656]
----> pbest : [18.36909368]
----> pbest : [17.67585772]
----> pbest : [17.9282217]
----> pbest : [18.45000953]
----> pbest : [18.1839738]
----> pbest : [18.27221366]
----> pbest : [18.10557993]
----> pbest : [17.67993734]
----> pbest : [18.23752677]
-----> gbest : 17.675857719355285
iteration : #2
----> pbest : [17.67954788]
----> pbest : [17.6547127]
----> pbest : [17.67585772]
----> pbest : [17.86268853]
----> pbest : [18.26696195]
----> pbest : [17.67168644]
----> pbest : [18.25602935]
----> pbest : [17.95588994]
----> pbest : [17.66499143]
----> pbest : [17.77013484]

```

```
-----> gbest : 17.654712703051374
iteration : #3
----> pbest : [17.64353718]
----> pbest : [17.64186571]
----> pbest : [17.65228374]
----> pbest : [17.68132769]
----> pbest : [17.64800654]
----> pbest : [17.64164574]
----> pbest : [17.64525141]
----> pbest : [17.76475098]
----> pbest : [17.6430629]
----> pbest : [17.680333]
-----> gbest : 17.641645744700085
iteration : #4
----> pbest : [17.64109661]
----> pbest : [17.64110287]
----> pbest : [17.64162046]
----> pbest : [17.64117503]
----> pbest : [17.64096911]
----> pbest : [17.64102275]
----> pbest : [17.64103867]
----> pbest : [17.64114667]
----> pbest : [17.64122051]
----> pbest : [17.65273212]
-----> gbest : 17.640969114708284
iteration : #5
----> pbest : [17.64093577]
----> pbest : [17.64095529]
----> pbest : [17.64093672]
----> pbest : [17.64102595]
----> pbest : [17.64090565]
----> pbest : [17.64093804]
----> pbest : [17.64099051]
----> pbest : [17.64098776]
----> pbest : [17.64094507]
----> pbest : [17.64090528]
-----> gbest : 17.640905279351703
iteration : #6
----> pbest : [17.64091961]
----> pbest : [17.64091283]
----> pbest : [17.64089599]
----> pbest : [17.64089784]
----> pbest : [17.64089851]
----> pbest : [17.6409133]
```

```
----> pbest : [17.64096932]
----> pbest : [17.64089635]
----> pbest : [17.64090267]
----> pbest : [17.6408942]
-----> gbest : 17.640894201728837
iteration : #7
----> pbest : [17.64089779]
----> pbest : [17.64089571]
----> pbest : [17.6408931]
----> pbest : [17.64089322]
----> pbest : [17.64089537]
----> pbest : [17.6408973]
----> pbest : [17.64089355]
----> pbest : [17.64089304]
----> pbest : [17.64089439]
----> pbest : [17.64089311]
-----> gbest : 17.640893035179527
iteration : #8
----> pbest : [17.64089394]
----> pbest : [17.64089254]
----> pbest : [17.64089272]
----> pbest : [17.64089253]
----> pbest : [17.64089254]
----> pbest : [17.64089253]
----> pbest : [17.64089255]
----> pbest : [17.64089253]
----> pbest : [17.64089323]
----> pbest : [17.64089255]
-----> gbest : 17.64089252897281
iteration : #9
----> pbest : [17.64089252]
----> pbest : [17.64089252]
----> pbest : [17.64089252]
----> pbest : [17.64089252]
----> pbest : [17.64089252]
----> pbest : [17.64089252]
----> pbest : [17.64089252]
----> pbest : [17.64089252]
----> pbest : [17.64089282]
----> pbest : [17.64089253]
-----> gbest : 17.6408925201901
iteration : #10
----> pbest : [17.64089252]
----> pbest : [17.64089252]
```

