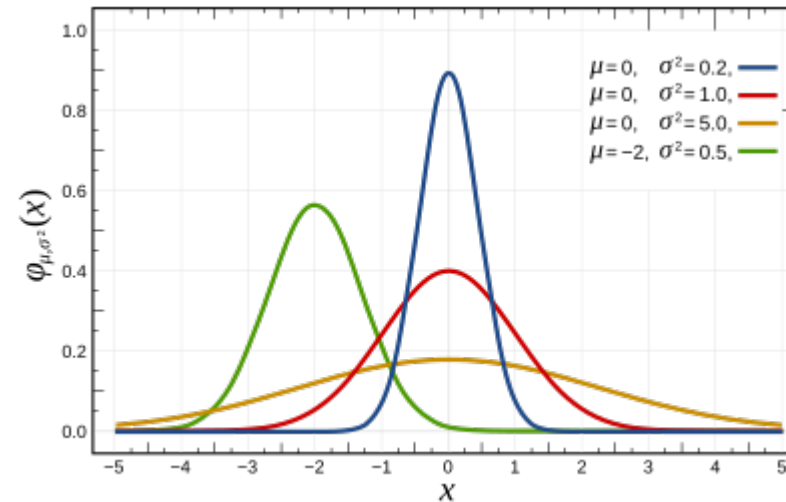
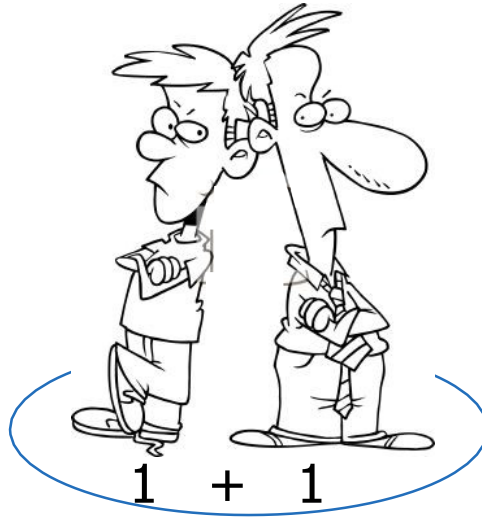


# HW2: Implementation of ES(1+1) with 1/5 Rule



The red curve is the *standard normal distribution*

HW2 program will be used for training (optimizing weight values) for simple Neural Networks for HW3

LTU CS  
CJ Chung

# HW2

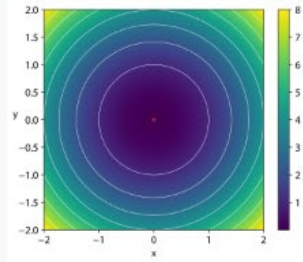
- **ES11\_15\_yourName.ipynb** file is provided on Canvas
- Complete all the missing part of the program to solve 5 optimization functions using ES(1+1) with 1/5 rule introduced in class.
- 5 objective functions with search domain as  $-5 \leq x_i \leq 5$  are:

(1) findroot: objective function to find the root of the following function using this ES(1+1) with 1/5 rule:

$$f(x) = x^3 - 2x^2 - x + 2 = (x+1)(x-1)(x-2)$$

minimize  $f(x) = |x^3 - 2x^2 - x + 2|$       *Note that there are 3 roots*

(2)

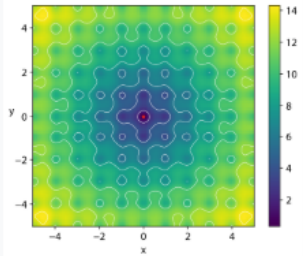
Sphere  
function

$$f(\mathbf{x}) = \sum_{i=1}^n x_i^2$$

$$f(x_1, \dots, x_n) = f(0, \dots, 0) = 0$$

Use  $n$  as 20

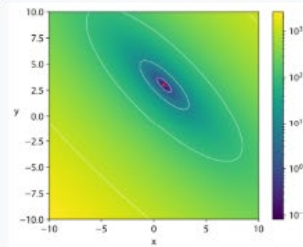
(3)

