



**Repeat until (Employed Bee (EB) <= 5)**

**Employed Bee Phase (Step 7- Step 12) [Number of EB = 5]**

**EB1: To find out better solution. In ABC, not changing all the variables only one of the decision variable will change**

**Step 7:**

Select the random variable to change. Let the changing variable be 3 of food source 1.

$$X^1 = [4 \quad 0 \quad \mathbf{1} \quad 8]$$

**Step 8:**

Select the random partner to change, Let the partner food source be SN= 4

$$X^4 = [2 \quad 1 \quad \mathbf{4} \quad 9]$$

**Step 9:**

Create new food source, Let random value of  $\emptyset = 0.81$

$$X_{new}^{1,3} = X^{1,3} + \emptyset(x^{1,3} - X^{4,3})$$

$$X_{new}^{1,3} = 1 + (0.81)(1 - 4) = -1.43$$

**Step 10:**

Check decision variable boundary conditions.

Check boundary of decision variable  $X_{new}^{1,3}$ . Condition violates as -1.43 does not satisfy  $0 \leq X_i \leq 10$  condition. It violates lower boundary condition.

$$X_{new}^{1,3} = \max(-1.43, \quad lb) = \max(-1.43, 0) = 0$$

$$X_{new}^1 = [4 \quad 0 \quad \mathbf{0} \quad 8]$$

**Step 11:**

Calculate Objective Function and Fitness values with new value of  $X^1$ .

$$f(X_{new}^1) = 4^2 + 0^2 + 0^2 + 8^2 = 80$$

$$fit(X_{new}^1) = \frac{1}{1 + 80} = 0.0123$$

**Step12:**

Perform Greedy Selection

$$fit(X^1) = 0.0122 < fit(X_{new}^1) = 0.0123$$

**change in Population (Food source 1 values )Trial is successful, So trial value will remain '0'.**

$$P = \begin{bmatrix} 4 & 0 & 0 & 8 \\ 3 & 1 & 9 & 7 \\ 0 & 3 & 1 & 5 \\ 2 & 1 & 4 & 9 \\ 1 & 2 & 8 & 3 \end{bmatrix} \quad f = \begin{bmatrix} 4^2 + 0^2 + 0^2 + 8^2 \\ 3^2 + 1^2 + 9^2 + 7^2 \\ 0^2 + 3^2 + 1^2 + 5^2 \\ 2^2 + 1^2 + 4^2 + 9^2 \\ 1^2 + 2^2 + 8^2 + 3^2 \end{bmatrix} = \begin{bmatrix} 80 \\ 140 \\ 35 \\ 102 \\ 78 \end{bmatrix} \quad Fit = \begin{bmatrix} 0.0123 \\ 0.0071 \\ 0.0278 \\ 0.0097 \\ 0.0127 \end{bmatrix} \quad t = \begin{bmatrix} \mathbf{0} \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \quad \text{No Change in trial}$$

**EB2:**

**Step 7:**

Select the random variable to change. Let the changing variable be 1 of Food source SN= 2

$$X^2 = [3 \quad 1 \quad 9 \quad 7]$$

**Step 8:**

Select the random partner to change, Let the partner food source be SN= 3

$$X^3 = [0 \quad 3 \quad 1 \quad 5]$$

**Step 9:**

Create new food source, Let random value of  $\phi = 0.19$

$$X_{new}^{2,1} = X^2 + \phi(x^{2,1} - X^{3,1})$$

$$X_{new}^{2,1} = 3 + (0.19)(3 - 0) = 3.57$$

**Step 10:**

Check decision variable boundary conditions.

