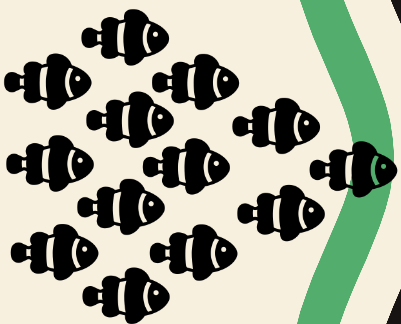
# EVOLUTIONARY COMPUTATION ALGORITHM

WEEK #3

MENGSAY'S NOTES

# CONTENT



# PARTICLE SWARM OPTIMIZATION

## BASIC CONCEPT

# SWARM

- Certain types of birds and fish live in large swarm to protect themselves from enemies and to find food efficiently.
- Even small birds and fish can evade enemy attacks because they can appear to be large individuals when they are in a swarm(group).

# SWARM

- From the standpoint of the individual, being in a swarm also has the **dilution effect** of reducing the probability of predation on oneself.
- It is easier to fly or swim behind other individuals with less resistance.
- When searching for the location of food, many individuals can search a wide area at once.

# SWARM

- It is said that the behavior of all individuals in a swarm is based on the following behavioral model.
    1. behavior is influenced only by nearby individuals
    2. try to stay close to other individuals, but do not go beyond a certain distance
    3. moves with the speed of other individuals

# SWARM

- Information is exchanged among individuals belonging to a flock, and information about the location of food and the direction of movement is quickly transmitted to all individuals in the flock.
- As a result, the entire flock can take actions to achieve their goals efficiently.

# BASIC CONCEPT OF PSO

- Particle Swarm Optimization: PSO
  - By James Kennedy and Russ Eberhart (1995)
- Mainly focus on:
  - All individuals move in unison.
  - Moves in response to the actions of other individuals, adjusting its speed accordingly.
  - Information about the location of food is transmitted to the entire swarm.
- Individuals that act in warm, such as fish and birds, are called particles, and groups of particles are called particle swarm.

