A Novel Bio-inspired Algorithm based on the Foraging Behaviour of the Bottlenose Dolphin

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Abstract

Nature has various biological activities which has simulated the development of many elegant algorithms for problem-solving since it exhibits extremely heterogeneous and captivating phenomenon. The bio-inspired tactics have several mesmeric features and choices compared to conventional optimization solvers. Genetic Algorithm (GA)are adaptive heuristic search algorithm based on the evolutionary ideas of natural selection and has significant benefits over more typical search of optimization techniques.Self-organization technique automates the selection of appropriate parameter values of GA during execution without the user's intervention. GA explores the multi-parameter space of solution and in each iterative step; chromosomes are altered. To blend self-organization and GA, it is essential to understand its various aspects clearly. In GA, the selection of appropriate parameters is difficult, reducing run time and avoiding premature convergence is difficult. In this paper, a new Bio-inspired optimization algorithm has been proposed based on the foraging behaviour of the Bottlenose dolphin. Oneof the famous combinatorial hard problems of Traveling Salesman Problem (TSP) is being chosen as thetest bed.

1. Introduction

Bio-inspired computing is a new scientific discipline that applies biological principles to develop new engineering solutions for medicine, industry, the environment, and many other fields that have previously not been touched by the biology revolution. Optimization is finding an alternative with the most cost effective or highest achievable performance under

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the constraints by maximizing desired factors and minimizing undesired ones. Bio Inspired can be applied in any domains such that optimization can be performed. Optimization means finding the best possible/desirable solution. Optimization problems are wide ranging and numerous.The problems they solve involve the interaction of an organism/system with the real world.

Self-organization is presented as an alternative to natural selection as the primary mechanism underlying the evolution of function in biological systems. Self-organization systems are an increasingly attractive dynamic processes without a central control, emerge global order from local interactions of lower level components in a bottom up approach. An ant colony's activities, such as coordinated attack when threatened or the building of complex trail networks, require elaborate coordination and decision making.

The advantage of blending the concept of self-organization enhances the working efficiency of other techniques to find a solution of huge search problem. The major importance of using the self-organising technique is that the problem of premature-convergence can be overcome i.e. a population for an optimization problem converged too early, resulting in being not fully optimized. The parental solutions, through the aid of genetic operators, are not able to generate off-springs that are superior to their parents. Premature convergence can happen in case of loss of genetic variation (every individual in the population is identical). The problem is resolved by using various operators of GA.

Self-organizing Selection Operator the choice of selection operator is usually one or combination of more than one operator. Certain conditions are defined to choose the appropriate selection operator for a particular problem for example based on the average fitness of the generated chromosome. Crossover/ Mutation operation is performed with a specified number of methods and based on the average fitness of the resulting chromosome; an appropriate method is chosen.Their rates adapted from an initial very high rate to a minimum optimal rate. Chromosomes corresponding to the larger and smaller crossover/ mutation rate are generated. In addition generate a chromosome corresponding to the current value obtained by increase or decrease in the rate.

The organization of the paper is as follows: Section2 offers sufficient biological background information of bottlenose dolphin toimprove the understanding of this paper. Section 3 describes theproposed technique and algorithm. The discussion about the paperis

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summarizedin Section 4. And finally, Section 5 presents the conclusion of the work recited in this paper

2. Biological Background

Bottlenose dolphins are one of 76 cetacean species and marine mammals. They are well known as the intelligent and charismatic stars of many aquarium shows. Bottlenose Dolphins can swim up to 260 m below the surface of the ocean. Bottlenose Dolphins are social beings as they cooperate among each to get food. To do this, they work in teams to optimize the effort of hunting. Bottlenose Dolphins use a technique called echolocation to find food and navigate. This technique is performed by sending ultrasounds through the water which is bounced back to the dolphin and then is detected by the dolphin in an organ called Mellon which decodes the message very much like a sonar.

Bottle-nose dolphins are great communicators. Sounds vary in volume, wavelength, frequency, and pattern. Various sounds produced by them are: Clicking, SqueakingCreaking, Buzzing Clicks. They can make a unique signature whistle that may help individual dolphins recognize each other.The frequency of the sounds produced by a bottlenose dolphin ranges from 0.2 to 150 kHz.The lower frequency vocalizations (about 0.2 to 50 kHz) are likely used in social communication. Social signals have their most energy at frequencies less than 40 kHz.Higher frequency clicks (40 to 150 kHz) are primarily used for echolocation.By this complex system of echolocation, dolphins can determine size, shape, speed, distance, direction, and even some of the internal structure of objects in the water.