Ackley  
function

$$f(x, y) = -20 \exp \left[ -0.2 \sqrt{0.5 (x^2 + y^2)} \right] - \exp[0.5 (\cos 2\pi x + \cos 2\pi y)] + e + 20$$

$$f(0, 0) = 0$$

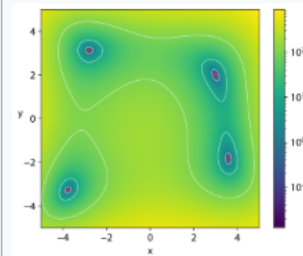
(4)

Booth  
function

$$f(x, y) = (x + 2y - 7)^2 + (2x + y - 5)^2$$

$$f(1, 3) = 0$$

(5)

Himmelblau's  
function

$$f(x, y) = (x^2 + y - 11)^2 + (x + y^2 - 7)^2.$$

$$\text{Min} = \begin{cases} f(3.0, 2.0) & = 0.0 \\ f(-2.805118, 3.131312) & = 0.0 \\ f(-3.779310, -3.283186) & = 0.0 \\ f(3.584428, -1.848126) & = 0.0 \end{cases}$$

# A sample expected output (1 /4)

----- findroot2 -----

T=0, Min\_Eval= 0.00001 at [1.00000632], gen=1016

T=1, Min\_Eval= 0.00003 at [2.00000944], gen=1498

T=2, Min\_Eval= 0.00002 at [2.00000502], gen=1366

System Success = 100.0%

Average # of generations used = 1,293

----- sphere\_n -----

T=0, Min\_Eval= 0.00004 at [ 4.86711734e-04 4.02301854e-03 -2.44914436e-03 1.44283467e-03

-7.84474253e-05 -1.62282379e-03 -3.99814421e-04 -1.27332571e-04

4.22905242e-04 7.79189208e-04 -1.39760326e-03 -1.26270169e-03

-2.14024193e-03 -9.32837862e-04 -7.48129941e-04 2.89771569e-04

-7.16231505e-04 -7.05439464e-04 -2.29114161e-03 5.70322612e-06], gen=1382

T=1, Min\_Eval= 0.00004 at [-0.00046407 0.00344629 0.00032897 0.00050425 -0.00214914 0.00042268

0.00026882 -0.0004115 0.00316019 -0.00111952 0.0007591 -0.00012328

0.00232848 0.0003027 -0.00028458 -0.00144004 -0.00146663 -0.00172993

0.00027397 -0.00146657], gen=1353

T=2, Min\_Eval= 0.00005 at [ 1.03855344e-03 2.15064709e-03 -7.35689411e-04 3.63427408e-04

-1.97675374e-03 4.87973265e-04 -8.10039103e-04 -2.38617155e-03

-6.31022201e-04 9.02150652e-04 -4.82734497e-05 8.15149267e-04

3.74913874e-03 -4.35468223e-04 2.35799922e-03 -1.10238584e-03

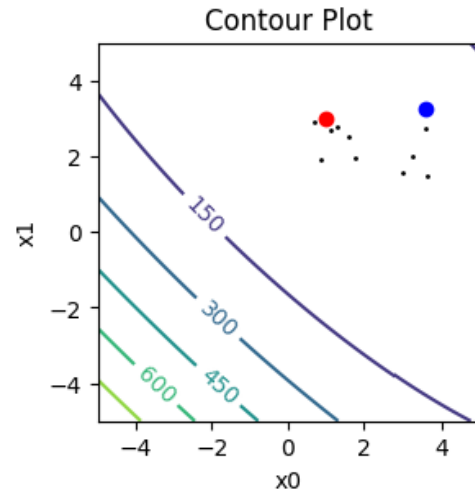
3.22868093e-04 1.62646540e-03 -1.79330028e-03 9.65114288e-04], gen=1434