```

----> pbest : [17.64089252]
----> pbest : [17.64089252]
----> pbest : [17.64089252]
----> pbest : [17.64089252]
----> pbest : [17.64089252]
----> pbest : [17.64089252]
----> pbest : [17.64089267]
----> pbest : [17.64089252]
-----> gbest : 17.64089251912668
The best solution is: [[-5.00144056e-01  1.66516043e+00 -2.66354133e+00 -1.1
3795470e+00
  6.75715889e+00  2.87807566e+00  3.33055286e+00 -5.51299790e+00
 -8.15852785e+00 -9.50293992e-01  3.69561225e+00 -4.00781277e+00
 -3.05914054e+00  7.21441021e+00  3.72867389e+00  8.07538612e+00
  2.85534389e+00 -5.63889407e+00  2.40530722e+00 -7.11592185e+00
 -5.21913317e+00  6.60485532e+00  1.27930843e+00  2.70803294e+00
 -6.64797665e+00 -1.61226227e+00 -3.69709238e+00  5.17517967e-01
 -7.12005171e+00  5.64401079e+00  2.34902386e+00 -3.15240103e+00
 -4.38330809e+00  8.00524845e-01  6.26410502e+00  3.42490273e-01
 -1.98166846e+00  3.34643732e+00  2.42011745e-01 -4.12156811e+00
 -5.39662131e+00  5.40032361e+00  2.01604210e+00  4.04009194e+00
  2.40943094e+00  9.48105880e-01  3.02199530e+00  5.39903683e+00
  1.14298851e+00  3.35817552e+00 -1.67378479e+00  1.18074030e+00
  5.80366192e+00 -6.25929417e+00  5.93569916e+00  1.99212951e+00
  1.38927509e+00  4.06522065e+00 -7.44887711e-02 -3.77873415e+00
 -5.12526906e+00  3.77126146e+00 -1.33883276e+00 -3.15377286e+00
 -1.66652172e+00  1.04920753e+00  3.81293611e+00 -5.03617082e+00
 -4.16601345e+00  2.32655161e+00  3.61358703e+00 -1.44269361e+00
 -7.46008523e-01  1.75966122e+00 -5.19314817e+00  3.73721429e+00
  8.10625777e-03 -2.84350122e+00 -8.86962151e-01 -4.54692412e+00
  1.60234130e+00  4.05962644e+00 -8.10429775e-01 -4.25124016e+00
  3.18242457e+00  1.73399489e+00 -5.74164826e+00  1.82530502e+00
  6.81446301e-01  2.94255908e+00 -3.52794554e+00  9.82297714e-01
  1.42137404e+00 -9.67122390e-01  3.91774600e+00  7.63291157e+00
  2.33165554e+00 -5.95533757e+00  5.43282601e+00  3.25499758e+00
 -2.97072189e+00  2.42187954e+00  3.08081812e+00  3.90136918e+00
 -1.64163020e+00 -4.07516904e+00  6.28975547e+00  1.19284201e+00
 -2.45471515e+00  4.43214066e+00 -4.64423143e+00 -4.16530501e+00
 -4.25764477e+00  1.16331372e+00 -8.96581356e+00  1.03582590e+00
  6.94344682e+00 -2.39789392e+00  9.86728293e-01 -4.24871754e+00
  2.54431566e+00  3.93968644e+00  5.65532909e+00  5.01918587e+00
  2.10735772e+00  5.36328717e+00  4.12101270e+00 -8.74950309e-02
 -2.18949329e+00 -5.18907630e+00  3.60686203e+00  7.45454674e-01
  1.09062966e+01  5.88626321e+00 -2.14043934e+00]] in n_iterations: 10

```

----- # Round 6 -----

iteration : #1

----> pbest : [18.32279315]
----> pbest : [18.3236171]
----> pbest : [18.39767154]
----> pbest : [18.18659145]
----> pbest : [17.92729825]
----> pbest : [17.90883867]
----> pbest : [17.74651975]
----> pbest : [18.33176866]
----> pbest : [18.03332945]
----> pbest : [17.95844427]
-----> gbest : 17.74651974946118

iteration : #2

----> pbest : [17.85054139]
----> pbest : [17.6812182]
----> pbest : [17.83831033]
----> pbest : [17.70925054]
----> pbest : [17.92729825]
----> pbest : [17.82439065]
----> pbest : [17.74651975]
----> pbest : [18.2225988]
----> pbest : [17.84842768]
----> pbest : [17.71120301]
-----> gbest : 17.68121820363464

iteration : #3

----> pbest : [17.6688072]
----> pbest : [17.64190407]
----> pbest : [17.66323872]
----> pbest : [17.65143635]
----> pbest : [17.75103851]
----> pbest : [17.66616457]
----> pbest : [17.68166855]
----> pbest : [17.65271784]
----> pbest : [17.65580398]
----> pbest : [17.65242092]
-----> gbest : 17.641904065291115

iteration : #4

----> pbest : [17.6411917]
----> pbest : [17.64105926]
----> pbest : [17.64472545]
----> pbest : [17.64394466]
----> pbest : [17.64526944]
----> pbest : [17.64129067]


```
----> pbest : [17.65628705]
----> pbest : [17.64143034]
----> pbest : [17.64207478]
----> pbest : [17.64105424]
-----> gbest : 17.641054243478045
iteration : #5
----> pbest : [17.640911]
----> pbest : [17.64095034]
----> pbest : [17.64093224]
----> pbest : [17.64178173]
----> pbest : [17.64123284]
----> pbest : [17.64093724]
----> pbest : [17.64447144]
----> pbest : [17.64091408]
----> pbest : [17.64113642]
----> pbest : [17.64093204]
-----> gbest : 17.640910996656654
iteration : #6
----> pbest : [17.64089825]
----> pbest : [17.64090687]
----> pbest : [17.64089456]
----> pbest : [17.64094176]
----> pbest : [17.6409004]
----> pbest : [17.64090025]
----> pbest : [17.64121266]
----> pbest : [17.64090112]
----> pbest : [17.64089636]
----> pbest : [17.64089936]
-----> gbest : 17.640894562531752
iteration : #7
----> pbest : [17.64089512]
----> pbest : [17.6408938]
----> pbest : [17.64089307]
----> pbest : [17.64089993]
----> pbest : [17.64089278]
----> pbest : [17.64089419]
----> pbest : [17.64094357]
----> pbest : [17.64089588]
----> pbest : [17.6408933]
----> pbest : [17.64089456]
-----> gbest : 17.640892782893797
iteration : #8
----> pbest : [17.64089369]
----> pbest : [17.64089261]
```

```

----> pbest : [17.64089263]
----> pbest : [17.64089287]
----> pbest : [17.64089259]
----> pbest : [17.64089373]
----> pbest : [17.64089632]
----> pbest : [17.64089354]
----> pbest : [17.64089285]
----> pbest : [17.6408937]
-----> gbest : 17.640892588242608
iteration : #9
----> pbest : [17.64089272]
----> pbest : [17.64089254]
----> pbest : [17.64089256]
----> pbest : [17.64089259]
----> pbest : [17.64089255]
----> pbest : [17.64089256]
----> pbest : [17.64089253]
----> pbest : [17.6408926]
----> pbest : [17.64089273]
----> pbest : [17.64089296]
-----> gbest : 17.640892529589674
iteration : #10
----> pbest : [17.64089252]
----> pbest : [17.64089252]
----> pbest : [17.64089253]
----> pbest : [17.64089252]
----> pbest : [17.64089254]
----> pbest : [17.64089252]
----> pbest : [17.64089252]
----> pbest : [17.64089252]
----> pbest : [17.64089252]
----> pbest : [17.64089253]
----> pbest : [17.64089263]
-----> gbest : 17.64089251969414
The best solution is: [[ 2.43509292 -1.83663071 -2.3971459 0.74558339
3.73236351
3.84846985 3.73569487 -2.54109208 -0.06362172 4.38643136
0.42745483 -4.13576134 -12.25941057 -6.21192255 -5.50647104
4.12439037 -1.24077674 2.49635704 -4.80589621 10.36192079
1.82387767 5.08042529 7.42709412 -0.30239424 5.58594372
-4.95233951 -10.0569457 -0.2389049 -2.57680622 -0.41764209
-0.35134595 11.34002753 0.82219096 -6.40883369 0.96964011
-11.91211276 -10.1517974 -1.89651018 -0.73240389 -4.78599436
-0.70636997 9.84910388 -2.38793416 5.74361235 0.09859675
12.06487025 -4.77569736 8.06952828 6.90425673 -4.12181697

```

-3.99591864	-6.14603985	-3.07097321	0.7057933	-2.56742799
5.84059296	6.99613573	3.62995715	3.69791862	-2.1620643
3.3226107	7.13150447	-0.89978261	3.86003679	-2.04693518
0.83708668	1.19308713	0.88542158	-0.54209705	6.12967756
4.85680091	-1.73066293	0.57264617	-1.73124332	1.53276398
7.90893778	-5.12893261	-9.83996443	6.60241463	-4.29565129
-10.58492805	-3.82206663	-9.1054801	-0.9371625	5.98482107
5.13037317	6.13537015	-3.16515827	9.41638385	-4.4613915
-1.82735562	-0.82764114	9.42123828	7.86090314	-2.96760674
-3.39839783	-7.4145279	-3.00605063	-2.05778912	6.91636765
3.87226356	-0.11945596	-0.35241427	-6.48885944	-1.79612548
3.9362412	-7.21263878	-1.38304727	4.37554039	0.11818144
-8.69136617	2.53912981	-9.21361565	6.11910256	6.21333563
3.20114257	-0.5107796	0.91726933	-5.55304573	0.06394098
1.71999509	2.89840583	-0.39362491	5.41690075	2.48143191
7.36923133	0.61538875	6.17639063	2.3899186	4.51100531
7.46666736	9.32373539	-1.35349404	-2.39365395	-2.29637104]]

erations: 10

----- # Round 7 -----

iteration : #1

