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GRAPHICAL COMPUTING FOR BATIK PATTERN DESIGN BASED ON L-SYSTEM

Eka Wahyu Hidayat[*1], Muhammad Adi Khairul Anshary[2], Rahmi Nur Shofa[3]

[1,2]Informatics, Engineering Faculty, Universitas Siliwangi, Indonesia
[3]Information Systems, Engineering Faculty, Universitas Siliwangi, Indonesia
Email: [1]ekawahyu@unsil.ac.id, [2]adikhairul@unsil.ac.id, [3]rahmi.shofa@unsil.ac.id

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Abstract

The challenge faced by the batik industry in the industrial era 5.0 is the adaptation to technology in the production process. One way to overcome this challenge is to start from the basics in the batik industry, namely the creative process of designing batik patterns. It is important to pay special attention to this process to enhance digital transformation in the batik industry. The purpose of this paper is to present the design and creation of batik patterns using the L-System-based fractal approach. Previous research has shown that the L-System can be used to model plant growth in 2D and 3D contexts. In a similar way, the L-System is used in this study to create batik patterns. Experiments were conducted through three stages, namely Data Acquisition, Data Identification, and Modeling. The experiment results in a dataset of batik motifs that can be used as parameters to replace line segments in the L-System. The design and creation of batik patterns using the L-System only needs to be done once, so that from one pattern, a variety of different motifs can be produced easily by simply changing the parameters. This shows that the design and creation of batik patterns using L-System is more efficient and practical. In addition, the fractal dimension calculation is used to understand and describe the fractal properties of the resulting objects. In this study, it was found that there are four motifs without ornaments that have higher fractal dimension values than motifs with equivalent ornaments.

Keywords: *batik, fractal, l-system, patterns*

KOMPUTASI GRAFIS UNTUK DESAIN POLA BATIK BERBASIS L-SYSTEM

Abstrak

Tantangan yang dihadapi oleh industri batik dalam era industri 5.0 adalah adaptasi terhadap teknologi dalam proses produksinya. Salah satu cara mengatasi tantangan tersebut adalah dengan memulai dari hal yang mendasar dalam industri batik, yaitu proses kreatif dalam merancang pola batik. Penting untuk memberikan perhatian khusus pada proses ini guna meningkatkan transformasi digital dalam industri batik. Tujuan dari makalah ini adalah untuk mempersembahkan desain dan kreasi pola batik menggunakan pendekatan fraktal berbasis L-System. Penelitian sebelumnya telah menunjukkan bahwa L-System dapat digunakan untuk memodelkan pertumbuhan tanaman dalam konteks 2D dan 3D. Dengan cara yang serupa, L-System digunakan dalam penelitian ini untuk menciptakan pola batik. Eksperimen dilakukan melalui tiga tahap, yaitu Akuisisi Data, Identifikasi Data, dan Pemodelan. Hasil eksperimen menghasilkan dataset motif batik yang dapat digunakan sebagai parameter untuk menggantikan segmen garis dalam L-System. Desain dan kreasi pola batik menggunakan L-System hanya perlu dilakukan satu kali, sehingga dari satu pola, variasi motif yang berbeda dapat dihasilkan dengan mudah hanya dengan mengubah parameter. Hal ini menunjukkan bahwa desain dan kreasi pola batik menggunakan L-System lebih efisien dan praktis. Selain itu, perhitungan dimensi fraktal digunakan untuk memahami dan menggambarkan sifat-sifat fraktal dari objek yang dihasilkan. Dalam penelitian ini, ditemukan bahwa ada empat motif tanpa ornamen yang memiliki nilai dimensi fraktal lebih tinggi daripada motif dengan ornamen yang setara.

Kata kunci: *batik, fraktal, l-system, pola.*

1. INTRODUCTION

Research on morphological evolution and synthesis using artificial life to describe plant development has been successfully conducted in the field of biological modeling technology and has been developed by various scientists [1] [2]. The use of fractal-based computer modeling for plant growth visualization has also been investigated in 2D and 3D contexts [3] [4]. This approach can be adapted to different domains, such as creating fractal-based batik motifs. This research aims to extend the concepts described in [2][3][4] to produce two-dimensional and three-dimensional visualizations of trees. In this research, it successfully depicts plant growth using the L-System method. With a similar approach, the techniques used can be applied to create batik patterns. The Fractal-based L-System approach provides flexibility in pattern development in computer graphics without the need to use CAD (Computer Aided Design).