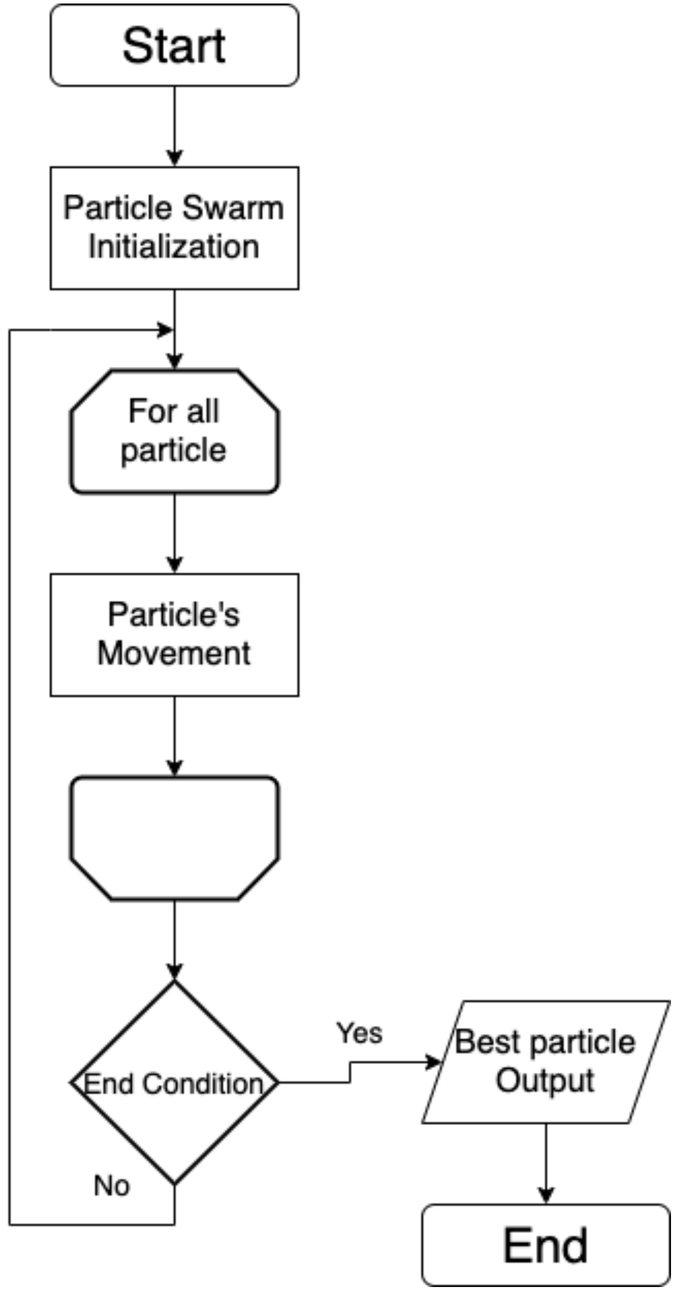
# BASIC CONCEPT OF PSO

- We call the best position found so far by the entire swarm is the **Global Best**, the best position in the vicinity is the **Local Best**, and the best position found so far by oneself is the **Personal Best**
- Each particle is assumed to perform the following actions.

# BASIC CONCEPT OF PSO

- Each particle is assumed to perform the following actions.
    1. Getting information on Global Bests
    2. Getting information about Local Bests.
    3. Remember Personal Best.
    4. Determine travel velocity and destination location at next time based on location information in 1 or 2 and 3.

# ALGORITHM



Start
Particle Swarm Initialization
For all particle
Particle's Movement
End Condition
Yes
No
Best particle Output
End

# VELOCITY AND LOCATION

- $\overrightarrow{x_i}(t)$ :Current location of particle
- $\overrightarrow{v_i}(t)$ :Current velocity of particle
- $\overrightarrow{g}(t)$ :Current global best information
- $\overrightarrow{p_i}(t)$ :Current personal best information

$$\overrightarrow{v_i}(t+1) = I\overrightarrow{v_i}(t) + A_g\{\overrightarrow{g}(t) - \overrightarrow{x_i}(t)\} \times rand[0,1]$$
$$+ A_p\{\overrightarrow{p_i}(t) - \overrightarrow{x_i}(t)\} \times rand[0,1]$$

$$\overrightarrow{x_i}(t+1) = \overrightarrow{x_i}(t) + \overrightarrow{v_i}(t+1)$$

# EXAMPLE ON REGRESSION

- Apply on Regression Problem

$$y = w_0 + w_1 x_1 + \cdots + w_d x_d$$

  - Standardised partial regression

    $Y = c_1 X_1 + \cdots + c_d X_d \quad c_i \in [-1,1] \ (i = 1, \cdots, d)$

  - Dataset $\{(\boldsymbol{x}_n, y_n)\}_{n=1}^{N}$, $\boldsymbol{x}_n = (x_1^n, \cdots, x_d^n)^\top$
  - Objective: To minimize error function

$$\sum_{n=1}^{N} \left( y_n - \sum_{i=1}^{d} c_i x_i^n \right)^2 \to \min$$

  - Here we consider solution (coefficients) as position of partial

$$\overrightarrow{x_i}(t) = (c_1 \cdots c_d)^\top$$

# FIREFLY ALGORITHM

## BASIC CONCEPT

# MOVEMENT OF FIREFLIES

- In the movement process of a pair of fireflies, the other is moved toward the more highly rated of the two individuals.
- How close to move to the other is determined by the degree of attractiveness of the other.
- Since attractiveness for fireflies is the intensity of light, we define attractiveness based on the properties of light **intensity**.

