Data Structure Class - Assignment 1 student: 洪浩育 studentId: M113040047

Environment

```
$ uname -a
Linux tim-Vostro-5402 5.15.0-48-generic

$ gcc --version
gcc (Ubuntu 9.4.0-1ubuntu1~20.04.1) 9.4.0
```

Program

* How to build the code

1. `cd assignment1` go to the project folder
2. `make` run make to build the file
3. you will see the executable file "main" in build folder
4. `make clean` delete the build folder

```
tim@tim-Vostro-5402:~/CS/coding/data_structure_class$ cd assignment1/
tim@tim-Vostro-5402:~/CS/coding/data_structure_class/assignment1$ make
Building /home/tim/CS/coding/data_structure_class/assignment1/build/src/saddlePoint.o
g++  -I/home/tim/CS/coding/data_structure_class/assignment1/include -I/home/tim/CS/coding/data_struct
ure_class/assignment1/include -I/home/tim/CS/coding/data_structure_class/assignment1/external -MMD -M
P  -c /home/tim/CS/coding/data_structure_class/assignment1/src/saddlePoint.cpp -o /home/tim/CS/coding
/data_structure_class/assignment1/build/src/saddlePoint.o
Building /home/tim/CS/coding/data_structure_class/assignment1/build/src/main.o
g++  -I/home/tim/CS/coding/data_structure_class/assignment1/include -I/home/tim/CS/coding/data_struct
ure_class/assignment1/include -I/home/tim/CS/coding/data_structure_class/assignment1/external -MMD -M
P  -c /home/tim/CS/coding/data_structure_class/assignment1/src/main.cpp -o /home/tim/CS/coding/data_s
tructure_class/assignment1/build/src/main.o
Linking /home/tim/CS/coding/data_structure_class/assignment1/build/main
g++ /home/tim/CS/coding/data_structure_class/assignment1/build/src/saddlePoint.o /home/tim/CS/coding/
data_structure_class/assignment1/build/src/main.o -o /home/tim/CS/coding/data_structure_class/assignm
ent1/build/main
tim@tim-Vostro-5402:~/CS/coding/data_structure_class/assignment1$ cd build
tim@tim-Vostro-5402:~/CS/coding/data_structure_class/assignment1/build$ ls
main  src
```

```
tim@tim-Vostro-5402:~/CS/coding/data_structure_class/assignment1$ make clean
rm -rf  /home/tim/CS/coding/data_structure_class/assignment1/build 2>&1
Cleaning done !
```

* How to run the code

1. `make run` / `./build/main` run main in build folder
2. choose the function as the program prompt
3. choose the range of the xAxis
4. choose the range of the yAxis
5. it will output the matrix and all the saddle point