System Success = 100.0%

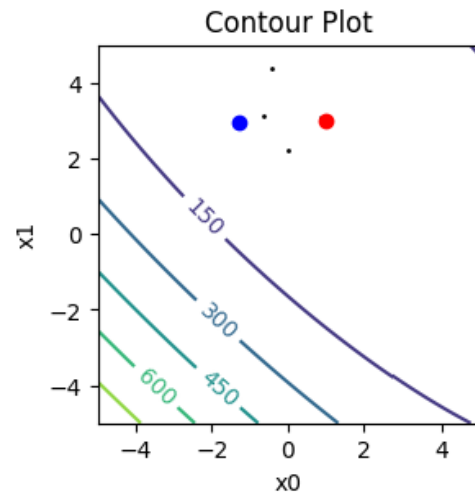
Average # of generations used = 1,390

# A sample expected output (2 /4)

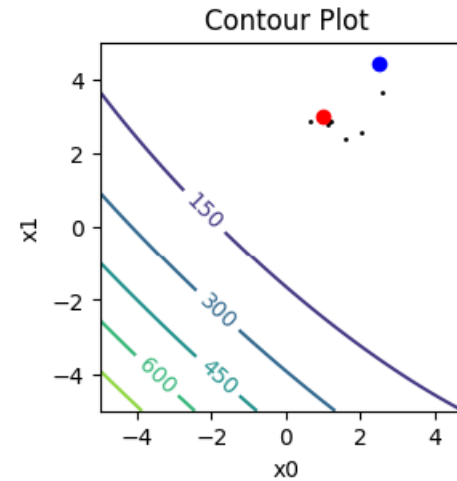
----- booth -----  
T=0, Min\_Eval= 0.00003 at [1.00145089 2.99667858], gen=558



T=1, Min\_Eval= 0.00003 at [0.99741715 3.00384483], gen=780



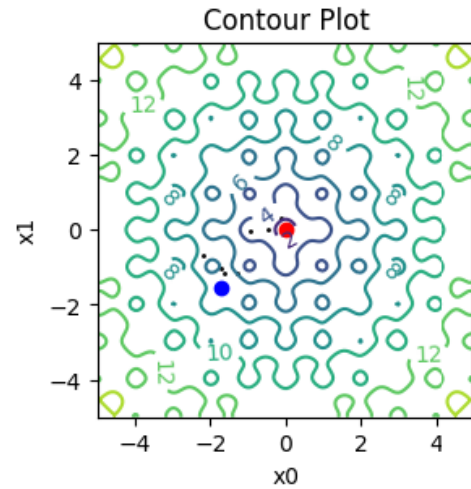
T=2, Min\_Eval= 0.00002 at [0.99839888 3.00305433], gen=343



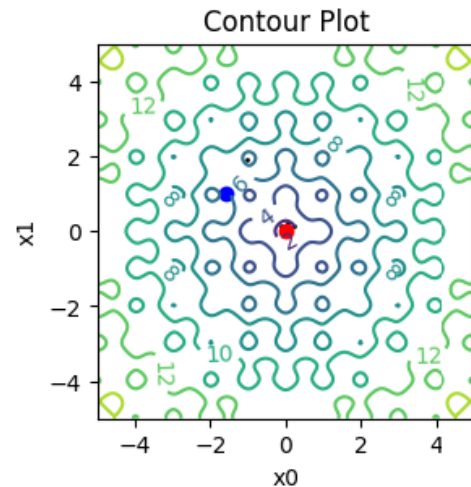
System Success = 100.0%  
Average # of generations used = 560

# A sample expected output (3 /4)

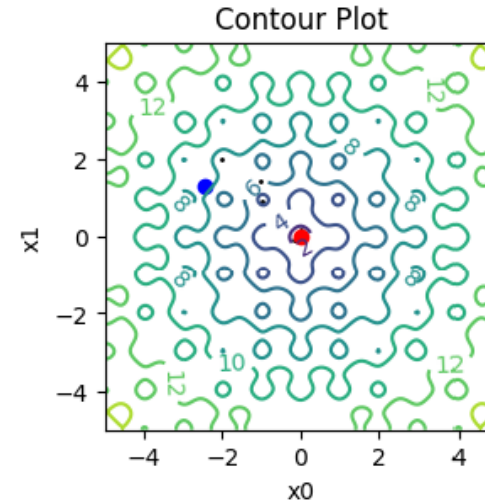
----- ackley -----  
T=0, Min\_Eval= 0.00002 at [-4.57895759e-06 4.02745263e-06], gen=1819



