THE GENERATIVE ADVERSARIAL NETWORKS AND TEXTILE DESIGN

TOWARDS AN AUGMENTED CRAFTSMANSHIP IN THE CONTEXT OF DIGITAL AND SUSTAINABLE FASHION

CLAUDIA RUGGIERO

Università degli Studi della Campania 'Luigi Vanvitelli', Italy
claudia.ruggiero@unicampania.it
Orcid 0009-0003-8744-9002

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.
Competing Interests: The Author(s) declare(s) no conflict of interest
DOI: 10.36253/fh-3661

Abstract

This contribution investigates the application of Generative Adversarial Networks (GANs) to the generation of textile patterns, aiming to evaluate the technical and design feasibility of an AI-driven approach in the context of digital and sustainable fashion. A hybrid visual dataset was constructed, comprising historical ornamental motifs and contemporary patterns, carefully selected to ensure morphological coherence and modular repeatability. This dataset was used to train a GAN model on Google Colab, monitoring the visual evolution of the generative outputs at different stages of training. Preliminary results show the emergence of recognizable structures potentially applicable to textile design; however, technical issues persist, such as digital noise, edge discontinuities, and insufficient resolution for fabric printing. These findings indicate the need for architectural and parametric optimizations, as well as specific evaluation criteria for seamless patterns. The study also highlights the importance of considering the computational costs of generative models from a sustainability perspective, outlining future directions aimed at improving visual quality, scalability, and integration into the industrial fashion design workflow.

Keywords*: Generative Design; Algorithmic Craftsmanship; Textile Heritage; Computational Aesthetics; Data-Drive Fashion.*

INTRODUCTION

The growing integration of artificial intelligence into design processes is significantly transforming both fashion aesthetics and the operational workflows of textile design. In particular, Generative Adversarial Networks (GANs) have demonstrated an emerging ability to synthesize complex images from structured datasets, offering new scenarios for material and formal exploration of textile surfaces.

Although the literature indicates growing interest in the use of GANs in the visual domain, research in textile design still exhibits limitations in three crucial areas: (i) the integration of cultural repertoires into generative training; (ii) the evaluation of pattern quality in terms of modular continuity and industrial applicability; (iii) the analysis of the computational impact of generative pipelines from a sustainability perspective.

In light of these challenges, the present research aims to assess the technical and design feasibility of using GAN models for generating patterns intended for digital fashion and textile printing. Specifically, the work investigates how hybrid datasets, based on historical ornamental motifs and contemporary patterns, can inform the synthesis of new surfaces through GANs.

The following research questions were defined:

RQ1. To what extent are GANs capable of generating modular patterns with visual coherence and potential seamlessness?

RQ2. What technical limitations emerge in the preliminary results, and which optimization strategies prove most effective?

RQ3. What computational implications arise from adopting GANs in a textile design workflow oriented toward sustainability?

The contribution of this paper lies in providing a preliminary experimental assessment of the potential of GANs for textile design, through a comparative analysis of the generative results and a reflection on the needs for optimization.

THEORETICAL BACKGROUND

The integration of artificial intelligence into design processes represents a structural change in the textile-fashion sector, affecting both aesthetic logics and design and production workflows. Among emerging technologies, Generative Adversarial Networks (GANs), introduced by Goodfellow et al. (2014), stand out for their ability to synthesize visually coherent images from reference datasets, opening up innovative scenarios for visual experimentation in textile design.

The approach adopted here is based on a co-creation paradigm in which AI does not replace the designer but expands their exploratory and interpretative capabilities. This dialogic vision is rooted in theories of situated and relational design (Manzini, 2015; Norman, 2013), which posit that design arises from the continuous interaction between material culture, data, and digital tools. In this perspective, AI acts as an epistemic partner (McQuillan, 2022), stimulating non-linear processes that are open to the emergence of unexpected forms.

The Italian textile tradition constitutes a dynamic and stratified visual heritage, increasingly accessible today thanks to the digitization of historical archives and industrial collections. Their transformation into computational datasets configures the archive as a living dataset (Collet, 2019), in which images cease to be static objects and become visual materials ready to be reworked in a generative way. This model follows the logic of aesthetic recombination (Shanken, 2014), according to which innovation arises from the semantic re-articulation of pre-existing forms.

The textile surface generated algorithmically introduces a new dimension of digital materiality: although not physical in its initial phase, it possesses an operational and symbolic potential that anticipates its future material incarnation (Ferraris, 2021; Baurley et al., 2017). Here, the designer's curation is not a subsequent phase, but a continuous action that guides the semantic value of the pattern through dataset selection, parameter modulation, and aesthetic validation of the output.