Bottle-nose Dolphins undergo daily cycles of activity which include feeding, socializing, traveling, and resting. Social learning is an important aspect of dolphin social life and dolphin behavioral development. In addition to vocal social learning, dolphins discover behaviors for foraging, play, and social interactions by observing other members of their social group. In specific we are going to discuss about the foraging behaviour of the Bottlenose Dolphin. The possibility that the acquisition ofspecialized foraging techniques by young dolphins is aided by their affiliation with their mother. Many of the literature regarding foraging techniques is based on different methods of manipulating or processing food items by group activity or individual.

A calf must be able to forage successfully before being completely weaned.Learning to forage appears to be a slow process,warranting the overlap between nursing and foraging for

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the first years of life.This contrasts with most mammals,where independent foraging does not begin until late lactation. A longer peroiod of dependence allows for the infant to learn specialized foraging skills from its mother or its own while still nutiotionally depedent on and protected by mother.Individuals have the opportunity to associate in a number of small groups or to travel alone, allowing individuals to benefit from the group structure as well as from individual foraging success.Specific types of foraging were identified and given names.

The foraging behavior of the bottlenose dolphin can be individual or through groups. Here we are going to propose a new bio-inspired algorithm based on the individual foraging activity. Specifically two techniques namely Bottom grubbing and Rooster-tail foraging which belongs to the individual activity has been taken for the proposed work.

3. Proposed Methodology

3.1Bottom Grubbing Self Organization

Self-organization is an algorithmic approach adopted by the system that has the ability to adjust its own structure by local interactions without external interventions that emerges global behaviour i.e., self-control system. The basic biological operation that we self-organise as a separate algorithm is the foragingactivity performed by the Bottle-nose dolphin to catch its prey. The operation is as follows, the bottle-nose dolphin search for the area to find the food by moving slowly, when it identifies the location of the food, the dolphin will grill the surface using its beak. While grilling it changes the body position into vertical direction. Catches the food from the surface where it has grilled. After the attack of first prey it moves to identify the next location.

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3.2 Algorithm

Variables Used:

C Total number of cities, i.e. C =$C_1, C_2, \dots, C_n$

i, j, k, l Individual city,

dDistance between the cities

t_dTotal distance,

$Indiv\ P_1$Number of cities in $\left\{C_1, C_2, \dots, C_{\frac{n}{2}}\right\}$,

$Indiv\ P_2$Number of cities in $\left\{C_{\frac{n}{2}+1}, \dots, C_n\right\}$,

m Highest distance ,

seqPath covered by the individuals

MaxGenMaximum generation

IndivCurrent individual taken from generation

N Maximum number of individuals in the generation

Gen Current generation in the process

Initialize MaxGen=100, Gen=0, N=100 and Indiv=0, m=1

Step 1: Repeat

{

Repeat

Select Indiv from Gen

{

Repeat

{

Initialize the dolphin's population and food locations.

$$C = \{C_1, C_2, \dots, C_n\}$$

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Step 2: Divide the cities into two equal half's.

$$Indiv\ P_1 = \left\{C_1, C_2, \ldots, C_{\frac{n}{2}}\right\}$$

$$Indiv\ P_2 = \left\{C_{\frac{n}{2}+1}, \ldots, C_n\right\}$$

Step 3: Evaluate the total distance t_d among the cities.

Step 4: Find the highest distance in $Indv\ P_1$ and $Indv\ P_2$.

If $d_1(C_iC_j) > d(C_I, C_J)$

Where,

$C_I = Indiv\ P_1 / \{C_i\}$

$C_J = Indiv\ P_1 / \{C_j\}$

If $d_1(C_kC_l) > d(C_K, C_L)$

Where,

$C_K = Indiv\ P_2 / \{C_k\}$

$C_L = Indiv\ P_2 / \{C_l\}$

Step 5:$Swap\ (C_j, C_l)$ and goto Step 3.

