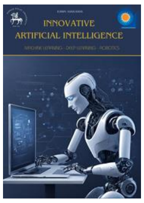

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RESEARCH ARTICLE

GANs in Architecture and AI-Assisted Floor Plan Design: An Examination of ArchiGAN

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Abstract

This study examines the interaction between artificial intelligence and architecture by taking the ArchiGAN project as a case study. ArchiGAN, a Generative Adversarial Networks (GAN)-based approach, generates apartment floor plans through a three-stage pipeline: (I) defining the building footprint mass, (II) re-partitioning the program and arranging windows, and (III) furnishing layouts. Each of these steps is executed through a separate Pix2Pix-based model, enabling an interactive design process with user input. The study highlights ArchiGAN's innovative contributions in demonstrating the applicability of machine learning to architectural design, proposing a new paradigm grounded in human–machine collaboration, and its scalability to multi-unit housing design. Nevertheless, technical limitations are evident, such as the continuity of load-bearing elements, the restriction of outputs to raster formats, and the inability to generate high-resolution results. The findings suggest that GAN-based methods should be positioned not as standalone solutions but rather as hybrid tools that support designers' intuitive decision-making. This case study provides a valuable framework for architectural artificial intelligence research, both methodologically and practically.

Keywords: *GAN, ArchiGAN, Floor plan, Architectural design, Architecture and artificial intelligence*

1. Introduction

The rapid development of Artificial Intelligence (AI) technologies has led to profound transformations not only in engineering and data science but also in creative disciplines. Architecture is among the fields most affected by this shift. Traditionally, the design process has relied on architects' intuitive decisions, professional experience, and ability to balance visual and functional requirements. Today, however, machine learning and deep learning algorithms are redefining this process by offering the capacity to analyze quantitative aspects of design, learn spatial relationships, and propose alternative design scenarios.

In this context, Generative Adversarial Networks (GANs) have become increasingly prominent in architectural research. GANs, consisting of a generator and a discriminator trained in an adversarial game framework, can produce data that closely resembles human-generated outputs. Due to their ability to perform image-to-image translation, learn spatial organization, and generate forms, GANs are being considered as design assistants or creative partners in architecture. Foundational studies such as [1], [2], and [3] have demonstrated the applicability of GAN-based models in floor plan analysis, spatial generation, and human–machine collaboration.

Building upon this academic and technical foundation, the "ArchiGAN" project, developed by Stanislas Chaillou at Harvard University, stands out as one of the most comprehensive explorations of GAN applications in architectural design. ArchiGAN generates apartment floor plans through a three-stage chain of models: (I) building footprint massing, (II) program repartition and window placement, and (III) furniture layout. Each stage is executed using Pix2Pix-based conditional GAN models, enabling an interactive design process shaped by user input. This approach establishes a novel "design loop" between architect and machine, integrating intuitive decision-making with statistical learning.

The contributions of ArchiGAN to the field of architecture can be evaluated on three levels. First, it demonstrates the scalability of architectural design, offering integrated solutions from individual units to the apartment scale. Second, it proposes a hybrid human–machine collaboration model that preserves designers' agency within the process. Third, it functions as a research platform fostering dialogue between data science and architecture. Nevertheless, the project also entails certain limitations: the continuity of load-bearing systems, the restriction of outputs to raster formats, and the need for higher-resolution visualizations emerge as technical barriers to its integration into current architectural practice.

This case study positions ArchiGAN as one of the early examples of AI applications in architecture and aims to discuss its contributions from both methodological and practical perspectives. The ultimate objective of this study is to reveal the potential of GAN-based modeling approaches in architectural design processes, assess their limitations, and provide insights for future research.

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Literature Review

A detailed literature review on the use of artificial intelligence (AI) in the discipline of architecture is presented below. AI plays a significant role in architecture by offering both creative and technical solutions in conceptual design, automation, and visualization processes [4]. Evolutionary algorithms and deep learning techniques, in particular, enrich the design process by enabling architects to generate diverse design alternatives [5]. These developments are critical for addressing new demands in architectural production and expanding creative possibilities. The integration of big data and distributed AI accelerates architectural data analysis on digital platforms such as BIM and CAD, thereby increasing the efficiency of complex structural and environmental evaluations. This allows architects to make more comprehensive and accurate design decisions. Furthermore, AI-assisted visualization tools enhance motivation and conceptual understanding in architectural education [6]. Generative models and deep neural networks improve the aesthetic quality of architectural visualization and strengthen client engagement. However, challenges such as cost, user experience, and ethical concerns remain pressing issues [7].