Check boundary of decision variable  $X_{new}^{2,1}$ . Condition satisfies as 3.57 lies in boundary values  $0 \leq X_i \leq 10$ .

$$X_{new}^2 = [3.57 \quad 1 \quad 9 \quad 7]$$

**Step 11:**

Calculate Objective Function and Fitness values with new value of  $X^2$ .

$$f(X_{new}^2) = 3.57^2 + 1^2 + 9^2 + 7^2 = 143.74$$

$$fit(X_{new}^2) = \frac{1}{1 + 143.74} = 0.0069$$

**Step12:**

Perform Greedy Selection

$$fit(X^2) = 0.0071 > fit(X_{new}^2) = 0.0069$$

**Trial Changed to 1**

**No Change in Population and increase trial(2) to '1'.**

$$P = \begin{bmatrix} 4 & 0 & 0 & 8 \\ 3 & 1 & 9 & 7 \\ 0 & 3 & 1 & 5 \\ 2 & 1 & 4 & 9 \\ 1 & 2 & 8 & 3 \end{bmatrix} \quad f = \begin{bmatrix} 4^2 + 0^2 + 0^2 + 8^2 \\ 3^2 + 1^2 + 9^2 + 7^2 \\ 0^2 + 3^2 + 1^2 + 5^2 \\ 2^2 + 1^2 + 4^2 + 9^2 \\ 1^2 + 2^2 + 8^2 + 3^2 \end{bmatrix} = \begin{bmatrix} 80 \\ 140 \\ 35 \\ 102 \\ 78 \end{bmatrix} \quad Fit = \begin{bmatrix} 0.0123 \\ 0.0071 \\ 0.0278 \\ 0.0097 \\ 0.0127 \end{bmatrix} \quad t = \begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

**EB3:**

**Step 7:**

Select the random variable to change. Let the changing variable be 1 of Food source SN= 3

$$X^3 = [0 \quad 3 \quad 1 \quad 5]$$

**Step 8:**

Select the random partner to change, Let the partner food source be SN= 1

$$X^1 = [4 \quad 0 \quad 0 \quad 8]$$

**Step 9:**

Create new food source, Let random value of  $\emptyset = -0.56$

$$X_{new}^{3,1} = X^3 + \emptyset(x^{3,1} - X^{1,1})$$

$$X_{new}^{3,1} = 0 + (-0.56)(0 - 4) = 2.24$$

**Step 10:**

Check decision variable boundary conditions.

Check boundary of decision variable  $X_{new}^{3,1}$ . Condition satisfies as 2.24 lies in boundary values  $0 \leq X_i \leq 10$ .

$$X_{new}^3 = [2.24 \quad 3 \quad 1 \quad 5]$$

**Step 11:**

Calculate Objective Function and Fitness values with new value of  $X^3$ .

$$f(X_{new}^3) = 2.24^2 + 3^2 + 1^2 + 5^2 = 40.176$$

$$fit(X_{new}^3) = \frac{1}{1 + 40.176} = 0.024$$

**Step12:**

Perform Greedy Selection

$$fit(X^3) = 0.0278 > fit(X_{new}^3) = 0.024$$

**Trial Changed to 1**

**No change in Population and increase trial (3) to '1'.**

$$P = \begin{bmatrix} 4 & 0 & 0 & 8 \\ 3 & 1 & 9 & 7 \\ 0 & 3 & 1 & 5 \\ 2 & 1 & 4 & 9 \\ 1 & 2 & 8 & 3 \end{bmatrix} \quad f = \begin{bmatrix} 4^2 + 0^2 + 0^2 + 8^2 \\ 3^2 + 1^2 + 9^2 + 7^2 \\ 0^2 + 3^2 + 1^2 + 5^2 \\ 2^2 + 1^2 + 4^2 + 9^2 \\ 1^2 + 2^2 + 8^2 + 3^2 \end{bmatrix} = \begin{bmatrix} 80 \\ 140 \\ 35 \\ 102 \\ 78 \end{bmatrix} \quad Fit = \begin{bmatrix} 0.0123 \\ 0.0071 \\ 0.0278 \\ 0.0097 \\ 0.0127 \end{bmatrix} \quad t = \begin{bmatrix} 0 \\ 1 \\ 1 \\ 0 \\ 0 \end{bmatrix}$$