Step 6: If t_d decreases repeat from Step 4

Else

If $d_1(C_iC_j) > d(C_I, C_J)$& If $d_{m+1}(C_kC_l) > d(C_K, C_L)$

$Swap\ (C_j,\ C_l)$and goto Step 3

If t_d decreases repeat from Step 4

Else

If $d_{m+1}(C_iC_j) > d(C_I, C_J)$& If $d_1(C_kC_l) > d(C_K, C_L)$

$Swap\ (C_j,\ C_l)$andgoto Step 3

Increment m

Repeat Step 6

Step 7: If (seq is repeated)

Then rep = true;

}until (rep != true)

Insert the Indiv into next generation

Indiv ++;

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```
}until (Indiv<N)
Gen ++;
}until (Gen <MaxGen)
```

3.3 Algorithm Description

Consider the problem of finding the shortest path connecting the cities $C = \{C_1, C_2, \dots, C_n\}$with$d$ indicating the distance between the cities. This problem has been defined based on the bottom grubbing technique possessed by the Bottle-nose dolphin used for searching the food and captures it with a grilling motion. It is proposed to solve the Travelling Sales Person problem where the shortest distance has to be obtained

The cities$C$ are related to the food sources. The dolphin has to visit each and every food sources i.e. every city has to be visited. Individual consists of cities. N individuals form the single generation.The process is executed for N Generations (gen). For an assumption maximumgeneration (max gen=100) are taken into consideration.In every iteration,the best individual selected from each generation is transfused to next generation. The sequence (seq) with the shortest distance is addressed as the best individual. The process continues until the individual with the minimum total distance (t_d) is obtained from the last generation.

The procedure starts by selecting the first individual from the 0^{th} generation. The individual is divided into two equal halves.

