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The Function Discovery of Closed Curve using a Bug Type of Artificial Life

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Abstract — **The function, which represents the closed curve, is found from the sampling data by S-System in this study. Two methods are proposed. One is the extension of S-System. The data x and y are regarded as input data, and the data z=0 as output data. To avoid the trap into the invalid function, the judgment points (x_j, y_j) are introduced. They are arranged in the inside and the outside of the closed curve. By introducing this concept, the functions representing closed curve are found by S-System. This method is simple because of a little extension of S-System. It is, however, difficult for the method to find the complex function like a hand-written curve. Then another method is also proposed. It uses the system incorporating the argument function. The closed curve can be expressed by the argument function. The relatively complex function, which represents the closed curve like a hand-written curve, is found by utilizing argument function.**

I. INTRODUCTION

J. Koza first proposed the function discovery system based on Genetic Programming (GP) [1]. However, the system has some disadvantages; (i) the schema tends to get destroyed, (ii) the solution does not stabilize and (iii) the function length becomes extremely long or extremely sort. We thus have proposed an improved system called S-System overcoming these disadvantages, and a method to improve the search ability is also proposed [2][3]. We have already applied S-System effectively in a number of search problems including the fields like design of optical elements, electronic circuit design and image recognition. In addition, in the previous paper, we proposed a non-linear optimization method incorporated S-System that significantly reduces the time for the discovery [4].

However, the function representing closed curve is not found by S-System. In this study, the function, which represents the closed curve, is found from the sampling data by new method. Two methods are proposed. One is the extension of S-System. This method is simple because of a little extension of S-System. It is, however, difficult for the method to find the complex function like a hand-written curve. Then, another method is also proposed. It uses the system incorporating the argument function. The relatively complex function, which represents the closed curve like a hand-written curve, is found by utilizing argument function.

II. ALGORITHM OF FUNCTION DISCOVERY

The outline of the function-discovery system called S-System is mentioned here.

A. Main routine

Figure 1 is the flowchart of the algorithm of function-discovery by the use of a bug type of A-life proposed by us [2]. The flow is summarized as follows.

(1) Numerous bugs with the arbitrary function are generated at random. The number ***Pop*** is selected from the numerous bugs in order of high fitness.

(2) The generation ***Gene*** of the bug is set to 0.

(3) The value of the internal energy, $energy_p$, of all the bugs is initialized to 0.

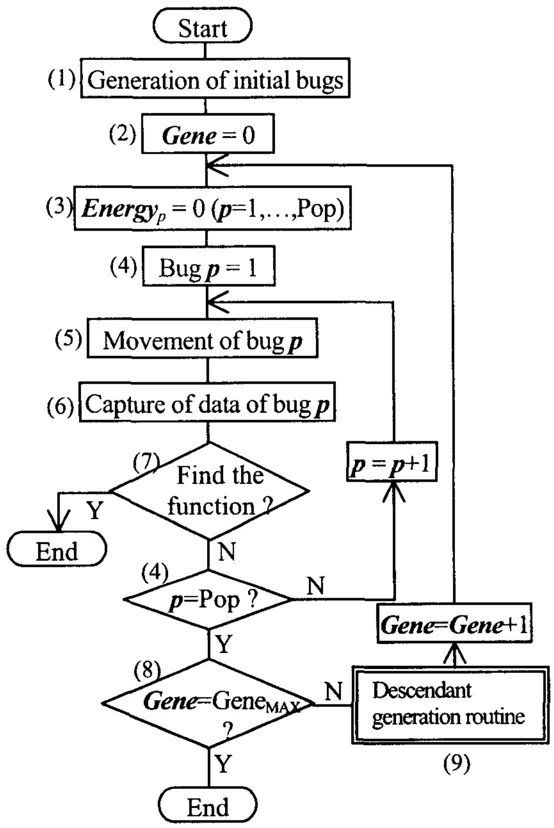


Fig. 1 The flowchart of the algorithm of function-discovery using the bug type of artificial life.

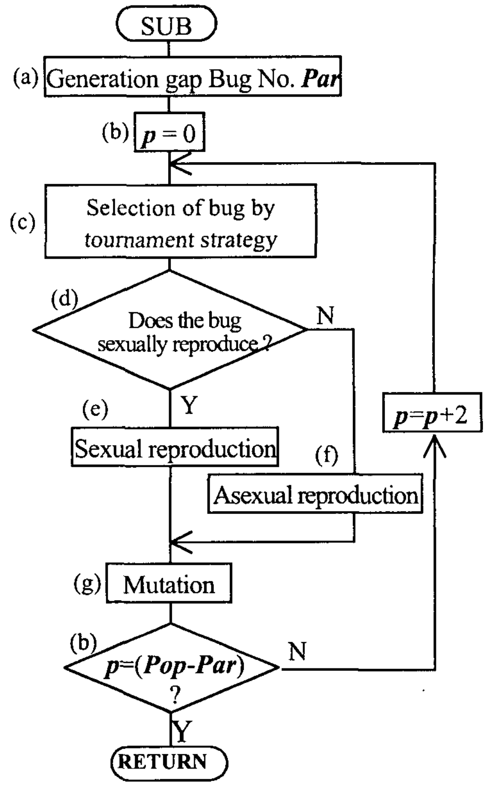


Fig. 2 The flowchart of descendant-generation routine.