From an ethical standpoint, the establishment of interdisciplinary guidelines for the responsible use of AI in architecture is crucial to preserving creativity and cultural diversity [8]. Moreover, the development of educational and policy models to ensure the effective and equitable application of AI has emerged as a central theme in the literature [9]. AI and machine learning have been shown to improve both the speed and accuracy of architectural visualization processes, facilitating more effective modeling of complex building designs [10]. The integration of AI with adaptive architecture has been examined for its role in creating environmentally responsive, interactive, and self-regulating spaces. Supported by cybernetic approaches, machine learning, and data processing techniques, such systems transform architecture from static structures into dynamic, user-interactive environments. The potential of AI in building design, energy optimization, and enhancing user experience is highlighted, while its ethical, psychological, and societal dimensions are also discussed [11].

In the conceptual design stage, AI has been found to enhance innovation, contributing significantly to form generation and design analysis [12]. AI models function as decision-support systems in architectural conceptual design, offering rapid prototyping and design diversity. User-controlled AI-based prototyping systems have been reported to improve design quality and facilitate the rapid testing of alternative solutions [13].

The role of AI technologies in architectural and interior design education has gained increasing importance. While text-to-image systems often generate daisy-like flower visuals, it has been observed that the Stable Diffusion 2.1 model produces more diverse outputs [14]. In an interior design-focused study, AI tools were shown to accelerate experimental design processes and enhance overall student satisfaction, although challenges such as accurately interpreting prompts and overcoming technical limitations were noted [15]. Within the context of biophilic design, tools like Leonardo AI have been identified as creative triggers for generating nature-inspired spaces [16]. A study conducted with students from Istanbul Kent University revealed that AI tools accelerate early design processes and enhance creativity; however, some outputs were perceived as unrealistic, and systematic integration of such tools into curricula was recommended [17].

AI-supported tools have been found to strengthen students' creative and analytical skills, particularly in visualizing complex themes, and to contribute to the integration of sustainability into studio education. In educational and library contexts, tools such as DALL·E and Midjourney provide interactive, visually oriented learning scenarios, though ethical issues such as copyright and bias also arise. Stable Diffusion, enhanced by extensions such as ControlNet and LoRA, increases creative control, while techniques like ESRGAN make it possible to generate professional-quality visuals [18].

In the context of industrial design, human–AI collaboration has been assessed from ethical, pedagogical, and functional perspectives, with an emphasis on safeguarding human-centered creativity [19,20]. The Stable Diffusion SDXL model has demonstrated its potential in integrating formal and structural accuracy in architectural façade design [21]. Within an experimental model of architectural education, AI was shown to contribute significantly to idea generation and data analysis, though integration often remained fragmented [22].

AI offers new opportunities for efficiency, sustainability, and creativity in architectural design, supporting data-driven decision-making through generative algorithms and BIM integration [23]. Visualization systems such as Midjourney, DALL·E, and Stable Diffusion are widely used in conceptual development, facilitating effectiveness in parametric design and client presentations [24]. The integration of virtual reality into architectural education provides interactive and decision-support tools, particularly for understanding modeling and construction details [25,26].

AI-driven architecture is evolving to contribute to sustainability goals through low-energy chip designs and biological computation [27]. The use of text-based generative AI tools in architectural education facilitates the rapid visualization of abstract ideas, though human contribution remains indispensable for achieving high-quality outputs [28]. Finally, AI contributes to green architecture, particularly through sustainable material selection and energy efficiency, playing a vital role in reducing environmental impacts [29]. Systems that support conceptual design processes transform traditional drawing practices into 3D environments, providing intuitive and holistic digital workflows [30].

2. Materials and Methods

This study is structured around a single-case analysis method in order to examine artificial intelligence (AI)-based architectural design approaches. The focus of the research is the *ArchiGAN* project, developed by Stanislas Chaillou at Harvard University in 2019. This case was selected because it demonstrates the potential of machine learning in architecture through both methodological innovations and multi-scalar design applications.

The study materials are organized into three categories. First, primary sources such as Chaillou's thesis, technical reports, and project outcomes related to ArchiGAN were examined. Second, the literature on GAN architectures—particularly the Pix2Pix approach—was reviewed; in this context, [31] provides a framework for image-to-image translation models, while [1] and [2] contribute comparative perspectives on floor plan analysis and the intersection of AI and design. Finally, visual outputs generated by ArchiGAN—including floor plans, furniture layouts, and apartment-scale results—were employed as case materials.

