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CURVE RECONSTRUCTION BY CUBIC BALL ON ARABIC FONTS USING BUTTERFLY OPTIMIZATION ALGORITHM

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ABSTRACT

The Butterfly Optimization algorithm (BOA) is taken into account as a new metaheuristic algorithm family. Researchers were drawn to this metaheuristic algorithm due to the potential offered to solve the problems broadly. The BOA algorithm was employed to obtain the best solution to the curve fitting problem by using the cubic Ball curve. Sum Square Error (SSE) is used to evaluate the error generated between two curves because the goal of this research is to shrink the distance between the extracted shape images and the generated curve by parametric equation. The pre-processing steps need to be followed before enter to the curve reconstruction process. According to the findings of this analysis, the proposed method did not successfully generate a fit cubic Ball curve because the shape formed on the boundary extraction is not closely fitted. The error generated has tarnished the expected results, and the method proposed need to be improved eventually.

Keywords: *Butterfly Optimization Algorithm, Cubic Ball Curve, Metaheuristic Algorithm*

1. INTRODUCTION

Curve reconstruction is just the process of reconstructing a curve by mathematical function. This process is really convenient for a given set of data points that could be subject to certain restricts. It has become crucial issues that researchers have recently emphasized, especially in solving reverse engineering problems [1].

In general, curve fitting is an essential part of curve reconstruction. Curve fitting objectively identify a set of data points that can accurately represent a given curve. In the literature, various splines, such as Bezier curves and B-splines, are used to solve curve fitting problems [2]. However, [1] and [3] tend to choose cubic ball curve to reconstruct the curve from the images that is proposed. Using the Bezier curve, the researchers began to build a piecewise cubic Bezier curve at each sub-interval of data points in order to improve the smoothness of interpolation [4]. Nonetheless, [5] reported that the Ball curve is similarly to Bezier curve but have better properties than the Bezier curve.

The Optimization methods that are constructed based on soft computing have been employed as an effort to find the best solutions for large number of problems, in particular for complex engineering problems. This majorly contributed by the inefficiency of conventional optimization algorithms into dealing with complex problems. These approaches may compute in a short amount of time, but do not promise the best solution every time. Several numbers of soft computing methods have drawn the interest of researchers, such as Differential Evolution (DE), Genetic Algorithm (GA), and Artificial Bee Colony Algorithm (ABC) [1]. This article intends to apply the currently invention metaheuristic algorithm namely Butterfly Optimization Algorithm (BOA) due to more efficiency offered compare to DE, ABC and GA [6].

1.1. The Related Works

Splines have been the most broadly used computational tools in the fields of geometric modelling, computer graphics, numerical simulation, automated manufacturing, Computer Aided Geometric Design (CAGD), signal fitting, and iamage/video processing for the several

decades. Lately, reconstructing certain fonts of calligraphy using a spline approach is rapidly gaining popularity.

Several studies in font reconstruction have yielded promising results by integrating curve fitting with modern soft computing. For instance [2], [7], [8], proposed Arabic font reconstruction using Cubic Bezier and soft computing. Chinese font reconstruction by combining Cubic Bezier with soft computing called Differential Evolution (DE) was handled by [9]. Based on the previous works which are presented by [1], however they have employed the same approach in [9] where not only works on Chinese font but also on some images were properly fitted. Summarily, much of works are dealing with Cubic Bezier Polynomial but limited practicing with Cubic Ball Polynomial. According to [1], Cubic Ball has given better computational speed compared to Cubic Bezier but provides similar abilities in the curve generated.

In addition, the current optimization method that such implemented on [2], [7], [8] and [9] obviously close to efficient and precise particularly on Chinese and Arabic font reconstruction. To the best of our knowledge, the Butterfly Optimization Algorithm (BOA) performed better than Differential Evolution (DE), Genetic Algorithm (GA), and Artificial Bee Colony Algorithm (ABC) in the field of engineering design. Despite this, there has been a lack of research investigating the BOA's potential as soft computing, specifically in the font reconstruction field.

Motivated by these issue, the paper's intent is to propose a font reconstruction employing certain Arabic letters using Ball Curve. The Butterfly Optimization Algorithm (BOA) will act as the soft computing in this research. Ball curve and BOA are selected methods due to the advantages they provide. The main content of this research is to fitting the Cubic Ball curve using new optimization technique namely BOA into reconstructing the Arabic font.

In the final result, the proposed integration scheme makes it possible either to reconstruct the font better or to require a modification for improvement to make the method proposed produce the best result in the future.

1.2. Limitation of Study

As noted at the beginning of the discussion, majority of scholars only studied using Bezier Curve with $n = 3$ and often referred to as the Cubic Bezier. Nonetheless, Ball curve is being applied in this research by employing the same value of n and straightly requiring 4 control points for curve development that knew as v_0 , v_1 , v_2 , and v_3 .