```

----> pbest : [18.09685787]
----> pbest : [17.66480758]
----> pbest : [17.9826997]
----> pbest : [18.31793294]
----> pbest : [18.25550297]
----> pbest : [18.06093878]
----> pbest : [18.37427642]
----> pbest : [18.19369605]
----> pbest : [18.42141099]
----> pbest : [18.16496794]
-----> gbest : 17.66480758420732

```

iteration : #2

```

----> pbest : [17.64701302]
----> pbest : [17.66480758]
----> pbest : [17.93068052]
----> pbest : [17.66340744]
----> pbest : [17.70277898]
----> pbest : [17.71675493]
----> pbest : [17.67734264]
----> pbest : [17.67645771]
----> pbest : [17.79988893]
----> pbest : [17.6490116]
-----> gbest : 17.647013016429238

```

iteration : #3

```
----> pbest : [17.63001617]
----> pbest : [17.64366745]
----> pbest : [17.66778301]
----> pbest : [17.65096697]
----> pbest : [17.62866957]
----> pbest : [17.62894469]
----> pbest : [17.62858815]
----> pbest : [17.6287223]
----> pbest : [17.63993301]
----> pbest : [17.63092613]
-----> gbest : 17.62858815035963
iteration : #4
----> pbest : [17.62808201]
----> pbest : [17.6279911]
----> pbest : [17.64214783]
----> pbest : [17.63176917]
----> pbest : [17.62774146]
----> pbest : [17.62775165]
----> pbest : [17.62783654]
----> pbest : [17.62776042]
----> pbest : [17.62790776]
----> pbest : [17.62806356]
-----> gbest : 17.627741463016058
iteration : #5
----> pbest : [17.62760054]
----> pbest : [17.62769542]
----> pbest : [17.62811422]
----> pbest : [17.62763775]
----> pbest : [17.62762251]
----> pbest : [17.62762459]
----> pbest : [17.62757835]
----> pbest : [17.62762631]
----> pbest : [17.62758778]
----> pbest : [17.62760586]
-----> gbest : 17.627578345291305
iteration : #6
----> pbest : [17.62756196]
----> pbest : [17.62757287]
----> pbest : [17.62761168]
----> pbest : [17.62763775]
----> pbest : [17.62762251]
----> pbest : [17.62756217]
----> pbest : [17.62757835]
----> pbest : [17.62756065]
```

```
----> pbest : [17.62758778]
----> pbest : [17.62760586]
-----> gbest : 17.627560651850956
iteration : #7
----> pbest : [17.62755083]
----> pbest : [17.62754549]
----> pbest : [17.62753542]
----> pbest : [17.62763775]
----> pbest : [17.62756185]
----> pbest : [17.62756217]
----> pbest : [17.62757835]
----> pbest : [17.62756065]
----> pbest : [17.62758778]
----> pbest : [17.62755623]
-----> gbest : 17.62753542034792
iteration : #8
----> pbest : [17.62753681]
----> pbest : [17.62754549]
----> pbest : [17.62753396]
----> pbest : [17.62763775]
----> pbest : [17.62753539]
----> pbest : [17.62755776]
----> pbest : [17.62754324]
----> pbest : [17.62753539]
----> pbest : [17.62755019]
----> pbest : [17.62753599]
-----> gbest : 17.627533961612027
iteration : #9
----> pbest : [17.62753364]
----> pbest : [17.62753257]
----> pbest : [17.62753333]
----> pbest : [17.62753469]
----> pbest : [17.62753192]
----> pbest : [17.62753272]
----> pbest : [17.62753252]
----> pbest : [17.62753255]
----> pbest : [17.62753277]
----> pbest : [17.62753268]
-----> gbest : 17.627531916955483
iteration : #10
----> pbest : [17.62753208]
----> pbest : [17.62753164]
----> pbest : [17.62753154]
----> pbest : [17.62753297]
```