CAD is the use of computers to assist in the creation, modification, function, analysis or application of designs. While Computer Aided Design (CAD) software has many advantages, such as increasing efficiency in the design process, there are some drawbacks to be aware of such as the limitations of human creativity, human error, and being too complex for simple projects. CAD can be a very powerful tool for realizing design ideas, but it can sometimes limit human creativity. Errors in setup or modeling can lead to inaccurate or unsafe results. The use of CAD may be too powerful for some simple or non-complex projects. In some cases, using traditional tools or manual methods can be more efficient and economical. The use of CAD for manufacturing will be very efficient, but the design idea is usually done at the beginning. For example, producing a batik pattern design can be done in a simple way.

In the industrial sector in Southeast Asia, the batik industry is in the category of small and medium enterprises (SMEs) and faces various challenges in the 21st century [5]. Innovation efforts are continuously made to support the development of the batik industry with the latest technology. Batik has a fractal nature with recurring motifs in its pattern. An iterative batik pattern is a batik design created through an approach that involves repeating certain stages in the batik-making process, creating a complex and variegated pattern. The repetition of the same motif or design element on a batik cloth is a common way of depicting iterative batik patterns, especially in stamped batik. It is important to maintain consistency in size, spacing and direction between repeated motifs during the batik design process to ensure neat and consistent results.

Studies on batik motifs have found mathematical patterns that can be represented through basic geometric shapes and implemented automatically into computers [6]. Generative batik using the fractal approach can be generated through a series of repetitive production rules from the L-System grammar. Research related to abstract image generation with Deep Learning approach has been done before [7]. Indonesian traditional batik motifs are often used as references in various studies, especially as a data set for batik motif classification [8]. Previous studies have shown that the L-System can be used to create patterns such as Koch curves [9]. However, so far, there are still few studies that discuss in detail how batik patterns can be created generatively using the fractal approach with L-System.

The problem arising from this context is how to implement innovation in the batik industry through the use of technology. This starts with the most fundamental step, which is the automation of batik pattern making with the help of computers. In this research, we propose the use of L-System to create generative batik patterns with a novel approach. In the modern world, many batik artisans use a digital approach with the help of computers. Various computer applications have been invented to assist in the digital batik design process. We found that L-System, which was originally used for plant growth visualization, can be used to create batik patterns with various repeatable motifs. The result of using L-System produces batik patterns that are geometric in nature. The experimental results show that the use of L-System proves to be quite efficient in creating batik patterns that have repeatable motifs.

2. MATERIAL AND METHODS

2.1. Fractal Based on L-System

L-System (Lindenmayer System) based fractals are a type of fractal built through the application of recursive rules to create complex and repetitive geometric shapes. The L-System was originally invented by a biological theoretical scientist named Aristid Lindenmayer in 1968 with the initial goal of modeling plant growth and cell structure. However, since then, the L-System has been widely used in computer art and mathematics to create various types of fractals [4] [10] [11].

2.2. Basic Concepts of L-System

The basic principle of L-System based fractals involves applying simple recursive rules to create complex geometric shapes. Here is an overview of its essence:

- Axioms: L-System-based fractals start with axioms, which are initial shapes or symbols. These axioms serve as the starting point in the fractal creation process.
- Production Rules: Production rules are a set of rules that describe how to replace symbols in the fractal at each iteration. These rules determine what symbols should be replaced by other symbols and with what. For example, if there is a symbol "A" and the production rules state that "A" should be replaced by "AB," then at each iteration, each symbol "A" will be replaced by "AB."
- Iteration: The fractal creation process involves a series of iterations or recursive steps. At each iteration, the production rules are applied to all

symbols in the fractal, and the result is a more complex fractal.
- Symbols: symbols are used to represent elements in the fractal. They are characters or signs used in the production rules. Each symbol has a specific meaning in the fractal context.
- Order or Iteration Rate (Order): The iteration level or order determines the extent to which iteration will be applied to the fractal. The higher the iteration level, the more complicated the resulting fractal.