In addition, a novel methodology incorporated recent metaheuristic approach of butterfly optimization algorithm (BOA) is the main focusing that act as a soft computing into optimize the curve generated by searching the optimal two (2) control points, v_1 and v_2 .

Only three (3) kinds of Arabic letters are used in this study. Arabic font was selected because according to [7] non Roman letters are more difficult to reconstruct. Therefore, the main contribution through the conducted study, the significant integration ability of the Cubic Ball curves and BOA into solving Arabic font reconstruction, was exposed appropriately.

The study is divided into six parts, namely an introduction to the Cubic Ball curve, followed by the BOA process described in general. Then, border extraction and corner detection are described in more detail, using three types of Arabic fonts. Next, chord length parameterization and curve fitting are discussed. Finally, conclusions are drawn based on the results obtained.

2. CUBIC BALL CURVE

As shown by [1], [10], the cubic Ball curve is given by:-

$$P(u)=\sum_{i=0}^{3} v_i \beta_i^3(u) \quad \text{for} \quad 0 \le u \le 1 \tag{1}$$

where v_i is called control point and β_i^3 is knew as cubic basis ball function,

$$\begin{aligned} \beta_0^3 &= (1-u)^2 \\ \beta_1^3 &= 2u(1-u)^2 \\ \beta_2^3 &= 2u^2(1-u) \\ \beta_3^3 &= u^2 \end{aligned} \tag{2}$$

On the Cubic Ball curve development, only four (4) control points is involved, $v_i(x,y)$, where i varies from zero to three. Therefore, based on (1) cubic Ball curve is possible to illustrate as,

$$P(u)=v_0\beta_0^3(u)+v_1\beta_1^3(u)+\ldots \\ v_2\beta_2^3(u)+v_3\beta_3^3(u) \quad (3)$$

According to (3), control points, v_0 and v_3 are the end points while v_1 and v_2 are two middle points. Figure 1 show the Cubic Ball Curve illustration.

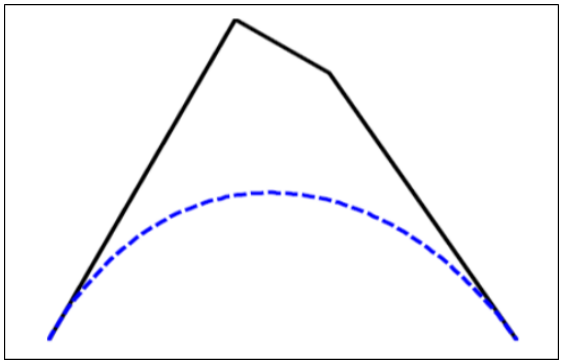

Figure 1: The Cubic Ball Curve illustration

Ordinarily, the number of point requirement between cubic ball function equation and cubic Bezier curve is identical, However, when some recent studies have proved the advantages of this function, this function has great potential. Almost often mentioned are the capability curves into producing curves in a shorter period of time. In addition, the properties of endpoint interpolation enable this function to be used as a suitable interpolation for point-to-point connections. Hence, a function which has the ability to interpolate each point is required in curve reconstruction. Subsequently, proper interpolation can be created by using cubic Ball basis.

3. BUTTERFLY OPTIMIZATION ALGORITHM

In the past, natural heuristic named meta-heuristic algorithms have attracted the attention of many researchers [6]. This might be caused by the advantages offered such as flexibility, simplicity, gradient-free and independently [11]. Butterfly optimization algorithm (BOA) is a subcategory of naturally inspired meta-heuristic algorithms that belongs to a group of biologically inspired algorithms [12]. BOA is primarily influenced by the food foraging behavior of butterflies, which serve as search agents to perform optimization in BOA [6], [13]. Biologically speaking, butterflies have sensory receptors that are used to smell/perceive the fragrance of food/flowers. These sensory receptors are called chemoreceptors, and they are scattered on the body parts of butterflies.

In the framework of BOA, it is assumed that butterflies have characteristics as follows:

1. Each butterfly emits a certain fragrance, which can help them attract each other.

2. Butterflies randomly hunt for food or fly towards the butterfly that emits the most fragrance.
3. The landscape of the objective function is used to determine the intensity of butterfly stimulation.

In BOA, the fragrance, f_i is intensity function of the butterfly stimulus [14] which is defined as the magnitude of fragrance perceived that can another butterfly felt [13]. The f_i can be expressed as below:

$$f_i=cI^a \quad (4)$$

Where c is the sensory modality, I is the stimulus intensity, and a is the power exponent depending on the modality, which explains the change in the degree of absorption. The values of a and c lies between 0 and 1, i.e. $c\in[0,1]$.