**EB4:****Step 7:**

Select the random variable to change. Let the changing variable be 2 of Food source SN= 4

$$X^4 = [2 \quad \mathbf{1} \quad 4 \quad 9]$$

**Step 8:**

Select the random partner to change, Let the partner food source be SN= 3

$$X^1 = [0 \quad \mathbf{3} \quad 1 \quad 5]$$

**Step 9:**

Create new food source, Let random value of  $\emptyset = -0.6$

$$X_{new}^{4,2} = X^{4,2} + \emptyset(x^{4,2} - X^{3,2})$$

$$X_{new}^{4,2} = 3 + (-0.6)(3 - 1) = 2.2$$

**Step 10:**

Check decision variable boundary conditions.

Check boundary of decision variable  $X_{new}^{4,2}$ . Condition satisfies as 2.2 lies in boundary values  $0 \leq X_i \leq 10$ .

$$X_{new}^4 = [2 \quad 2.2 \quad 4 \quad 9]$$

**Step 11:**

Calculate Objective Function and Fitness values with new value of  $X^3$ .

$$f(X_{new}^4) = 2^2 + 2.2^2 + 4^2 + 9^2 = 105.84$$

$$fit(X_{new}^3) = \frac{1}{1 + 105.84} = 0.0093$$

**Step12:**

Perform Greedy Selection

$$fit(X^4) = 0.0097 > fit(X_{new}^3) = 0.0093$$

**Trial Changed to 1**

**No Change in Population and increase trial (4) to '1'.**

$$P = \begin{bmatrix} 4 & 0 & 0 & 8 \\ 3 & 1 & 9 & 7 \\ 0 & 3 & 1 & 5 \\ 2 & 1 & 4 & 9 \\ 1 & 2 & 8 & 3 \end{bmatrix} \quad f = \begin{bmatrix} 4^2 + 0^2 + 0^2 + 8^2 \\ 3^2 + 1^2 + 9^2 + 7^2 \\ 0^2 + 3^2 + 1^2 + 5^2 \\ 2^2 + 1^2 + 4^2 + 9^2 \\ 1^2 + 2^2 + 8^2 + 3^2 \end{bmatrix} = \begin{bmatrix} 80 \\ 140 \\ 35 \\ 102 \\ 78 \end{bmatrix} \quad Fit = \begin{bmatrix} 0.0123 \\ 0.0071 \\ 0.0278 \\ 0.0097 \\ 0.0127 \end{bmatrix} \quad t = \begin{bmatrix} 0 \\ 1 \\ 1 \\ \mathbf{1} \\ 0 \end{bmatrix}$$

**EB5:****Step 7:**

Select the random variable to change. Let the changing variable be 4 of Food source SN= 5

$$X^5 = [1 \quad 2 \quad 8 \quad 3]$$

**Step 8:**

Select the random partner to change, Let the partner food source be SN= 3

$$X^1 = [0 \quad 3 \quad 1 \quad 5]$$

**Step 9:**

Create new food source, Let random value of  $\emptyset = 0.81$

$$X_{new}^{5,4} = X^{5,4} + \emptyset(x^{5,4} - X^{3,4})$$

$$X_{new}^{5,4} = 3 + (0.81)(3 - 5) = 1.38$$

**Step 10:**

Check decision variable boundary conditions.

