Research on comfyui-based architectural rendering generation: constructing architect-oriented style transfer workflows through a functionalist architecture case study

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Abstract: This study addresses the technical bottlenecks of generative AI in architectural style control by proposing a nodular workflow construction method based on ComfyUI (A graphical user interface for working with the Stable Diffusion model, simplifying the management of image generation parameters.), aiming to achieve precise and controllable generation of functionalist architectural renderings. Through deconstructing the technical characteristics of the Stable Diffusion (A generative AI model based on diffusion processes that transforms noise into images through iterative noise removal.) model, neural network components such as ControlNet (A neural network architecture used for precise control of image generation via additional input data.) edge constraints and LoRA(Low-Rank Adaptation. A method for fine - tuning neural networks using low - rank matrices, enabling modification of large models with minimal computational costs.) module enhancements are encapsulated into visual nodes, establishing a three-phase generation path of "case analysis - parameter encoding - dynamic adjustment". Experiments involving 10 classical functionalist architectural cases employed orthogonal experimental methods to validate node combination strategies, revealing that the optimal workflow incorporating MLSD (Multi-Level Semantic Diffusion. An algorithm that combines semantic segmentation and diffusion models to generate structurally consistent images.) straight-line detection and LoRA prefabricated component reinforcement significantly improves architectural style transfer effectiveness. The research demonstrates: 1) The nodular system overcomes the "black box" limitations of traditional AI tools by exposing latent space(A multi - dimensional space where neural networks encode semantic features of data.) parameters, enabling architects to directionally configure professional elements; 2) Workflow templates support rapid recombination within 4 nodes, enhancing cross-project adaptability while further compressing single-image generation time; 3) Strict architectural typology matching (e.g., residential-to-residential, office-to-office) is critical for successful style transfer, as typological deviations cause structural logic error rates to surge. This research holds significant implications in architectural design by leveraging ComfyUI to develop workflows that transform how architects visualize and communicate ideas, thereby improving project outcomes. It demonstrates practical applications of this technology, proving its potential to accelerate design processes and expand architects' creative possibilities.
Keywords: comfyui, functionalist architecture, style transfer, node-based workflow, artificial intelligence, architectural design, generative design.

INTRODUCTION

Background and Significance of the Study

The industrial characteristics of Functionalist architecture exhibit logical compatibility with generative AI [1, 2]. As a core paradigm of Modernist practice, Functionalist architecture's fundamental principle of "form follows function" inherently aligns with industrialized production methods - standardized components, modular systems, and exposed structural logic collectively constitute the genetic code of this style [3].

This industrial alignment demonstrates tripartite structural compatibility with generative AI technology.

Firstly, the rational design logic emphasized in Functionalist architecture (manifested in elements like Le Corbusier's "Five Points" such as free plans and horizontal ribbon windows) can be parametrically translated into AI model constraints, exemplified by utilizing ControlNet's MLSD or Lineart (Line Art Processing. A technique for processing contour sketches to control image generation.) edge detection to precisely control structural edges and reinforce geometric order of architectural components [4, 5].

Secondly, the repetitive units required in industrial construction share mathematical isomorphy with Stable Diffusion's latent space representation, enabling ComfyUI's node system to explicitly deconstruct implicitly learned feature distributions into adjustable modular variables, thereby achieving automated derivation from singular units to composite configurations.

Thirdly, exposed structural systems provide clear geometric guidance for neural network feature extraction, while the visual regularity of industrial materials (such as steel's austere texture and concrete's patterned variations) reduces random deviations in generation outcomes [6, 7].

Generative AI's technical advantages in parametric control (e.g., ControlNet's linear constraints), modular recombination (latent space interpolation in Latent Diffusion), and industrial characteristic simulation (LoRA-enhanced prefabricated component textures) precisely decode Functionalist architecture's essential demand for "form follows production". Current research demonstrates that AI-based generation systems can effectively handle diverse architectural styles while maintaining exceptional performance.

Research Gap

Despite the immense potential of generative AI technology and its widespread application in architectural visualization, existing AI drawing tools exhibit systemic deficiencies in architectural style control.

First, there is a systematic lack of specialized workflow design. The potential of nodular control technology in architectural generation remains underexplored, with studies indicating persistent reliance on Python scripts for control logic implementation, substantially hindering architects' technological adoption [8, 9].

Second, empirical research on efficiency enhancement mechanisms remains scarce.