6. `./build/main < test_case > output` this will give you all the saddle points of the three functions(range -5 0.5 5)

```
tim@tim-Vostro-5402:~/CS/coding/data_structure_class/assignment1/build$ ./main
This executable is used for finding the saddle point of given function and parameters

Please select the function:
  1: y * sin(x) - x * cos(y)
  2: -cos(x) + sin(y)
  3: sqrt(x^2 + y^2)
  4: exit the program
input here: 2

please enter the range of the x y axis, and the format is 'start step end'(e.g. 0 0.5 5)
x axis: -5 0.5 5
y axis: -5 0.5 5
```

```
this is the matrix based on the given function and axis range:

    x/y|-5.0000 -4.5000 -4.0000 -3.5000 -3.0000 -2.5000 -2.0000 -1.5000 -1.0000 -0.5000  0.0000  0.5000  1.0000  1.5000  2.0000  2.5000  3.0000  3.5000  4.0000  4.5000  5.0000
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------
-5.0000| 0.6753  0.6939  0.4731  0.0671 -0.4248 -0.8821 -1.1930 -1.2812 -1.1251 -0.7631 -0.2837  0.1958  0.5578  0.7138  0.6256  0.3148 -0.1425 -0.6344 -1.0405 -1.2612 -1.2426
-4.5000| 1.1697  1.1883  0.9676  0.5616  0.0697 -0.3877 -0.6985 -0.7867 -0.6307 -0.2686  0.2108  0.6902  1.0523  1.2083  1.1201  0.8093  0.3519 -0.1400 -0.5460 -0.7667 -0.7481
-4.0000| 1.6126  1.6312  1.4104  1.0044  0.5125  0.0552 -0.2557 -0.3439 -0.1878  0.1742  0.6536  1.1331  1.4951  1.6511  1.5629  1.2521  0.7948  0.3029 -0.1032 -0.3239 -0.3053
-3.5000| 1.8954  1.9140  1.6933  1.2872  0.7953  0.3380  0.0272 -0.0610  0.0950  0.4570  0.9365  1.4159  1.7779  1.9340  1.8458  1.5349  1.0776  0.5857  0.1797 -0.0411 -0.0225
-3.0000| 1.9489  1.9675  1.7468  1.3408  0.8489  0.3915  0.0807 -0.0075  0.1485  0.5106  0.9900  1.4694  1.8315  1.9875  1.8993  1.5885  1.1311  0.6392  0.2332  0.0125  0.0311
-2.5000| 1.7601  1.7787  1.5579  1.1519  0.6600  0.2027 -0.1082 -0.1964 -0.0403  0.3217  0.8011  1.2806  1.6426  1.7986  1.7104  1.3996  0.9423  0.4504  0.0443 -0.1764 -0.1578
-2.0000| 1.3751  1.3937  1.1729  0.7669  0.2750 -0.1823 -0.4932 -0.5813 -0.4253 -0.0633  0.4161  0.8956  1.2576  1.4136  1.3254  1.0146  0.5573  0.0654 -0.3407 -0.5614 -0.5428
-1.5000| 0.8882  0.9068  0.6861  0.2800 -0.2119 -0.6692 -0.9800 -1.0682 -0.9122 -0.5502 -0.0707  0.4087  0.7707  0.9268  0.8386  0.5277  0.0704 -0.4215 -0.8275 -1.0483 -1.0297
-1.0000| 0.4186  0.4372  0.2165 -0.1895 -0.6814 -1.1388 -1.4496 -1.5378 -1.3818 -1.0197 -0.5403 -0.0609  0.3012  0.4572  0.3690  0.0582 -0.3992 -0.8911 -1.2971 -1.5178 -1.4992