T=1, Min\_Eval= 0.00002 at [-6.41934275e-07 -5.31341081e-06], gen=1727



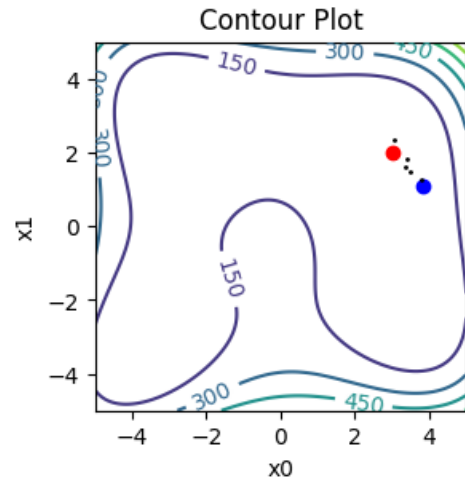
T=2, Min\_Eval= 0.00005 at [-4.06699044e-06 1.67554237e-05], gen=1890



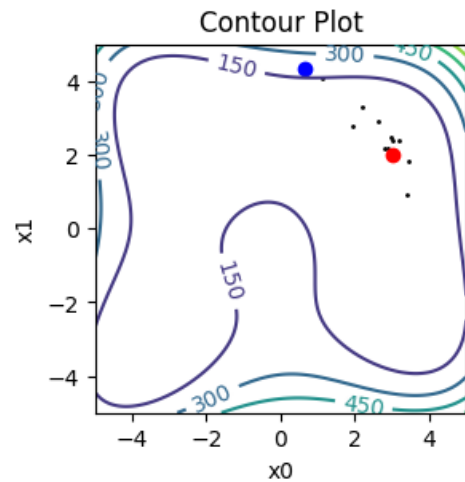
System Success = 100.0%  
Average # of generations used = 1,812

# A sample expected output (4 /4)

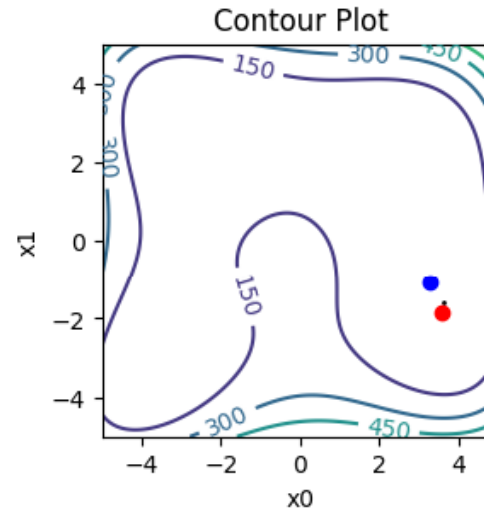
----- himmelblau -----  
T=0, Min\_Eval= 0.00001 at [2.99952212 2.00041348], gen=924



T=1, Min\_Eval= 0.00000 at [2.99991188 2.00040288], gen=766



T=2, Min\_Eval= 0.00002 at [ 3.58502393 -1.84807062], gen=752



System Success = 100.0%  
Average # of generations used = 814

# HW2 Instructions

- Submitted file must have your name: **ES11\_15\_yourName.ipynb**
- Required markdown text cell in the beginning of the code.  
Please make sure to specify the % of generative AI tool use
- Do not change other parts of the code. Complete only missing parts
- Your submitted .ipynb file must run correctly for the 5 functions and must include run results including contour plots
- Please read the rule in the syllabus for pre-checking before the deadline



# HW2 is important

HW2 program will be used for training (optimizing weight values) for simple Neural Networks for HW3

# Quiz #1

- Wed Sep 10<sup>th</sup>, 2025
- You must come to the class to take the exam
- No make up exam is allowed