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Editorial

The Transformation of the Architect’s Role in the AI Era: From Creative Generation to Human–AI Collaboration

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ABSTRACT: Artificial intelligence (AI) is rapidly embedding itself in architectural workflows, reshaping architects’ authority while enabling new human–machine collaborations. This paper traces the technical evolution from parametric tools to multimodal generative platforms, reviews recent scholarship on AI-driven role shifts, conducts case-based analysis of typical design platforms across concept gener-ation, spatial configuration, performance simulation, visualization, and communication. Based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology, representative studies and cases over the past 6 years were sys-tematically searched, and 59 articles related to AI design were included. The results show that, AI has been widely integrated into the workflow of various stages of architectural design, and different types of AI models have formed a collaborative and coupled mechanism in multi-stage tasks. Architects’ roles are transforming along three paths: from form-makers to creative directors who curate prompts and narratives, to system integrators who orchestrate cross-platform workflows, and to ethical supervisors respon-sible for contextual adequacy, social impact, and risk control. AI excels at exhaustive searching, rapid iteration, and optimization, whereas architects remain irreplaceable in defining problems, interpreting ambiguous constraints, and synthesizing cultural and spatial values. Clarifying these task boundaries and capability requirements provides a framework for updating architectural ed-ucation and practice, helping architects reposition themselves as strategic coordinators and value guardians within intelligent, data-driven design ecologies.

KEYWORDS: ai; architectural roles; generative design; human–ai collaboration; architectural education

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1. Introduction

Architectural design has long been regarded as an innovative activity that integrates artistic expression, hu-manistic narrative, and scientific rationality. Architects are not only responsible for configuring spatial form, but also act as “translators” and “constructors” of socio-cultural meaning, thereby establishing their professional sub-jectivity at the intersection of multiple knowledge domains [1]. However, with the rapid rise of a new technological revolution driven by generative artificial intelligence (Generative AI), this conventional understanding is undergo-ing profound disruption.

Since 2022, general-purpose models such as ChatGPT, Midjourney, DALL·E, Runway, and Pixverse have emerged in quick succession. They have been widely adopted in architectural practice for image generation, text authoring, and video presentation, and are gradually extending into core design processes including concept gener-ation, functional planning, parametric optimization, and even structural simulation (Appendix Figure A1). AI is no longer a “passive tool”; rather, it intervenes proactively in architects’ spatial cognition and design judgment as a “collaborative intelligent agent” [2]. This shift not only redefines the ontological meaning of “design”, but also fun-damentally challenges architects’ creative authority, value judgments, and professional boundaries [3].

Building on these general models, a series of architecture-specific vertical systems—such as Spacely AI, Forma, PKPM-AID, and Xkool AI—have recently emerged. These systems can automatically generate design schemes that comply with development indicators and regulatory constraints, and further refine them through iterative feedback to optimize performance, demonstrating a high degree of adaptability to architectural logic and urban sys-tems [4-6]. This evolution raises a set of critical questions: Will architects be replaced? Is their creative agency being eroded by “algorithmic logic”? Is architectural design being alienated by a technology-driven “efficiency para-digm”? These questions concern not only the self-identification of architects as professionals, but also the theoreti-cal reconstruction of architecture and the renewal of architectural education in the age of AI [7, 8].

Despite a significant increase in research on the application of artificial intelligence in architectural design in recent years, existing studies remain predominantly fragmented and tool-oriented. On the one hand, relevant liter-ature predominantly focuses on showcasing the capabilities of individual technologies or specific platforms—such as generative imagery, parametric modelling, or performance simulation—while lacking a systematic overview of the entire AI-assisted architectural design process. On the other hand, no clear and unified theoretical framework has yet emerged to define the boundaries of application, collaborative relationships, and structural impacts on the architect's role across different phases of architectural design for various types of AI design tools. Particularly con-cerning the professional role of architects, existing research largely remains at the level of descriptive discussions about ‘technological empowerment’ or ‘efficiency enhancement,’ lacking comprehensive summaries and model-based expressions grounded in systematic literature analysis. Consequently, how to systematically integrate the relationship between AI design tools, design processes, and the transformation of the architect's role within the ar-chitectural context remains a significant gap in current research

2. The integration and evolution of AI and architecture

2.1 Development stages of AI-assisted architectural design

The penetration of AI into architectural design has been incremental, following a progressive transition from a “computational tool” to a “collaborative partner.” This evolution can be broadly divided into 3 stage: The auxiliary computation phase, The collaborative augmentation phase, and Tthe full-process integration phase (Figure 1)—each associated with distinct technical platforms and functional characteristics.