-0.5000| 0.0813  0.0999 -0.1208 -0.5268 -1.0187 -1.4761 -1.7869 -1.8751 -1.7191 -1.3570 -0.8776 -0.3982 -0.0361  0.1199  0.0317 -0.2791 -0.7365 -1.2284 -1.6344 -1.8551 -1.8365
 0.0000|-0.0411 -0.0225 -0.2432 -0.6492 -1.1411 -1.5985 -1.9093 -1.9975 -1.8415 -1.4794 -1.0000 -0.5206 -0.1585 -0.0025 -0.0907 -0.4015 -0.8589 -1.3508 -1.7568 -1.9775 -1.9589
 0.5000| 0.0813  0.0999 -0.1208 -0.5268 -1.0187 -1.4761 -1.7869 -1.8751 -1.7191 -1.3570 -0.8776 -0.3982 -0.0361  0.1199  0.0317 -0.2791 -0.7365 -1.2284 -1.6344 -1.8551 -1.8365
 1.0000| 0.4186  0.4372  0.2165 -0.1895 -0.6814 -1.1388 -1.4496 -1.5378 -1.3818 -1.0197 -0.5403 -0.0609  0.3012  0.4572  0.3690  0.0582 -0.3992 -0.8911 -1.2971 -1.5178 -1.4992
 1.5000| 0.8882  0.9068  0.6861  0.2800 -0.2119 -0.6692 -0.9800 -1.0682 -0.9122 -0.5502 -0.0707  0.4087  0.7707  0.9268  0.8386  0.5277  0.0704 -0.4215 -0.8275 -1.0483 -1.0297
 2.0000| 1.3751  1.3937  1.1729  0.7669  0.2750 -0.1823 -0.4932 -0.5813 -0.4253 -0.0633  0.4161  0.8956  1.2576  1.4136  1.3254  1.0146  0.5573  0.0654 -0.3407 -0.5614 -0.5428
 2.5000| 1.7601  1.7787  1.5579  1.1519  0.6600  0.2027 -0.1082 -0.1964 -0.0403  0.3217  0.8011  1.2806  1.6426  1.7986  1.7104  1.3996  0.9423  0.4504  0.0443 -0.1764 -0.1578
 3.0000| 1.9489  1.9675  1.7468  1.3408  0.8489  0.3915  0.0807 -0.0075  0.1485  0.5106  0.9900  1.4694  1.8315  1.9875  1.8993  1.5885  1.1311  0.6392  0.2332  0.0125  0.0311
 3.5000| 1.8954  1.9140  1.6933  1.2872  0.7953  0.3380  0.0272 -0.0610  0.0950  0.4570  0.9365  1.4159  1.7779  1.9340  1.8458  1.5349  1.0776  0.5857  0.1797 -0.0411 -0.0225
 4.0000| 1.6126  1.6312  1.4104  1.0044  0.5125  0.0552 -0.2557 -0.3439 -0.1878  0.1742  0.6536  1.1331  1.4951  1.6511  1.5629  1.2521  0.7948  0.3029 -0.1032 -0.3239 -0.3053
 4.5000| 1.1697  1.1883  0.9676  0.5616  0.0697 -0.3877 -0.6985 -0.7867 -0.6307 -0.2686  0.2108  0.6902  1.0523  1.2083  1.1201  0.8093  0.3519 -0.1400 -0.5460 -0.7667 -0.7481
 5.0000| 0.6753  0.6939  0.4731  0.0671 -0.4248 -0.8821 -1.1930 -1.2812 -1.1251 -0.7631 -0.2837  0.1958  0.5578  0.7138  0.6256  0.3148 -0.1425 -0.6344 -1.0405 -1.2612 -1.2426

------------------------------------------------------------
Saddle point(s) found at:

X =  -3.0000, Y =  -1.5000, Value =  -0.0075
X =   3.0000, Y =  -1.5000, Value =  -0.0075
X =   0.0000, Y =   1.5000, Value =  -0.0025
------------------------------------------------------------
```

