A Simple Butterfly Lifecycle Algorithm for Measuring Company’s Growth Performance

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Abstract. Five states of butterfly metamorphoses in its lifecycle naturally inspire algorithm creation. A simple butterfly lifecycle algorithm (BLCA) was successfully created by imitating a real butterfly lifecycle in five stages study; preliminary analysis, literature review, input-process-output analysis, logic analysis, and algorithm construction. The algorithm was represented thru activity diagram, pseudo-code, and class diagram. The dummy case of measuring company growth performance used to experimentally test the algorithm.

1. Introduction
A lot of nature phenomenon are technically occupied to become an inspiration for computer scientists to construct a novel algorithm as a scientific method. The nature-stimulated algorithms were implemented in solving problems in numerous cases. For examples of them are [1] with their ant colony optimization algorithm, [2] with their bee colony algorithm, [3] with their grey-wolf algorithm, [4] with their water-flow algorithm, etc. They configured an algorithm by imitating the nature phenomenon.

Several researchers conducted their research with those nature-inspired algorithm as main their methods. [5] and [6] who operated the algorithm of ant colony optimization for scheduling jobs and solving routing problem. Furthermore, [7] and [8] who functioned bee colony algorithm for urban traffic controlling and clustering documents. Then, [9] and [10] who used water flow algorithm for road traffic engineering and text line segmentation.

This study was done to construct a novel algorithm via impersonating the lifecycle of real butterfly; e.g. stages/states of butterfly lifecycle, a proper humidity or temperature for life, a weight of egg, an age of egg, a weight of caterpillar, etc. A novel algorithm produced is freely named a simple butterfly lifecycle algorithm (BLCA). Then, the algorithm was tested in measuring the company growth performance, where all indicator parameters of company growth performance were analogized from parameters of the constructed BLCA.

The novel algorithm is going to enrich academically the types of algorithm mocked by real world’s phenomenon. Also, the study performed encourages the scientists/researchers coming from several science domains to collaborate/cooperate to each other in a scientific concerted work in delivering new methodical approach to solve the problem.
2. The Phenomenon of Butterfly Lifecycle

Several points to describe the phenomenon of butterfly lifecycle (BLC) are coming from analysis of a number of electronic references, e.g. [11], [12], and [13]. Five stages/states of BLC are egg, caterpillar, instar, chrysalis, and butterfly [11]; where each stage/state has a uniqueness and the growing will be well in humidity 88% ± 4% [12] and temperature 22°C ± 12°C [13].

All stages/states of BLC consume approximately 31 days more. Where, states “Caterpillar” and “Instar” spend more than fifty percent of whole process. The significant changes occur in state “Chrysalis” (one state before “Butterfly”); where a caterpillar radically transforms by having antennae, sucking-mouth, and wonderful wings. This form makes a butterfly has a beautiful appearance [11].

3. Research Methodology

A nature phenomenon is a starting point of the study being conducted. The study was done based on five simple stages (see Figure 1); where two main methods underlie all stages, i.e. desk-based study and simple program design [14]. The study itself finally produced a simple BLCA. In the first stage “Preliminary Analysis”, analysis of real BLC was performed via real environment. Then, the analysis was continued via electronic or conventional devices, e.g. video, YouTube channel, magazine, etc. Thru this stage, the references were successfully collected with main references are [11], [12], and [13].

| Input                  | Process                                      | Output                                      |
|------------------------|----------------------------------------------|---------------------------------------------|
| egg, day, leaf, temperature, predatorNumber, humidity, weight, length, width | 1. Sperm and ovum meet to become egg          | caterpillar, instar, chrysalis, antennae, suckingMouth, wing, butterfly |
|                        | 2. Caterpillar eat and change its skin five times (as instar) |                                             |
|                        | 3. Caterpillar turn into chrysalis            |                                             |
|                        | 4. Chrysalis prepares to become butterfly     |                                             |
|                        | 5. Butterfly come out from chrysalis          |                                             |

Table 1. Input-process-output identification.

Determination of parameters and analysis of input-process-output were carefully accomplished in stage three “Input-Process-Output Analysis”. Here, nine input parameters, five main processes, and seven output parameters were identified. The result of third stage is exhibited in Table 1. The more detailed processes of BLC were analysed and orchestrated in stages four and five. The result can be illustrated in forms of activity diagram, pseudo-code, and class diagram.

4. Result and Experimental Test

Based on Table 1, generally, there are five stages/states in butterfly lifecycle; egg, caterpillar, chrysalis, instar, and butterfly. All stages/states are depicted in state diagram in Figure 2. The quality of each
stage/state depends on four strong parameters: temperature, predatorNumber, humidity, and food (in this case it is represented by parameter leaf).

Figure 2. State diagram of butterfly lifecycle stages/states.

