# Implementation of Wolf Pack Algorithm for unconstrained optimization

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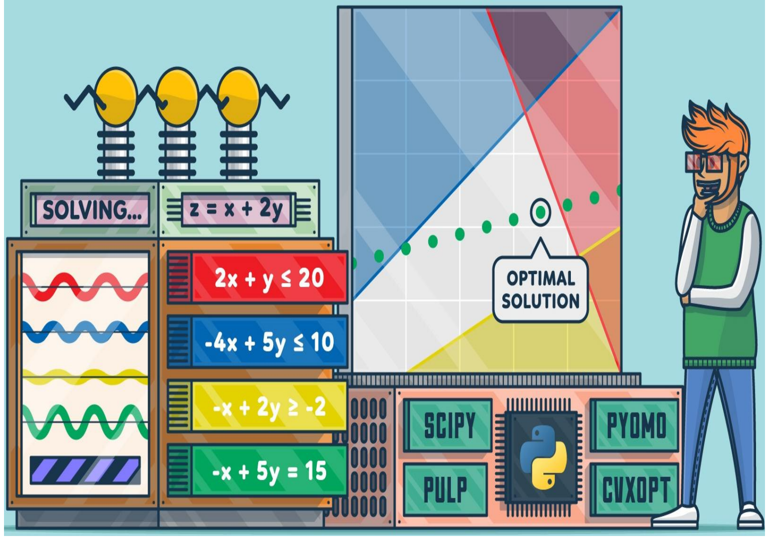
# Introduction

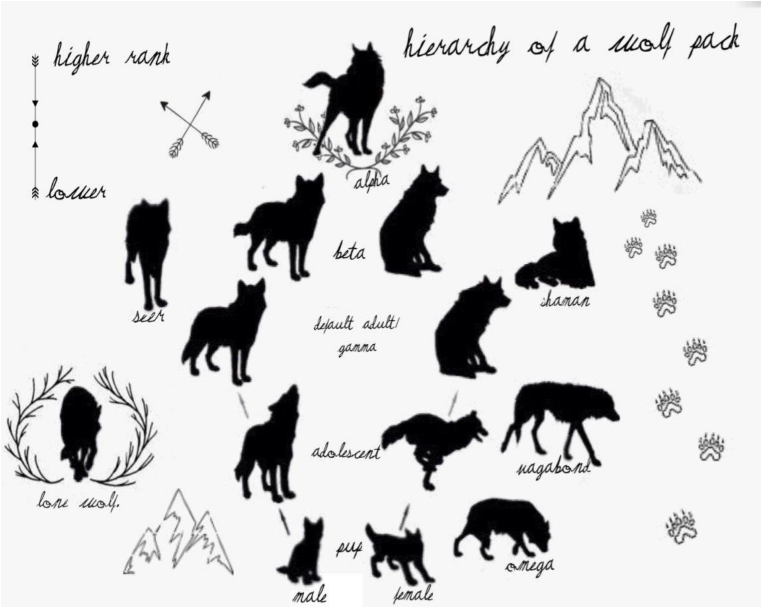
- Global optimization becomes problem due to great search space and high dimensions adding up.
- The animals in nature have developed the powerful swarm intelligence which gave us new ideas to solve the optimization problem.
- Many intelligent optimization algorithms made by researcher to tackle the problem are ACO, PSO, ABC and AFSA.
- General unconstrained optimization can be formulated as below