(4) The procedures from (5) to (7) are repeated for all the bugs; the bug number ranges from 1 to ***Pop***.

(5) The bug ***p*** moves. This means that the values of constants $\overline{K}$ in the chromosome change slightly. That is to say, the values of $\overline{K}$ are replaced by $\overline{K}+\overline{dK}$, where $\overline{dK}$ is the small change of $\overline{K}$, $\overline{K}=(K_1,K_2,\cdots,K_n)$, $\overline{dK}=(dK_1,dK_2,\cdots,dK_n)$ and ***n*** is the number of constants in the chromosome. This concept is based on Ref. [5]. The details are given in Ref. [2].

(6) The bug ***p*** catches the observation data (i.e., fitness fit_p of bug ***p*** is calculated from the observation data).

(7) In the case that fitness fit_p reaches the threshold fitness Fit_{TH}, this algorithm ends. This means a bug has discovered the function *f*.

(8) The algorithm ends when the current generation ***Gene*** reaches the maximum Generation $Gene_{\max}$.

(9) After the descendant-generation-routine is called, ***Gene*** is added to 1 and the algorithm returns to procedure (3).

B. Descendant-generation-routine

The flowchart is displayed in Fig. 2, and is summarized as follows.

(a) Based on the generation-gap, ***Par*** bugs are selected and they are passed down to the next generation. The elite strategy is adopted for the generation-gap.

(b) The bug number ***p*** is set to be 0. By the repetition of the following procedures from (c) to (g), ***Pop*** - ***Par*** bugs are generated.

(c) A bug is selected by the tournament strategy.

(d) The selected bug is judged whether it has the ability to sexually reproduce. In the case that the selected bug has the ability of sexual reproduction, procedure (e) is performed. In the other case, procedure (f) is carried out.

(e) The bug finds its partner, and they produce two children by crossover. Jump to procedure (g).

(f) Two children are produced by asexual reproduction.

(g) A part of the chromosome is changed by mutation at the rate of R_{mut}.

Thus, the descendants of the number of ***Pop*** are generated. For the details sexual/asexual reproduction and mutation, see Ref. (2).

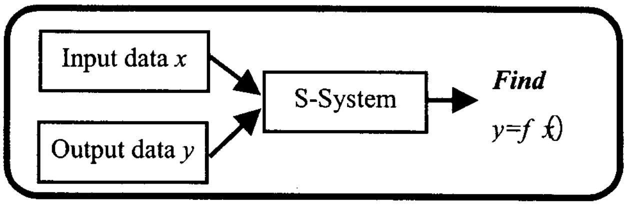
In this study, we regard the points on the computer screen as output data $\boldsymbol{y}$ and the ones on the projected screen as input data $\boldsymbol{x}$. The function $\boldsymbol{G}$ that expresses the relationship between $\boldsymbol{x}$ and $\boldsymbol{y}$ is estimated by using the S-system.

III. HOW TO FIND CLOSED CURVE

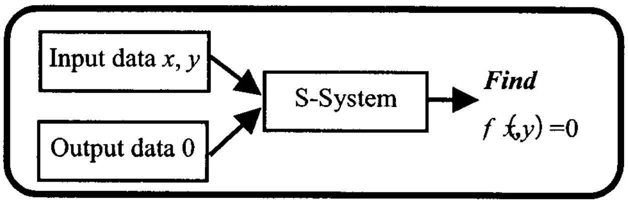
A. Improvement of S-System

In this study, we try to find the function which represents the closed curve from the sampling data. Figure 3(a) shows the outline of conventional function-discovery system. When the two types of sampling data x, y are given into S-System, the system find the function $y=f(x)$ which represents the relationship between them. However, it cannot be applied to find the closed curve. For example, as for a circle with radius 1, two functions $f_1(x)=\sqrt{1-x^2}$ and $f_2(x)= -\sqrt{1-x^2}$ exist against input data x. To solve this problem, we regard the data x and y as input data, and the data z=0 as output data as shown in Fig.3 (b). By this concept, it is guessed that function $f(x,y)$ which satisfies the relation of $f(x,y)$ =0 is found. Nevertheless, the purpose function is not found only by this concept. Because the function like $kx+ky=0$ (k=0) is always valid at any closed curves. Such the function is found by the concept in Fig.3 (b). To avoid the trap to such the function, the judgment points (x_j, y_j) are introduced as shown in Fig.4. They are arranged in the inside and outside of the closed curve. The input data x and y (i.e. sampling data) are on the closed curve. If the judgment point (x_j, y_j) is substituted for the function $f(x, y)$ and the value of $f(x_j, y_j)$ equals 0, the function $f(x, y)$ is regarded as invalid function. By introducing this concept, the function is found without the trap to invalid function.