```

----> pbest : [17.62753134]
----> pbest : [17.62753112]
----> pbest : [17.62753119]
----> pbest : [17.62753162]
----> pbest : [17.62753114]
----> pbest : [17.62753161]
-----> gbest : 17.62753111699682
The best solution is: [[ 3.03845046 -3.89302501  6.8836846 -3.65777431  1.8
6283443  1.43343328
-4.96547967  5.04809082  6.93648495  1.37795872  2.50468218 -2.31293199
 5.33628226  0.59975596 -3.81059698  2.37812957 -5.19302163 -4.40015623
 3.79643068 -0.15275569 -1.03055298  0.17189295  3.06583779 -2.82263967
-1.67614546  0.71572627  3.06850371  0.3543676 -2.63683435 -1.6944723
-0.99258626  2.22522225 -2.02939019 -4.53342838  2.02473246  2.94769794
-0.26799636  3.06895559  0.32937018 -4.05963258 -1.69653127 -2.48960976
-0.94284363  6.00155526  1.77615118 -3.35601453  1.41712398 -0.18446832
 3.32085721 -3.92824456 -0.56432923 -3.66136151 -1.98853121 -1.60470451
-1.83391117 -0.80808988 -0.7215308  3.22651541  5.25352898 -3.41520272
-5.11453651  0.77806725 -3.53078047  1.98851168 -1.51835112 -0.45997538
 0.41814344 -2.45130866 -0.35589287  2.04513877 -3.04412272 -4.1766506
 0.80109617  3.56804231  0.47218764 -0.33929782  4.23753738  2.0290496
 2.02423098 -4.20790334  0.18245229  2.09576958 -3.55699718 -0.76592377
-1.37306982 -2.90870276  2.82025723  1.61900829 -0.7929491 -3.08939143
-5.083387  6.4687556 -1.21491357 -1.40090923 -2.82685816  0.33292688
 1.87966282  5.47256838  0.39856228 -3.86243177 -0.16933868 -4.55422489
 2.46625149 -1.22494787  2.15122353 -1.19197596 -2.68812126 -3.10237754
-5.01008791  1.72624023  0.36694433  4.32441216 -0.39438727 -0.38146583
-1.86062052 -0.56651296  5.23162461  1.00364915  4.03412297  1.11412929
-4.77627618  1.38247937  3.40829841 -5.63039498  2.01424135 -1.57061381
-1.43828547  7.48611472  3.72784713  5.02120003  4.48679912 -0.80548107
 3.36370269  3.60545087 -4.84759301]] in n_iterations: 10
----- # Round 8 -----
iteration : #1
----> pbest : [17.96367372]
----> pbest : [18.35497616]
----> pbest : [18.23184493]
----> pbest : [17.80490356]
----> pbest : [17.82400146]
----> pbest : [17.88444431]
----> pbest : [17.73269313]
----> pbest : [17.99400671]
----> pbest : [17.98115452]
----> pbest : [17.90595581]
-----> gbest : 17.732693125912633

```

```
iteration : #2
----> pbest : [17.88251319]
----> pbest : [17.82391392]
----> pbest : [18.12256298]
----> pbest : [17.80490356]
----> pbest : [17.72559131]
----> pbest : [17.7732354]
----> pbest : [17.73269313]
----> pbest : [17.74818965]
----> pbest : [17.93149532]
----> pbest : [17.8983068]
-----> gbest : 17.72559131368844
iteration : #3
----> pbest : [17.73325149]
----> pbest : [17.67392002]
----> pbest : [17.68025779]
----> pbest : [17.80490356]
----> pbest : [17.69097842]
----> pbest : [17.7732354]
----> pbest : [17.73184471]
----> pbest : [17.66819638]
----> pbest : [17.73193213]
----> pbest : [17.76697089]
-----> gbest : 17.66819638090788
iteration : #4
----> pbest : [17.69825749]
----> pbest : [17.65544295]
----> pbest : [17.64740412]
----> pbest : [17.6537411]
----> pbest : [17.67960587]
----> pbest : [17.66828726]
----> pbest : [17.66554035]
----> pbest : [17.66454655]
----> pbest : [17.70297339]
----> pbest : [17.65013556]
-----> gbest : 17.647404120121596
iteration : #5
----> pbest : [17.6552077]
----> pbest : [17.64302547]
----> pbest : [17.64219119]
----> pbest : [17.63604793]
----> pbest : [17.6614686]
----> pbest : [17.63884548]
----> pbest : [17.6456863]
```

```
----> pbest : [17.64388172]
----> pbest : [17.65606863]
----> pbest : [17.63409969]
-----> gbest : 17.634099687521957
iteration : #6
----> pbest : [17.63985088]
----> pbest : [17.63465686]
----> pbest : [17.63991967]
----> pbest : [17.63604793]
----> pbest : [17.64053489]
----> pbest : [17.63616339]
----> pbest : [17.635022]
----> pbest : [17.63465332]
----> pbest : [17.63527568]
----> pbest : [17.63409969]
-----> gbest : 17.634099687521957
iteration : #7
----> pbest : [17.63526284]
----> pbest : [17.63465686]
----> pbest : [17.6346536]
----> pbest : [17.63440711]
----> pbest : [17.63373744]
----> pbest : [17.63613199]
----> pbest : [17.635022]
----> pbest : [17.63465332]
----> pbest : [17.63527568]
----> pbest : [17.63409969]
-----> gbest : 17.633737440895953
iteration : #8
----> pbest : [17.63517725]
----> pbest : [17.63460598]
----> pbest : [17.63419992]
----> pbest : [17.63440711]
----> pbest : [17.63373744]
----> pbest : [17.63533809]
----> pbest : [17.634562]
----> pbest : [17.63398913]
----> pbest : [17.63505524]
----> pbest : [17.6336239]
-----> gbest : 17.633623903607926
iteration : #9
----> pbest : [17.63351755]
----> pbest : [17.63356619]
----> pbest : [17.63397327]
```