The analytical process was conducted along ArchiGAN's three-stage generative sequence: defining the building footprint and massing, re-partitioning the program and configuring window layouts, and, finally, arranging furniture placement. Each stage was implemented through Pix2Pix-based conditional GAN models. Within the study, the methodological functioning of the model and its contributions to architectural design were critically assessed.

The case of ArchiGAN was analyzed along three primary axes. First, the organization of the design process was examined, with particular attention to the model's production stages and modes of user interaction. Second, under the theme of architectural representation and production, the generated floor plans, furniture layouts, and apartment-scale outcomes were analyzed from both visual and functional perspectives. Finally, within the framework of technical limitations and future potentials, the strengths and weaknesses of the model were discussed, and implications were drawn regarding the development of human–machine collaborative design paradigms. This tripartite approach enables the case to be evaluated not only as a technical application but also as a methodological framework for architectural practice and theory.

To enhance the validity and reliability of the research, the use of multiple data sources was prioritized. Cross-validation between primary project documents, literature review, and visual outputs strengthened the robustness of the findings. Although the single-case nature of the study limits its generalizability, the methodological framework offered by ArchiGAN allows for theoretical inferences regarding AI applications in architecture.

Necessity of the Study

Artificial intelligence (AI), and particularly Generative Adversarial Networks (GANs), constitute a significant research agenda in architecture due to their capacity to learn from visual data and generate new content. In addressing complex problems such as floor plan design, furniture arrangement, and spatial organization at the apartment scale, approaches like *ArchiGAN* provide alternative tools that can support designers. However, such studies remain at an experimental stage, and both their technical limitations and their potential for integration into architectural practice have not yet been sufficiently explored. Therefore, examining the methodological framework of ArchiGAN and evaluating the architectural significance of its outputs may yield new insights into the paradigm of human–machine collaboration.

Research Questions

- To what extent does the ArchiGAN model provide functional outcomes in the generation of apartment-scale floor plans?
- In terms of human–machine collaboration, how does ArchiGAN's process design influence the architect's decision-making?
- Considering its current limitations, what future directions does ArchiGAN open up for research in architecture?

Research Hypotheses

H1: ArchiGAN, through its three-stage generative pipeline, provides partial yet original contributions to the architectural decision-making process in apartment plan design.

H2: Compared to previous GAN-based attempts, ArchiGAN is innovative in its focus on multi-unit scale design; however, it remains limited in ensuring structural continuity and producing high-resolution outputs.

H3: The integration of approaches such as ArchiGAN with optimization algorithms and vector-based data generation will render the potential of artificial intelligence in architecture more applicable.

3. Project Analysis Within the Context of the Case Study

Introduction of the Project

ArchiGAN is a pioneering initiative that aims to demonstrate how artificial intelligence can be employed as a transformative tool in the field of architecture. Based on Stanislas Chaillou's 2019 thesis at Harvard University, this approach experimentally investigates the generation of residential building floor plans and interior layouts through Generative Adversarial Networks (GANs). The project functions not only as a technical prototype but also as a conceptual framework that emphasizes the interaction between the architect and artificial intelligence.

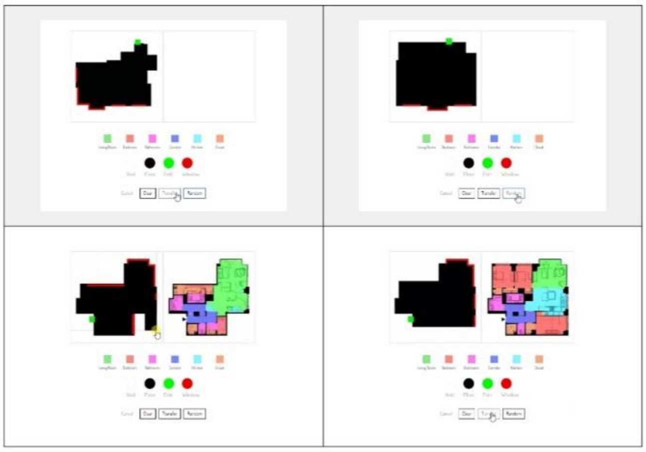

Figure 1. Interface Design and Operational Flow of GAN Architectures [32]

ArchiGAN's core innovation lies in the gradual generation of apartment plans through a three-stage production pipeline:

- *Building footprint (mass/footprint):* The creation of a typical building mass based on parcel data.
- *Space reallocation (program subdivision):* The division of unit interiors into rooms and the placement of door and window positions.
- *Furniture layout:* The functional furnishing of the programmed rooms (Figure 1).