# LIGHT INTENSITY

- The further away the light source is from the light source($d$), the wider the area of illumination becomes, and thus the weaker the intensity($I(d)$) of the observed light becomes.
- Inverse Square Law $I(d) \propto \frac{1}{d^2}$
- By the time light reaches the observation point from the light source ($I_0$), it is absorbed by the air that exists in between (absorbed rate $\gamma$).
- Lambert–Beer Law $I(d) = I_0 e^{-\gamma d}$

# LIGHT INTENSITY AND MOVEMENT

- Here we consider $I(d) = I_0 e^{-\gamma d^2}$
- Focus on firefly $F_i$ , $F_j$ at position $\overrightarrow{p_i}, \overrightarrow{p_j}$ at time $t$

Distance $d_{ij} = \left\| \overrightarrow{p_j}(t) - \overrightarrow{p_i}(t) \right\|_2$

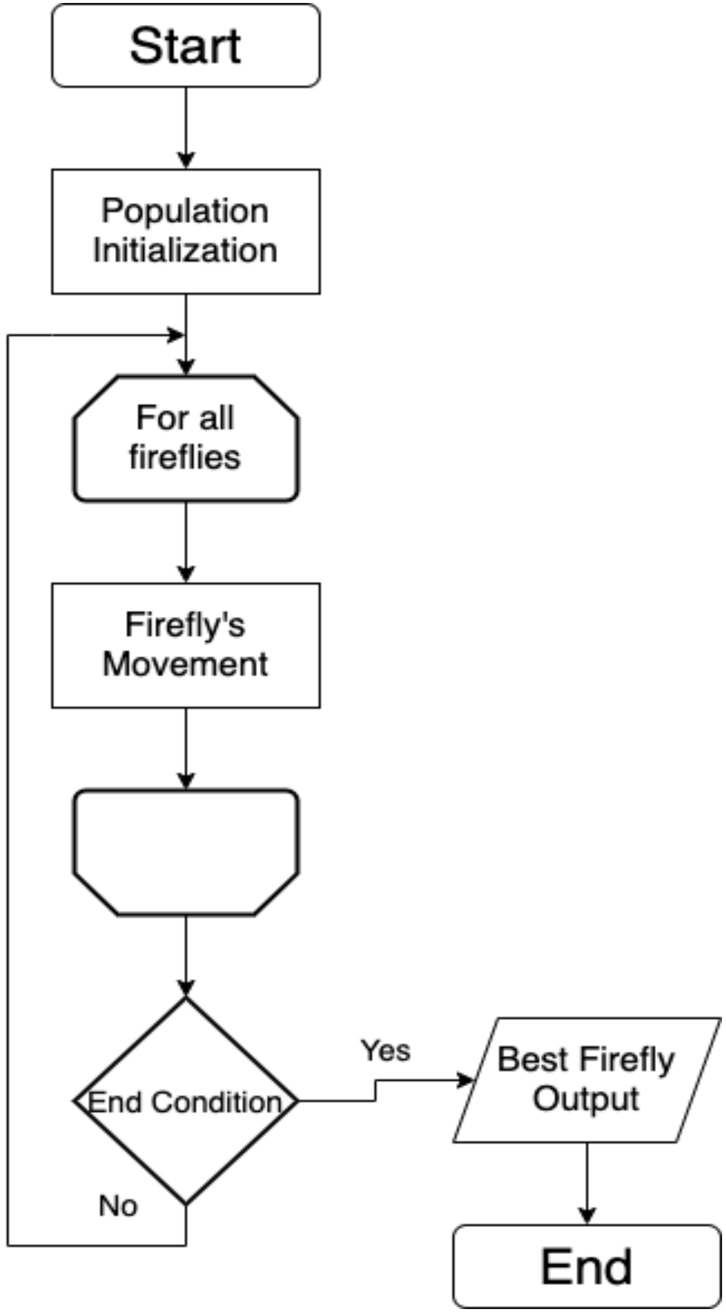
Attractiveness of $F_j$ $attract(F_i, F_j) = \beta_0 e^{-\gamma d_{ij}^2}$

Next position after a movement

$$\overrightarrow{p_i}(t+1) = \overrightarrow{p_i}(t) + attract(F_i, F_j)\left(\overrightarrow{p_j}(t) - \overrightarrow{p_i}(t)\right) + \alpha \overrightarrow{\epsilon_i}$$

$\overrightarrow{\epsilon_i}$ : randomness vector (Gaussian/Uniform distribution)