Test Results

1. F (X,Y) = Y * sin X – X * cos Y, (-5, 0.5, 5)

```
    x/y|-5.0000 -4.5000 -4.0000 -3.5000 -3.0000 -2.5000 -2.0000 -1.5000 -1.0000 -0.5000  0.0000  0.5000  1.0000  1.5000  2.0000  2.5000  3.0000  3.5000  4.0000  4.5000  5.0000
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------
-5.0000|-3.3763 -5.3691 -7.1039 -8.0385 -7.8267 -6.4030 -3.9986 -1.0847  1.7426  3.9085  5.0000  4.8674  3.6604  1.7921 -0.1629 -1.6084 -2.0732 -1.3260  0.5675  3.2612  6.2129
-4.5000|-3.6112 -5.3475 -6.8515 -7.6354 -7.3876 -6.0490 -3.8277 -1.1480  1.4538  3.4604  4.5000  4.4379  3.4089  1.7846  0.0824 -1.1613 -1.5224 -0.7927  0.9687  3.4503  6.1641
-4.0000|-2.6494 -4.2488 -5.6418 -6.3946 -6.2304 -5.0966 -3.1782 -0.8523  1.4044  3.1319  4.0000  3.8887  2.9180  1.4182 -0.1510 -1.3126 -1.6896 -1.0970  0.4126  2.5624  4.9187
-3.5000|-0.7611 -2.3163 -3.6909 -4.5053 -4.5173 -3.6810 -2.1581 -0.2786  1.5403  2.8961  3.5000  3.2469  2.2418  0.7738 -0.7549 -1.9270 -2.4126 -2.0499 -0.8846  0.8407  2.7467
-3.0000|  1.5566  0.0027 -1.3965 -2.3154 -2.5466 -2.0506 -0.9662  0.4239  1.7620  2.7033  3.0000  2.5622  1.4798  0.0005 -1.5307 -2.7562 -3.3933 -3.3033 -2.5254 -1.2674  0.1454
-2.5000|  3.7015  2.1661  0.7598 -0.2465 -0.6796 -0.5067  0.1566  1.0746  1.9492  2.4932  2.5000  1.8947  0.7523 -0.7209 -2.2373 -3.4990 -4.2704 -4.4358 -4.0280 -3.2201 -2.2832
-2.0000|  5.1138  3.6702  2.3299  1.3096  0.7479  0.6710  0.9863  1.5054  1.9899  2.2098  2.0000  1.3005  0.1713 -1.2225 -2.6509 -3.8755 -4.7079 -5.0555 -4.9445 -4.5134 -3.9792
-1.5000|  5.4130  4.1725  3.0095  2.0865  1.5075  1.2920  1.3708  1.6023  1.8079  1.8151  1.5000  0.8176 -0.1870 -1.3901 -2.6192 -3.6955 -4.4775 -4.8959 -4.9704 -4.8049 -4.5620
-1.0000|  4.4910  3.5758  2.7122  2.0087  1.5344  1.3025  1.2668  1.3329  1.3818  1.2983  1.0000  0.4568 -0.3012 -1.1915 -2.0991 -2.9048 -3.5144 -3.8816 -4.0195 -3.9974 -3.9237
-0.5000|  2.5390  2.0520  1.5909  1.2098  0.9433  0.7980  0.7508  0.7545  0.7496  0.6785  0.5000  0.1991 -0.2093 -0.6838 -1.1669 -1.5991 -1.9333 -2.1462 -2.2445 -2.2628 -2.2553
 0.0000|-0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000 -0.0000 -0.0000 -0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
 0.5000|-2.5390 -2.0520 -1.5909 -1.2098 -0.9433 -0.7980 -0.7508 -0.7545 -0.7496 -0.6785 -0.5000 -0.1991  0.2093  0.6838  1.1669  1.5991  1.9333  2.1462  2.2445  2.2628  2.2553
 1.0000|-4.4910 -3.5758 -2.7122 -2.0087 -1.5344 -1.3025 -1.2668 -1.3329 -1.3818 -1.2983 -1.0000 -0.4568  0.3012  1.1915  2.0991  2.9048  3.5144  3.8816  4.0195  3.9974  3.9237
 1.5000|-5.4130 -4.1725 -3.0095 -2.0865 -1.5075 -1.2920 -1.3708 -1.6023 -1.8079 -1.8151 -1.5000 -0.8176  0.1870  1.3901  2.6192  3.6955  4.4775  4.8959  4.9704  4.8049  4.5620
 2.0000|-5.1138 -3.6702 -2.3299 -1.3096 -0.7479 -0.6710 -0.9863 -1.5054 -1.9899 -2.2098 -2.0000 -1.3005 -0.1713  1.2225  2.6509  3.8755  4.7079  5.0555  4.9445  4.5134  3.9792
 2.5000|-3.7015 -2.1661 -0.7598  0.2465  0.6796  0.5067 -0.1566 -1.0746 -1.9492 -2.4932 -2.5000 -1.8947 -0.7523  0.7209  2.2373  3.4990  4.2704  4.4358  4.0280  3.2201  2.2832
 3.0000|-1.5566 -0.0027  1.3965  2.3154  2.5466  2.0506  0.9662 -0.4239 -1.7620 -2.7033 -3.0000 -2.5622 -1.4798 -0.0005  1.5307  2.7562  3.3933  3.3033  2.5254  1.2674 -0.1454
 3.5000|  0.7611  2.3163  3.6909  4.5053  4.5173  3.6810  2.1581  0.2786 -1.5403 -2.8961 -3.5000 -3.2469 -2.2418 -0.7738  0.7549  1.9270  2.4126  2.0499  0.8846 -0.8407 -2.7467
 4.0000|  2.6494  4.2488  5.6418  6.3946  6.2304  5.0966  3.1782  0.8523 -1.4044 -3.1319 -4.0000 -3.8887 -2.9180 -1.4182  0.1510  1.3126  1.6896  1.0970 -0.4126 -2.5624 -4.9187
 4.5000|  3.6112  5.3475  6.8515  7.6354  7.3876  6.0490  3.8277  1.1480 -1.4538 -3.4604 -4.5000 -4.4379 -3.4089 -1.7846 -0.0824  1.1613  1.5224  0.7927 -0.9687 -3.4503 -6.1641
 5.0000|  3.3763  5.3691  7.1039  8.0385  7.8267  6.4030  3.9986  1.0847 -1.7426 -3.9085 -5.0000 -4.8674 -3.6604 -1.7921  0.1629  1.6084  2.0732  1.3260 -0.5675 -3.2612 -6.2129

------------------------------------------------------------
Saddle point(s) found at:

No saddle point found
------------------------------------------------------------
```