$$Indiv\ P_1 = \left\{C_1, C_2, \dots, C_{\frac{n}{2}}\right\}$$

$$Indiv\ P_2 = \left\{C_{\frac{n}{2}+1}, \dots, C_n\right\}$$

Where $Indiv\ P_1$implies the first half of the individual

$Indiv\ P_2$implies the second half of the individual

After the individual is divided, evaluate the total distance t_d between the cities. Find thehighest distance from$Indiv\ P_1$and$Indiv\ P_2$. Swap the cities positioned at the right side of the highest distancein $Indiv\ P_1$ and$Indiv\ P_2$. Again calculate the total distancet_d. If the t_d value decreases repeat the steps. If the t_d value increases, find the first highest distance from the $Indiv\ P_1$and second highest distance from the$Indiv\ P_2$. If thet_d value increases further repeat the above process by taking the second highest value, third highest value and so on.

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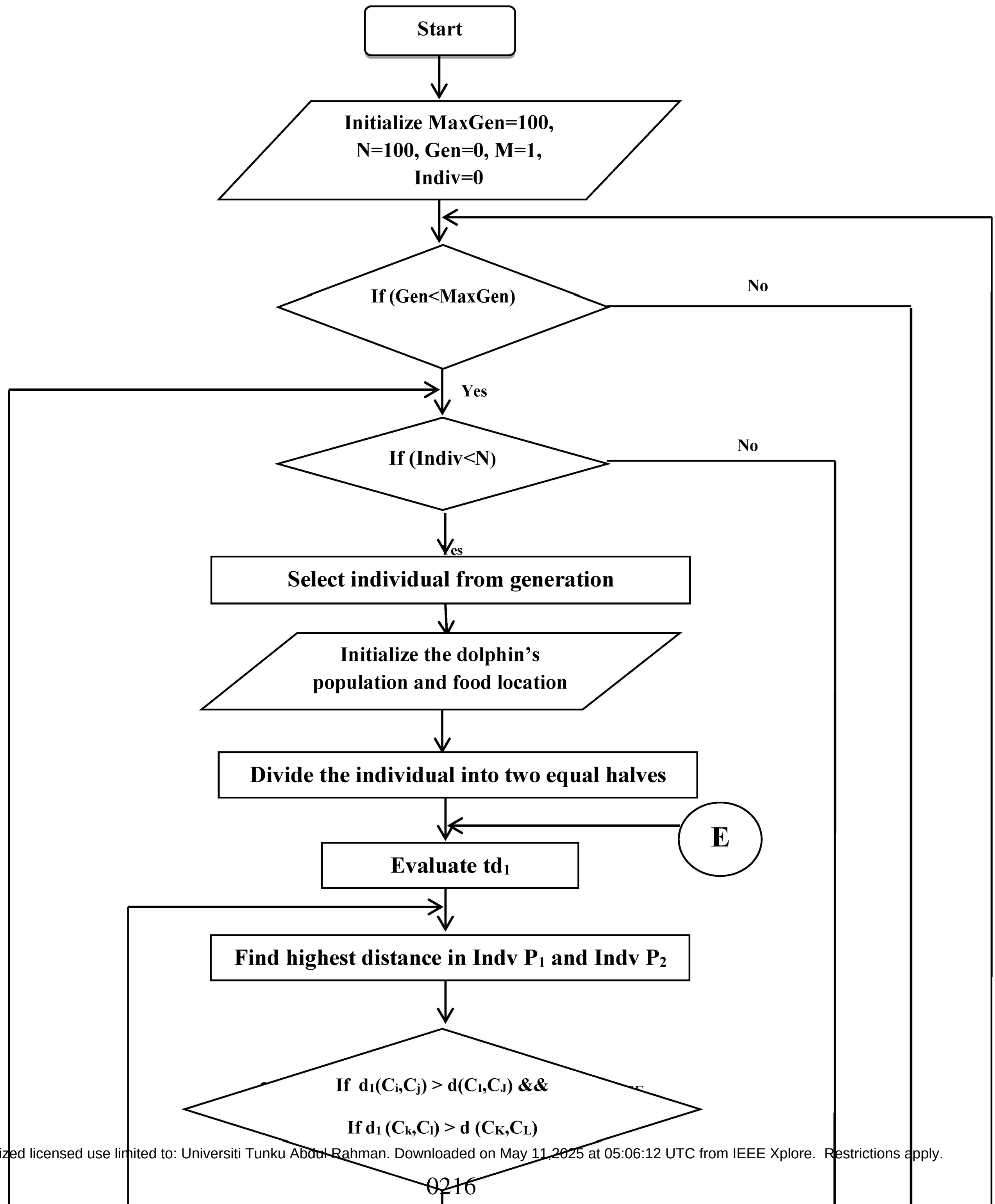
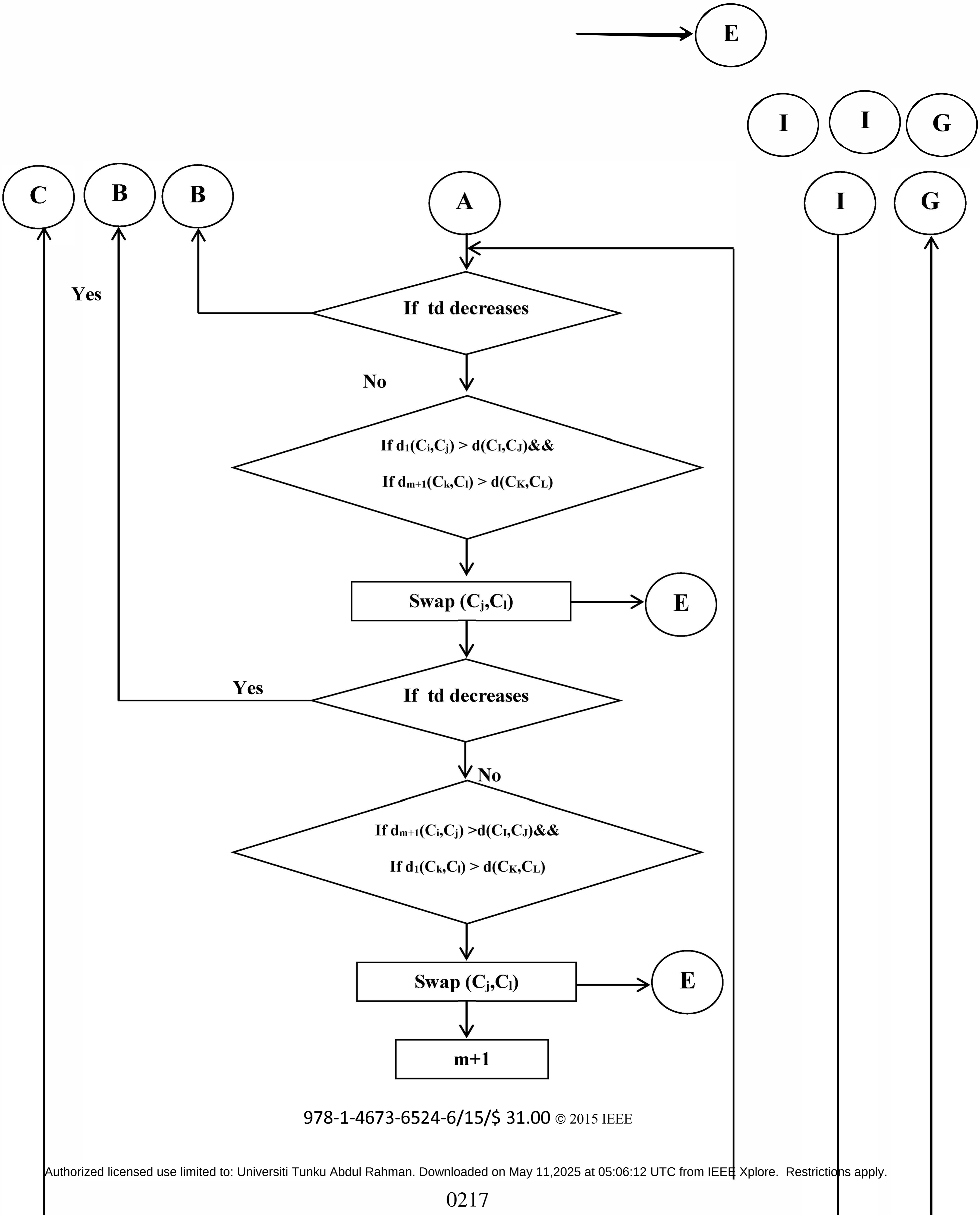
Otherwise, do the usual procedure for decreases condition. If the sequence repeats stop the process.

3.4 Flowchart





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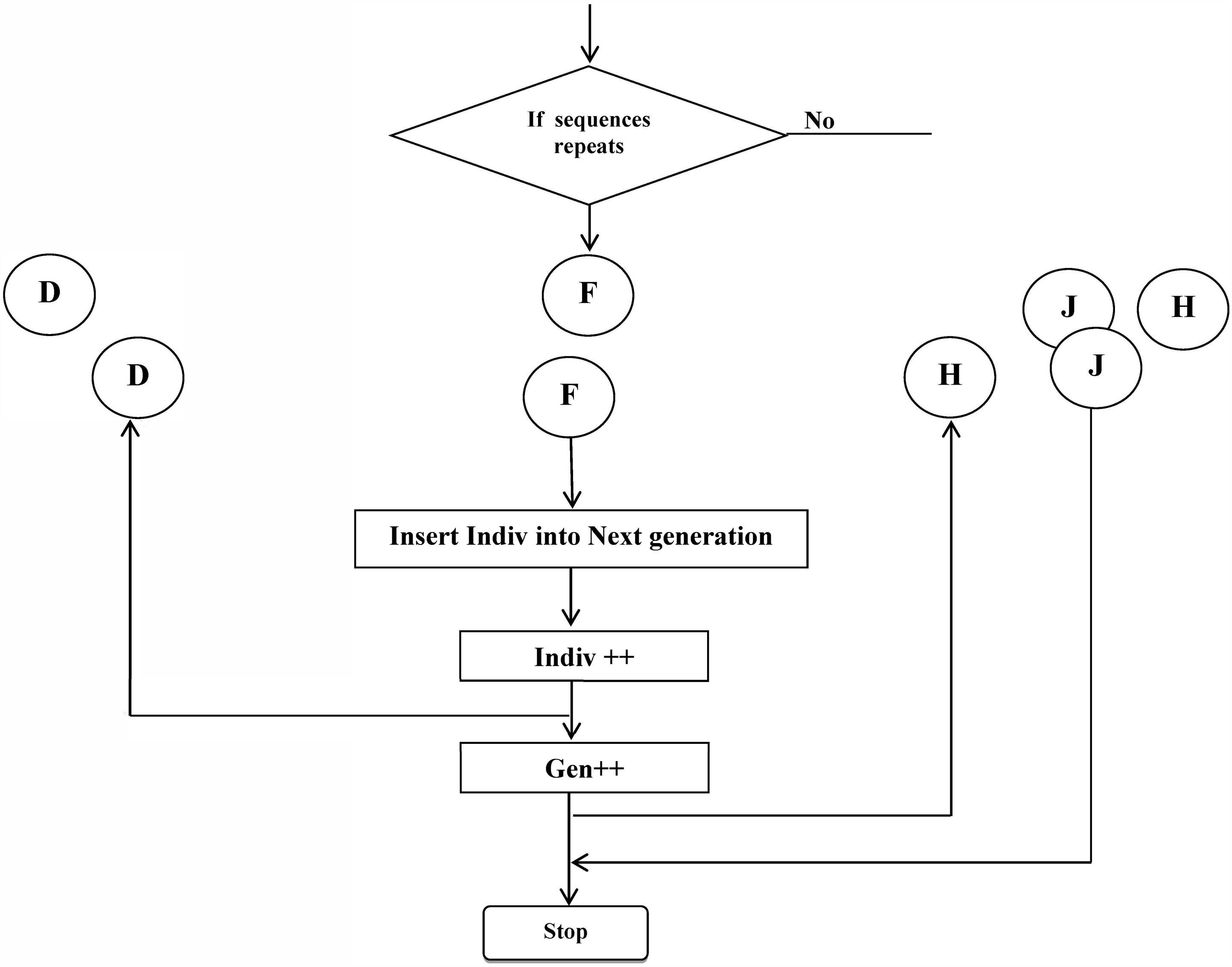

3.5 Workout Example

The algorithm is explained step-by step as follows:

STEP-1

- Food sources are considered as cities. Let us consider 10 cities initially. Distance between the cities is assigned.

1	2	3	4	5	6	7	8	9	10
10	65	15	74	24	70	44	68	1	

STEP-2

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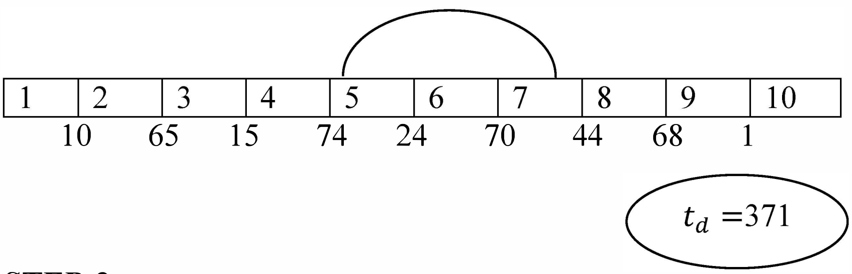
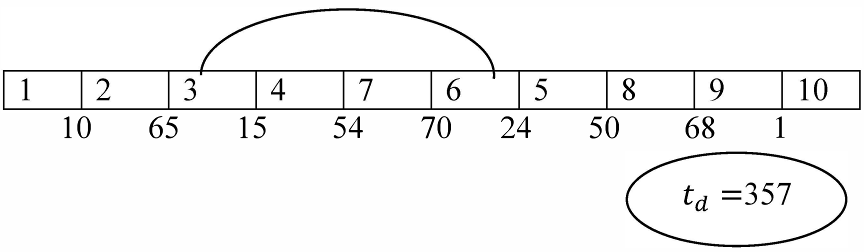
- Nodes are divided into two halves. Initially ,the operation to be performed here is :
  Take first highest value from the first half and second half respectively.