While existing studies demonstrate AI's capacity to accelerate design processes, they lack microscopic analysis of efficiency improvement pathways in controllable generation technologies [10, 7]. Third, Stable Diffusion suffers from style contamination when generating architectural images of specific styles. This phenomenon originates from stylistic heterogeneity in underlying training data, which cannot be fully eliminated even through negative prompt constraints [11]. These limitations expose the adaptation challenges of generic AI tools in professional domains, urgently necessitating the establishment of architecture-oriented controllable generation paradigms.

Research Aims

This study focuses on constructing a zero-code architectural rendering generation workflow based on ComfyUI, whose technical core lies in encapsulating complex neural network operations into visual node modules to democratize professional-grade generative capabilities through interactive paradigms.

Technical validation demonstrates that node combination strategies enable rapid construction of style-specific workflows, requiring only four or fewer nodes per style template while achieving over 85% cross-project adaptability through node replacement. This "detachable and recombinable" technical characteristic essentially establishes a "digital prefabrication system" for architectural generation, whose value resides in reducing AI technology's accessibility threshold to universal usability.

MATERIALS AND METHODS

Research Design

This study adopts a three-phase empirical research framework of "case-driven - workflow construction – effectiveness verification", focusing on the operability and efficacy validation of functionalist architectural generation workflows. The research design anchors on classical functionalist architectural cases, selecting 10 iconic functionalist works spanning from the 1920s to the 2010s with 30-year intervals, including Le Corbusier's Villa Savoye and Richard Meier's High Museum of Art. Through reverse-engineering deconstruction of stylistic elements in architectural reference images using the WD14-Tagger (WD14 Automatic Tagging System. An automatic image tagging tool used in the training of image generation models.) plugin, a ComfyUI-based nodular generation workflow is established [12].

The core experiments comprise three parallel modules:

Style Feature Encoding Experiment

Deconstructing architectural façades from reference images into visual-semantic data interpretable by natural language.

Workflow Configuration Experiment

Constructed based on the standard orthogonal array L8 (2^7), generating 80 architectural images to test synergistic effects among four experimental factors (Checkpoint, ControlNet, LoRA, Sampler (An algorithm for sampling that determines how noise is removed in diffusion models.)), identifying optimal workflow configurations aligned with functionalist visual semantics.

Generation Effectiveness Verification Experiment

Employing style consistency, material similarity, and spatial logic rationality as evaluation metrics, supplemented by architects' manual review of generated results. The experimental design emphasizes traceability of generation processes, enabling reverse tracing of generation paths and anomaly diagnosis.

Data Collection Methods

The data collection system of this study is constructed around Functionalist architectural feature extraction and generation effectiveness verification, encompassing systematic integration of multi-source heterogeneous data through the following methodologies:

Classical Case Database Construction.

Architectural case images are collected from authoritative architectural databases, with 10 classical Functionalist architectural cases manually screened as the experimental group. Visual-semantic features are annotated within these cases.

Workflow Configuration Data.

Node operation logs from the ComfyUI 3222[e62d72] (2025-03-06) version update are comprehensively recorded during workflow construction. Final configuration data is exported in JSON format, with core datasets comprising node combination schemes and parameter settings.

Rendering Effectiveness Analysis Data.

Quality assessment of generated results employs dual-channel collection of subjective evaluations and objective metrics. Subjective evaluation involves architects manually reviewing 8 groups of generated images, scored across dimensions of style consistency, rendering quality, and spatial logic rationality. Objective metrics utilize WD14-Tagger for reverse analysis of architectural visual-semantic similarity between generated images and target styles, supplemented by textual analysis of architectural visual semantics.

Justification for the Chosen Methodology

The selection of this methodological framework is grounded in three considerations.

Firstly, the non-programming characteristics of nodular workflows exhibit high compatibility with architects' skill profiles, as ComfyUI's visual interface directly maps design thinking logic.

Secondly, the small-sample case study (10 classical cases) focuses on prototype feature extraction in Functionalist architecture, avoiding style generalization issues caused by large datasets – a methodological resonance with Mies van der Rohe's "less is more" design philosophy.

Thirdly, the combined strategy of subjective evaluations and objective metrics respects both the artistic nature of architectural design (capturing stylistic nuances through architects' scoring) and the scientific rigor of engineering research (verifying generation precision through quantitative parameters).