Check boundary of decision variable  $X_{new}^{5,4}$ . Condition satisfies as 1.38 lies in boundary values  $0 \leq X_i \leq 10$ .

$$X_{new}^5 = [1 \quad 2 \quad 8 \quad 1.38]$$

**Step 11:**

Calculate Objective Function and Fitness values with new value of  $X^5$ .

$$f(X_{new}^5) = 1^2 + 2^2 + 8^2 + 1.38^2 = 70.9044$$

$$fit(X_{new}^5) = \frac{1}{1 + 70.9044} = 0.0139$$

**Step12:**

Perform Greedy Selection

$$fit(X^5) = 0.0127 < fit(X_{new}^5) = 0.0139$$

**Change in Population and Trial=0.**

**No Change in trial**

$$P = \begin{bmatrix} 4 & 0 & 0 & 8 \\ 3 & 1 & 9 & 7 \\ 0 & 3 & 1 & 5 \\ 2 & 1 & 4 & 9 \\ 1 & 2 & 8 & 1.38 \end{bmatrix} \quad f = \begin{bmatrix} 4^2 + 0^2 + 0^2 + 1.38^2 \\ 3^2 + 1^2 + 9^2 + 7^2 \\ 0^2 + 3^2 + 1^2 + 5^2 \\ 2^2 + 1^2 + 4^2 + 9^2 \\ 1^2 + 2^2 + 8^2 + 1.38^2 \end{bmatrix} = \begin{bmatrix} 80 \\ 140 \\ 35 \\ 102 \\ 70.9 \end{bmatrix} \quad Fit = \begin{bmatrix} 0.0123 \\ 0.0071 \\ 0.0278 \\ 0.0097 \\ 0.0139 \end{bmatrix} \quad t = \begin{bmatrix} 0 \\ 1 \\ 1 \\ 1 \\ 1 \\ 0 \end{bmatrix}$$

$$P = \begin{bmatrix} 4 & 0 & 0 & 8 \\ 3 & 1 & 9 & 7 \\ 0 & 3 & 1 & 5 \\ 2 & 1 & 4 & 9 \\ 1 & 2 & 8 & 1.38 \end{bmatrix} \quad f = \begin{bmatrix} 4^2 + 0^2 + 0^2 + 8^2 \\ 3^2 + 1^2 + 9^2 + 7^2 \\ 0^2 + 3^2 + 1^2 + 5^2 \\ 2^2 + 1^2 + 4^2 + 9^2 \\ 1^2 + 2^2 + 8^2 + 1.38^2 \end{bmatrix} = \begin{bmatrix} 80 \\ 140 \\ 35 \\ 102 \\ 70.9 \end{bmatrix} \quad Fit = \begin{bmatrix} 0.0123 \\ 0.0071 \\ 0.0278 \\ 0.0097 \\ 0.0139 \end{bmatrix} \quad t = \begin{bmatrix} 0 \\ 1 \\ 1 \\ 1 \\ 0 \end{bmatrix}$$

## Probability Computation Phase

### Step 13:

Probability Compute To share Employed bees collected food information to onlooker bees

$$Probability = 0.9 * \left( \frac{fitness}{\max(fitness)} \right) + 0.1$$

$$probability = \begin{bmatrix} 0.9 * \left( \frac{0.0123}{0.0278} \right) + 0.1 \\ 0.9 * \left( \frac{0.0071}{0.0278} \right) + 0.1 \\ 0.9 * \left( \frac{0.0278}{0.0278} \right) + 0.1 \\ 0.9 * \left( \frac{0.0097}{0.0278} \right) + 0.1 \\ 0.9 * \left( \frac{0.0139}{0.0278} \right) + 0.1 \end{bmatrix} = \begin{bmatrix} 0.5 \\ 0.33 \\ 1 \\ 0.41 \\ 0.55 \end{bmatrix}$$