    - In First half - first highest value is 74
    - In Second half- first highest value is 70
- Swap the cities 5 and 7. The total distance t_d has been calculated.



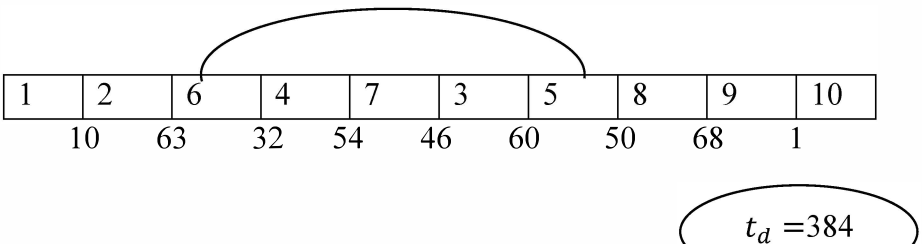
STEP-3

- Take first highest value from the first half and second half respectively.
    - In First half - first highest value is 65
    - In Second half- first highest value is 70
- Swap the cities 3 and 6. The total distance t_d has been calculated.
- Here the t_d value decreases.



STEP-4

- Since the t_d value decreases, take the first highest value from the first half and second half respectively.
    - In First half - first highest value is 63
    - In Second half- first highest value is 68
- Swap the cities 6 and 5. The total distance t_d has been calculated.
- Here the t_d value increases.



STEP-5

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- Since the t_d value increases, take the first highest value from the first half and second highest value from second half respectively.
    - In First half - first highest value is 74
    - In Second half- second highest value is 68
- Swap the cities 4 and 9. The total distance t_d has been calculated.
- Here the t_d value decreases.

1	2	5	4	7	3	6	8	9	10

10 11 74 54 46 3 4 68 1

t_d =271

STEP-6

- Since the t_d value decreases, take the first highest value from the first half and second half respectively.
    - In First half - first highest value is 35
    - In Second half- first highest value is 64
- Swap the cities 7 and 10. The total distance t_d has been calculated.
- Here the t_d value decreases.

1	2	5	9	7	3	6	8	4	10

10 11 33 35 46 3 4 26 64

t_d =232

STEP-7

- Since the t_d value decreases, take the first highest value from the first half and second half respectively.