```

----> pbest : [17.63440711]
----> pbest : [17.63373744]
----> pbest : [17.63533809]
----> pbest : [17.63346024]
----> pbest : [17.63376837]
----> pbest : [17.63505524]
----> pbest : [17.6336239]
-----> gbest : 17.633460238992587
iteration : #10
----> pbest : [17.63351755]
----> pbest : [17.63356619]
----> pbest : [17.63344119]
----> pbest : [17.63440711]
----> pbest : [17.63373744]
----> pbest : [17.63533809]
----> pbest : [17.63346024]
----> pbest : [17.63376837]
----> pbest : [17.63505524]
----> pbest : [17.63353489]
-----> gbest : 17.633441193895866
The best solution is: [[-1.97488502e+00  8.56539634e-01  3.33317485e+00  6.6
2995522e-01
-1.60087568e+00  1.43892986e+00 -2.41782241e+00  1.70059082e+00
 2.26514975e+00  2.88732619e+00  3.35212126e-01  1.09561697e+00
 5.46589034e-01  1.85436440e+00  3.23400065e-01  1.34048749e+00
-2.22922330e+00 -1.45622036e-01 -3.60522393e+00 -1.56101740e+00
-4.14499749e-01  1.87157243e+00  1.12566642e+00 -1.55315401e-01
 1.92998268e-01  2.80899985e+00  2.83525633e+00 -1.41188133e+00
-1.86986754e+00  1.47774060e+00  7.54993902e-01  1.04998136e+00
 1.11024823e+00  1.89351310e+00 -1.18896777e+00  2.45430824e+00
-4.03544679e-02 -1.31893980e+00  4.82212656e-01  3.89778892e+00
 1.71606022e+00  1.20218736e+00  6.04009198e-01  1.37973563e+00
-2.54257345e-01  1.85237379e+00  5.12009546e-01 -2.70457802e+00
-1.00678533e+00 -1.05777864e+00 -1.77611254e-01  1.59107114e+00
 1.29760205e+00  2.06901532e-01 -1.37473910e+00  1.46010174e+00
-2.16999472e+00 -3.31973701e-01 -4.54486477e-02 -2.12905085e+00
-2.58383488e-01 -4.21071496e-01  1.29194148e+00  2.21492285e+00
-1.49998810e+00 -5.06862477e-01 -1.50744962e+00 -1.68578232e+00
 2.47547701e+00  1.08937963e+00  2.22016768e+00 -1.68174881e+00
 1.93603657e+00  1.65762012e+00 -1.04286863e+00  2.53679179e+00
 9.83905508e-01 -2.00958210e+00 -1.94769316e-03  1.84417551e-01
 1.92774821e-01 -9.44687265e-01  2.59434243e-01 -4.01520777e-01
 1.92734269e+00  1.19939166e+00 -2.36121635e+00  2.45755004e+00
-1.14828785e+00  3.12016287e+00 -5.58235893e-01  1.74511620e+00

```

```

3.20944300e+00 -1.48518087e+00 1.26955437e+00 5.88334038e-03
7.20614627e-01 -3.67847861e+00 -1.04536562e-01 -1.18798665e+00
-9.68787715e-01 2.69587141e+00 1.00934056e-01 -8.95458360e-01
-9.55337186e-01 -1.93830539e+00 -1.93373405e+00 3.56369696e+00
-1.02075270e+00 1.41684472e+00 -4.92276543e-01 -8.70319284e-01
-9.89676094e-01 1.15956246e+00 5.84272040e-01 2.34659076e+00
2.72415349e+00 -2.55128934e+00 -6.95392297e-02 -2.65753069e+00
-2.18721228e+00 6.83366725e-02 1.15616136e+00 2.49330992e+00
1.93752626e+00 2.09332817e-01 1.35041155e+00 -3.43419891e-01
3.70609757e-01 -2.97553207e+00 2.48069109e-01 2.80706493e+00
1.45062207e+00 4.18398922e-01 1.61216846e+00]] in n_iterations: 10
----- # Round 9 -----
iteration : #1
----> pbest : [18.24306742]
----> pbest : [18.02237882]
----> pbest : [18.17743997]
----> pbest : [18.19843893]
----> pbest : [18.3561632]
----> pbest : [18.49234695]
----> pbest : [18.26576765]
----> pbest : [18.36612859]
----> pbest : [17.98864339]
----> pbest : [18.17003775]
-----> gbest : 17.98864338876041
iteration : #2
----> pbest : [18.19217145]
----> pbest : [17.99338821]
----> pbest : [17.7430393]
----> pbest : [18.06363931]
----> pbest : [18.01918925]
----> pbest : [17.99583534]
----> pbest : [18.03201586]
----> pbest : [18.30296385]
----> pbest : [17.98864339]
----> pbest : [17.73862878]
-----> gbest : 17.738628778360493
iteration : #3
----> pbest : [17.69438884]
----> pbest : [17.95454076]
----> pbest : [17.60909544]
----> pbest : [17.89852509]
----> pbest : [17.70987151]
----> pbest : [17.70464691]
----> pbest : [18.03201586]

```

```
----> pbest : [17.63151083]
----> pbest : [17.91733761]
----> pbest : [17.61786306]
-----> gbest : 17.60909544061025
iteration : #4
----> pbest : [17.64492025]
----> pbest : [17.62555328]
----> pbest : [17.60177874]
----> pbest : [17.61546683]
----> pbest : [17.61005823]
----> pbest : [17.6032394]
----> pbest : [18.03201586]
----> pbest : [17.59835069]
----> pbest : [17.71395348]
----> pbest : [17.60665171]
-----> gbest : 17.598350687974428
iteration : #5
----> pbest : [17.61372746]
----> pbest : [17.59790299]
----> pbest : [17.59800842]
----> pbest : [17.5976252]
----> pbest : [17.59808151]
----> pbest : [17.59772958]
----> pbest : [18.03201586]
----> pbest : [17.59776554]
----> pbest : [17.61836353]
----> pbest : [17.6008775]
-----> gbest : 17.5976252016884
iteration : #6
----> pbest : [17.59759221]
----> pbest : [17.59777408]
----> pbest : [17.59773747]
----> pbest : [17.59758651]
----> pbest : [17.59756033]
----> pbest : [17.59761713]
----> pbest : [17.59763347]
----> pbest : [17.59765444]
----> pbest : [17.59776226]
----> pbest : [17.59772094]
-----> gbest : 17.597560331006395
iteration : #7
----> pbest : [17.5975549]
----> pbest : [17.59763284]
----> pbest : [17.59755746]
```