The egg is going to obtain the most optimum condition in an environment with temperature is in between 10°C and 34°C [13], humidity is in between 84% and 92% [12], and there is no predator (predatorNumber = 0) [12]. It occurs in four days. The clear algorithm for stage/state “Egg” is depicted in Figure 3, where con1 represents the conditions of (temperature>=10) and (temperature<=34), (humidity>=84) and (humidity<=92), and (predatorNumber=0); con2 signifies the condition of day<=4; and activity initiate characterizes day=0, length=0, width=0, weight=0, egg=0, caterpillar=0, instar=0, chrysalis=0, and butterfly=0.

Figure 3. Activity diagram for describing stage/state “Egg”.

Stages/states “Caterpillar” and “Instar” are represented in Figure 4 (they are also mentioned in pseudo-code in Listing 1); starting point is symbolized with caterpillar=1 and egg=0. It denotes that egg has changed to become caterpillar. In this state, caterpillar consumes food (leaf). It consumes approximately more than 10 leaves in a day [15]; if it does not do that, it will die. To denote this condition, parameter leaf is randomized (leaf=random(0-15)).
Figure 4. Activity diagram for describing states “Caterpillar” and “Instar”.

Listing 2 – Pseudo-code of states “Caterpillar” and “Instar”
BEGIN
caterpillar=1; egg=1; weight=random(0.40-0.50);
length=random(2-6); width=random(0.4-1.5);
DOWHILE (in Star<=5)
count=0;
  IF ((predatorNumber=1) and (leaf<10)) THEN
    IF (in Star<5) THEN
      IF (count<3) THEN
        count++; day++;
predatorNumber=random(0/1);
leaf=random(0-15); weight=weight+88.21;
length=length+random(1.35-2.29);
width=width+random(0.26-0.38);
      ELSE
        in Star++;
      ENDIF
    ELSE
      count++; day++;
leaf=random(0-15); weight=weight+88.21;
length=length+random(1.35-2.29);
width=width+random(0.26-0.38);
    ENDIF
  ELSE
    finish
  ENDIF
ELSE
  count++; day++;
leaf=random(0-15); weight=weight+88.21;
length=length+random(1.35-2.29);
width=width+random(0.26-0.38);
ENDIF
ELSE
  finish
ENDIF
ENDDO
In addition, caterpillar is going to still alive if there is no predator (predatorNumber=0) [12]. Other phenomenon was captured here; where the caterpillar is going to change its skin (molting) in five times. The first until fourth change, each consumes three days, and the last one (the fifth change) consumes five days. The condition of every time its skin changes is signified by incrementing instar (instar++). The con3, con4, con5, and con6 are respectively denoting the conditions of (predatorNumber=1) and (leaf<10), instar<5, count<3, and count!=5. Totally, the stages/states “Caterpillar” and “Instar” consume 17 days; where each day affects weight, length, and width increase are respectively 88.21mg, 1.82mm ± 0.47mm, and 0.32mm ± 0.06mm.

![Activity diagram for describing states “Chrysalis” and “Butterfly”](image)

**Figure 5.** Activity diagram for describing states “Chrysalis” and “Butterfly”.

Finally, state “Chrysalis” occurs in more than ten days. In that period, antennae, sucking-mouth, and wing are growing. They represented by antennae=1, suckingMouth=1, and wing=1; consequently, butterfly=1 and chrysalis=0. The stage is figured in Figure 5, where con7 technically symbolizes a condition of day>31.

Furthermore, three types of parameter are technically produced that cause the condition of egg until butterfly good or bad via randomization process. They are temperature (in 4 days), humidity (in 4 days), predatorNumber (in 31 days), and food/leaf (17 days) which respectively randomized by operations temperature=random(0-100), humidity=random(0-100), predatorNumber=random(0/1), and leaf=random(0-15). Then, if the parameters’ value compared to 31 days (time of lifecycle); it is able to be analogized that one parameter condition fulfilled respectively affects 0.07, 0.07, 0.56, and 0.30 to the quality of butterfly’s lifecycle condition (condition of egg until butterfly). The effect values can symbolize the parameter weight or coefficient. It is able to be stated as equation (1) or (2); where \(LP\) is a lifecycle performance, \(K\) is a coefficient, \(P\) is a parameter, \(A\) represents temperature parameter, \(B\) signifies humidity parameter, \(C\) embodies predator number parameter, and \(D\) is denoting a leaf parameter.

\[
LP_{\text{Final}} = \left( \sum_{i=1}^{4} K_i P_i \right) LP_{\text{Total}}
\]  

(1)

\[
LP_{\text{Final}} = (0.07A + 0.07B + 0.56C + 0.30D) LP_{\text{Total}}
\]  

(2)
Based on analysis above, the high level configuration of algorithm could be depicted in class diagram. Naturally, there are two types of class: Butterfly and Environment with specific their attributes. Parameters which are determined as the attributes of butterfly are weight, length, width, antennae, suckingMouth, wing, eggState, caterpillarState, instarState, chrysalisState, and butterflyState. Then, the parameters which are defined as environment attributes are temperature, predatorNumber, humidity, and leafNumber. The clear figure of class diagram is presented in Figure 6.