**Repeat until (Onlooker Bee (OB) <= 5)**  
**Onlooker Bee Phase (Step 14- Step 20) [Number of OB = 5]**

**OB1:**

**Step 14:**

Select a food Source. Let the selected food source = 1

**Step 15:**

Select a random number  $r = 0.39$

**Step 16:**

Check if  $r < \text{probability} \Rightarrow 0.39 < 0.5$  **Valid**

**[Further Steps of onlooker bees are same as of employed bees]**

**Step 17:**

Select the random variable to change. Let the changing variable be 4 of Food source SN= 1

$$X^1 = [4 \quad 0 \quad 0 \quad \mathbf{8}]$$

**Step 18:**

Select the random partner to change, Let the partner food source be SN= 3

$$X^3 = [0 \quad 3 \quad 1 \quad \mathbf{5}]$$

**Step 19:**

Create new food source, Let random value of  $\emptyset = -0.68$

$$X_{new}^{1,4} = X^{1,4} + \emptyset(x^{1,4} - X^{3,4})$$

$$X_{new}^{1,4} = 8 + (-0.68)(8 - 5) = 5.96$$

**Step 20:**

Check decision variable boundary conditions.

Check boundary of decision variable  $X_{new}^{1,4}$ . Condition satisfies as 5.96 lies in boundary values  $0 \leq X_i \leq 10$ .

$$X_{new}^1 = [4 \quad 0 \quad 0 \quad 5.96]$$

**Step 21:**

Calculate Objective Function and Fitness values with new value of  $X^1$ .

$$f(X_{new}^1) = 4^2 + 0^2 + 0^2 + 5.96^2 = 51.52$$

$$fit(X_{new}^3) = \frac{1}{1 + 51.52} = 0.019$$

**Step 22:**

Perform Greedy Selection  $fit(X^1) = 0.0123 < fit(X_{new}^1) = 0.019$

**Change in Population and Trial=0.**

**No Change in trial**

$$P = \begin{bmatrix} 4 & 0 & 0 & 5.96 \\ 3 & 1 & 9 & 7 \\ 0 & 3 & 1 & 5 \\ 2 & 1 & 4 & 9 \\ 1 & 2 & 8 & 1.38 \end{bmatrix} \quad f = \begin{bmatrix} 4^2 + 0^2 + 0^2 + 5.96^2 \\ 3^2 + 1^2 + 9^2 + 7^2 \\ 0^2 + 3^2 + 1^2 + 5^2 \\ 2^2 + 1^2 + 4^2 + 9^2 \\ 1^2 + 2^2 + 8^2 + 1.38^2 \end{bmatrix} = \begin{bmatrix} 51.52 \\ 140 \\ 35 \\ 102 \\ 70.9 \end{bmatrix} \quad Fit = \begin{bmatrix} 0.019 \\ 0.0071 \\ 0.0278 \\ 0.0097 \\ 0.0139 \end{bmatrix} \quad t = \begin{bmatrix} \mathbf{0} \\ 1 \\ 1 \\ 1 \\ 0 \end{bmatrix}$$



**OB2:****Step 14:**

Select a food Source. Let the selected food source = 2

**Step 15:**

Select a random number  $r = 0.2$

**Step 16:**

Check if  $r < \text{probability} \Rightarrow 0.2 < 0.33$  **Valid**

**[Further Steps of onlooker bees are same as of employed bees]****Step 17:**

Select the random variable to change. Let the changing variable be 3 of Food source SN= 2

$$X^2 = [3 \quad 1 \quad 9 \quad 7]$$

**Step 18:**

Select the random partner to change, Let the partner food source be SN= 5

$$X^3 = [1 \quad 2 \quad 8 \quad 1.38]$$

**Step 19:**

Create new food source, Let random value of  $\emptyset = -0.32$

$$X_{new}^{2,3} = X^{2,3} + \emptyset(x^{2,3} - X^{3,3})$$

$$X_{new}^{2,3} = 9 + (-0.32)(9 - 8) = 8.68$$

**Step 20:**

Check decision variable boundary conditions.