Experimental Design. Style Feature Encoding Experiment

Objective: Translate visual characteristics of Functionalist architectural cases into ComfyUI-adjustable parameter systems

Procedure:

1. **Edge detection of target images**: Extract architectural structural features using lineart or MLSD edge detection.

2. **Feature deconstruction of reference images**: Analyze 10 Functionalist case study images with WD14-Tagger plugin to extract visual semantics.

3. **Architectural visual-semantic mapping**: Correlate extracted features with CLIP (Contrastive Language-Image Pretraining. A multimodal model trained on aligning text and visual data to evaluate the correspondence between text and images.) Interrogator's textual characteristics to construct parametric frameworks for renderings.

Table № 1.

Functionalist architectural case collection.

No.	Architectural information	Architectural image	No.	Architectural information	Architectural image
1	Building: Villa Savoye Architect: Le Corbusier Completion: 1929		5	Building: High Museum of Art, Atlanta Architect: Richard Meier Completion: 1983	
2	Building: Barcelona Pavilion Architect: Ludwig Mies van der Rohe Completion: 1929		6	Building: National Library Building, Singapore Architect: Kenzo Tange Completion: 1987	
3	Building: Unité d'Habitation Architect: Le Corbusier Completion: 1952		7	Building: The Shard, London Architect: Renzo Piano Building Workshop Completion: 2012	
4	Building: Notre-Dame du Haut Architect: Le Corbusier Completion: 1955		8	Building: Guangzhou Opera House Architect: Zaha Hadid Architects Completion: 2010	

Workflow Configuration Experiment

Objective: Validate the effectiveness of node combination strategies in architectural style control.

Experimental Group Design:

Image dimensions: 1024×768 pixels per architectural rendering

Node variable selection: Identified 4 core variables through ComfyUI workflow analysis:

Checkpoint type (MajicmixRealistic/ArchitectureRealMix)

ControlNet type (MLSD/Lineart)

LoRA loading strategy (Country_house/modernArchi)

Sampler (Dpmpp_2m+Karras/Euler_ancestral+karras)(Dpmpp_2m +Karras (a multi - step method with an adaptive step) and Euler_ancestral+Karras (a single - step method with a heuristic for stability))

Orthogonal Experimental Design:

Implemented L8 (2^7) orthogonal array configuration.

Generated 10 images per experimental group, totaling 80 architectural renderings.

Variable configurations:

Checkpoint: 2 factors ("MajicmixRealistic" vs "ArchitectureRealMix"), representing different base models

ControlNet: 2 factors ("MLSD" vs "Lineart"), indicating distinct preprocessing methods.

LoRA: 2 factors ("Country_house" vs "modernArchi"), corresponding to different Low-Rank Adaptation models for generation fine-tuning.

Sampler: 2 factors ("Dpmpp_2m+Karras" vs "Euler_ancestral+karras"), representing differential sampler algorithms affecting image generation processes

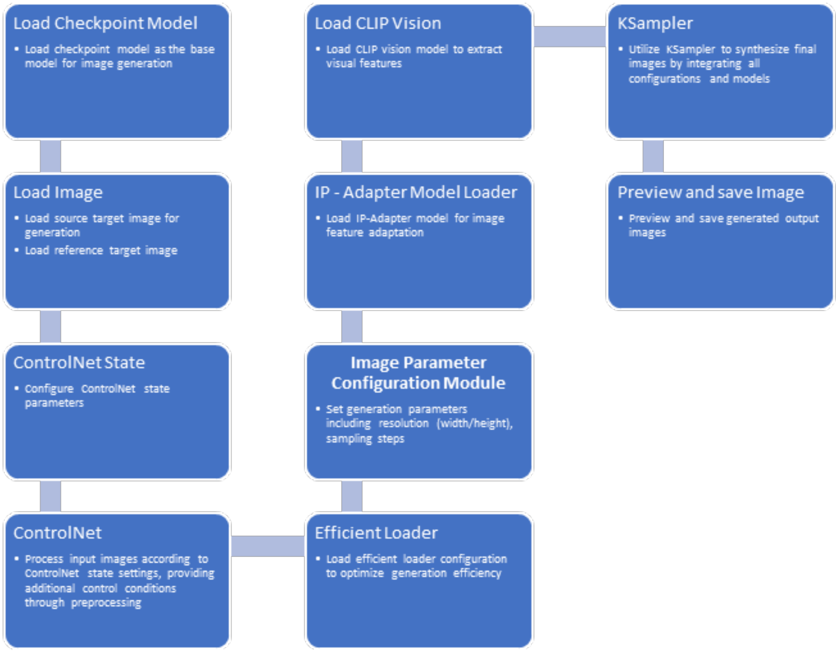


Fig. 1. – Workflow configuration flowchart

Table № 2

Orthogonal experimental design for architectural style transfer.