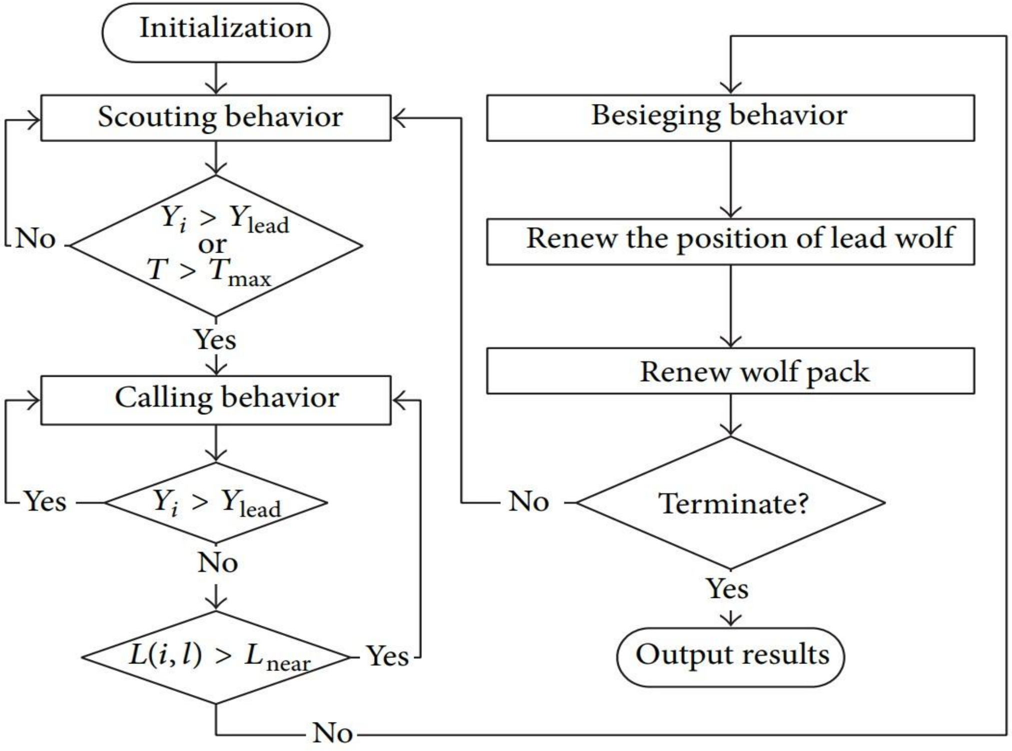
$$\text{min or max } f(X), \quad X = (x_1, x_2, x_3, \ldots\ldots, x_n)$$

# Wolf pack

- A Harsh living environment and constant evolution for centuries have created their rigorous optimization system and subtle hunting behavior gave us ideas to solve the problem.
- They have social work division. There are three division in their groups
  - Lead wolf - smartest and most ferocious
  - Elite wolves - Act as a scout.
  - Ferocious wolves - Hunter
- They works as a group to find a prey, hunt and distribute the food among the group.

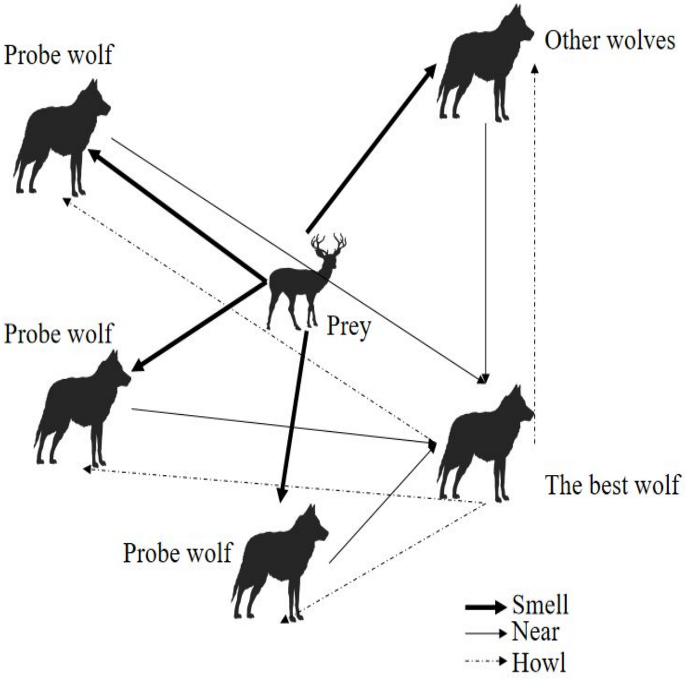


# Flow chart of the wolf pack algorithms



# Generating the Lead wolf

- Lead wolf is responsible for commanding the wolves and constantly making decision by evaluating surrounding situation and perceiving information from other wolves.
- The lead wolf will be decided on the basis of highest smell concentration $Y=f(X)$ where, $f(X)$ is the objective function and $X_i=(x_{i1}, x_{i2}..., x_{in})$ is the position of $i^{th}$ wolf
- It will continuously compare with the other wolves, if the lead wolf will be replaced if some other wolf will find better $Y$.