```
----> pbest : [17.59757557]
----> pbest : [17.59755539]
----> pbest : [17.59757938]
----> pbest : [17.59756096]
----> pbest : [17.59758887]
----> pbest : [17.59757491]
----> pbest : [17.59755541]
-----> gbest : 17.597554901003722
iteration : #8
----> pbest : [17.59755336]
----> pbest : [17.59755962]
----> pbest : [17.59755363]
----> pbest : [17.59755332]
----> pbest : [17.5975535]
----> pbest : [17.59755435]
----> pbest : [17.59755355]
----> pbest : [17.5975537]
----> pbest : [17.59755535]
----> pbest : [17.59755353]
-----> gbest : 17.597553315472954
iteration : #9
----> pbest : [17.59755336]
----> pbest : [17.59755344]
----> pbest : [17.5975536]
----> pbest : [17.59755332]
----> pbest : [17.5975535]
----> pbest : [17.59755435]
----> pbest : [17.59755355]
----> pbest : [17.59755344]
----> pbest : [17.59755383]
----> pbest : [17.59755353]
-----> gbest : 17.597553315472954
iteration : #10
----> pbest : [17.59755334]
----> pbest : [17.59755311]
----> pbest : [17.59755346]
----> pbest : [17.59755332]
----> pbest : [17.59755334]
----> pbest : [17.59755435]
----> pbest : [17.59755355]
----> pbest : [17.59755338]
----> pbest : [17.59755353]
----> pbest : [17.59755333]
-----> gbest : 17.597553108240785
```

The best solution is: [[3.68541099 1.17995523 -5.12649551 0.11856028 2.7
5701412 -6.4502716