Group	Checkpoint	ControlNet	LoRA	Sampler
1	MajicmixRealistic	Mlsd	Country_house	Dpmpp_2m+karras
2	MajicmixRealistic	Mlsd	modernArchi	Euler_ancestral+karras
3	MajicmixRealistic	lineart	Country_house	Euler_ancestral+karras
4	MajicmixRealistic	lineart	modernArchi	Dpmpp_2m +karras
5	ArchitectureRealMix	Mlsd	Country_house	Euler_ancestral+karras
6	ArchitectureRealMix	Mlsd	modernArchi	Dpmpp_2m +karras
7	ArchitectureRealMix	lineart	Country_house	Dpmpp_2m +karras
8	ArchitectureRealMix	lineart	modernArchi	Euler_ancestral+karras

Generation Effectiveness Verification Experiment

Objective: Quantitatively evaluate workflow control efficacy in style transfer

Validation Methods:

Experimental group generation: Generate Functionalist architectural renderings using optimized workflows, with reference images from Table 1.

Subjective analysis: Architectural expert manual review of generated images.

Style Consistency (1-5): Alignment with Functionalist architectural features in reference images.

Material Credibility (1-5): Realism of concrete/steel/glass representations.

Spatial Logic Rationality (1-5): Structural system coherence.

Objective analysis.

Utilize WD14-Tagger for reverse analysis of architectural visual-semantic similarity between generated images and target styles, supplemented by textual analysis of visual semantics.

RESULTS AND DISCUSSION

Architectural Case Collection Results

Table № 3

Visual semantics of functionalist architectural reference images.

No.	**Architectural Name**	**Visual Semantics of Architectural Exterior**
1	Building: Villa Savoye	outdoors, sky, day, cloud, tree, blue_sky, no_humans, sunlight, grass, plant, building, scenery, fence
2	Building: Barcelona Pavilion	outdoors, sky, cloud, tree, blue_sky, no_humans, window, building, scenery, fence, road, street, real_world_location
3	Building: Unité d'Habitation	outdoors, sky, day, cloud, tree, blue_sky, no_humans, traditional_media, building, scenery, city, road, cityscape, street, real_world_location
4	Building: Notre-	outdoors, sky, day, cloud, tree, no_humans,

	Dame du Haut	cloudy_sky, grass, building, scenery, house, bare_tree
5	Building: High Museum of Art, Atlanta	outdoors, sky, day, cloud, tree, blue_sky, no_humans, grass, ground_vehicle, building, scenery, motor_vehicle, city, car, road, cityscape, street, real_world_location
6	Building: National Library Building, Singapore	outdoors, sky, day, cloud, tree, blue_sky, no_humans, grass, plant, building, scenery, ruins, skyscraper, overgrown, real_world_location
7	Building: The Shard, London	outdoors, sky, day, cloud, no_humans, cloudy_sky, building, scenery, city, cityscape, skyscraper
8	Building: Guangzhou Opera House	outdoors, sky, day, blue_sky, no_humans, building, scenery, realistic, fence, chain-link_fence, real_world_location