Global and local search are the two main stages involved in BOA. Since the butterfly can feel the fragrance of the best butterfly in the search space, it will move towards the best butterfly in simple words find the best position, $g*$ which is called the global search stage of BOA. Hence, the relation defining as follows:

$$x_i^{t+1}=x_i^t+\left(r^2\times g^*-x_i^t\right)\times f_i \quad (5)$$

where x is a vector representing the position of the i-th butterfly at time t and r is a random number, $r\in[0,1]$. The best current position is representing by $g*$. If the butterfly cannot sense the smell of other butterflies, it will move forward randomly. At this stage is called local search. This can be described by (6).

$$x_i^{t+1}=x_i^t+\left(r^2\times x_j^t-x_k^t\right)\times f_i \qquad (6)$$

where x_j^t and x_k^t are vectors representing the positions of the j-th and k-th butterflies at time, t, r is a random number, $r\in[0,1]$ and f_i is fragrance of i-th butterfly. Into switching global search and local search is by applying switch probability, p in BOA.

4. PRE-PROCESSING STEPS AND CURVE RECONSTRUCTION

This section has described the features of each step-in detail about a few pre-processing steps which ought to be performed before the curve reconstruction (known as curve fitting process) initially begins. The pre-processing steps normally are defined as boundary extraction, corner detection, and lastly, it's followed by chord length parameterization step before the curve fitting process undertakes.

The layout procedure of the pre-processing and curve fitting operation can indeed be illustrated as shown in the figure 2.

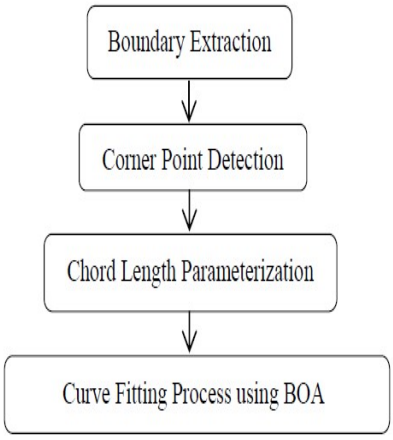

Figure 2: The Layout Procedure of The Pre-Processing Steps and Curve Fitting Operation

The procedure layout of the pre-processing and curve fitting operation can indeed be illustrated as shown in the figure above.

4.1. The Shape Extraction and Corner Point Detection

At the initial step, the original image's boundary has to be extracted before curve reconstruction started. The boundary of the extracted image graphically represents the object's shapes. There are many algorithms that have been used to extract the shapes [1], [2], [15], [16]. In this work, a MATLAB function called boundary is used to take out the boundary of the digitized image, then the shape of the Arabic font images is extracted.

After knowing the boundary points, the corner points on the extracted image are detected accordingly. The corner point is defined as the point where the contour is divided into multiple segments before curve fitting [1]. Generally, the corner points play vital role in the shape representation which is known as shape boundary capturing process [2]. According to [1] and [2], there have been several corner detection algorithms discovered, likes Davis algorithm, Harris algorithm, Rosenfeld and Johnston algorithm, and SAM06 algorithm. The corner points are detected by employing the SAM06 algorithm under this research. Table 1 shows the Arabic font images with corner point detection over the original shape extraction.

4.2. Chord Length Parameterization

On above, the curve that generated by cubic Ball function is developed by four control points and let (7) be presented as following,

$$P(u)=(1-u)^2 v_0+2u(1-u)^2 v_1+\ldots \\ 2u^2(1-u)v_2+u^2 v_3 \qquad (7)$$

Next, expression (7) is be presented in matrix form as below

$$P(u)=\begin{bmatrix}1 & u & u^2 & u^3\end{bmatrix}\times\ldots \\ \begin{bmatrix}1 & 0 & 0 & 0\\ -2 & 2 & 0 & 0\\ 1 & -4 & 2 & 1\\ 0 & 2 & -2 & 0\end{bmatrix}\begin{bmatrix}v_0\\ v_1\\ v_2\\ v_3\end{bmatrix} \qquad (8)$$

Before the intermediate points estimation of v_1 and v_2, the value of u in (8) ought to be predicted at first. The Chord length parameterization is applied in this study as an effort to estimate the value of u associated with each point by the following method.

$$u_i=\begin{cases}0 & if\ i=1\\ \dfrac{|\beta_1\beta_2|+|\beta_2\beta_3|+\ldots+|\beta_i\beta_{i+1}|}{|\beta_1\beta_2|+|\beta_2\beta_3|+\ldots+|\beta_{n-1}\beta_n|} & if\ 2\le i\le n-1\\ 1 & if\ i=n\end{cases} \quad (9)$$

4.3. Curve Reconstruction

Centered at top List There are three (3) Arabic fonts selected in this study which are Lam Alif (لا), Kha (خ), and Kaf (ک). Then, the pre-processing steps as mentioned above are employed to interpolate the data. The soft computing algorithms, namely Butterfly Optimization Algorithm (BOA) is put in application to seek the appropriate of two intermediate points known as v_1 and v_2 . Following that, these points are used to obtain the parametric curve that donates the best optimal results for the given value of u .