2. F (X,Y) = -cos X + sin Y

```
   x/y|-5.0000 -4.5000 -4.0000 -3.5000 -3.0000 -2.5000 -2.0000 -1.5000 -1.0000 -0.5000  0.0000  0.5000  1.0000  1.5000  2.0000  2.5000  3.0000  3.5000  4.0000  4.5000  5.0000
------------------------------------------------------------------------------------------------------------------------------------------------------------------
-5.0000| 0.6753  0.6939  0.4731  0.0671 -0.4248 -0.8821 -1.1930 -1.2812 -1.1251 -0.7631 -0.2837  0.1958  0.5578  0.7138  0.6256  0.3148 -0.1425 -0.6344 -1.0405 -1.2612 -1.2426
-4.5000| 1.1697  1.1883  0.9676  0.5616  0.0697 -0.3877 -0.6985 -0.7867 -0.6307 -0.2686  0.2108  0.6902  1.0523  1.2083  1.1201  0.8093  0.3519 -0.1400 -0.5460 -0.7667 -0.7481
-4.0000| 1.6126  1.6312  1.4104  1.0044  0.5125  0.0552 -0.2557 -0.3439 -0.1878  0.1742  0.6536  1.1331  1.4951  1.6511  1.5629  1.2521  0.7948  0.3029 -0.1032 -0.3239 -0.3053
-3.5000| 1.8954  1.9140  1.6933  1.2872  0.7953  0.3380  0.0272 -0.0610  0.0950  0.4570  0.9365  1.4159  1.7779  1.9340  1.8458  1.5349  1.0776  0.5857  0.1797 -0.0411 -0.0225
-3.0000| 1.9489  1.9675  1.7468  1.3408  0.8489  0.3915  0.0807 -0.0075  0.1485  0.5106  0.9900  1.4694  1.8315  1.9875  1.8993  1.5885  1.1311  0.6392  0.2332  0.0125  0.0311
-2.5000| 1.7601  1.7787  1.5579  1.1519  0.6600  0.2027 -0.1082 -0.1964 -0.0403  0.3217  0.8011  1.2806  1.6426  1.7986  1.7104  1.3996  0.9423  0.4504  0.0443 -0.1764 -0.1578
-2.0000| 1.3751  1.3937  1.1729  0.7669  0.2750 -0.1823 -0.4932 -0.5813 -0.4253 -0.0633  0.4161  0.8956  1.2576  1.4136  1.3254  1.0146  0.5573  0.0654 -0.3407 -0.5614 -0.5428
-1.5000| 0.8882  0.9068  0.6861  0.2800 -0.2119 -0.6692 -0.9800 -1.0682 -0.9122 -0.5502 -0.0707  0.4087  0.7707  0.9268  0.8386  0.5277  0.0704 -0.4215 -0.8275 -1.0483 -1.0297
-1.0000| 0.4186  0.4372  0.2165 -0.1895 -0.6814 -1.1388 -1.4496 -1.5378 -1.3818 -1.0197 -0.5403 -0.0609  0.3012  0.4572  0.3690  0.0582 -0.3992 -0.8911 -1.2971 -1.5178 -1.4992
-0.5000| 0.0813  0.0999 -0.1208 -0.5268 -1.0187 -1.4761 -1.7869 -1.8751 -1.7191 -1.3570 -0.8776 -0.3982 -0.0361  0.1199  0.0317 -0.2791 -0.7365 -1.2284 -1.6344 -1.8551 -1.8365