Finally, the issue of computational sustainability emerges as a new critical front in generative design. The need to understand the energy impacts, operational logics, and life cycle of AI models is part of the regulatory and methodological framework promoted by sustainability in contemporary fashion (European Commission, 2022; Fletcher & Tham, 2019). This perspective confirms the relevance of a transdisciplinary approach in which digital innovation, environmental responsibility, and cultural valorization coexist within a conscious design ecosystem.

METHODOLOGY

The experimentation was structured as a four-phase pipeline: (i) construction and curation of the dataset; (ii) training of a Generative Adversarial Network (GAN) model; (iii) qualitative evaluation of the generative results; (iv) exploratory classification via a convolutional neural network (CNN) to support visual curation.

DATASET

The dataset was constructed through the collection and curation of ornamental motifs from both historical and contemporary sources, in order to explore a diversified range of visual grammars relevant to the fashion sector. In total, approximately 200 digitized textile pattern images were selected: ornamental motifs drawn from Italian historical archives and stylistic samples recurrent in current textile design.

All images were preprocessed to 256×256 px (RGB) format, with square cropping, noise reduction, and pixel value normalization. 15% of the images were discarded due to lack of modularity or the presence of visual artifacts. The curation ensured morphological coherence and ornamental repeatability, essential prerequisites for evaluating the potential seamlessness of the generated patterns.

GAN MODEL AND TRAINING PARAMETERS

A Deep Convolutional GAN (DCGAN) model (Radford et al., 2016) was used in a Google Colab environment. The model was trained for 100 epochs and monitored through the periodic generation of samples to evaluate the generator's

Deep Convolutional GAN (DCGAN) model

Parameter	Value
Input/Output resolution	256x256 px
Batch size	64
Learning rate	0.0002
Beta1 (Adam)	0.5
Latent noise (z-dim)	100
Output save frequency	every 20 epochs

Tab. 01

ability to learn the dataset's modular structure (Tab.01).

The configuration adopted follows best practices for GAN training stability: a low learning rate and using Adam with $\beta 1 = 0.5$ reduce the risk of mode collapse, while a batch size of 64 provides a balance between gradient quality and the computational limits of the cloud platform. This setup allows for the progressive observation of the morphological emergence of the generated patterns.

QUALITATIVE EVALUATION AND CATEGORIZATION

The quality of the outputs was evaluated through visual analysis based on three criteria:

- Ornamental coherence (legibility of form, symmetry)
- Modular continuity (absence of visible seams)
- Digital noise and artifacts (spurious pixels, distortions)

A CNN was trained in a supervised manner to classify the images from the dataset and the synthesized samples into ornamental macro-categories (geometric, floral, mixed), achieving a preliminary accuracy of 79%. This classification supported the curatorial analysis of the patterns, highlighting cases of semantic failure that should be addressed in future optimizations.

METHODOLOGICAL LIMITATIONS

The training was conducted on a small-scale dataset and in a computational environment with limited resources. The output resolution, while sufficient for a preliminary analysis, does not yet meet the industrial requirements for textile printing ($\geq$ 300 DPI). Furthermore, in the current phase, no mechanisms have been implemented to guarantee perfect tileability (e.g., periodic padding); such mechanisms will be integrated in future developments to improve seamlessness.

RESULTS

The analysis of outputs generated by the DCGAN model highlights the progressive emergence of ornamental configurations over the course of training. In the initial epochs, the synthesized samples are dominated by visual noise with low formal coherence; subsequently, the network partially learns the dataset's modular syntax, generating patterns characterized by rudimentary symmetries and basic geometric repetitions (Fig. 01).