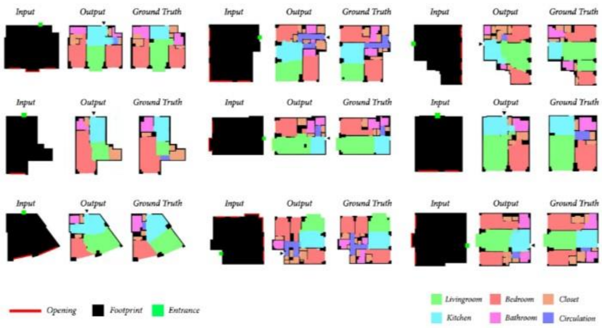

Figure 2. Comparative Outcomes Across GAN-Based Models [32]

These three stages were individually trained using Pix2Pix-based GAN models and subsequently chained together to form a "production stack." This approach allows the user to revise, fine-tune, and actively participate in the design process at each stage. In doing so, the project offers not a fully automated system but rather a hybrid decision-support mechanism grounded in human–machine collaboration.

The scalability of ArchiGAN is demonstrated by its applicability beyond single-family houses to multi-unit apartment typologies. The system is capable of multi-unit planning, controlling window, door, and circulation layouts at the floor plate level, thereby proposing more realistic apartment solutions. However, limitations such as the lack of structural continuity and the confinement of outputs to raster formats hinder its direct integration into architectural practice. To address these challenges, the researcher anticipated that future developments could incorporate higher-resolution Pix2PixHD models and vector-based conversion methods (Figure 2) (Figure 3).

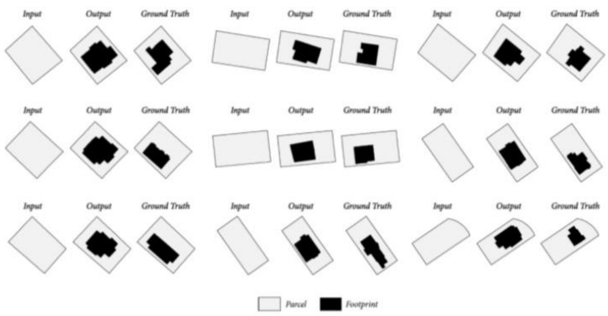

Figure 3. Performance Evaluation of Models on Building Footprint Generation [32]

In conclusion, ArchiGAN represents not merely a technical experiment but the initial steps toward a paradigm shift in the integration of GANs into the architectural design process. By combining the intuitive decision-making capacity of the human designer with the computational learning power of the machine, this framework offers a significant conceptual model for envisioning how AI-assisted production can be structured within the discipline of architecture.

3.1 Organization of the Design Process: Analysis of the Model's Production Stages and Human–Machine Interaction

In the ArchiGAN project, the design process is structured through a gradual and modular organization. This organization is not merely a technical sequence but can also be interpreted as an approach that redefines the interaction between artificial intelligence and the architect within architectural practice.

The model is built upon three main stages of production:

- **Defining the Building Footprint**: In the first stage, the building mass and plot boundaries are defined based on parcel data. This step establishes the spatial framework of the design, forming the foundation for subsequent outputs.
- **Program Reallocation**: In the second stage, the floor plan is subdivided into rooms, and the circulation, along with door and window placements, is determined. This organizes the relationship between functional distribution and spatial configuration.
- **Furniture Layout**: In the final stage, the programmed rooms are furnished according to functional usage scenarios. This step demonstrates that the model accounts not only for space itself but also for modes of occupation and use.

Each stage was trained with a separate GAN model, and the chaining of outputs ensured the continuity of the design process. In this way, instead of isolated and fragmented solutions, a sequential and integrated design logic emerged (Figure 4).

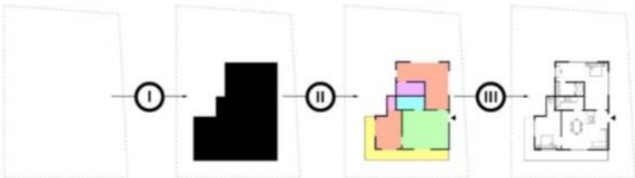

Figure 4. Generation stack in three models; (I)footprint massing, (II) program repartition, (III) furniture layout [32]

User–Machine Interaction

One of the most striking aspects of the project is that the process is not reduced to a purely automatic production mechanism; instead, it deliberately leaves space for user intervention. At each stage, the user can revise, redirect, or even reject the model's proposed outputs. This approach safeguards the architect's authority over the design, while positioning the AI's contributions as a decision-support mechanism rather than a substitute for human agency.