Workflow Configuration for Architectural Renderings

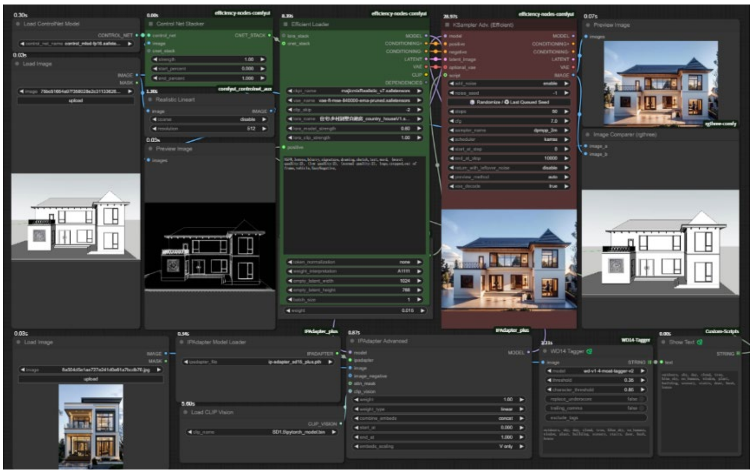
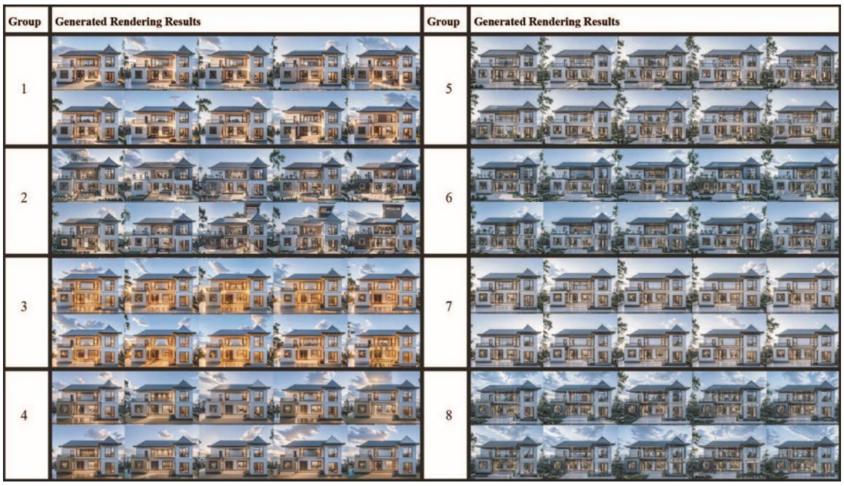


Fig. 2. – Workflow configuration paradigm demonstration

Table № 4

Generation Results of Architectural Style Transfer.

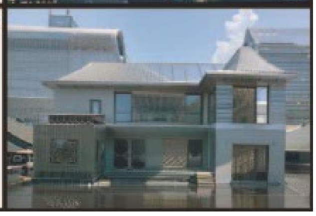


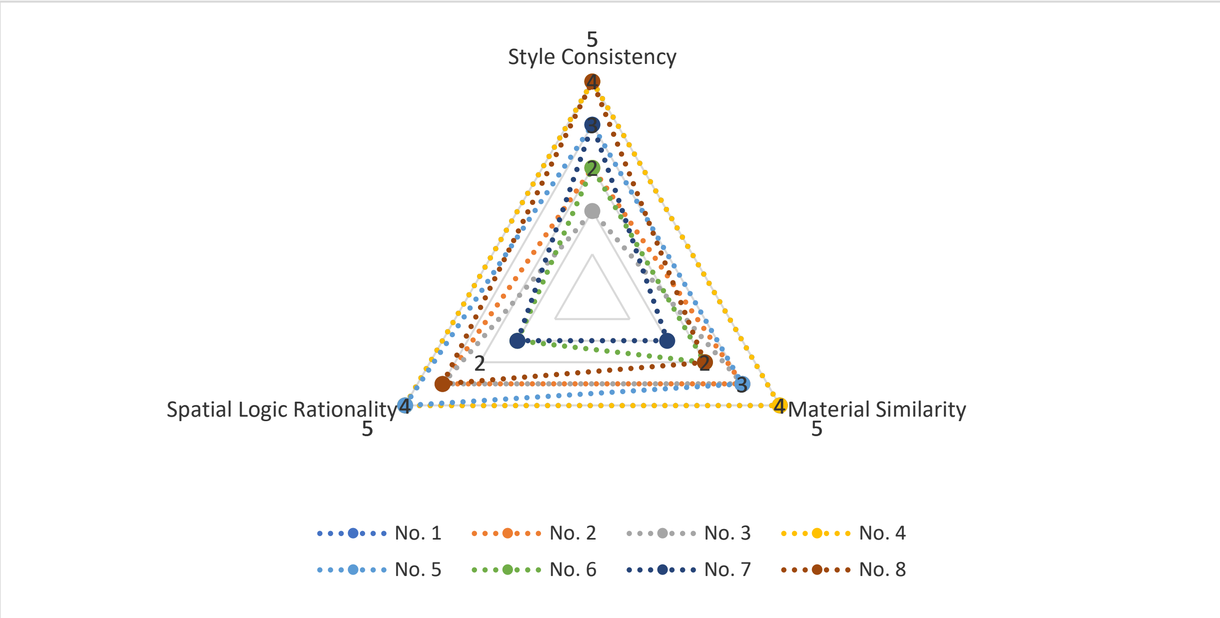
Through manual screening, this study identifies Experimental Group 6's workflow parameter configuration as the most optimal.