 0.0000|-0.0411 -0.0225 -0.2432 -0.6492 -1.1411 -1.5985 -1.9093 -1.9975 -1.8415 -1.4794 -1.0000 -0.5206 -0.1585 -0.0025 -0.0907 -0.4015 -0.8589 -1.3508 -1.7568 -1.9775 -1.9589
 0.5000| 0.0813  0.0999 -0.1208 -0.5268 -1.0187 -1.4761 -1.7869 -1.8751 -1.7191 -1.3570 -0.8776 -0.3982 -0.0361  0.1199  0.0317 -0.2791 -0.7365 -1.2284 -1.6344 -1.8551 -1.8365
 1.0000| 0.4186  0.4372  0.2165 -0.1895 -0.6814 -1.1388 -1.4496 -1.5378 -1.3818 -1.0197 -0.5403 -0.0609  0.3012  0.4572  0.3690  0.0582 -0.3992 -0.8911 -1.2971 -1.5178 -1.4992
 1.5000| 0.8882  0.9068  0.6861  0.2800 -0.2119 -0.6692 -0.9800 -1.0682 -0.9122 -0.5502 -0.0707  0.4087  0.7707  0.9268  0.8386  0.5277  0.0704 -0.4215 -0.8275 -1.0483 -1.0297
 2.0000| 1.3751  1.3937  1.1729  0.7669  0.2750 -0.1823 -0.4932 -0.5813 -0.4253 -0.0633  0.4161  0.8956  1.2576  1.4136  1.3254  1.0146  0.5573  0.0654 -0.3407 -0.5614 -0.5428
 2.5000| 1.7601  1.7787  1.5579  1.1519  0.6600  0.2027 -0.1082 -0.1964 -0.0403  0.3217  0.8011  1.2806  1.6426  1.7986  1.7104  1.3996  0.9423  0.4504  0.0443 -0.1764 -0.1578
 3.0000| 1.9489  1.9675  1.7468  1.3408  0.8489  0.3915  0.0807 -0.0075  0.1485  0.5106  0.9900  1.4694  1.8315  1.9875  1.8993  1.5885  1.1311  0.6392  0.2332  0.0125  0.0311
 3.5000| 1.8954  1.9140  1.6933  1.2872  0.7953  0.3380  0.0272 -0.0610  0.0950  0.4570  0.9365  1.4159  1.7779  1.9340  1.8458  1.5349  1.0776  0.5857  0.1797 -0.0411 -0.0225
 4.0000| 1.6126  1.6312  1.4104  1.0044  0.5125  0.0552 -0.2557 -0.3439 -0.1878  0.1742  0.6536  1.1331  1.4951  1.6511  1.5629  1.2521  0.7948  0.3029 -0.1032 -0.3239 -0.3053
 4.5000| 1.1697  1.1883  0.9676  0.5616  0.0697 -0.3877 -0.6985 -0.7867 -0.6307 -0.2686  0.2108  0.6902  1.0523  1.2083  1.1201  0.8093  0.3519 -0.1400 -0.5460 -0.7667 -0.7481
 5.0000| 0.6753  0.6939  0.4731  0.0671 -0.4248 -0.8821 -1.1930 -1.2812 -1.1251 -0.7631 -0.2837  0.1958  0.5578  0.7138  0.6256  0.3148 -0.1425 -0.6344 -1.0405 -1.2612 -1.2426

------------------------------------------------------------
Saddle point(s) found at:

X =  -3.0000, Y =  -1.5000, Value =  -0.0075
X =   3.0000, Y =  -1.5000, Value =  -0.0075
X =   0.0000, Y =   1.5000, Value =  -0.0025
------------------------------------------------------------
```