```
1.44270168 1.126745 -2.59511044 -3.80975741 -1.42845994 -1.978687
0.15825789 -2.98585587 1.69582401 -3.28916841 -1.65539933 -1.48864844
3.65394296 -5.76718161 0.50489541 7.18765295 -4.76069577 5.75811941
-4.44817487 -2.90249523 2.65946154 0.56384006 -0.68676011 -2.25385067
-2.99193343 -0.96730383 -2.73271029 1.29950323 -4.02721399 0.08016797
-2.35228747 -1.2582923 -3.75538429 -3.31416941 1.93135994 3.51951414
-1.25673079 -2.24857077 -4.93210906 5.27375485 -2.99159398 1.30159528
-0.88151166 -2.51061344 -4.35162362 1.79887215 0.75202798 -1.64019652
-3.9045928 2.80946466 6.52809062 3.2681188 -4.32540649 4.13081869
1.93738199 -0.56949391 3.32236271 -0.92673077 3.93604633 -5.39715863
6.8879065 4.01175905 2.11077587 -0.72404864 3.17969903 5.81864196
-5.82697226 5.27331741 2.65262567 1.18201255 -5.39780927 4.73892442
4.70010983 1.14219477 1.0808823 -4.45483801 -1.94781135 -3.38533228
-0.8364854 -0.42085407 -2.4128965 2.42926789 4.64607755 2.5661814
-3.30468307 -1.86116872 -3.74322896 4.16380608 2.54010653 -2.95122331
2.93545957 3.22833894 1.31707336 1.89761735 -4.62811087 3.12495742
-7.88722732 -5.70431944 -3.54909809 3.36070154 5.93798134 -1.31460049
0.18017363 2.58527488 -6.56227933 -0.33947606 0.42941903 4.06722991
-2.51589676 3.59154152 -0.56854266 4.80755935 -4.40211945 -4.48899094
2.35496049 4.29372575 -1.31098376 3.58694409 -1.27049946 -6.92633096
-0.51874196 2.27321339 -2.39942411 -2.85627873 2.22191348 -0.09484893
2.80155451 -1.94422791 6.60358395]] in n_iterations: 10
```

การทดลองที่ 1 : การทดลองเปลี่ยนโครงสร้างของ Multilayer perceptron (Hidden layer , layer)

- n_iterations = 10
- n_particles = 10
- c1 = 1.2
- c2 = 1.4
- $W = (1/2*(c1+c2))+0.3$

ผลการทดลองที่ 1 :

Hidden layer 1	Hidden layer 2	Iteration	g_best
2	-	1	18.00538808163395
2	-	2	17.96673232352557
2	-	3	17.858448629453253
2	-	4	17.78552325481207
2	-	5	17.738549751496265
2	-	6	17.700776583774577
2	-	7	17.679119158730977
2	-	8	17.662886643907438
2	-	9	17.655702495749974
2	-	10	17.651988418649502
5	-	1	17.823811493579896
5	-	2	17.78913476654413
5	-	3	17.70865358396295
5	-	4	17.66471859913042
5	-	5	17.653171075858634
5	-	6	17.644398586378543
5	-	7	17.6421927783463
5	-	8	17.6421927783463
5	-	9	17.641601851558804
5	-	10	17.64110692835963

Hidden layer 1	Hidden layer 2	Iteration	g_best
8	-	1	17.766007684068132
8	-	2	17.717723205036812
8	-	3	17.655033565101213
8	-	4	17.64578428155221
8	-	5	17.642840108152157
8	-	6	17.641534234929104
8	-	7	17.641097932007295
8	-	8	17.6410342196003
8	-	9	17.641030042998697
8	-	10	17.641030042998697
10	-	1	17.802974836545012
10	-	2	17.802974836545012
10	-	3	17.724769950930142
10	-	4	17.676149796752902
10	-	5	17.672371561226928
10	-	6	17.669352181894578
10	-	7	17.65795087875403
10	-	8	17.656054019922937
10	-	9	17.649052812285742
10	-	10	17.649052812285742
15	-	1	17.784751803977244
15	-	2	17.71559665807288
15	-	3	17.650841983637875
15	-	4	17.645179282655388
15	-	5	17.64160864530061
15	-	6	17.64103938817289
15	-	7	17.640941559503034
15	-	8	17.640941559503034
15	-	9	17.640930909403927

Hidden layer 1	Hidden layer 2	Iteration	g_best
15	-	10	17.640930909403927
2	5	1	18.058831063060513
2	5	2	18.01922321936464
2	5	3	17.858889341265776
2	5	4	17.746312933587202
2	5	5	17.687030831694777
2	5	6	17.65659620149382
2	5	7	17.646321769548717
2	5	8	17.643148189386654
2	5	9	17.641611322089393
2	5	10	17.641179228680873
7	8	1	17.825502021577968
7	8	2	17.78404785133928
7	8	3	17.676309386194244
7	8	4	17.646153666583157
7	8	5	17.641922748320976
7	8	6	17.641012167968768
7	8	7	17.640903850869172
7	8	8	17.640893999473544
7	8	9	17.640892721209884
7	8	10	17.64089252833696
15	15	1	17.768882630571635
15	15	2	17.69548655948311
15	15	3	17.643385150940006
15	15	4	17.6409981167713
15	15	5	17.640899625084074
15	15	6	17.640892572449804
15	15	7	17.64089251919279
15	15	8	17.640892519002808

Hidden layer 1	Hidden layer 2	Iteration	g_best
15	15	9	17.640892518999063
15	15	10	17.64089251899905

วิเคราะห์ผลการทดลองที่ 1 :

จะเห็นว่าการเพิ่มของจำนวน Node ใน Hidden layer นั้นมีผล ดูจากในช่วงต้องตารางจะเห็นว่า กรณีที่มีจำนวนของ Hidden layer น้อยนั้นจะส่งผลให้มีจำนวน error average มากกว่า ส่วนที่มีจำนวน Hidden layer มากกว่าใน ขั้นตอน ๆมา แต่ในกรณีของการเพิ่ม Hidden layer กลับไม่ส่งผลมากแต่เป็นการส่งผลเพียงเล็กน้อยถึงอาจหมายถึงไม่ส่งผลต่อการลด error average เลย โดยดูจากในช่วง Hidden layer 1 = 2 , Hidden layer 2 = 5 ในช่วง iteration แรกๆนั้นจะมีค่ามากพอๆกันหรือมากกว่า กรณีที่เป็น Hidden layer 1 = 2 เพียงตัวเดียว แต่ ในช่วงปลายของ Hidden layer 1 = 15 และ Hidden layer 2 = 15 กลับทำผลเฉลี่ยออกมาได้ดีที่สุด จึงไม่สามารถสรุปได้ว่า Hidden layer นั้นมีผลต่อการลดค่า error average

การทดลองที่ 2 : การทดลองเพิ่ม-ลด ค่า c1 และ c2

- n_iterations = 10
- n_particles = 10
- Structure [8,10,1]
- $W = (1/2 * (c1 + c2)) + 0.3$

ผลการทดลองที่ 2 :

c1	c2	g_best
0.25	1	17.82574999578676
0.5	1	17.69416106438929
1.0	1	17.675853235605697
1.25	1	17.66943391464948
1	0.25	17.910591700107478
1	0.5	17.70798841571437
1	1.25	17.661233477078124

วิเคราะห์ผลการทดลองที่ 2 :

จะเห็นว่าการเพิ่มค่า $c1$ และ $c2$ นั้นส่งผลต่อค่า g_best ซึ่งในผลจะออกมาว่า ยิ่งเพิ่มค่า $c1$ และ $c2$ จะยิ่งทำให้ได้ค่า g_best ที่มีค่าดีมากขึ้น แต่ก็ยังเป็นผลเสียเช่นกันเนื่องจากการใช้ค่า $c1$ และ $c2$ ที่มากเกินไป อาจส่งผลให้เกิดการลู่เข้าสู่ local min ซึ่งจะทำให้ไม่สามารถปรับเปลี่ยนค่า position ได้อีก ซึ่งเป็นผลเสียทำให้ไม่เกิดการพัฒนาใน Model แต่ถ้าเราใช้ $c1$ และ $c2$ ให้เหมาะสมก็จะเป็นผลดีต่อการ train เพราะจะทำให้การเคลื่อนที่ของ particles เป็นไปอย่างถูกต้องและรวดเร็วมากขึ้น

การทดลองที่ 3 : การทดลองเพิ่ม-ลด $n_iterations$ และ $n_particles$

- $c1 = 1.2$
- $c2 = 1.4$
- $W = (1/2*(c1+c2))+0.3$
- Structure [8,10,1]

ผลการทดลองที่ 3 :

iterations	n_particles	g_best
1	10	17.739292470608223
2	10	17.732525646928245
5	10	17.731915745072357
10	10	17.731721853165986
10	1	18.038970783198774
10	2	17.67881157595578
10	5	17.673519929071404
10	10	17.64251391417346

วิเคราะห์ผลการทดลองที่ 3 :

จะเห็นว่าในการเพิ่มหรือลด iterations หรือ particles นั้นมีผลต่อการเปลี่ยนแปลงของค่า g_best ซึ่งยังมีค่า iterations และ $n_particles$ มากก็จะมีค่า g_best ดีมากขึ้น โดยการเพิ่มจำนวนของ particles ดูจะส่งผลต่อค่า g_best มากกว่า กรณีของการเพิ่ม iterations แต่ในที่นี้ ผลอาจเกิดการผิดพลาดได้เพราะ อาจจะเกี่ยวข้องกับการสุ่ม position ของ particles ในตอนแรก ซึ่ง ตำแหน่งอาจจะไปอยู่ใกล้กับตำแหน่งที่ดีที่สุดก็ได้

Code :