Check boundary of decision variable  $X_{new}^{2,3}$ . Condition satisfies as 8.68 lies in boundary values  $0 \leq X_i \leq 10$ .

$$X_{new}^2 = [3 \quad 1 \quad 8.68 \quad 7]$$

**Step 21:**

Calculate Objective Function and Fitness values with new value of  $X^1$ .

$$f(X_{new}^2) = 3^2 + 1^2 + 8.68^2 + 7^2 = 134.34$$

$$fit(X_{new}^2) = \frac{1}{1 + 134.34} = 0.0074$$

**Step 22:**

Perform Greedy Selection  $fit(X^2) = 0.0071 < fit(X_{new}^2) = 0.0074$

**Change in Population and change trial back to '0'.**

**No Change in trial**

$$P = \begin{bmatrix} 4 & 0 & 0 & 5.96 \\ 3 & 1 & 8.68 & 7 \\ 0 & 3 & 1 & 5 \\ 2 & 1 & 4 & 9 \\ 1 & 2 & 8 & 1.38 \end{bmatrix} \quad f = \begin{bmatrix} 4^2 + 0^2 + 0^2 + 5.96^2 \\ 3^2 + 1^2 + 8.68^2 + 7^2 \\ 0^2 + 3^2 + 1^2 + 5^2 \\ 2^2 + 1^2 + 4^2 + 9^2 \\ 1^2 + 2^2 + 8^2 + 1.38^2 \end{bmatrix} = \begin{bmatrix} 51.52 \\ 134.34 \\ 35 \\ 102 \\ 70.9 \end{bmatrix} \quad Fit = \begin{bmatrix} 0.019 \\ 0.0074 \\ 0.0278 \\ 0.0097 \\ 0.0139 \end{bmatrix} \quad t = \begin{bmatrix} 0 \\ 0 \\ 1 \\ 1 \\ 0 \end{bmatrix}$$

**OB3:****Step 14:**

Select a food Source. Let the selected food source = 3

**Step 15:**

Select a random number  $r = 0.57$

**Step 16:**

Check if  $r < \text{probability} \Rightarrow 0.57 < 1$  **Valid**

**[Further Steps of onlooker bees are same as of employed bees]****Step 17:**

Select the random variable to change. Let the changing variable be 2 of Food source SN= 3

$$X^3 = [0 \quad 3 \quad 1 \quad 5]$$

**Step 18:**

Select the random partner to change, Let the partner food source be SN= 4

$$X^4 = [2 \quad 1 \quad 4 \quad 9]$$

**Step 19:**

Create new food source, Let random value of  $\phi = 0.07$

$$X_{new}^{3,2} = X^{3,2} + \phi(x^{4,2} - X^{3,2})$$

$$X_{new}^{3,2} = 3 + (0.07)(3 - 1) = 3.14$$

**Step 20:**

Check decision variable boundary conditions.

Check boundary of decision variable  $X_{new}^{3,2}$ . Condition satisfies as 3.14 lies in boundary values  $0 \leq X_i \leq 10$ .

$$X_{new}^3 = [0 \quad 3.14 \quad 1 \quad 5]$$

**Step 21:**

Calculate Objective Function and Fitness values with new value of  $X^1$ .

$$f(X_{new}^3) = 0^2 + 3.14^2 + 1^2 + 5^2 = 35.8596$$

$$fit(X_{new}^3) = \frac{1}{1 + 35.8596} = 0.027$$

**Step 22:**

Perform Greedy Selection  $fit(X^3) = 0.0278 > fit(X_{new}^3) = 0.027$

**No Change in Population and add 1 in Trial.**

**Trial = trial+1**

$$P = \begin{bmatrix} 4 & 0 & 0 & 5.96 \\ 3 & 1 & 8.68 & 7 \\ 0 & 3 & 1 & 5 \\ 2 & 1 & 4 & 9 \\ 1 & 2 & 8 & 1.38 \end{bmatrix} \quad f = \begin{bmatrix} 4^2 + 0^2 + 0^2 + 5.96^2 \\ 3^2 + 1^2 + 8.68^2 + 7^2 \\ 0^2 + 3^2 + 1^2 + 5^2 \\ 2^2 + 1^2 + 4^2 + 9^2 \\ 1^2 + 2^2 + 8^2 + 1.38^2 \end{bmatrix} = \begin{bmatrix} 51.52 \\ 134.34 \\ 35 \\ 102 \\ 70.9 \end{bmatrix} \quad Fit = \begin{bmatrix} 0.019 \\ 0.0074 \\ 0.0278 \\ 0.0097 \\ 0.0139 \end{bmatrix} \quad t = \begin{bmatrix} 0 \\ 0 \\ 2 \\ 1 \\ 0 \end{bmatrix}$$