    - In First half - first highest value is 33
    - In Second half- first highest value is 54
- Swap the cities 9 and 7. The total distance t_d has been calculated.
- Here the t_d value decreases.

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1	2	5	9	10	3	6	8	4	7
	10	11	33	1	52	3	4	26	54

t_d=194

STEP-8

- Since the t_d value decreases, take the first highest value from the first half and second half respectively.
  - In First half - first highest value is 38
  - In Second half- first highest value is 52

- Swap the cities 7 and 3. The total distance t_d has been calculated.
- Here the $t_d$value decreases.

1	2	5	7	10	3	6	8	4	9
	10	11	38	13	52	3	4	26	5

t_d=162

STEP-9

- Since the t_d value decreases, take the first highest value from the first half and the second highest value from the second half respectively.
  - In First half - first highest value is 60
  - In Second half- second highestvalue is 26
- Swap the cities 3 and 4. The total distance t_d has been calculated.
- Here the $t_d$value increases.

1	2	5	3	10	7	6	8	4	9
	10	11	60	52	13	70	4	26	5

t_d=251

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STEP-10

- Since the t_d value increases further, take the second highest value from the first half and first highest value from second half respectively.
    - In First half - second highest value is 64
    - In Second half- first highest value is 70
- Swap the cities 10 and 6. The total distance t_d has been calculated.
- Here the t_d value increases.

1	2	5	4	10	7	6	8	3	9

10 11 74 64 13 70 4 2 29

t_d =277

STEP-11

- Since the t_d value increases further, take the first highest value from the first half and third highest value from second half respectively.
    - In First half - first highest value is 74