# ALGORITHM


Start
Population Initialization
For all fireflies
Firefly's Movement
End Condition
Yes
No
Best Firefly Output
End

# EXAMPLE ON REGRESSION

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  – Standardised partial regression

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  – Dataset $\{(\boldsymbol{x}_n, y_n)\}_{n=1}^{N}, \boldsymbol{x}_n = (x_1^n, \cdots, x_d^n)^\top$

  – Objective: To minimize error function

$$\sum_{n=1}^{N} \left( y_n - \sum_{i=1}^{d} c_i x_i^n \right)^2 \to \min$$

  – Here we consider solution (coefficients) as position of firefly

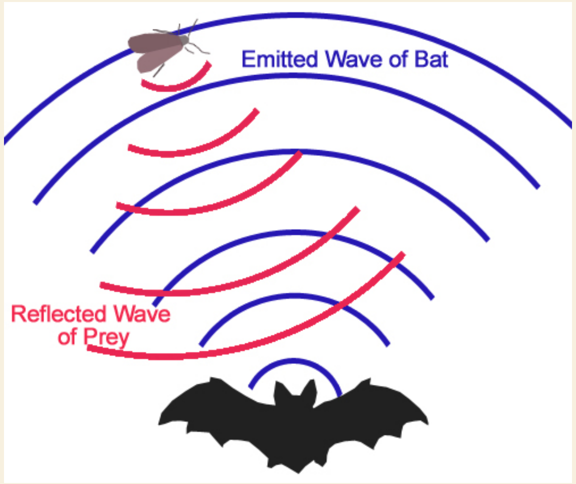
$$\overrightarrow{p_i}(t) = (c_1 \cdots c_d)^\top$$

# BAT ALGORITHM

## BASIC CONCEPT

# ECHOLOCATION OF BATS

- There are two types of bats: large fruit-eating bats and small insect-eating bats.
- Small bats have the ability of **echolocation**, which is the ability to locate prey or obstacles through the echoes of ultrasonic waves that they send out.




https://commons.wikimedia.org/wiki/File:Bat_echolocation.jpg

# ECHOLOCATION OF BATS

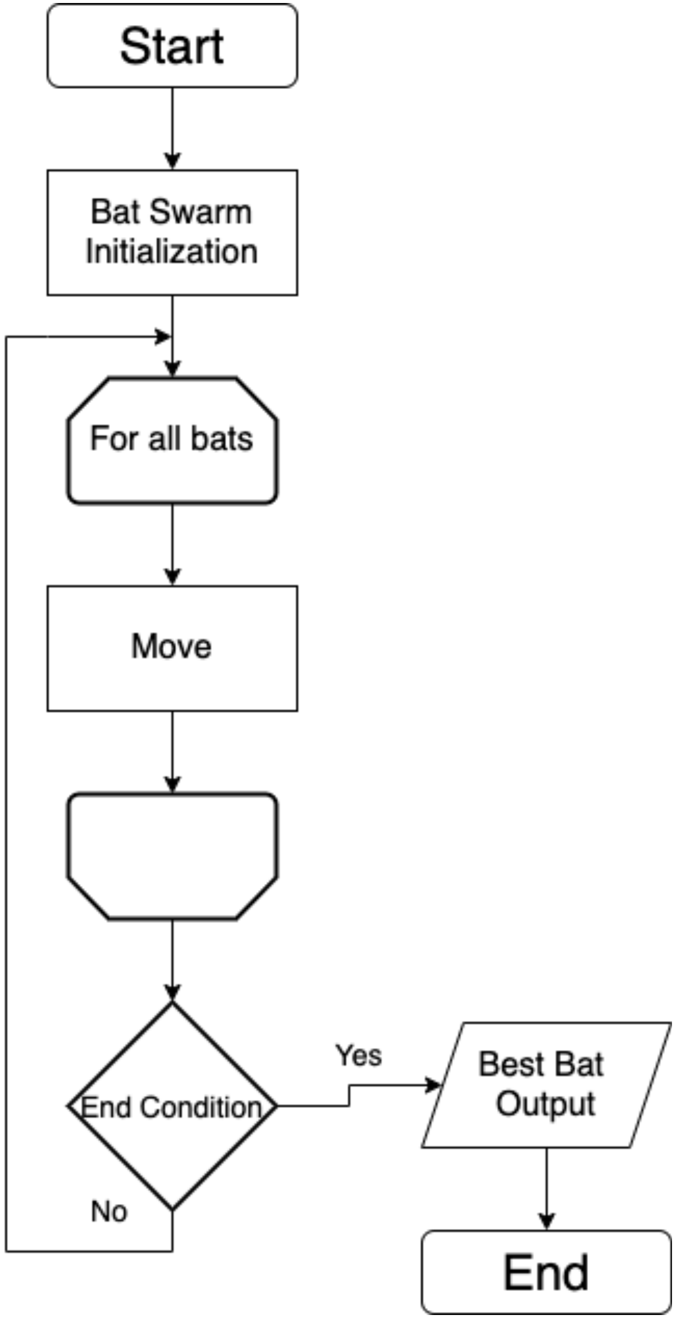
- One bat can hear the ultrasonic wave other bats are transmitting to define the prey.
- As a result, the other bats know that their prey is nearby, and when they hear the sound, they go to the source of the ultrasound.
- To prevent confusion, bats change the frequency of the ultrasonic waves each time they transmit.
- In this way, they can distinguish the reflected sound from the ultrasonic waves they sent out and accurately grasp the situation around us.