This interaction model emphasizes a hybrid mode of collaboration, rather than an automation paradigm in which the machine assumes full control. While the architect maintains intuitive and context-sensitive decision-making, the AI accelerates and diversifies the design process through its capacity to generate alternatives.

Nevertheless, certain limitations can be observed in the model's organization. Since outputs are generated in raster format, direct integration into architectural production workflows is difficult. Moreover, the model does not address issues such as structural continuity and constructional feasibility, which restricts its role to that of an experimental prototype rather than a fully applicable design tool.

In conclusion, the organizational framework of ArchiGAN can be seen as a significant attempt to redefine the role of AI in architectural design. Through both its systematic structuring of the production stages and the interaction it establishes with the user, the model offers a guiding framework for envisioning the future of AI-assisted design in architecture.

3.2 Examination of Architectural Representation Forms and Production Practices

The **ArchiGAN project** is not merely an experiment in the automation of spatial generation; it is equally significant in terms of the transformation of architectural representational forms and the reorganization of production processes. The manner in which design is mediated through computational representation does not remain confined to the level of visualization; rather, it fundamentally shapes the very logic by which architectural decisions are conceived and produced.

Modes of Representation

The outputs of the model are floor plans and spatial organizations generated in raster format. This differentiates ArchiGAN from conventional vector-based and parametric modes of representation in architecture, proposing instead a new visual language. At the same time, however, these outputs lack the technical accuracy and scalability required for direct integration into architectural production processes. Here, representation does not function merely as a communicative tool; it operates as an interface between artificial intelligence and the user. Unlike traditional drawing practices, which emphasize geometric precision, GAN-based generation produces probabilistic variations and suggestions. Consequently, the nature of representation shifts from a notion of "definitive outcome" to one of "negotiable proposition."

Throughout architectural history, representation has stood at the core of both the intellectual and productive dimensions of design. In traditional practice, representation was realized through drawings, models, and sketches, serving as an intermediary language between the designer and the built object. Drawings were not only a medium for conveying the construction of space but also a reflection of the architect's thought process. In this sense, representation has functioned simultaneously as a tool for communication and a method of thinking in architectural production.

With the advent of digital design tools, representational practices evolved from vector-based drawings to parametric models. These tools preserved geometric precision while enabling the integrated processing of structural, spatial, and technical data. Thus, representation came to serve not only as a means of visualization but also as a tool for control and verification.

ArchiGAN's approach introduces a new rupture within this historical continuity. While traditional drawing conveys the architect's will directly and with authority, ArchiGAN's outputs generate suggestions that guide the architect's decisions yet simultaneously await reinterpretation and reshaping. In this respect, representation transforms from an authoritative medium of transmission into an interactive and open-ended dialogue environment.

In conclusion, ArchiGAN's notion of architectural representation signifies a departure from the principles of accuracy and coherence inherent to conventional tools, reconfiguring representation around the concepts of plurality, probability, and collaboration within AI-assisted design.

Logic of Production

ArchiGAN's production process is structured upon a step-by-step hierarchical organization. Beginning with the building mass, progressing through the functional subdivision of interior spaces, and culminating in the arrangement of furniture, these stages reorganize architectural production by fragmenting it into distinct components. In doing so, the process moves away from a singular holistic conception and instead gravitates toward a modular assembly logic.

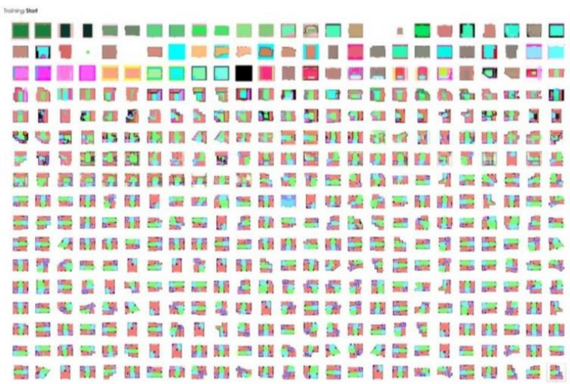

Figure 5. Computational Masterplanning via GAN Architecture [32]

This organizational framework also redefines the architect's role within the design process. The architect is no longer solely the designer but also becomes an active agent who selects, adjusts, and filters the machine's outputs. In this sense, the production process evolves into a collaborative partnership between human and machine (Figure 5).

