AKIRATECH : Journal of Computer and Electrical Engineering
Vol. 3, No. 3 (2026),
e-ISSN 3047-7522

AI System Design for Modern Batik Pattern Generation Based on Progressive Growth of Generative Adversarial Networks (PGGAN) with the Integration of Jember Local Wisdom

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Article Info

Article history:

Received March 10, 2026
Revised November 04, 2026
Accepted November 05, 2026

Keywords:

Progressive Growing of GANs (pGGAN)
Batik Jember
Next.js
Local Wisdom

ABSTRACT

Batik is an Indonesian cultural heritage that has deep aesthetic and philosophical value. In Jember Regency, the Labako batik motif is a unique visual identity that represents agrarian culture through the symbol of tobacco leaves. Although *Deep Learning technologies* such as *Deep Convolutional Generative Adversarial Networks* (DCGAN) have been used for motif generation, the model has limitations in producing high-resolution images with complex details consistently. This research aims to design an artificial intelligence system based on *the Progressive Growing of Generative Adversarial Networks* (PGGAN) to produce modern batik patterns that integrate Jember's local wisdom. The system development method used is **the Spiral Model** which includes the planning, risk analysis, development, and evaluation stages. This system is designed using **the Next.js** framework for the user interface and **MySQL** as a database management system to store assets and order information. The result of this research is in the form of a system architecture design and workflow that is able to progressively increase image resolution starting from 16×16 pixels to 2000×2000 pixels. This design is expected to be a technical foundation in the development of digital platforms that are able to preserve local culture through generative technological innovation.

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DOI: https://doi.org/10.63935/akiratech.v3i3.292

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1. INTRODUCTION

Batik is a traditional Indonesian artwork that has deep aesthetic and philosophical value, and has been internationally recognized by UNESCO as *Masterpiece of the Oral and Intangible Heritage of Humanity*. This cultural heritage is not just a visual ornament, but a symbol that represents local identity, geographical conditions, social values, and the history of the people in various regions. One of the regions with a very specific wealth of motifs is Jember Regency, East Java, which is known through Labako batik—referring to motifs that carry elements of tobacco leaves. The use of this motif not only reflects the visual identity of the region, but also represents the important role of tobacco in the economic sector, agrarian culture, and local history of the Jember people.[1]

Along with the rapid development of information technology, the opportunity to innovate in the preservation of batik through Artificial Intelligence (AI) is increasingly wide open, especially through the use of technology *Deep Learning* for automatic pattern generation. In addition, the integration of AI-based computational strategies in academic environments has also been shown to be able to strengthen students' critical thinking skills, demonstrating the effectiveness of AI as a catalyst in the development of high-level

ISSN 3047-7522

thinking skills.[2] Some previous studies have attempted to implement the architecture of *Deep Convolutional Generative Adversarial Networks* (DCGAN) which is able to produce artificial visual images that resemble natural patterns. Although DCGAN has been shown to have the potential to support the digitization of batik motifs, this technology still has major obstacles in producing high-resolution images consistently. The use of DCGAN for motifs with complex structures often results in blurry, broken, or missing images that are the hallmarks of the beauty of batik.[3]

As a solution to these limitations, this study proposes the design of a system-based *Progressive Growing of Generative Adversarial Networks* (pGGAN) which trains the model gradually from low to high resolution, namely from 4 X 4 pixels to 1024 X 1024 pixels. This approach allows the learning process to be more stable so that the resulting image is much sharper, more realistic, and has richer details than the previous method. The main focus of this research lies in designing a web-based system architecture and interface to make it easier for users to automatically produce Jember batik motifs. By integrating the value of local wisdom, this system is expected to contribute not only to technological innovation, but also to the preservation of local culture through creative and adaptive digital approaches.[4]

2. RESEARCH METHODS

2.1. Research Stages

This research was carried out through a series of systematic stages located at the Department of Information Technology Building, Jember State Polytechnic, with a duration of ten months. The series of activities began with a literature study to strengthen the theoretical foundation regarding batik, Jember local wisdom, and the Progressive Growing of GANs (pGGAN) method. The next stage included collecting data on Labako batik motifs and designing a system using a measurable development framework. The research was closed with system testing and in-depth analysis of the generative results of the batik motifs produced.