**OB4:****Step 14:**

Select a food Source. Let the selected food source = 4

**Step 15:**

Select a random number  $r = 0.95$

**Step 16:**

Check if  $r < \text{probability} \Rightarrow 0.95 > 0.41$  **Invalid**

**Generate New solution for this same Food Source. And onlooker Bee 4 will go for Food source 5.**

**Step 14:**

Select a food Source. Let the selected food source = 5

**Step 15:**

Select a random number  $r = 0.54$

**Step 16:**

Check if  $r < \text{probability} \Rightarrow 0.54 > 0.55$  **Valid**

**Step 17:**

Select the random variable to change. Let the changing variable be 1 of Food source SN= 5

$$X^5 = [1 \quad 2 \quad 8 \quad 1.38]$$

**Step 18:**

Select the random partner to change, Let the partner food source be SN= 2

$$X^2 = [3 \quad 1 \quad 8.68 \quad 7]$$

**Step 19:**

Create new food source, Let random value of  $\emptyset = 0.5$

$$X_{new}^{5,1} = X^{5,1} + \emptyset(x^{5,1} - X^{2,1})$$

$$X_{new}^{5,1} = 1 + (0.5)(1 - 3) = 0$$

**Step 20:**

Check decision variable boundary conditions.

Check boundary of decision variable  $X_{new}^{5,1}$ . Condition satisfies as 0 lies in boundary values  $0 \leq X_i \leq 10$ .

$$X_{new}^5 = [0 \quad 2 \quad 8 \quad 1.38]$$

**Step 21:**

Calculate Objective Function and Fitness values with new value of  $X^1$ .

$$f(X_{new}^5) = 0^2 + 2^2 + 8^2 + 1.38^2 = 68.9044$$

$$fit(X_{new}^5) = \frac{1}{1 + 68.9044} = 0.014$$

**Step 22:**

Perform Greedy Selection  $fit(X^5) = 0.0139 < fit(X_{new}^5) = 0.014$

**Change in Population and Trial=0.**

**No change in Trial**

$$P = \begin{bmatrix} 4 & 0 & 0 & 5.96 \\ 3 & 1 & 8.68 & 7 \\ 0 & 3 & 1 & 5 \\ 2 & 1 & 4 & 9 \\ 0 & 2 & 8 & 1.38 \end{bmatrix} \quad f = \begin{bmatrix} 4^2 + 0^2 + 0^2 + 5.96^2 \\ 3^2 + 1^2 + 8.68^2 + 7^2 \\ 0^2 + 3^2 + 1^2 + 5^2 \\ 2^2 + 1^2 + 4^2 + 9^2 \\ 0^2 + 2^2 + 8^2 + 1.38^2 \end{bmatrix} = \begin{bmatrix} 51.52 \\ 134.34 \\ 35 \\ 102 \\ 69.9 \end{bmatrix} \quad Fit = \begin{bmatrix} 0.019 \\ 0.0074 \\ 0.0278 \\ 0.0097 \\ 0.0141 \end{bmatrix} \quad t = \begin{bmatrix} 0 \\ 0 \\ 2 \\ 1 \\ 0 \end{bmatrix}$$