The reconfiguration of the relationship between representation and production marks a significant turning point in the history of architecture's digitalization. However, the system's inability to ensure structural accuracy and its restriction of outputs to the level of visual suggestions prevent it from serving as a fully applicable architectural production tool. Nevertheless, the ArchiGAN experiment provides a valuable experimental framework for understanding how the boundaries between representation and production can be redrawn through artificial intelligence.

3.3 Analysis of Technical Constraints and Future Potential in AI-Supported Architectural Design

AI-supported architectural design models, particularly those based on GANs, still entail a number of technical constraints:

- ***Data Representation and Raster Outputs:*** Most GANs produce raster-based outputs, which complicates integration with conventional vectorial and parametric modes of architectural representation. Since raster outputs cannot be directly transferred into CAD or BIM environments, they pose challenges in terms of scalability and technical accuracy.
- ***Structural Inconsistencies:*** In multi-story buildings, the continuity of the load-bearing system cannot always be guaranteed, often leading to misalignments between floors. This results in significant limitations on the engineering dimension of the design.
- ***Lack of Geometric Precision:*** Unlike traditional drawing practices that rely on measurement and geometric clarity, GANs tend to generate probabilistic variations. This shifts the design outcome from a "definitive solution" to a "negotiable proposal."
- ***Computational Power and Training Requirements:*** Producing high-quality outputs demands powerful GPU infrastructure, extensive datasets, and lengthy training periods. These requirements remain a limiting factor for scalability.

Future Potential

Despite these limitations, AI-assisted architectural design demonstrates several promising future directions:

- **New Forms of Representation:** Even when generating raster-based outputs, GAN-driven models introduce a new visual language to architecture. This language prioritizes exploratory and experimental dimensions of design over strict technical accuracy.

- **Human–Machine Interaction:** Thanks to the layered structure of these models, users can intervene at every stage, rendering the design process interactive and negotiable. This approach transforms design from a purely instrumental procedure into a collaborative production practice.
- **Scalability Potential:** Once raster outputs are translated into vectorial data—through tools such as Pix2PixHD or hybrid raster–vector conversion models—direct integration with BIM and CAD systems will become feasible.
- **Integration with Optimization:** The "intuitive" solutions generated by GANs, when combined with traditional optimization algorithms, have the potential to simultaneously enhance both creativity and engineering efficiency.

At present, AI-assisted design is not yet a fully practical technical tool; rather, it operates mainly as a generator of ideas and proposals in the early stages of design. Nevertheless, this role has the capacity to fundamentally reshape architectural representation practices:

- Representation is no longer limited to drawings or plans but becomes a dynamic interface between human and machine.
- Instead of delivering definitive solutions, it offers flexible, plural, and debatable proposals.
- Once technical accuracy and data integrity are achieved, these systems may become indispensable components of architectural design.

3.4 Architectural Evaluation and Theoretical Extensions of the ArchiGAN Model

The ArchiGAN model represents a significant exploration of the potential of artificial intelligence–based generative systems within architectural production. However, the model necessitates a deeper architectural inquiry, as its current structure largely confines design generation to the two-dimensional plan level. Such an approach overlooks the inherently three-dimensional and spatial nature of architectural design, in which volumetric, sectional, and experiential qualities play decisive roles. The model's tripartite system—comprising site footprint, plan generation, and functional allocation—operates exclusively on the ground floor, without accommodating inter-floor variation. In real architectural practice, each floor may differ due to changes in elevation, the presence of atriums, or the spatial requirements of diverse functions. The replication of a single plan across all levels results in uniformity and a consequent reduction in volumetric quality. Incorporating vertical transitions, galleries, and differentiated levels into the generative process would therefore contribute to more architecturally rich and spatially coherent outcomes.

From a functional perspective, the absence of defined relationships among programmatic zones constitutes a major limitation. Functional adjacency and relational organization—such as the proximity of bedrooms to bathrooms, the orientation of study spaces toward daylight, or the continuity between kitchens and dining areas—are fundamental determinants of architectural quality. Within the current ArchiGAN framework, these relationships are not algorithmically encoded, resulting in geometrically subdivided layouts devoid of programmatic logic. Similarly, contextual and environmental factors—such as orientation, view, privacy, and variations in height—are critical parameters that remain unaddressed. For instance, northern light may be preferable for workspaces, while wet areas require limited exposure for reasons of privacy and hygiene. Integrating such contextual parameters into the model's data structure would significantly enhance its architectural validity.