2.2. System Development Methods

This research applies the Spiral Model as a risk-based software development method, where development is carried out through an iterative cycle that includes four main phases in each stage. The cycle begins with the Planning stage to set the system's objectives and collect specific data, such as the Labako batik motif and the implicit trigonometric function that serves as the basis for visual patterns. Furthermore, Risk Analysis is carried out to identify various potential technical obstacles, including the risk of overfitting the pGGAN model and the challenges in integrating local wisdom values into the algorithm. Entering the Development (Engineering) phase, technical implementation is carried out using the Python programming language for AI modeling and a Next.js framework for web interfaces supported by the Postgres database system. Finally, the Evaluation stage is carried out which includes validation of design results by batik experts and quantitative visual quality measurements to ensure that the system has met the expected aesthetic and functional standards.[5]



Image 1 Model Spiral Method Design

2.3. Data Collection and Analysis Techniques

The primary data used was in the form of digital images of typical Jember batik motifs (Labako) collected through official websites, design platforms, and academic publications. In addition to visual data,

data on mathematical function formulas (trigonometry) was also prepared as a visual basis for digital patterns. Data analysis was carried out quantitatively using Fréchet Inception Distance (FID) and Inception Score (IS) metrics to measure the level of statistical similarity and sharp quality of images compared to the original data.

2.4. System Planning (IPO)

The working logic of this generative system is built with an Input, Process, Output (IPO) approach to guarantee a consistent data flow. In detail, the elements are described in the following diagram and description:

- **Input:** Users enter parameters in the form of batik names, color options (solid or gradient), and local symbol icons (such as tobacco leaves).
- **Process:** The system learns the shape of the icon, integrates implicit trigonometric functions, and runs a pGGAN model that trains gradually, starting at 16 x 16 pixel resolution until progressively improving.
- **Output:** Produces high-resolution images of modern batik motifs (up to 2000 x2000 pixels) available in downloadable digital file format.[5], [6]

The system is validated using the Black Box Testing method to ensure that all functional features, from parameter input to the process of downloading motif results, run according to the specifications that have been set.

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Komponen	Deskripsi
Input	- Nama batik khas daerah - Pilihan warna (solid atau gradasi) - Ikon kota atau simbol lokal (contoh: daun tembakau)
Proses	- Mempelajari bentuk ikon atau logo yang dimasukkan pengguna - Memilih fungsi implisit trigonometri yang cocok - Warna dimasukkan sebagai parameter tambahan - pGGAN menghasilkan motif dasar secara bertahap - Ukuran dan detail motif diperbesar hingga resolusi tinggi - Kombinasi akhir motif AI dan matematis menjadi satu kesatuan desain
Output	- Gambar motif batik baru - File gambar digital yang bisa di download

Image 2 IPO Design

3. RESULTS AND DISCUSSION

3.1. System needs analysis

Based on the identification of problems in the development of digital batik motifs, several key functional needs that must be met by the system are determined. First, the system must be able to receive interactive input from users in the form of batik names, choice of color schemes (solid or gradation), and selection of local icons such as tobacco leaves. Second, the system must have a pGGAN-based generative engine that is able to process motifs gradually to produce high-resolution images up to 2000 x 2000 pixels to be suitable for use on an industrial scale. Third, the system must provide a collaborative ecosystem that allows registered users to save design results and forward them to batik through the new order feature. Non-functional needs include the responsiveness of the user interface built with Next.js and the reliability of data storage using MySQL.

3.2. Workflow planning

The system is designed with a Next.js-based web application as the main control center that manages the interaction between users and artificial intelligence machines. This application interacts with **the MySQL**

ISSN 3047-7522

database to manage user account data, *prompt history*, visual assets, and partnership data with local batik. The workflow begins when the user enters visual assets and instructions which are then processed by the pGGAN model through the stages of increasing the resolution from 16 x 16 pixels to reach a sharp final resolution. The final result of the batik motif is then stored in the database and can be accessed by batik makers as production partners to be realized into physical batik fabric. This integration flow ensures that technological innovation remains based on the manual production process by local artists.