The fractal L-System consists of a symbolic alphabet that can be used to create a string of symbols, a collection of production rules that extend each symbol into a larger string of symbols, an initial "axiom" string to start the construction, and a mechanism to translate the resulting string into a geometric structure [2].

As a simple example of an L-System, we can refer to the Koch curve, where the production rules replace each line segment with a series of smaller segments as each iteration progresses. With each iteration, the curve becomes more complex and approaches a fractal structure. In our research, the line segments are replaced by images of batik motifs. Transformation in the context of digital-based activities has the potential to simplify and speed up processes that were previously done manually [12] [13] [14].

2.3. Batik Fractal

Fractal batik is an art form that integrates batik motifs with fractal elements. Batik, which is a traditional Indonesian art, involves the process of dyeing cloth with specific patterns using special techniques, while fractals are geometric patterns with repetitive and complex structures in a mathematical context. Although batik and fractals are two different concepts, they are combined in a new type of batik [15] [16]. The Fractal Batik Community has been trying to popularize the art of fractal batik as part of social activities that use advanced technology [17]. The process of designing batik patterns with fractals involves the merging of Indonesian batik tradition and mathematical principles applied through computers. Art patterns that were originally produced by the hands of batik makers can be replicated using computational and mathematical techniques, creating various innovations in the world of batik. There is no denying that fractal batik is a new breakthrough that combines the nuances of modern technology with the beauty of traditional batik.

2.4. Fractal Dimension Using Box-Counting

The box counting method is a mathematical technique used to estimate the fractal dimension of complex [18], autonomous-similar, or fractal geometry objects. Fractals are mathematical objects that exhibit autonomous-similarity at different scales, meaning they have similar structures or patterns when you zoom in or out of their images. The box counting method involves dividing the object of interest into a grid of boxes of a fixed size or scale, and then counting the number of boxes that contain parts of the object.

$$D_{(s)} = \frac{\log N_{(s)}}{\log\ (s)} \tag{1}$$

In this context, N(s) refers to the number of boxes containing the image, where s is the ratio of segment lengths. Ns describes how many boxes of size s contain information about the object or how many boxes are needed to cover the entire object, while Ds is the fractal dimension of the object with boxes of size s. The graph depicts the result of the distribution of log(N(s)) against log(s).

2.5. Research Method

An overview of the research methodology in this study is shown in Figure 1. The process begins with conducting literature studies from various reference sources and filtering information according to research needs. Next, material collection is carried out in the form of real objects from industrial commodities that are considered feasible to be used as new batik motifs. The next stage is to execute the experimental method, which are structured as shown in Figure 2, where experiments are carried out gradually on a laboratory scale until they achieve the desired results, namely the formation of Production Rules on the L-System grammar for certain batik patterns. The last step is the Evaluation and Dissemination stage, where the research results are evaluated and disseminated.

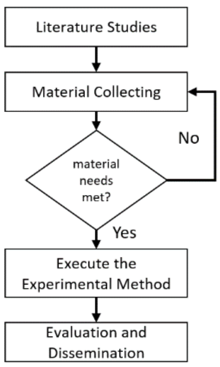

Figure 1. Research method

2.6. Experiment Method

The experimental stage of this method consists of three main parts: Data Acquisition, Data Identification, and Modeling. The modeling stage is done by using the fractal batik pattern maker application. The purpose of the modeling process is to simulate and visualize the batik pattern, and calculate the fractal dimension. Details of the activities in this experimental method will be explained in more detail in the research results section.