Flexibility and furnishing logic represent additional dimensions currently absent from the model. In architectural design, the placement and variability of furniture or built-in elements are central to defining spatial use and adaptability. Since ArchiGAN operates on rigid plan schemata, it cannot yet produce layouts that respond dynamically to user preferences or shifting programmatic needs. Likewise, the omission of the structural system—particularly the positioning of load-bearing elements, core structures, or column grids—reduces the model's constructability and realism. Future versions of the model should therefore incorporate structural parameters as guiding variables in the generative process, thereby aligning architectural and structural reasoning.

Typologically, the study's focus on a single apartment-based configuration limits its scope within architectural discourse. Architectural typologies, by their nature, embody diverse spatial organizations and contextual relationships. Expanding the model to encompass a broader range of building types—such as educational, cultural, or office structures—would increase its theoretical depth and applicability.

Overall, while ArchiGAN provides valuable insights into computational design thinking, it cannot yet function autonomously as a design decision-making tool. Nonetheless, its integration within a hybrid framework—where the architect and the artificial intelligence system collaborate—presents a promising pathway. The introduction of an interactive interface that allows architects to intervene, guide, or override algorithmic decisions could transform the model from a generative mechanism into a co-creative design partner, thus preserving human agency and intuition within computational processes.

From a technical standpoint, enhancing the model through vector-based conversion methods would strengthen its practical integration into architectural workflows. The ability to produce CAD/BIM-compatible outputs is essential for ensuring interoperability within contemporary digital design environments. Enabling the seamless transfer of GAN-generated data into CAD or BIM platforms would not only improve the model's usability in professional contexts but also prevent information loss across design stages. Such integration is indispensable for bridging experimental computational design research with applied architectural practice.

In conclusion, ArchiGAN should not be viewed merely as a form-generation tool, but as a conceptual framework capable of engaging with the multidimensional nature of architectural reasoning. Re-envisioning the model to incorporate spatial variability, contextual intelligence, and designer interaction will reinforce its architectural legitimacy and position it as a valuable instrument in the evolving discourse on artificial intelligence–driven design methodologies.

3.5 Findings

Based on the analyses conducted on ArchiGAN, it becomes evident that both its technical limitations and future potentials have been delineated. This observation offers significant insights into the current state of AI-assisted architectural design and how it may evolve in the future. The fact that the outputs are generated in raster format prevents their integration with vector-based systems such as CAD and BIM, which are widely used in architecture. This limitation is attributed to the inherent nature of GAN architectures, which operate primarily on visual data. It is anticipated that higher-resolution frameworks such as Pix2PixHD, or hybrid raster–vector conversion systems, may bridge this gap. The inability to ensure structural continuity in multi-story buildings appears to stem from the lack of engineering-informed spatial integrity in the training data. This issue could potentially be resolved through the diversification of datasets and the incorporation of structural parameters into the model. While traditional architecture emphasizes precision in scale and geometry, GAN-based productions are characterized by their probabilistic variations, an intrinsic feature of the model. This quality redirects the design process from producing definitive solutions toward generating a spectrum of design proposals. Furthermore, the reliance on high-performance GPUs and long training periods for producing high-quality outputs reflects the limited accessibility of current AI technologies. However, with decreasing hardware costs and the proliferation of cloud-based solutions, this limitation is expected to be mitigated in the medium term.

In contrast, ArchiGAN is perceived as introducing a novel visual language to architecture. This language emphasizes not only the technical accuracy of design but also its exploratory and pluralistic dimensions. The model's staged generative logic, which leaves room for user intervention, transforms the design process into an interactive negotiation environment. Such an approach is anticipated to move architectural practice away from the authoritative tradition of drawing and toward a more collaborative and participatory mode of design. With advancements in Pix2PixHD and hybrid vector conversion models, the system is expected to achieve direct integration with CAD- and BIM-based workflows. This development is likely to significantly reduce issues of technical accuracy and applicability in AI-assisted design. Moreover, when GAN-based intuitive proposals are combined with parametric and optimization-driven algorithms, they may provide solutions that are both creatively rich and technically robust. This integration is foreseen to enable a versatile and balanced production practice in future architectural design.

In conclusion, ArchiGAN's current limitations are largely attributed to the early-stage maturity of the technology and the partial misalignment between its data-driven framework and structural realities. Nevertheless, the project is regarded as a pioneering experiment that may catalyze a paradigm shift in architectural representation and production practices. The role of artificial intelligence in design is thus being redefined—not as a definitive problem-solver, but as a generative, negotiative, and collaborative agent.