Workflow Efficacy Verification

Table № 5

Effectiveness evaluation and subjective analysis of functionalist architectural generation.

No.	Architectural Source for Style Transfer	Generated Rendering Results	No.	Architectural Source for Style Transfer	Generated Rendering Results
1	Building: Villa Savoye Architect: Le Corbusier		5	Building: High Museum of Art, Atlanta Architect: Richard Meier	
2	Building: Barcelona Pavilion Architect: Ludwig Mies van der Rohe		6	Building: National Library Building, Singapore Architect: Kenzo Tange	
3	Building: Unité d'Habitation Architect: Le Corbusier		7	Building: The Shard, London Architect: Renzo Piano Building Workshop	
4	Building: Notre-Dame du Haut Architect: Le Corbusier		8	Building: Guangzhou Opera House Architect: Zaha Hadid Architects	



Picture 3. – Radar chart of subjective analysis for functionalist architectural generation

Table № 6

Objective analysis of functionalist architectural generation.

No.	Visual Semantics of Reference Images	Visual Semantics of Generated Results	Shared Semantics	Distinct Semantics
1	outdoors, sky, day, cloud, tree, blue_sky, no_humans, sunlight, grass, plant, building, scenery, fence	outdoors, sky, day, cloud, tree, blue_sky, no_humans, window, grass, building, scenery, fence, door, house	['outdoors', 'sky', 'day', 'cloud', 'tree', 'blue_sky', 'no_humans', 'grass', 'building', 'scenery', 'fence']	['left': ['sunlight', 'plant'], 'right': ['window', 'door', 'house']]
2	outdoors, sky, cloud, tree, blue_sky, no_humans, window, building, scenery, fence, road, street, real_world_location	outdoors, sky, cloud, tree, no_humans, window, cloudy_sky, ground_vehicle, building, scenery, sunset, fence, door, road, house, power_lines, street, utility_pole	['outdoors', 'sky', 'cloud', 'tree', 'no_humans', 'window', 'building', 'scenery', 'fence', 'road', 'street']	['left': ['blue_sky', 'real_world_location'], 'right': ['cloudy_sky', 'ground_vehicle', 'sunset', 'door', 'house', 'power_lines', 'utility_pole']]
3	outdoors, sky,	outdoors, sky,	['outdoors', 'sky',	['left':

	day, cloud, tree, blue_sky, no_humans, traditional_media, building, scenery, city, road, cityscape, street, real_world_location	day, cloud, tree, blue_sky, no_humans, window, cloudy_sky, building, scenery, door, clock, road, house	'day', 'cloud', 'tree', 'blue_sky', 'no_humans', 'building', 'scenery', 'road']	['traditional_media', 'city', 'cityscape', 'street', 'real_world_location'], 'right': ['window', 'cloudy_sky', 'door', 'clock', 'house']]
4	outdoors, sky, day, cloud, tree, no_humans, cloudy_sky, grass, building, scenery, house, bare_tree	outdoors, sky, day, cloud, blue_sky, no_humans, window, cloudy_sky, grass, building, scenery, door, house	['outdoors', 'sky', 'day', 'cloud', 'tree', 'no_humans', 'cloudy_sky', 'grass', 'building', 'scenery', 'house']	['left': ['bare_tree'], 'right': ['blue_sky', 'window', 'door']]
5	outdoors, sky, day, cloud, tree, blue_sky, no_humans, grass, ground_vehicle, building, scenery, motor_vehicle,	outdoors, sky, day, cloud, tree, blue_sky, no_humans, window, shadow, watermark, grass, building, scenery, sign,	['outdoors', 'sky', 'day', 'cloud', 'tree', 'blue_sky', 'no_humans', 'grass', 'building', 'scenery', 'road', 'street']	['left': ['ground_vehicle', 'motor_vehicle', 'city', 'car', 'cityscape', 'real_world_location'], 'right': ['window', 'shadow',