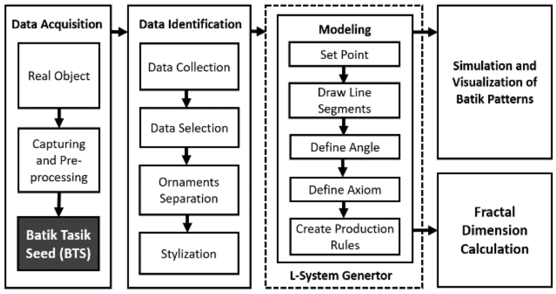

Figure 2. Experiment method for visualization and calculation

3. RESULT

The results obtained reflect the achievements according to the experimental method, which follows the steps illustrated in Figure 2, which can be explained as follows:

3.1. Data Acquisition

These steps aim to generate a new dataset of batik motifs that will serve as replacement elements for "lines" in the L-System. This dataset is obtained by taking pictures directly from physical objects, as shown in the illustration in Figure 3. We selected six real objects from traditional heritage as potential batik motifs, including Bedog Galonggong, Kujang, Karambit, Payung Geulis, Kelom Geulis, and Ulekan. The reason we chose these is because they are very suitable to be used as batik motifs to enrich the collection of batik motifs inspired by traditional tools.

Figure 3. Capture real objects with the camera, the inset is the result of the photo and the result of transforming the photo into a 3D object

The next step involves preprocessing, where the photos are converted into 3D wireframe images. This process involves 3D rotation and image reshooting to get the best visual viewing angle. The end result of this step is a 2D image. Then, the 2D image was replicated by rotating at angles of 45^0, 90^0, 180^0, 255^0, 270^0, and 315^0 degrees. This results in 7 additional images of the original image. Next, from one original image, horizontal and vertical reflection transformations are performed, and ornaments are added. Thus, from one original seedling, a total of 42 different motif images are generated.

3.2. Data Identification

This step aims to identify 2D images that will be used in the design process. From the collection of images in the batik dataset, the best images that match the theme are selected to be used as motifs in the batik pattern. The selected motifs are then taken and the ornaments are separated, then the style is adjusted according to the user's needs. In this research, we try to use the traditional weapon motif "Kujang" and the motif "Parang Lengkung" as ornaments, as shown in Figure 4 below.

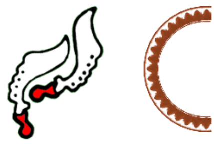

Figure 4. Sample motif "Kujang" and "Parang Lengkung"

3.3. Modeling

This stage aims to create batik patterns using the L-System approach in the Generator used, namely jBatik Pro. This process starts with setting up points, drawing line segments, determining angles, setting up Axioms, and creating production rules according to the generator used. As an experiment, we created the batik pattern "Lereng". The "Lereng" pattern is one of the commonly used types of batik patterns. Usually, it consists of diagonal lines that form a slope. These lines can vary in thickness, spacing, and direction. The grammar used in the formation of this pattern is provided in Table 1.

Table 1. Grammar for Lereng Kujang Pattern

grammar	properties
Axiom	?(3.9001)"(3.9001)-(90)A
Iteration	10
Angle	52
Rules	A=ff;+(0)"?[+FFFFFFFFFF]A
Image	kujang.png, parang_lengkung.png

The modeling stage produced a language in L-System called "Lereng Kujang Pattern," and the resulting pattern can be seen in Figure 5.

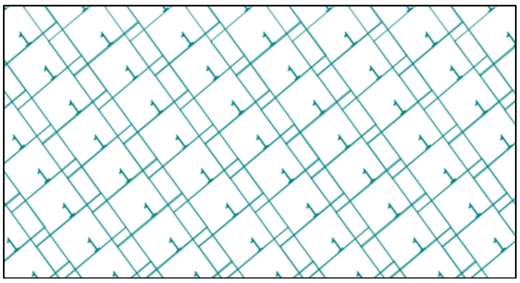

Figure 5. Lereng Kujang Pattern

3.4. Simulation and Visualization

This stage can be done after the wanted batik pattern has been formed. In the previous stage, we have created a grammar for the pattern "Lereng Kujang," as shown in Table 1. Using that grammar, the pattern as shown in Figure 5 is generated using the generator. Next, we replaced the line or box segments with motifs taken from the dataset, which are "kujang.png" and "parang_lengkung.png," until the geometric batik motif as shown in Figure 6 was formed.