3. F (X,Y) = sqrt(X^2 + Y^2)

```
   x/y|-5.0000 -4.5000 -4.0000 -3.5000 -3.0000 -2.5000 -2.0000 -1.5000 -1.0000 -0.5000  0.0000  0.5000  1.0000  1.5000  2.0000  2.5000  3.0000  3.5000  4.0000  4.5000  5.0000
------------------------------------------------------------------------------------------------------------------------------------------------------------------
-5.0000| 7.0711  6.7268  6.4031  6.1033  5.8310  5.5902  5.3852  5.2202  5.0990  5.0249  5.0000  5.0249  5.0990  5.2202  5.3852  5.5902  5.8310  6.1033  6.4031  6.7268  7.0711
-4.5000| 6.7268  6.3640  6.0208  5.7009  5.4083  5.1478  4.9244  4.7434  4.6098  4.5277  4.5000  4.5277  4.6098  4.7434  4.9244  5.1478  5.4083  5.7009  6.0208  6.3640  6.7268
-4.0000| 6.4031  6.0208  5.6569  5.3151  5.0000  4.7170  4.4721  4.2720  4.1231  4.0311  4.0000  4.0311  4.1231  4.2720  4.4721  4.7170  5.0000  5.3151  5.6569  6.0208  6.4031
-3.5000| 6.1033  5.7009  5.3151  4.9497  4.6098  4.3012  4.0311  3.8079  3.6401  3.5355  3.5000  3.5355  3.6401  3.8079  4.0311  4.3012  4.6098  4.9497  5.3151  5.7009  6.1033
-3.0000| 5.8310  5.4083  5.0000  4.6098  4.2426  3.9051  3.6056  3.3541  3.1623  3.0414  3.0000  3.0414  3.1623  3.3541  3.6056  3.9051  4.2426  4.6098  5.0000  5.4083  5.8310
-2.5000| 5.5902  5.1478  4.7170  4.3012  3.9051  3.5355  3.2016  2.9155  2.6926  2.5495  2.5000  2.5495  2.6926  2.9155  3.2016  3.5355  3.9051  4.3012  4.7170  5.1478  5.5902
-2.0000| 5.3852  4.9244  4.4721  4.0311  3.6056  3.2016  2.8284  2.5000  2.2361  2.0616  2.0000  2.0616  2.2361  2.5000  2.8284  3.2016  3.6056  4.0311  4.4721  4.9244  5.3852
-1.5000| 5.2202  4.7434  4.2720  3.8079  3.3541  2.9155  2.5000  2.1213  1.8028  1.5811  1.5000  1.5811  1.8028  2.1213  2.5000  2.9155  3.3541  3.8079  4.2720  4.7434  5.2202
-1.0000| 5.0990  4.6098  4.1231  3.6401  3.1623  2.6926  2.2361  1.8028  1.4142  1.1180  1.0000  1.1180  1.4142  1.8028  2.2361  2.6926  3.1623  3.6401  4.1231  4.6098  5.0990
-0.5000| 5.0249  4.5277  4.0311  3.5355  3.0414  2.5495  2.0616  1.5811  1.1180  0.7071  0.5000  0.7071  1.1180  1.5811  2.0616  2.5495  3.0414  3.5355  4.0311  4.5277  5.0249
 0.0000| 5.0000  4.5000  4.0000  3.5000  3.0000  2.5000  2.0000  1.5000  1.0000  0.5000  0.0000  0.5000  1.0000  1.5000  2.0000  2.5000  3.0000  3.5000  4.0000  4.5000  5.0000
 0.5000| 5.0249  4.5277  4.0311  3.5355  3.0414  2.5495  2.0616  1.5811  1.1180  0.7071  0.5000  0.7071  1.1180  1.5811  2.0616  2.5495  3.0414  3.5355  4.0311  4.5277  5.0249
 1.0000| 5.0990  4.6098  4.1231  3.6401  3.1623  2.6926  2.2361  1.8028  1.4142  1.1180  1.0000  1.1180  1.4142  1.8028  2.2361  2.6926  3.1623  3.6401  4.1231  4.6098  5.0990
 1.5000| 5.2202  4.7434  4.2720  3.8079  3.3541  2.9155  2.5000  2.1213  1.8028  1.5811  1.5000  1.5811  1.8028  2.1213  2.5000  2.9155  3.3541  3.8079  4.2720  4.7434  5.2202