# BASIC ALGORITHM

- Bat Algorithm
  - By Xin-She Yang (2010)
- Mainly focus on:
  - Search for prey by echolocation
  - Change the frequency of the ultrasonic waves each time they are transmitted.
  - The closer to the prey, the higher the pulse rate and the lower the volume.
  - Can hear the ultrasonic waves that other bats emit to take their prey.

# BASIC ALGORITHM

- Consumption
  - Use frequency, pulse rate, and volume to determine speed and destination while searching for prey.
  - The frequency changes every time of movement.
  - When move closer to the prey, increase the pulse rate and decrease the volume.
  - Get information about other bats that are near their prey.


Start
Bat Swarm Initialization
For all bats
Move
End Condition
Yes
No
Best Bat Output
End

# ALGORITHM

# MOVEMENT

- Bats move in one of three ways
  - Case1: Move towards the location of the best bats.
  - Case 2: Move to the vicinity of the good bat
  - Case 3: Move randomly
- Case 1:

$$\overrightarrow{v_i}(t+1) = \overrightarrow{v_i}(t) + f_i(t+1)\{\vec{g}(t) - \overrightarrow{p_i}(t)\}$$

$$\overrightarrow{p_i}(t+1) = \overrightarrow{p_i}(t) + \overrightarrow{v_i}(t+1)$$

$\overrightarrow{p_i}$ : position , $\overrightarrow{v_i}$: velocity , $\vec{g}(t)$:best bats' position ,$f_i(t)$: frequency

# MOVEMENT

- Case 2:

$$\overrightarrow{p_i}(t+1) = \vec{b}(t) + \bar{A}\vec{\epsilon}$$

$\overrightarrow{p_i}$ : position , $\vec{b}$: randomly selected good bat's position , $\vec{\epsilon}$:randomness vector, $\bar{A}$:average volume of all bats

# MOVEMENT

- Pulse Rate

$$r_i(t+1) = R_0(1 - e^{-\gamma t})$$

- Volume

$$A_i(t+1) = \alpha A_i(t)$$

# EXAMPLE ON REGRESSION

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  - Dataset $\{(\boldsymbol{x}_n, y_n)\}_{n=1}^{N}$ , $\boldsymbol{x}_n = (x_1^n, \cdots, x_d^n)^\top$
  - Objective: To minimize error function

$$\sum_{n=1}^{N} \left( y_n - \sum_{i=1}^{d} c_i x_i^n \right)^2 \rightarrow \min$$

  - Here we consider solution (coefficients) as position of bat

$$\overrightarrow{p_i}(t) = (c_1 \cdots c_d)^\top$$