The examples of the closed curves found by S-System are shown in Fig. 5. In the figure, the circle points are the sampling data (x, y), and the drawing curves are the functions which are found by S-System. From this figure, it is found



(a) Conventional model



(b) Impropved model

Fig.3 The outline of S-System

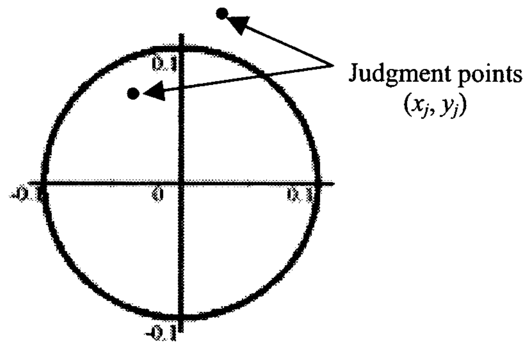


Fig.4 The judgment points in the inside and outside of the closed curve.

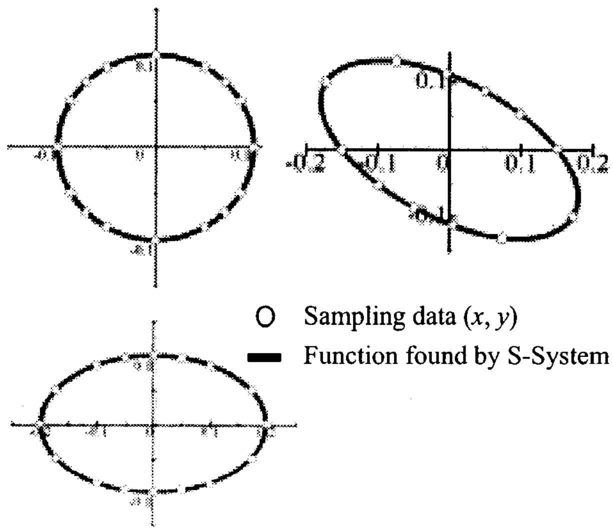
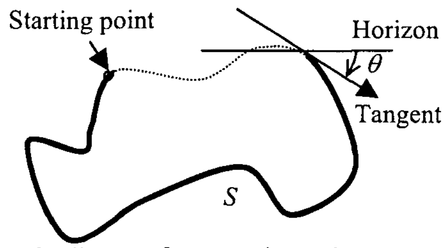


Fig. 5 The examples of closed curves found by S-System.

that the functions representing closed curve are found by S-System.

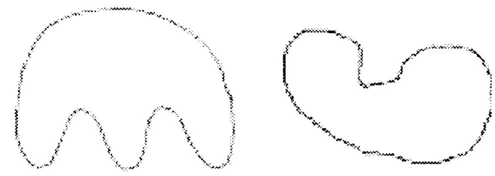
B. Function search utilizing argument function

It is, however, difficult for the above method to find the complex function like a hand-written curve in Fig.6. Then, another approach is attempted here. The closed curve can be expressed by the argument function. In Fig.6, the symbol S is the distance from the starting point and θ shows the angle between horizon and tangent as shown in Fig. (6). In this approach, the input data is regarded as θ and the output data is S. The correspondence of input data and output data is one-to-one. Therefore, the conventional S-System in Fig. 3(a) is available to the function search. As far as the data of one-to-one is concerned, the relatively complex function can be found by S-System. Some examples of the results are shown in Fig. 7. As shown in Fig. 7, the relatively complex function, which represents the closed curve like a hand-written curve, is found by utilizing argument function.

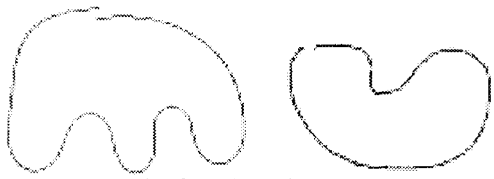


S : distance from starting point
θ : angle between horizon and tangent

Fig. 6 Expression of closed curve by argument function.



(a) Hand-written curves



(b) The functions found by argument function

Fig. 7 The examples of the functions found by argument function.

IV. CONCLUSION

The new methods for representing the closed curve as the function are proposed in this study. One is the extension of S-System, another is the method incorporating argument function. By these methods, the function is found from the sampling data which express the closed curve. Although the extended method of S-System is simple, the one incorporating argument function can find more complex closed curves.

References

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