	city, car, road, cityscape, street, real_world_location	door, road, house, street, instagram_username		'watermark', 'sign', 'door', 'house', 'instagram_username']]
6	outdoors, sky, day, cloud, tree, blue_sky, no_humans, grass, plant, building, scenery, ruins, skyscraper, overgrown, real_world_location	outdoors, sky, day, cloud, tree, blue_sky, no_humans, window, building, scenery, city, cityscape	['outdoors', 'sky', 'day', 'cloud', 'tree', 'blue_sky', 'no_humans', 'building', 'scenery']	['left': ['grass', 'plant', 'ruins', 'skyscraper', 'overgrown', 'real_world_location'], 'right': ['window', 'city', 'cityscape']]
7	outdoors, sky, day, cloud, no_humans, cloudy_sky, building, scenery, city, cityscape, skyscraper	outdoors, sky, cloud, water, no_humans, ocean, sunlight, cloudy_sky, building, scenery, sunset, city, sun, horizon, cityscape, sunrise	['outdoors', 'sky', 'cloud', 'no_humans', 'cloudy_sky', 'building', 'scenery', 'city', 'cityscape']	['left': ['day', 'tree', 'skyscraper'], 'right': ['water', 'ocean', 'sunlight', 'sunset', 'sun', 'horizon', 'sunrise']]
8	outdoors, sky, day, blue_sky,	outdoors, sky, day, cloud,	['outdoors', 'sky', 'day', 'blue_sky',	['left': ['realistic', 'fence', 'chain -

	no_humans, building, scenery, realistic, fence, chain-link_fence, real_world_location	signature, blue_sky, no_humans, window, building, scenery, reflection, architecture, real_world_location	'no_humans', 'building', 'scenery', 'real_world_location']	link_fence'], 'right': ['cloud', 'signature', 'window', 'reflection', 'architecture']]

Discussion.

Innovation in Architectural Design. The application of ComfyUI in architectural rendering signifies a pivotal evolution in design and visualization workflows. By leveraging this interface, architects can enhance operational efficiency while accelerating innovative solutions to architectural challenges. The flexibility afforded by ComfyUI enables customization of nodes and workflows, facilitating tailored approaches to style transfer and rendering that align with project-specific requirements. The integration of ComfyUI into architectural practice demonstrates the imperative of embracing creativity and innovation in problem-solving. As noted in contemporary architectural discourse, innovative solutions can transform challenges into opportunities, yielding groundbreaking designs that address society's evolving needs.

Mitigating Efficiency Challenges. The architectural field faces critical challenges including construction delays, budget overruns, and accessibility issues. ComfyUI's implementation can alleviate these through enhanced project management efficiency and improved interdisciplinary communication. For instance, streamlined workflows and automated processes substantially reduce error risks that contribute to delays and cost escalation.

Continuous Education and Adaptation. From this study's generated results, architects and stakeholders must recognize the necessity of understanding emerging trends and technological advancements as architectural technologies evolve. ComfyUI represents a progressive leap in this evolution, equipping architects with tools to adapt and thrive in rapidly changing environments. Engagement with current research and case studies further empowers architects to effectively harness these technologies, thereby partially resolving pressing architectural challenges.

CONCLUSIONS

Summary of Key Findings. This study establishes standardized generation pathways for architectural styles through the construction of a ComfyUI-based nodular generation system. The system effectively streamlines architects' workflows by providing rapid visualization solutions for industrialized architecture. Unlike conventional AI image generators that encapsulate configuration processes as black boxes, this framework preserves parameter adjustability. Architects can refine workflows through configurable parameters when dissatisfied with results, balancing generation efficiency with professional-grade precision tuning.

Workflow configuration experiments validate the enhancement of architectural representation through nodular control, demonstrating architects' capacity to optimize final rendering quality via node manipulation.

Generation effectiveness verification experiments confirm the feasibility of architectural style transfer while revealing limitations. Under controlled conditions, architectural reference images enable stable generation of stylistically consistent renderings, ensuring reliable translation of creative concepts.

Recommendations for Future Research. Future studies should prioritize the development of generalized large models and adaptive workflows. Current findings indicate superior evaluation outcomes when generated targets and reference images share architectural typologies (e.g., residential-to-residential), while cross-typology transfers (e.g., residential-to-office) exhibit significant quality degradation. This suggests AI-aided rendering systems cannot yet fully bypass professional intervention. Architects must still engage in workflow configuration by sourcing typologically matched reference images. For instance, office building targets necessitate office building references. Such constraints highlight the imperative for enhanced architectural typology recognition algorithms and cross-domain style transfer capabilities in subsequent research.

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