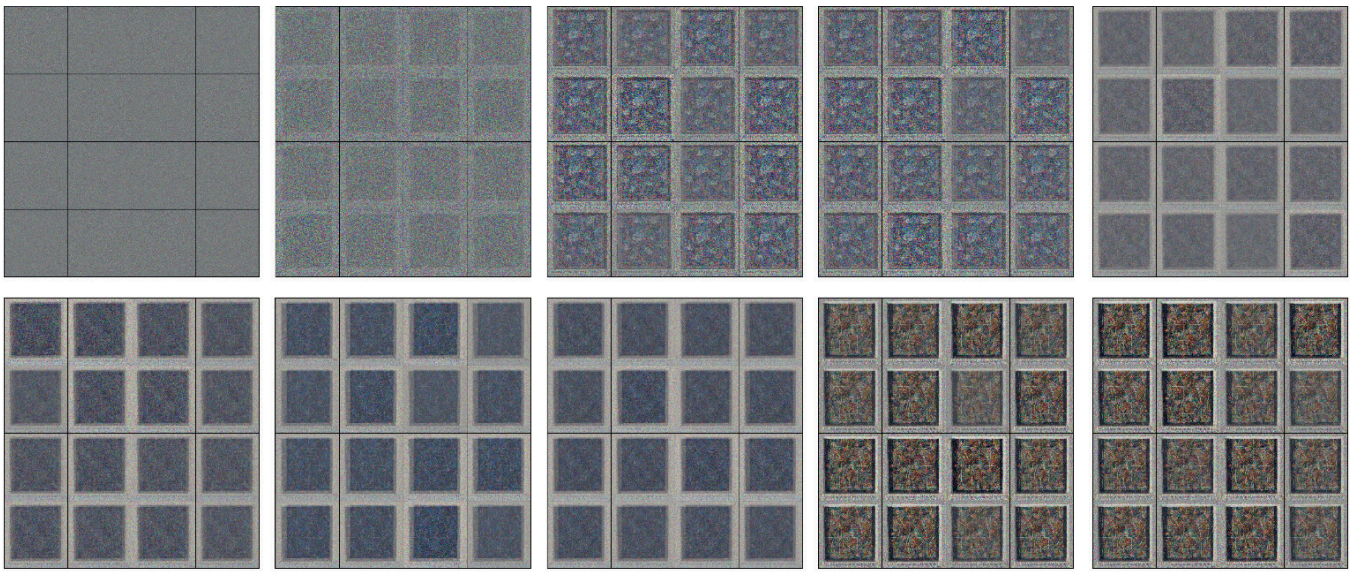

Fig. 01

The qualitative evaluation indicates that the model tends to recognize geometric motifs more consistently than floral ones, which undergo more pronounced morphological distortions. In general, ornamental legibility remains limited, and the lack of modular continuity prevents the immediate usability of the patterns on large surfaces (Tab. 02)

The results confirm the preliminary nature of the experiment: although the GAN shows signs of learning the ornamental grammar, the current quality does not meet the aesthetic and technical requirements of the fashion sector, which demand high resolution, guaranteed seamlessness, and visual coherence of the repeated module.

DISCUSSION AND IMPLICATIONS

GENERATIVE AI AS A CRITICAL AND RELATIONAL PARTNER

The use of Generative Adversarial Networks (GANs) in textile design is not limited to the automatic production of images but introduces a transformation of creative processes and the designer's role itself. GANs operate as epistemic partners (McQuillan, 2022), capable of activating design modes that are non-linear, exploratory, and open to the unexpected. Algorithmic generation temporarily suspends authorial intent, fostering an interaction that is not a delegation of creativity but a continuous negotiation between constraints, data, and human intentionality (Terzidis, 2006).

This configuration aligns with theories of relational design, in which authorship is distributed among a multitude of material and digital actants (Manzini, 2015). In this sense, GANs are not mere visual production tools, but apparatuses of revelation capable of deconstructing and recombining the ornamental codifications of tradition, projecting them into a new computational imaginary.

DATA-DRIVEN FASHION AND RELATIONAL SUSTAINABILITY

The experimentation fits into an emerging paradigm where fashion is understood as a connective and narrative system, no longer merely aesthetic or functional, but one permeated by information and interaction (Wakkary, 2021). In this context, the digital materiality of computational images assumes a primary role: they are not simple virtual simulacra, but cultural artifacts endowed with symbolic intensity, capable of

Qualitative evaluation

Criterion	Preliminary outcome	Observations
Ornamental coherence	2/3	Recognizable forms only in some cases
Seamlessness (edge continuity)	1/3	Edges are still unstable and misaligned
Digital noise and artifacts	3/3	High presence of stray pixels and distortions
Textile applicability	1/3	Outputs not yet printable

Legend: 3 = critical; 2 = medium; 1 = weak.

Tab. 02

generating emotional attachment and interpretive processes (Ferraris, 2021; Baurley et al., 2017).

This opens important prospects for relational sustainability in fashion: if a pattern is culturally recognizable and emotionally resonant, the usage life of a product increases and perceived obsolescence decreases (Fletcher & Tham, 2019). Artificial intelligence, if guided critically, can thus become a catalyst for a more ethical, participatory, and durable fashion, in dialogue with European sustainability policies (European Commission, 2022).

COMPUTATIONAL AESTHETICS AND ALGORITHMIC CURATION

The adoption of GANs requires questioning the cultural role of the generated patterns: if they express new formal possibilities, they must nevertheless undergo continuous critical curation to acquire meaning. In line with interpretative design principles (Krippendorff, 2006), every image is a sign that requires context to be read and valued.

The designer thus assumes the role of a semantic mediator, orchestrating the relationship between the dataset, algorithms, and symbolic codes. Without this human filter, the results risk straying from the reference ornamental repertoires, yielding forms that are culturally neutral or incoherent. Algorithmic curation is therefore a continuous act that preserves and renews the cultural relevance of the pattern.