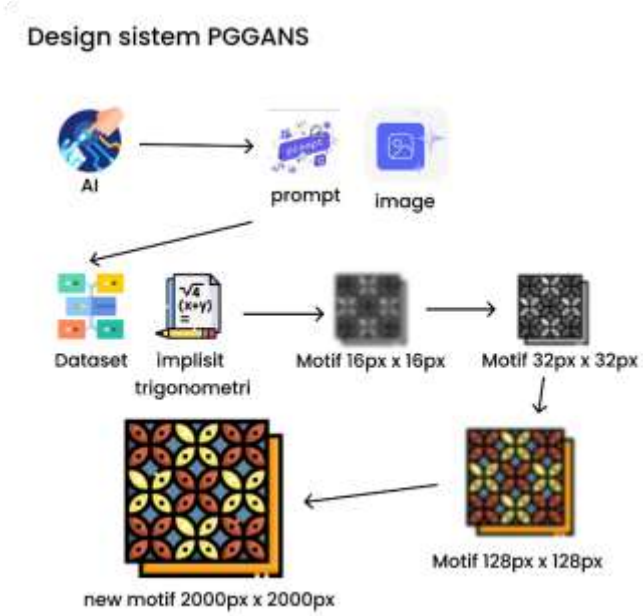


Image 3 PGGANS System Design

3.3. Mockup Design

The User Interface design stage is carried out as a visual representation to ensure an optimal user experience before the system is implemented. This mockup design was developed using the Figma platform to create a modern and responsive interface, which will later serve as a guide in the coding stage using the Next.js framework. The design is focused on several main pages, including a digital batik exhibition gallery, an interactive panel for prompt input and pGGAN color parameters, and an order management dashboard that connects users with local batik makers. The results of this mockup design serve as a technical blueprint to ensure that elements of Jember's local wisdom, such as tobacco leaf motifs, are presented aesthetically and functionally in high resolution. Through this design, the entire system workflow can be visually validated to minimize the risk of errors in the technical development phase.[7]

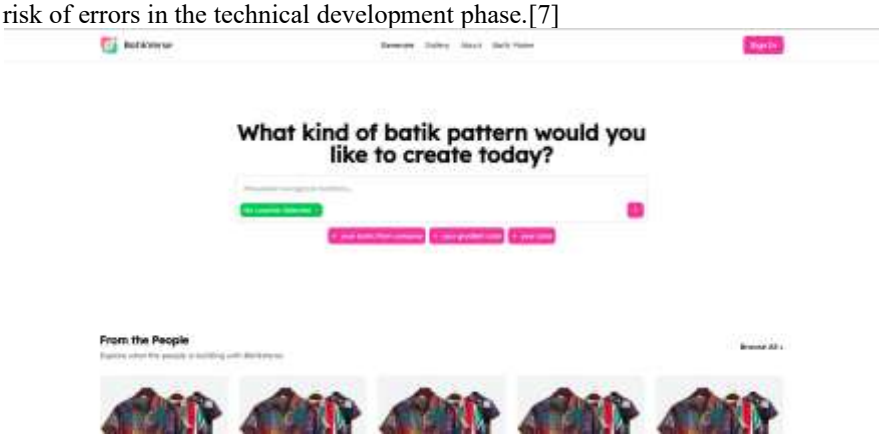


Figure 4 Generate Page Design

The interface design begins with the BatikVerse landing page which carries a minimalist concept with the main navigation consisting of the Generate, Gallery, About, and Batik Maker menus. In the middle of the page, there is a centralized input column with the question "What kind of batik pattern would you like to create today?" which functions as a place for users to enter visual instructions or prompts. This interface is also equipped with additional parameter buttons to make it easier for users to include special elements such as company icons, gradation color options, and solid color palettes in their batik designs. At the bottom, there is a "From the People" gallery feature that displays visualizations of the results of the implementation of motifs on original clothing products to provide a real picture of the potential production of the design.

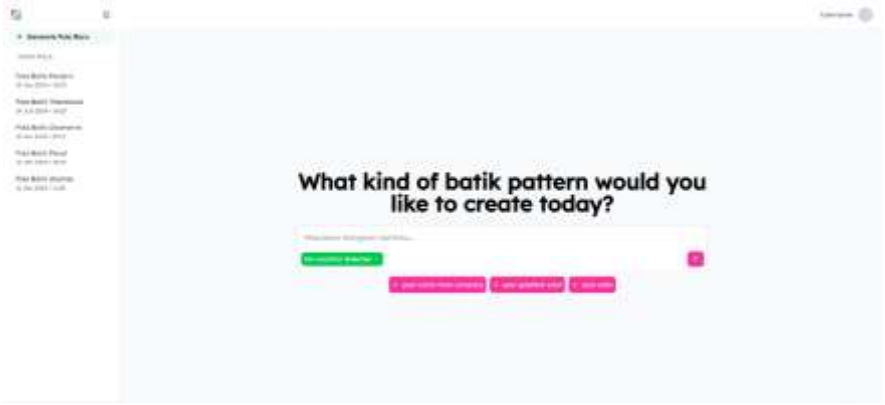


Figure 5 Chat Page Design

Furthermore, in the second image, which is an interaction page or chat page, the interface is designed to be more functional to support the process of working on motifs continuously. This page is equipped with a sidebar on the left that functions as a design history management in the "Your Pattern" list, which includes categories of previously produced motifs such as Modern, Traditional, Geometric, Floral, to Abstract Batik. Users can see the details of the creation time on each asset and use the "Generate New Patterns" feature to start a new creative process. Through this interface, users can still provide new instruction input on the main work areas while monitoring the progress of the digital batik design collection that they have stored in the system.