**OBS:****Step 14:**

Select a food Source. Let the selected food source = 1

**Step 15:**

Select a random number  $r = 0.41$

**Step 16:**

Check if  $r < \text{probability} \Rightarrow 0.41 < 0.5$  **valid**

**[Further Steps of onlooker bees are same as of employed bees]****Step 17:**

Select the random variable to change. Let the changing variable be 1 of Food source  $SN=5$

$$X^1 = [4 \quad 0 \quad 0 \quad 5.96]$$

**Step 18:**

Select the random partner to change, Let the partner food source be  $SN=2$

$$X^2 = [3 \quad 1 \quad 8.68 \quad 7]$$

**Step 19:**

Create new food source, Let random value of  $\emptyset = -0.87$

$$X_{new}^{1,1} = X^{1,1} + \emptyset(x^{1,1} - X^{2,1})$$

$$X_{new}^{1,1} = 4 + (-0.87)(4 - 3) = 3.13$$

**Step 20:**

Check decision variable boundary conditions.

Check boundary of decision variable  $X_{new}^{1,1}$ . Condition satisfies as 3.13 lies in boundary values  $0 \leq X_i \leq 10$ .

$$X_{new}^1 = [3.13 \quad 0 \quad 0 \quad 5.96]$$

**Step 21:**

Calculate Objective Function and Fitness values with new value of  $X^1$ .

$$f(X_{new}^1) = 3.13^2 + 0^2 + 0^2 + 5.96^2 = 45.3185$$

$$fit(X_{new}^1) = \frac{1}{1 + 45.3185} = 0.0216$$

**Step 22:**

Perform Greedy Selection  $fit(X^1) = 0.019 < fit(X_{new}^1) = 0.0216$

**Change in Population and Trial=0.**

**No change in Trial**

$$P = \begin{bmatrix} 3.13 & 0 & 0 & 5.96 \\ 3 & 1 & 8.68 & 7 \\ 0 & 3 & 1 & 5 \\ 2 & 1 & 4 & 9 \\ 0 & 2 & 8 & 1.38 \end{bmatrix} \quad f = \begin{bmatrix} 3.13^2 + 0^2 + 0^2 + 5.96^2 \\ 3^2 + 1^2 + 8.68^2 + 7^2 \\ 0^2 + 3^2 + 1^2 + 5^2 \\ 2^2 + 1^2 + 4^2 + 9^2 \\ 0^2 + 2^2 + 8^2 + 1.38^2 \end{bmatrix} = \begin{bmatrix} 45.32 \\ 134.34 \\ 35 \\ 102 \\ 69.9 \end{bmatrix} \quad Fit = \begin{bmatrix} 0.0216 \\ 0.0074 \\ 0.0278 \\ 0.0097 \\ 0.0141 \end{bmatrix} \quad t = \begin{bmatrix} 0 \\ 0 \\ 2 \\ 1 \\ 0 \end{bmatrix}$$

### Scout Bee Phase:

Memorize the Best solution, In the final onlooker bee step, Best solution is Food Source 3 i.e.

*Best Food Source,*

$$X^3 = [0 \quad 3 \quad 1 \quad 5] \quad \text{Objective Function } f = [35] \quad \text{Fitness} = [0.0278] \quad \text{Trial} = [2]$$

#### Step: 23

Select solutions for which trial > limit

#### Step: 24

Memorize it and Replace it with new random solution computed using equation

$$x_{mi} = lb + (ub - lb) * random(0,1)$$

Consider random = [0.31      0.21    0      0.19]

$$X^3 = [3.1 \quad 2.1 \quad 0 \quad 1.9]$$

#### Step: 25

Calculate Objective Function and Fitness values with new value of  $X^1$ .

$$f(X_{new}^1) = 3.1^2 + 2.1^2 + 0^2 + 1.9^2 = 17.63$$

$$fit(X_{new}^1) = \frac{1}{1 + 17.63} = 0.05$$

#### Step26:

Perform Greedy Selection       $fit(X_{old}^3) = 0.0278 < fit(X_{new}^3) = 0.05$

#### Step 27:

Reset Trial [3] to 0 which was earlier 2.

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