MADE IN ITALY AND FUTURE HERITAGE: OPPORTUNITIES AND RISKS

The integration of AI into textile design processes raises questions about compatibility with the identity values of Made in Italy, which are historically rooted in craftsmanship, cultural supply chains, and material care. This apparent gap can be bridged by considering that craftsmanship itself has, over history, incorporated innovative technologies without losing its identity (Antonelli, 2020). The Jacquard loom, a precursor to programming, stands as a symbolic precedent.

Following the logic of future heritage (Collet, 2019), GANs can contribute to the regeneration of ornamental heritage, provided that the designer acts as a guarantor of the stylistic recognizability of the territory. The greatest risks concern cultural decontextualization and the loss of ties to material roots: identity sustainability requires a mindful and situated digitalization that valorizes traditions while incorporating innovation.

CRITICAL IMPLICATIONS AND TRANSFORMATIONS UNDERWAY

The conducted experimentation shows that the relationship between designer, dataset, and algorithm is not a neutral operation, but a practice of cultural translation in which values, aesthetics, and memories are constantly negotiated. The integration of GANs into textile design is not limited to the generation of new forms, but opens a critical terrain in which to redefine the logics of meaning-making and quality production in contemporary fashion.

In this scenario, the relational dimension of the algorithmic surface implies a rethinking of the role of pattern within the fashion system: it is no longer a merely decorative element, but a semiotic device through which plural identities, social expectations, and territorial affiliations are articulated. GANs do not replace the artisanal gesture, but rather relaunch it in a computational horizon, enhancing its ability to create connections between past and future, between the local and the global.

The possibility of generating patterns as emerging repertoires from historical archives encourages us to recognize artificial intelligence not as an extractive technology, but as a facilitator of cultural continuity.

CONCLUSION AND FUTURE WORK

CRITICAL OUTCOME OF THE RESEARCH

investigating not only the technical potential of ornamental synthesis but above all the epistemological, cultural, and design implications of adopting artificial intelligence as a creative partner (McQuillan, 2022; Terzidis, 2006). Generative AI emerges as a device that is simultaneously generative and curatorial, capable of triggering a deep dialogue between historical archives and new emerging visual grammars (Manzini, 2015; Collet, 2019).

The project demonstrates how the textile pattern, traditionally tied to manual craftsmanship, supply chain, and territoriality, can be reinterpreted as a relational surface where memory, computation, and human intentionality intertwine (Baurley et al., 2017; Ferraris, 2021). In this perspective, GANs become epistemic allies, capable of expanding formal exploration and supporting processes of augmented craftsmanship, in continuity with the identity values of Made in Italy (Antonelli, 2020). Computational aesthetics is therefore not merely an experimental domain, but a critical field within which to redefine the material culture of fashion in a horizon of sustainability, circularity, and responsible innovation (Wakkary, 2021).

LIMITATIONS AS GENERATIVE CONDITIONS

The exploratory nature of the experimentation implies the presence of limitations that do not represent a shortcoming, but rather the very condition of possibility for the inquiry (Suchman, 2007; Wakkary, 2021). The restrictions imposed by the dataset's small scale, the image resolution, and the available computational resources have directed the focus toward what constitutes the heart of textile design: ornamental recognizability, the relationship with tradition, and the designer's critical role in selecting outcomes (Krippendorff, 2006).

Far from weakening the contribution of the research, these limitations highlight the need for a broader involvement of institutional and industrial actors, archives, manufacturers, museum hubs, so that the experimentation can evolve into a fully situated design practice in the context of Made in Italy (Collet, 2019; Antonelli, 2020).

PERSPECTIVES FOR A SITUATED AND CO-AUTHORIAL

The next developments of the research will unfold along dimensions that are not only technological but, above all, cultural (Manzini, 2015; Wakkary, 2021). The expansion of the dataset is not driven by a principle of computational efficiency, but by the need to map the identity complexity of Italian ornamental languages (Collet, 2019).

Similarly, the adoption of advanced architectures or more robust production pipelines is not aimed at mere technical optimization, but at strengthening the co-authorial nature of the process, in which the designer assumes the role of semantic director of visual heritage in transformation (McQuillan, 2022; Krippendorff, 2006).

In this way, the project aims to contribute to the creation of data-driven design ecologies in which fashion once again becomes a medium for connection, memory, and collective invention. In this perspective, the collaboration between artificial intelligence and contemporary craftsmanship does not replace Italian material culture, but expands it, preserving its heritage while imagining its future.

CAPTIONS

[Fig. 01]Evolution of samples generated during DCGAN training in Google Colab. The progression from initial noise to the formation of modular structures is visible, although still marred by visual artifacts, chromatic instability, and edge discontinuities that hinder the seamlessness required for industrial textile applications.

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