# Scouting Behavior

- The scouting behaviour is basically interpreted as exploration step of optimization.
- The wolves except for lead wolf will take $step_a$ in $h$ different direction and check if max$\{Y_{i1}, Y_{i2}..., Y_{ip}\} > Y_{0i}$ and update its position $X$.
- This step will be repeated until $Y_i > Y_{lead}$ or the maximum number of iterations $T_{max}$ is achieved for that behavior.

$$x_{id}^{p} = x_{id} + \sin\left(2\pi \times \frac{p}{h}\right) \times step_a^d, \quad p = \{1, 2\ldots, h\}$$

# Calling behavior

- Lead wolf will howl and summon the ferocious wolf for the hunt.
- The lead wolf is mapped as position of the prey, causing the ferocious wolves gather around the position of the lead wolf by taking step length of $step_b$.
- This behaviour will continue until $L(i,l)<L_{near}$ when no new leader is formed
- If $Y_i > Y_{lead}$, the lead wolf will be replaced by wolf *i* and all the wolf will take scouting behavior.

$$x_{id}^{k+1} = x_{id}^{k} + step_b^d \cdot \frac{\left(g_d^k - x_{id}^k\right)}{\left|g_d^k - x_{id}^k\right|}$$

# Besieging behavior

- Besieging is a procedure in which wolves move with step length of $step_c$ towards prey for the hunt.
- Except the lead wolf all the wolves take this step to kill the prey.
- Prey position will be the position of the lead wolf.
- The wolf will update its position only if $Y_{ik} > Y_{i0}$.

$$x_{id}^{k+1} = x_{id}^{k} + \lambda \cdot step_c^d \cdot \left|G_d^k - x_{id}^k\right|$$