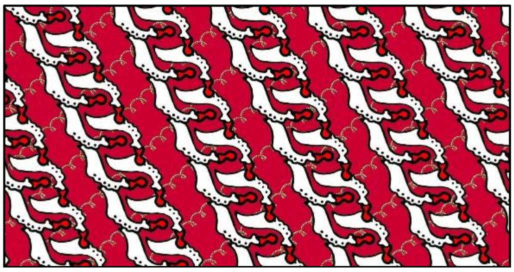

Figure 6. Result of batik motif Lereng Kujang pattern

With a similar approach, we conducted another experiment using different grammars as listed in Table 2 to create the batik pattern "Ceplokan" with the motifs "Kelom-Payung" and "Isen-Isen."

Table 2. Grammar for Ceplokan-Kelom Pattern

grammar	properties
Axiom	+A
Iteration	9
Angle	90
Rules 1st	A=f[-X]f[-Y]A X=c(1)Fc(2)Fc(1)Fc(2)Fc(1)Fc(2)Fc(1)Fc(2)F Y=c(2)Fc(1)Fc(2)Fc(1)Fc(2)Fc(1)Fc(2)Fc(1)F
Rules 2nd	A=f[-B]A B=FFFFFFFF
Image	payung3a0.png, kelom2b0.png, kawung_1.png

The "Ceplokan" batik pattern is one of the popular batik patterns in Indonesia. It is characterized by the presence of repeating geometric patterns that are usually circular or oval in shape arranged regularly across the surface of the batik cloth. The result can be seen in Figure 7.

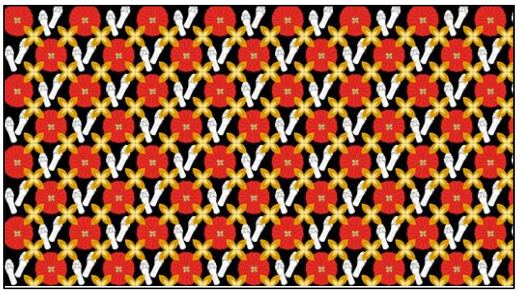

Figure 7. Result of Ceplokan kelom-payung pattern

We have run additional experiments by adopting the same parameters as listed in Table 2, but only changing the image properties with new image file that is "payung.png", "kelom2a45.png", dan "ceplokan.png". The result of the experiment produced a unique motif. In our research framework, this new motif is known as the "Ceplokan Kelom-Payung," as seen in Figure 8.

Figure 8. Result of Ceplokan kelom geulis pattern

Using the same batik pattern-forming parameters as listed in Table 2 and Table 3, by simply changing the image parameters, we were able to create batik patterns that still have the same basic structure, but have visually different batik motifs. This shows that once a batik pattern has been formed, further use of the L-System only requires adjusting the image parameters to produce a completely different batik motif in appearance.

With this approach, the batik design and creation process can be done quickly without the need to manually create batik motifs one by one. From the results of our experiments, the key in batik design and creation is to start with the formation of a batik pattern as a base. Furthermore, batik motifs can be created according to the user's preference. In this research, we have also created a dataset that can facilitate the design and creation process. Our dataset has been registered as Intellectual Property (IP) with registration number EC00202310472 on February 3, 2023.

3.5. Fractal Dimension Calculation

The fractal dimension is calculated using different s values, that is, 2, 3, 4, 6, 8, 12, 16, 32, and 64, for a total of 816 images in the batik motif dataset. The results of this calculation will be depicted in a graph showing the distribution of log(N(s)) against log(s). The average fractal dimension values for various batik motifs are described in Table 3.

Table 3. Average Dimension Fractal Of Image In Dataset

no	group of motif batik	DF average
1	Galonggong motifs group	1.442
2	Karambit motifs group	1.489
3	Kelom motifs group	1.371
4	Kujang motifs group	1.522
5	Mutu motifs group	1.243
6	Payung motifs group	1.356

The results of the fractal dimension calculations for each value of s in the overall dataset we possess indicate that the highest average value is found in the Kujang dataset group, at 1.522, as seen in Figure 9. Conversely, the lowest average value is observed in the Mutu/Ulekan dataset group, with a fractal dimension of 1.243, as depicted in Figure 10.