For experimental testing, a simple dummy case was taken. The dummy data operated to fulfill the case’s characteristic that is able to be solved by the proposed algorithm. However, numerous types of data describing the growth feature are also able to be exploited technically to be processed via this algorithm. The dummy data taken said that ten companies have historical data regarding profit (Profit) and customer number (Customer) increase per annual (Table 2). Both data are technically analogized with length and width increments of caterpillar in stages/states “Caterpillar” and “Instar”. All data use percentage unit; where length increment is 44.12% and width increment is 31.18%. Other data is regarding their performance in four aspects: partner relationship (PR), technology capability (TC), human resources (HR), and financial (F); where symbolized by temperature, humidity, predatorNumber, and leaf parameter respectively. Those performance data are represented in Table 3 (in scale 0-1).

![Class diagram of the constructed algorithm.](image)

**Table 2.** Dummy data of ten companies in profit and customer growth.

| Company | Profit (%) | Customer (%) |
|---------|------------|-------------|
| 1       | 76.00      | 39.00       |
| 2       | 18.00      | 32.00       |
| 3       | 70.00      | 12.00       |
| 4       | 85.00      | 90.00       |
| 5       | 61.00      | 47.00       |
| 6       | 70.00      | 94.00       |
| 7       | 63.00      | 9.00        |
| 8       | 24.00      | 82.00       |
| 9       | 76.00      | 52.00       |
| 10      | 23.00      | 39.00       |

By matching to artificial caterpillar’s length and width increments, the matching-distances (between company’s growth performance indicator and caterpillar’s length/width) of each company are acquired.
Then, by relatively contrasting with a hundred distance-point (as the largest distance where it indicates the worst), the measurement result is obtained. Finally the results are multiplied by summation of performance for four aspects (see equation (3) or (4)); where $GP$ is company’s growth performance. The final performance is exhibited in Figure 7; where the company number 5 has the best indicator value of growth performance and company number 6 has the poorest one.

**Table 3.** Dummy data of ten companies in partner relationship, technology capability, human resource, and financial growth.

| Company | PR  | TC  | HR  | F   |
|---------|-----|-----|-----|-----|
| 1       | 0.62| 0.96| 0.34| 0.94|
| 2       | 0.33| 0.68| 0.35| 0.45|
| 3       | 0.63| 0.48| 0.65| 0.63|
| 4       | 0.54| 0.80| 0.58| 0.95|
| 5       | 0.43| 0.37| 0.85| 0.76|
| 6       | 0.78| 0.58| 0.41| 0.33|
| 7       | 0.78| 0.66| 0.57| 0.62|
| 8       | 0.31| 0.61| 0.77| 0.93|
| 9       | 0.72| 0.88| 0.39| 0.51|
| 10      | 0.67| 0.64| 0.51| 0.97|

$$GP_{Final} = \left( \sum_{i=1}^{4} K_i P_i \right) GP_{Total}$$  \hspace{1cm} (3)

$$GP_{Final} = (0.07PR + 0.07TC + 0.56HR + 0.30F)GP_{Total}$$  \hspace{1cm} (4)

**Figure 7.** The growth performance for each company.

**5. Conclusion and Further Works**

Via five stages preliminary study, an algorithm which mimics a real phenomenon of butterfly lifecycle metamorphoses was fruitfully created. The algorithm that called a simple butterfly lifecycle algorithm inspired by step-by-step changes of egg-up-to-butterfly in its natural metamorphoses. Particularly in stages/states “Caterpillar” and “Instar”, it is able to be functioned to measure growth performance. In here, the dummy case of companies’ data regarding profit and customer number increment used to test the constructed algorithm. Also, the growth performance is able to be multiplied by other performance with specific coefficient that measured from behaviour of four parameters “temperature”, “humidity”, “predatorNumber”, and “leaf”.

More detailed study regarding butterfly lifecycle is used to make the constructed algorithm more prefect; e.g. the study of other related parameters, the quality of butterfly’s beauty, etc. The algorithm
also can be functioned to determine other case of growth performance, not only in one/two stages/states of artificial butterfly lifecycle, however in a whole lifecycle, includes by indicating attributes of butterfly itself (i.e. antennae, wing, and sucking-mouth). Possibly, the case with involving data series is relevant to be solved by BLCA.

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