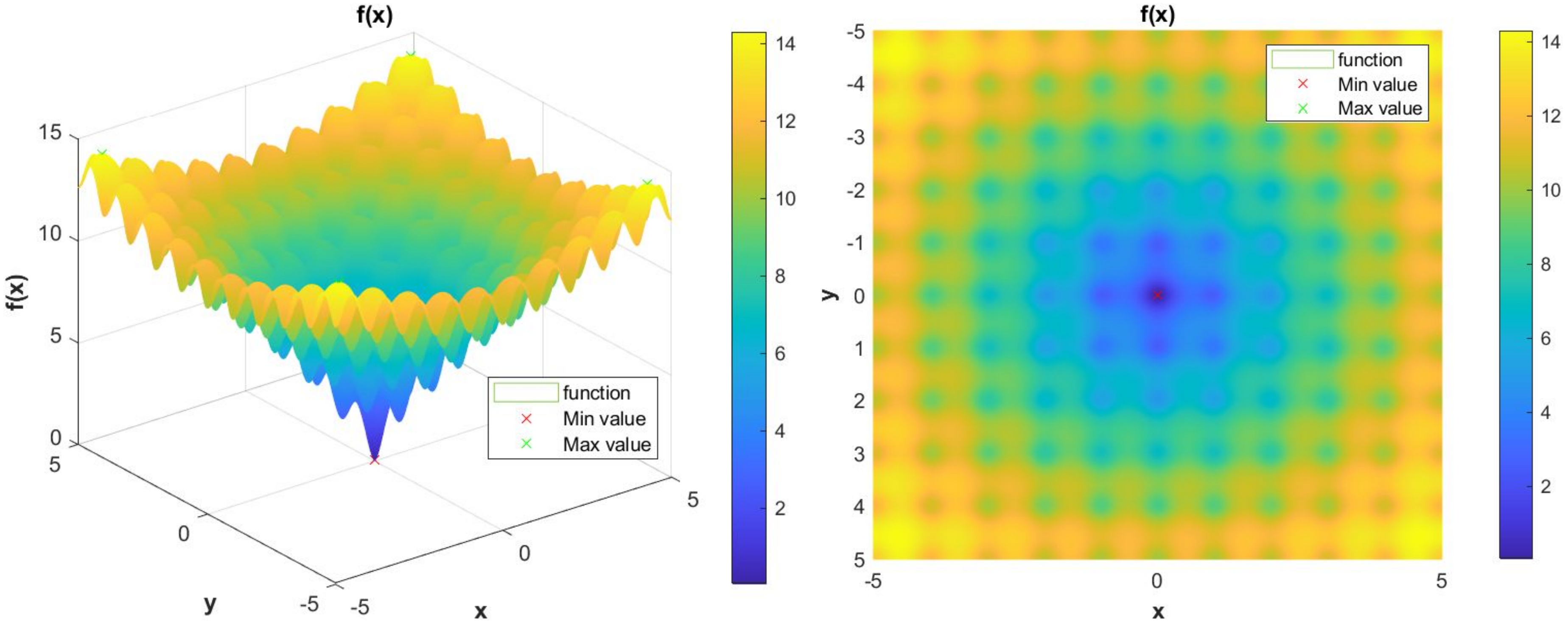
# Renew the wolf

- After the catching the prey, its divided among the wolves unequally.
- Stronger wolves get more food than weaker wolves.
- Simulation of this behaviour is done by making dead R wolves while generating the new R wolves near the position of the lead wolf.
- The position of the wolves will be updated using given equation
- Select R randomly as an integer in the range [*n*/(2·*β), n*/*β*], where *β* is the population renewing proportional coefficient.

$$x_{id} = g_d \cdot (1 + rand), \quad i = \{1,2\ldots, R\}$$

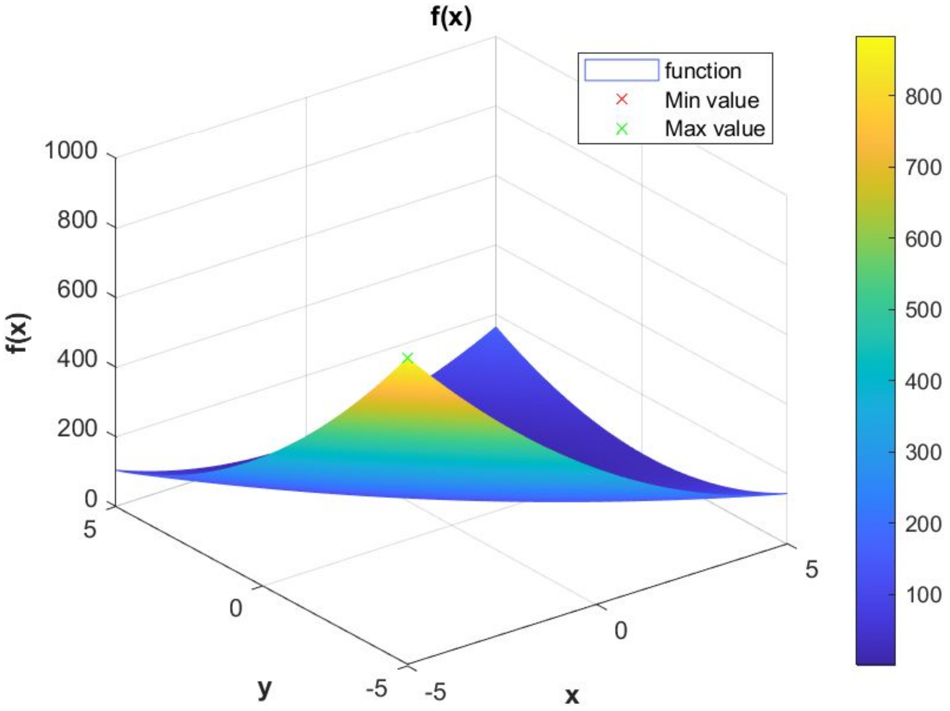
# Test functions

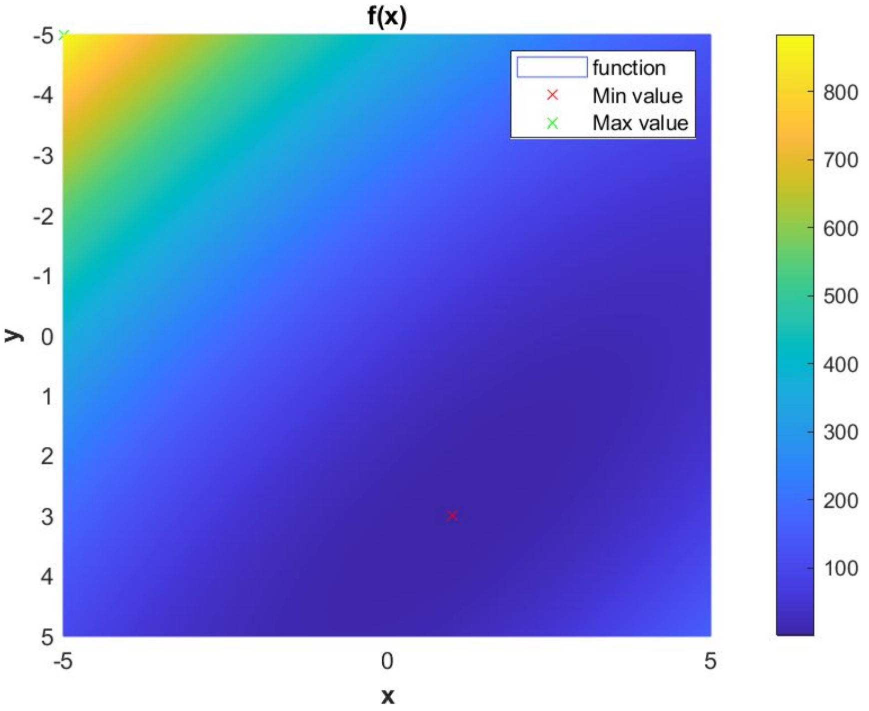
- We have experimented with 3 off-the-shelf test function which can be seen in next slides.
- Those functions are Auckley function, Booth function and Easom function.
- The auckley function is a multimodal function with optima $f(0,0) = 0$
- The booth function is with optima $f(1,3) = 0$
- The Easom function has its optima $f(\pi,\pi) = -1$