 2.0000| 5.3852  4.9244  4.4721  4.0311  3.6056  3.2016  2.8284  2.5000  2.2361  2.0616  2.0000  2.0616  2.2361  2.5000  2.8284  3.2016  3.6056  4.0311  4.4721  4.9244  5.3852
 2.5000| 5.5902  5.1478  4.7170  4.3012  3.9051  3.5355  3.2016  2.9155  2.6926  2.5495  2.5000  2.5495  2.6926  2.9155  3.2016  3.5355  3.9051  4.3012  4.7170  5.1478  5.5902
 3.0000| 5.8310  5.4083  5.0000  4.6098  4.2426  3.9051  3.6056  3.3541  3.1623  3.0414  3.0000  3.0414  3.1623  3.3541  3.6056  3.9051  4.2426  4.6098  5.0000  5.4083  5.8310
 3.5000| 6.1033  5.7009  5.3151  4.9497  4.6098  4.3012  4.0311  3.8079  3.6401  3.5355  3.5000  3.5355  3.6401  3.8079  4.0311  4.3012  4.6098  4.9497  5.3151  5.7009  6.1033
 4.0000| 6.4031  6.0208  5.6569  5.3151  5.0000  4.7170  4.4721  4.2720  4.1231  4.0311  4.0000  4.0311  4.1231  4.2720  4.4721  4.7170  5.0000  5.3151  5.6569  6.0208  6.4031
 4.5000| 6.7268  6.3640  6.0208  5.7009  5.4083  5.1478  4.9244  4.7434  4.6098  4.5277  4.5000  4.5277  4.6098  4.7434  4.9244  5.1478  5.4083  5.7009  6.0208  6.3640  6.7268
 5.0000| 7.0711  6.7268  6.4031  6.1033  5.8310  5.5902  5.3852  5.2202  5.0990  5.0249  5.0000  5.0249  5.0990  5.2202  5.3852  5.5902  5.8310  6.1033  6.4031  6.7268  7.0711

------------------------------------------------------------
Saddle point(s) found at:

X =   0.0000, Y =  -5.0000, Value =   5.0000
X =  -5.0000, Y =   0.0000, Value =   5.0000
X =   5.0000, Y =   0.0000, Value =   5.0000
X =   0.0000, Y =   5.0000, Value =   5.0000
------------------------------------------------------------
```

Questions for this project

1. Describe any challenges you encountered

- This is my first time writing C++. I spend a lot of time tring to understand the syntax of it. Beside of that, c++ provide many useful standard library, so I try to look through some of it and use in this homework.
- Makefile is also a big issue for me. I didn't really know how to use it, so did a lot of research. Finally, I am able to write a basic one, I'm still trying to make it more general, so I can apply it to a bigger project in the future. By the way, there is also one popular build program call CMake that support cross platform build. I'm still trying to walk through some basicc knowledge.
- I'm also trying to understand the testing paradigm of c++. In the next assignment I will try to include the unit test into the assignment.

2. What did you learn from this programming

- understand the basic programming of c++ and some of basic standard library
- know how to handle terminal IO in c++

- understand how to use function pointer and enum class
- understand the basic of makefile
- know how the basic matrix work in c++