When the perfect values for points v_1 and v_2 are found, an appropriate cubic Ball curve can be obtained. The goal of this study is to close the gap between the original shape of the boundary image and the boundary of the generated cubic Ball curve obtained through BOA. Hence, the potential of using Butterfly Optimization Algorithm (BOA) in curve fitting is clearly revealed through this article.

At this part, a number of parameters ought to be plugged in. According to [17], the best fit parameter values for Butterfly Optimization Algorithm (BOA) are the population size n is set at 50, the modular modality c is set to 0.01, and the power exponent a is augmented from 0.1 to 0.3 in the iteration process. Then, the value of the probability factor is, $p=0.8$ because it works better in most applications. On this study, 100 times of iteration is applied.

As the final result, Sum Squares Error (SSE) is used as the objective function, $f(x)$ into evaluating error between the generated curve's parametric points and original boundary images.

5. RESULT AND DISCUSSION

The objective of the research proposed is to shrink the distance between borders that was obtained from the original image and the fitted cubic Ball curve by the proposed method. Therefore, the maximum and average error of the sum of squares (SSE) are selected to obtain the error that is produced between the two curves. The exhibition of the shape of cubic Ball curve (Red line) over extracted boundary image (Blue Line) and the errors of the techniques proposed on the images are stated in table 2.

As illustrated visually, the reconstruction curve by cubic Ball function on boundary image are not closely fit to the selected image. Therefore, in term of the numerically, the error illustrated that the Butterfly Optimization Algorithm (BOA) is less practicality for curve fitting application since it produced a small error and hopping for better outcomes by looks for some improvement.

6. CONCLUSION

Into reconstructing the curve by applying the current optimization technique, Butterfly Optimization Algorithm (BOA) is adopted which acted as soft computing algorithms. This paper intended to exposed the potential Butterfly Optimization Algorithm (BOA) approach to approximate the extracted boundary images using a parametric cubic Ball curve for curve reconstruction. As knew, the BOA is considered as a new metaheuristic algorithm but this algorithm has been already proven that it can provide a better solution particularly in engineering designs. The Sum Square Error (SSE) indicator is utilized into determining the errors between the extracted boundary image and the generated boundary by parametric curve. Hence, the potential of using Butterfly Optimization Algorithm (BOA) in curve fitting is allowed to be revealed. As results appear, BOA is not performed well for solving curve fitting or curve reconstructing especially on the Arabic font application. Subsequently, the method proposed obviously requires some reasonable suggestion to follow, such as a hybrid method to proposed or enhancing the techniques, as an effort to provide method improvement and become better in future.

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Table 1: Corner points detection over the original shape extraction

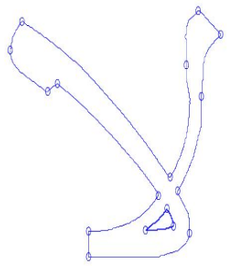
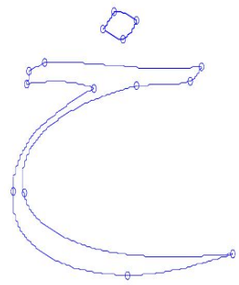
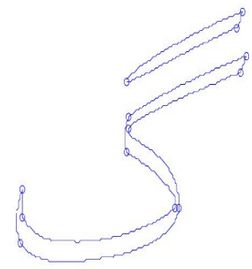
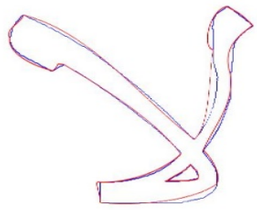
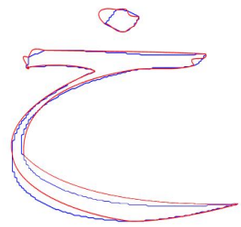
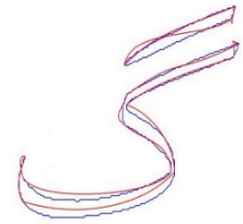
Images Name	Lam Alif	Kha	Kaf
Original Image			
Corner points on the extracted images			

Table 2: Corner points detection over the original shape extraction

Images Name	Lam Alif	Kha	Kaf
Images Extracted			
Minimum Error of SSE	328.1689	263.7736	193.1806
Average Error of SSE	420.7971	474.1893	320.8326

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