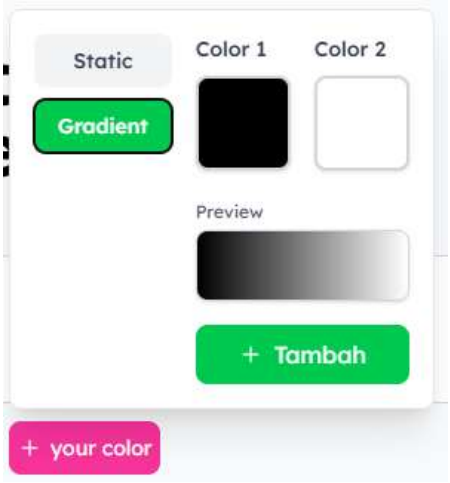


Figure 6 Add Color Design

ISSN 3047-7522



Figure 7 Design Text in Input with Prompt

Furthermore, the system provides an interactive color customization feature that allows users to choose between static and gradation color types through a dedicated control panel. In gradation mode, users can specify a blend of two different colors that are complemented by a real-time preview before the asset is added to the design parameters via the "+ Add" button. The implementation of all these inputs is visible in the input bar area, where various uploaded visual assets—such as identity photos or logos and color schemes—will appear as thumbnails in the text field along with the user's instructions. The merging of text commands such as "please make me batik from that logo and color" with image assets and color parameters in a single instruction line aims to provide users with full flexibility in directing generative models to produce personalized and accurate batik motifs.

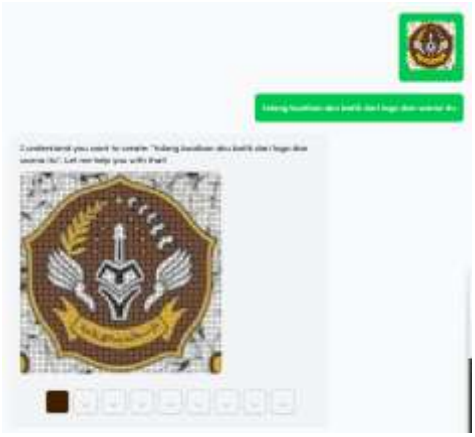


Figure 8 Design Finding Color From Logo



Figure 9 PGGANS Generate Design 500 x 500 Pixels

Once the instructions and visual assets are submitted, the system provides interactive feedback that displays the process of transforming the logo into the basic elements of the batik motif in real-time. In the initial stage, artificial intelligence extracts features from the user-uploaded logo, transforming it into a structured pixel representation accompanied by a main color palette at the bottom of the interface. The process then continues in the generation phase using the pGGAN model, where the system transparently shows the training progress through a label such as "PGGANS generated (2/4)" to inform the progressive nature of the formation of pattern details. The temporary results displayed are a repetitive pattern arrangement that unites elements of local wisdom with modern aesthetics, allowing users to monitor the evolution of the design from basic shapes to complex and original batik patterns.



Figure 10 Design Results Into Batik Patterns

The final stage of this generative process is marked with the label "PGGANS generated (4/4)", which indicates that the model has completed the entire progressive growth stage to produce the final output. The end result is a high-resolution batik pattern that displays very sharp details, where the previously selected logo and color scheme have blended harmoniously with traditional isen-isen ornaments. The visual quality produced at this stage proves the architectural excellence of pGGAN in maintaining the structural integrity of complex patterns, from fine lines to realistic color gradations. This high-resolution achievement ensures that the resulting digital batik motifs are not only aesthetically valuable, but also ready to be applied into real textile production processes as a manifestation of adaptive digitization of local wisdom.

3.4. Discussion of the plan

This system design offers a solution to inefficiencies in previous generative methods such as DCGAN which often result in blurry images or loss of detail in complex patterns. By implementing pGGAN, the model training process becomes more stable as it starts from a rough representation before processing complex details. The use of Next.js and MySQL provides a solid framework for system scalability, where the platform can handle multiple users at once without sacrificing access speed. Overall, the integration of trigonometric mathematical functions and the symbol of Jember (Labako) local wisdom into the AI architecture creates a new design methodology that is able to preserve local culture through a modern and efficient digital approach.[8]

4. CONCLUSION

The design of this system successfully integrates PGGAN technology with Jember's local wisdom in a web-based platform. The use of the Next.js framework and MySQL database is expected to provide stable performance for users in exploring modern batik designs. The next research will focus on model implementation and visual quality evaluation using *the Fréchet Inception Distance* (FID) metric.

ISSN 3047-7522

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