In the auxiliary computation phase, AI functions mainly as an integrated tool for form exploration and performance optimization. Parametric modeling environments such as Rhino + Grasshopper become assistants that extend architects’ capacity for formal expression. Through logical programming and geometric control, architects can pursue unprecedented free-form explorations. Practices such as Zaha Hadid Architects and UN Studio have widely adopted these technologies to construct a new language of “algorithmic aesthetics” [9, 10].At this stage, AI essentially remains an extension of computational automation, emphasizing the programmability of formal control.

In the collaborative augmentation phase, image-generation platforms represented by Midjourney and DALL·E, together with large language models such as ChatGPT, enable AI to intervene in architectural ideation and representation. Designers can rapidly produce sketches, spatial atmospheres, or textual scripts via prompt-based interaction, substantially improving efficiency in the conceptual stage [11, 12]. Meanwhile, AI systems exhibit basic learning and feedback capabilities, extracting semantic features from human input and forming preliminary logics of co-generation [13]. In this phase, AI is no longer merely a drafting tool, but a design assistant capable of providing substantive design suggestions.

The field is now entering a full-process integration phase, in which AI technologies are deeply embedded across the entire project lifecycle—from early-stage planning to performance simulation, construction, and operation—giving rise to systematized workflows characterized by closed-loop intelligent collaboration [14, 15]. For example, the Forma platform provides real-time feedback and optimization for wind environment, daylighting, and energy consumption; Xkool AI embeds building regulations within its functional generation logic; PKPM-AID is linked to structural simulation systems to enhance decision-making efficiency at the level of building physics; Finch platform synchronously orchestrates unit-assembly algorithms, development intensity constraints, and modular parameters, representing a typical application of “generative planning” in residential design[16].

Meanwhile, AI is gradually acquiring “cognitive authority” in architectural design through multimodal modes of interaction. Combinations such as “AI + VR” and “AI + video generation” assign AI a more complex role in immersive representation and user feedback collection[17]. This deepening embeddedness has prompted renewed scrutiny of architects’ professional identity: Will design degenerate into the operation and fine-tuning of algorithms? Will architectural expression be replaced by platform-prescribed aesthetics? These questions underscore the dual logic of AI participation: on the one hand, enhancing efficiency, and on the other, reshaping the value boundaries of the profession[18]. The three-stage evolution of artificial intelligence in architecture not only reflects the increasing complexity of tool forms, but more profoundly reconstructs the relationship between architects and technology. Its progression from "passive control" to "active collaboration," and ultimately to "co-construction of values," signals that architecture as a discipline is entering a new paradigm in the AI era, characterized by system-oriented design, semantic-driven processes, and ethical construction[19, 20].

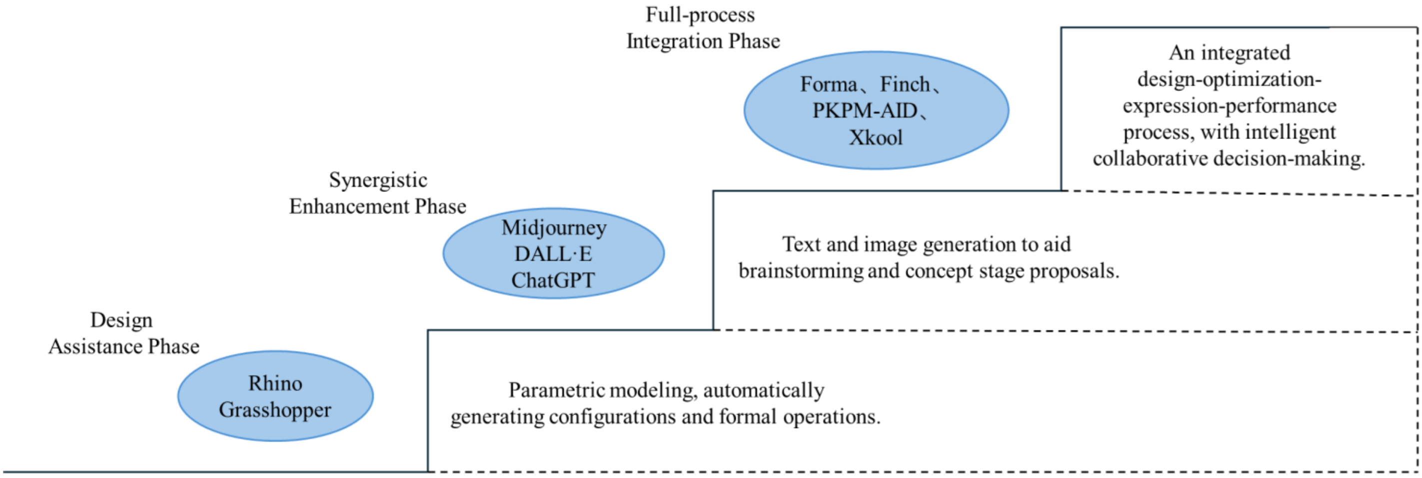


Figure 1. Development stages of AI integration into architectural design.