```
1. import numpy as np
2. import random
3. import pdb
4. import pandas as pd
5.
6. dataset = pd.read_excel('./AirQualityUCI.xlsx')
7. columns = dataset.columns
8.
9. data_ip = dataset[[columns[3],columns[6],columns[8],columns[10],columns[11],columns[12],columns[
10. 13],columns[14]]]
11. desire_op = dataset[[columns[5]]]
12.
13. class Particle():
14.     def __init__(self,layer):
15.         self.layer = []
16.         self.velocity = []
17.         self.weightmin = -1
18.         self.weightmax = 1
19.         self.fitness = 0
20.         self.position = []
21.         self.getweight(layer)
22.         self.pbest_position = self.position
23.         self.pbest_value = float('inf')
24.
25.     def getweight(self,layer):
26.         self.layer = layer
27.         chromolen = 0
28.
29.         for i in range(1,len(layer)):
30.             chromolen = chromolen + (layer[i-1]*layer[i])
31.         self.velocity = np.zeros(chromolen)
32. #         print(self.velocity)
33.
34.         gene = np.zeros(chromolen)
35.         for j in range(len(gene)):
36.             gene[j] = self.weightmin + (self.weightmax - self.weightmin)*random.random()
37.         self.position.append(gene)
38.
39.     def move(self):
40.         self.position = self.position + self.velocity
41.
42. class Space():
43.
44.     def __init__(self, target, n_particles,train_ip,train_op,layer):
45.         self.target = target
46.         self.n_particles = n_particles
47.         self.particles = []
48.         self.gbest_value = float('inf')
49.         self.weightmin = -1
50.         self.weightmax = 1
51.         self.layer = layer
52.         self.gbest_position = []
53.         self.get_gbest(self.layer)
54.         self.train_i = train_ip
55.         self.train_o = train_op
56.
57. #         print(self.gbest_position)
```

```

58.
59.     def get_gbest(self, layer):
60.         chromolen = 0
61.
62.         for i in range(1, len(layer)):
63.             chromolen = chromolen + (layer[i-1]*layer[i])
64.
65.         gene = np.zeros(chromolen)
66.         for j in range(len(gene)):
67.             gene[j] = self.weightmin + (self.weightmax - self.weightmin)*random.random()
68.         self.pogbest_position = gene
69.
70.     def set_pbest(self):
71.         for particle in self.particles:
72.             # print(particle.position)
73.             self.compute_fitness(particle)
74.             # print(particle.fitness)
75.             # fitness_cadidate = self.fitness(particle)
76.             if (particle.pbest_value > particle.fitness):
77.                 particle.pbest_value = particle.fitness
78.                 particle.pbest_position = particle.position
79.             print('----> pbest : ', particle.pbest_value)
80.
81.     def set_gbest(self):
82.         for particle in self.particles:
83.             self.compute_fitness(particle)
84.             # best_fitness_cadidate = self.fitness(particle)
85.             # print(particle.fitness)
86.             if (self.gbest_value > particle.fitness):
87.                 self.gbest_value = particle.fitness
88.                 self.gbest_position = particle.position
89.
90.     def move_particles(self):
91.         for particle in self.particles:
92.             global W
93.             # pdb.set_trace()
94.             new_velocity = (W*particle.velocity) + (c1*random.random()) * (np.array(particle.pbest_position) -
np.array(particle.position)) + (random.random()*c2) * (np.array(self.gbest_position) -
np.array(particle.position))
95.             particle.velocity = new_velocity
96.             particle.move()
97.
98.     def compute_fitness(self, particle):
99.         mlp = MLP(self.layer)
100.         mlp.init_weight(particle.position)
101.         particle.fitness = 0
102.         for i in range(len(self.train_i)) :
103.             error = mlp.forward(self.train_i.iloc[i], self.train_o.iloc[i])
104.             particle.fitness += error
105.         particle.fitness = particle.fitness/len(self.train_i)
106.         # print(chromosome.fitness)
107.
108.
109.     class MLP:
110.         def __init__(self, structure_layer):
111.             self.maxNode = 0
112.             self.structure = structure_layer
113.
114.             for i in structure_layer:
115.                 if self.maxNode < i :

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116.         self.maxNode = i
117.
118.         self.weight = np.zeros((len(structure_layer)-1,self.maxNode,self.maxNode))
119.     #         print(self.weight)
120.
121.     def initweight(self,chromosome):
122.         count = 0
123.     #         print(self.weight)
124.         for i in range(len(self.structure)-1):
125.             for j in range(self.structure[i]):
126.                 for k in range(self.structure[i+1]):
127.     #                     print(chromosome.position[count])
128.     #                     print(chromosome[count])
129.                     self.weight[i][j][k] = chromosome[0][count]
130.                     count = count+1
131.
132.     def forward(self,data,op):
133.         y = np.zeros((len(self.structure),self.maxNode))
134.     #         print(List(data.values())[2:])
135.         for i in range(len(data.values)):
136.             y[0][i] = data.values[i]
137.         for i in range(1,len(self.structure)):
138.             for j in range(self.structure[i]):
139.                 v = 0
140.                 for k in range(self.structure[i-1]):
141.                     v = v + y[i-1][k]*self.weight[i-1][k][j]
142.                 y[i][j] = self.sigmoid(v)
143.     #         print(abs(op.values-y[len(self.structure)-1][0]))
144.         return abs(op.values-y[len(self.structure)-1][0])
145.
146.     def sigmoid(self,v):
147.         return 1/(1+np.exp(-v))
148.
149.     c1 = 1.2
150.     c2 = 1.4
151.     W = (1/2*(c1+c2)-1)+0.3
152.
153.     n_iterations = 10
154.     n_particles = 10
155.     structure = [8,15,1]
156.
157.     for c in range(10):
158.         print("----- # Round "+str(c)+' ----- ')
159.         i = int(c*len(data_ip)*0.1)
160.         test_ip = data_ip[i:int(i+int(len(data_ip)*0.1))]
161.         test_op = desire_op[i:int(i+int(len(data_ip)*0.1))]
162.         train_ip = data_ip.drop(data_ip.index[i:i+int(len(data_ip)*0.1)])
163.         train_op = desire_op.drop(desire_op.index[i:i+int(len(data_ip)*0.1)])
164.
165.         particles_vector = []
166.         search_space = Space(1, n_particles,train_ip,desire_op,structure)
167.         particles_vector = [Particle(structure) for _ in range(search_space.n_particles)]
168.         search_space.particles = particles_vector
169.         iteration = 0
170.         while(iteration < n_iterations):
171.             print("iteration : #"+str(iteration+1))
172.             search_space.set_pbest()
173.             search_space.set_gbest()
174.             search_space.move_particles()
175.             iteration += 1
176.             print("-----> gbest : ", search_space.gbest_value[0])

```

```
177.  
178.         print("The best solution is: ", search_space.gbest_position, " in n_iterations:  
        ", iteration)
```