## Auckley Function

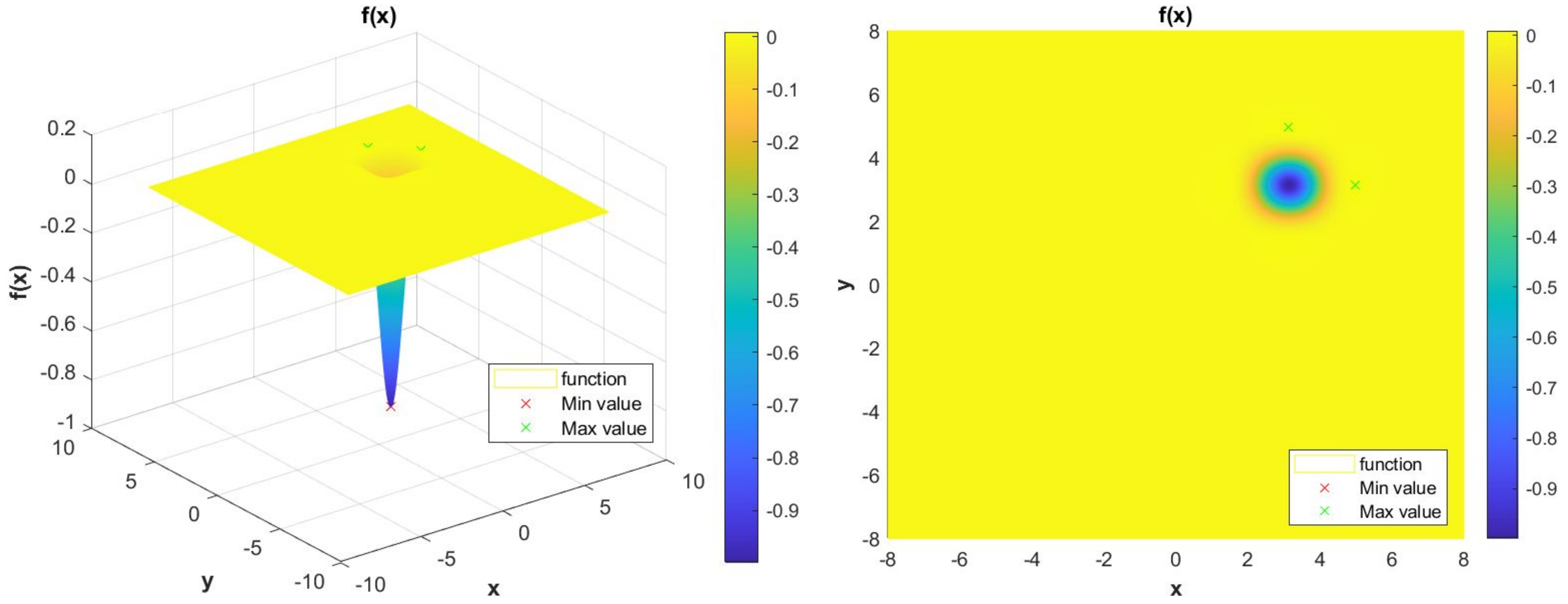
$$f(x,y) = -20e^{-20\sqrt{0.5(x^2+y^2)}} - e^{-0.5(\cos 2\pi x + \cos 2\pi y)} + e + 20$$