    - In Second half- third highest value is 22
- Swap the cities 4 and 3. The total distance t_d has been calculated.
- Here the t_d value increases.

1	2	5	4	10	7	6	8	3	9

10 11 74 32 70 13 40 22 9

t_d=281

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If the t_d value increases further repeat the above process by taking the fourth highest value, fifth highest value and so on. Otherwise, do the usual procedure for decreases condition.

If the sequence repeats stop the process.

4. Discussion

In summary, new bio-inspired algorithm has been proposed based on the foraging behaviour of the bottle-nose dolphin. TSP has been used as the test bed. The optimization problem has been solved with the various studies in the GA. The detailed background study of the bottle-nose dolphin has been made and according to the analysis it has great power of communication from which it can attack the prey. The self-organisation is done in accordance with our technique. Section 3 describes the proposed technique algorithm further followed by the description of the algorithm.

5. Conclusion

In this paper, a new Bio-inspired optimization algorithm has been proposed based on the foraging behaviour of the Bottlenose dolphin. One of the famous combinatorial hard problems of Traveling Salesman Problem (TSP) is being chosen as the test bed. The bottlenose dolphin's effective communication method called echolocation helps us to design a new optimization algorithm. The detailed working of the technique is specified so as to easily understand the operation performed in the paper. This optimization technique will be considered as the easy and most effective optimization algorithm in the near future.

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