4. Conclusions

This study aimed to evaluate the ArchiGAN project through a case analysis in order to reveal both the possibilities and limitations of AI-based architectural design approaches. The central objective of the research is to examine how generative methods grounded in GAN architecture can become functional within architectural practice, in which aspects they remain constrained, and what potential directions they indicate for the future.

The key findings of this study demonstrate that ArchiGAN's three-stage generative pipeline—comprising footprint, program/window placement, and furniture—can produce functional spatial proposals at the apartment scale. Its structure, which allows user intervention, foregrounds human–machine collaboration and shifts the design process toward an interactive and negotiative framework. However, the inability to directly transfer raster-based outputs into CAD/BIM environments, the lack of structural continuity, and the constraints of resolution constitute significant obstacles for practical application. The findings suggest that the integration of more advanced generative algorithms, hybrid raster–vector conversion methods, and optimization approaches could enhance the system's technical accuracy and scalability.

These results indicate that GAN-based models operate less as definitive solution providers and more as decision-support systems that generate possibilities. Similar to earlier studies in the literature, ArchiGAN remains limited in terms of structural accuracy and geometric precision. Yet, it makes an original contribution by focusing on the apartment scale and embedding user interaction into the process. In doing so, the project demonstrates that architectural representation can function not only as a vehicle for technical transmission but also as an interactive interface between human and machine.

Answers to the Research Questions

1. Functionality at the apartment scale: ArchiGAN has demonstrated the ability to generate functional layout proposals for multi-unit plans; however, it remains limited in terms of structural integrity and technical accuracy.

2. Human–machine collaboration: The system has actively engaged the user as part of the process, supporting the architect's intuitive decisions rather than fully replacing them.

3. Future directions: Key areas for advancement include higher-resolution generation, raster–vector transformation, the integration of structural rules, and the incorporation of optimization algorithms—all of which are expected to enhance practical applicability.

Testing of Hypotheses

H1: ArchiGAN's three-stage generative pipeline provides partial yet original contributions to the architectural decision-making process. → *Supported.*

H2: At the multi-unit scale, ArchiGAN is innovative but remains limited in producing structurally continuous and high-resolution outputs. → *Strongly supported.*

H3: Its integration with optimization algorithms and vector-based data generation will make it more applicable to architectural practice. → *Conditionally supported.*

Conclusion; ArchiGAN shifts the role of artificial intelligence in architecture from a paradigm of "full automation" to that of a "hybrid decision-support tool." Although current technical constraints do not yet allow for robust application, the conceptual framework introduced by ArchiGAN paves the way for more flexible, participatory, and data-driven design processes that integrate human intuition with machine learning.

Discussion; The findings of this research indicate that ArchiGAN makes notable contributions to the architectural design process, while also bringing certain limitations to the fore. Through its three-stage generative pipeline, the system enables designers to intervene at multiple scales, thereby strengthening human–machine interaction and rendering the process more interactive. Furthermore, its ability to generate functional layouts at the apartment scale can be considered a significant innovation compared to similar studies. However, the reliance on raster-based generation has complicated the transfer of outputs into CAD/BIM environments, while issues of structural continuity and low resolution have restricted the practical feasibility of the produced designs.

From an ethical perspective, the automation inherent in GAN-based generation raises questions regarding the potential limitation of the architect's agency. While ArchiGAN provides a powerful computational tool, over-reliance on automated outputs could reduce the architect's role in critical decision-making, highlighting the need for responsible integration of AI in design practice.

The notion of design agency is central to the evaluation of ArchiGAN's contribution. By allowing user intervention at each stage, the system preserves the architect's decision-making capacity, ensuring that the design process remains collaborative rather than fully automated. This hybrid approach emphasizes that AI should function as a supportive partner, enhancing creativity and efficiency without replacing human intuition.

Finally, the role of intuitive and context-sensitive decision-making is crucial in the design process. GAN outputs are inherently probabilistic and require reinterpretation, adjustment, and selection by the architect to generate meaningful, contextually appropriate solutions. This interaction exemplifies how computational design can be effectively combined with human expertise, reinforcing the importance of intuition in shaping architectural outcomes.

Consequently, although ArchiGAN presents an innovative approach that highlights the potential of artificial intelligence in architecture, in its current state it remains primarily an exploratory and experimental tool. In the future, if challenges related to technical accuracy, resolution, system integration, and ethical use are addressed, such systems could assume a more applicable and productive role within architectural design practice

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