Booth Function

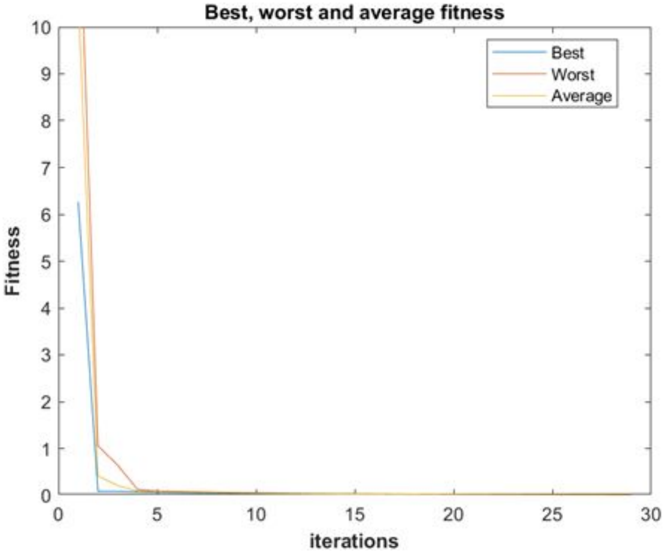
$$f(x, y) = (x + 2y - 7)^2 + (2x + y - 5)^2$$



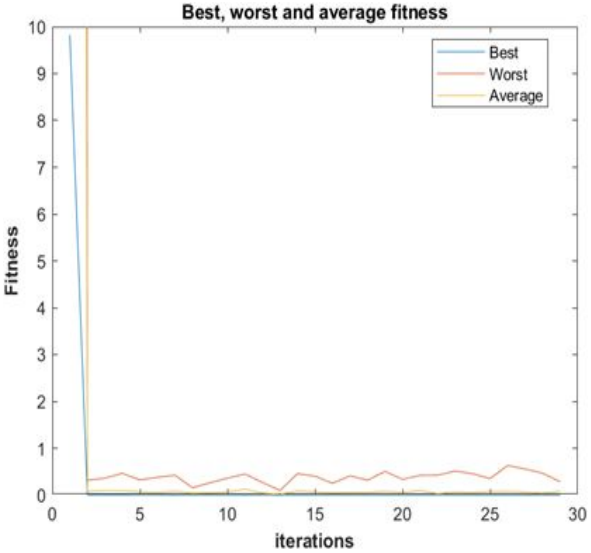
# Easom Function

$$f(x,y) = -\cos(x)\cos(y)\,e^{-((x-\pi)^2+(y-\pi)^2)}$$

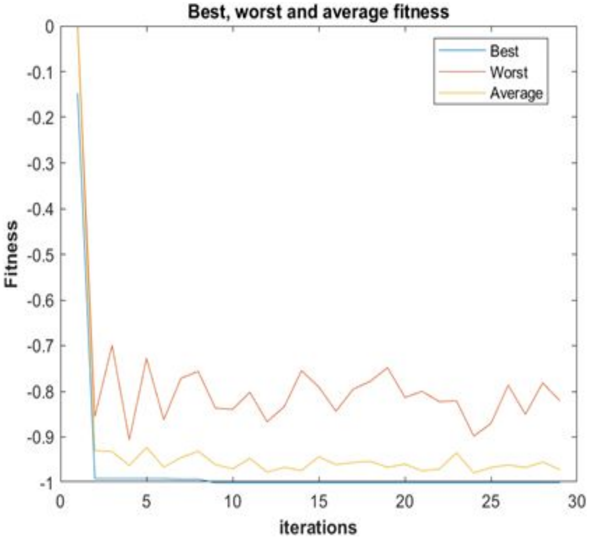
# Results



Auckley Function



Booth Function



Easom Function

# Conclusion

- The number of wolves is directly related to the rate of accuracy, but it is indirectly proportional to the rate of convergence.
- We need to select optimal value of $L_{near}$ as It will take a long time or may not even converge with really smaller value of $L_{near}$. Also, the larger value will take longer time to converge. However, the smaller value of the hyper-parameter $L_{near}$ ,will increase exploitation.
- The higher the value of S, the faster the convergence, however it may oscillate around the prey during besieging behavior. On the other hand, if we maintain the value of S smaller, it will take significantly longer to converge and finish the besieging behavior.
- WPA algorithm is a great optimization method, providing quick and accurate results.

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