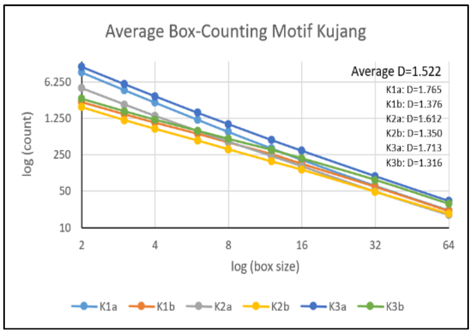

Figure 9. Average DF for Kujang motifs

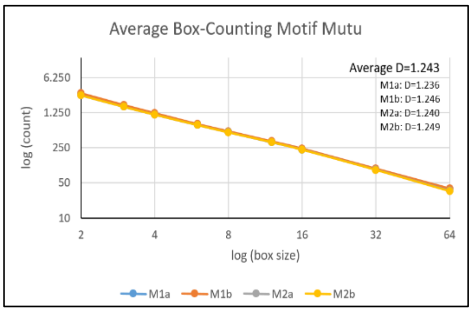

Figure 10. Average DF for Mutu motifs

Based on the calculation results, it can be seen that most of the batik seedlings with ornaments have a larger fractal dimension value than the batik seedlings without ornaments. This shows that there are some motifs without ornaments that have a more complex fractal structure or are closer to fractal properties than motifs with similar ornaments.

4. DISCUSSION

This research introduces the concept of using Graphical Computing in batik pattern design based on L-System. Graphical Computing is an approach that combines computational principles with graphic elements, specifically applied in creating batik pattern designs through the L-System approach.

The research findings indicate that utilizing L-System as the foundation for graphical batik pattern design has the potential to produce unique and captivating artworks. By leveraging the fractal principles within L-System, this research demonstrates that this approach can add depth and complexity to batik patterns, creating visuals that blend traditional beauty with computational innovation.

The discussion encompasses the ability of L-System to represent customizable fractal structures, providing batik designers with flexibility to create pattern variations with high levels of detail. Additionally, Graphical Computing offers a visual interface that facilitates designers in modifying and observing design changes in real-time, providing a creative and interactive experience.

We believe that the approach we use by using L-System is superior. There is a significant difference compared to using CAD or the Fractal Batik Generator. The main reason is because we do the preparatory stage of creating batik motif images first as a library, which can then be used in the generator application. This makes it possible to speed up the batik motif creation process. The generated library can be used repeatedly in the creation of motifs with different patterns using CAD or Fractal Batik Generator.

While this research contributes positively to the development of batik pattern designs, it should be noted that further research is needed to understand the potential for broader applications, including integration with textile industry technology and market responses to this innovation.

Overall, this research stimulates new thinking on how Graphical Computing and L-System can be applied in the context of batik art and design, opening doors for further development in combining local wisdom with modern technology.

5. CONCLUSION

The experimental results show that when the batik pattern has been formed, the motif can be implemented into the pattern easily by simply changing the motif image according to the user's wishes. The approach of using L-System in the jBatik Pro generator facilitates the batik pattern design process. The basic concept of L-System allows the creation of very complicated fractal batik patterns with relatively simple rules. In this paper, we successfully generate new batik motifs that can enrich Indonesia's batik motif heritage by focusing on image-based motifs, such as Lereng Kujang Pattern, Ceplokan Kelom-Payung Pattern, and Ceplokan Kelom-Geulis Pattern. These batik motifs were produced through a series of experiments in a laboratory setting.

The findings that show the fractal dimension value of batik seedlings without ornaments is higher than batik seedlings with ornaments occurs because in the preprocessing stage when converting batik motif seedlings with ornaments into batik seedlings without ornaments, there are ornaments that are detected as lines on pixels or a number of boxes that contain images, so they are counted in the Box-Counting method.

Overall, this experiment shows that L-System-based fractals are an interesting example of how mathematics can be used to generate a variety of shapes in the world of computing and art. This approach produces a variety of beautiful and interesting fractal shapes that can be used in computer art, science, and mathematics.

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