2.2. Reinventing the professional role of architects in the AI era

As AI becomes deeply embedded in the field of architecture, the traditional professional role of the architect is undergoing unprecedented challenges. Existing studies indicate that, under conditions where AI is extensively in-volved in design workflows [21], architects appear to be moving along two divergent trajectories: one is a path of marginalization, and the other is a path of dimensional elevation.

The marginalization path refers to the gradual replacement of architects' technical and repetitive functions by AI. Low-level tasks such as drawing production, preliminary scheme filtering, code compliance checking, and rendering can already be partially or even fully automated by platforms such as Finch, Spacely AI, and PKPM-AID. Liu Qingqing (2025) argues that the development of AI is turning the generation of a "good house" into a set of algorithmic templates, thereby compressing the depth of architects' involvement in the early conceptual stage [22]. Similarly, Wan Renwei et al. (2025) observe that in AI-assisted inspection of historic buildings, architects no longer determine the design path but instead act as back-end controllers of system logic variables [23].

By contrast, the dimensional elevation path suggests that AI does not erode the core value of architects; rather, it catalyzes a shift toward higher-level, composite roles in decision-making, integration, and ethical oversight. Feng Lujia (2025) proposes that the "AI + architecture" system is shaping a new professional matrix of "data mining + strategy definition + model control," promoting the transformation of architects from "draftspersons" to "collaborative governance designers" [24]. In landscape practice, Wu Bi (2025) similarly notes that architects intervene in AI generation mechanisms through prompt engineering, the guidance of cultural imagery, and corpus curation, thereby becoming curators of expressive direction rather than mere executors [25].

From a functional perspective, the architect's role within AI-assisted design can be summarised across three interrelated dimensions. Firstly, architects are progressively transitioning from form generators to creative directors, exercising directional control over AI outputs through prompt design, semantic framing, and conceptual guidance—particularly during conceptual generation and scheme exploration phases [26]. Secondly, as multi-platform and multi-model collaboration becomes standard practice, architects increasingly assume the role of system integrators. They coordinate data flows, parameter logic, and workflow sequences across different AI tools to ensure outputs align with regulations, performance requirements, and spatial contexts [27]. Thirdly, against the backdrop of expanding data-driven design and algorithmic decision-making, architects are entrusted with ethical oversight responsibilities. They must assess and rectify risks of bias within generative logic, evaluate cultural appropriateness, and gauge societal impacts [28].

These three dimensions do not represent a linear replacement relationship but operate concurrently across different design phases, constituting the composite competency structure of architects in the AI era. Comprehensive analysis indicates that AI possesses significant advantages in exhaustive search, rapid iteration, and performance optimisation, while architects remain irreplaceable in problem definition, contextual understanding, and value integration. This collaborative framework helps delineate the boundaries of human-machine capabilities and provides conceptual reference points for the transformation of architectural practice and education systems in the AI era (Table 1, Figure 2).

Meanwhile, the rise of AI ethics has re-empowered architects as "data supervisors" and "cultural mediators." Xu Zhou (2024) argues that, within intelligent sensing and interaction systems, architects must assume responsibility for the training logic of AI models, the biases in their feedback, and the consequences of their actions [29]. In his study on AI applications, Zhang Youguo (2022) similarly contends that the future of architectural design should take "local autonomy + cultural control" as core values to prevent global algorithmic systems from homogenizing spatial languages [30]. This implies that architects need multi-layered competencies in platform discernment, data correction, and cultural embedding, guiding technology toward greater publicness and diversity. AI is thus driving both a "functional reconfiguration" and a "competence reconfiguration" of the architect's role. The shift from tool operation to logical orchestration, and from visual judgment to ethical supervision, positions architects as strategic hubs within AI systems. This trend not only reshapes the internal knowledge structure of architecture, but also poses new challenges for architectural education, professional ethics, and standards of collaboration.

Table 1 Third-tier role reconstruction path

Role	Original identity	AI-era identity	Core competency requirements
Creative leader	Formal stylist, conceptual designer	Semantic director, semantic navigator	Prompt engineering, contextual control, image interpretation
Systems integrator	Draftsperson, technical illustrator	Platform orchestrator, workflow coordinator	Parameter configuration, cross-platform collaboration, construction of technical logics
Ethical supervisor	Aesthetic judge, narrative constructor	Value gatekeeper, cultural steward	Ethical evaluation, corpus governance, design of co-creation and negotiation mechanisms

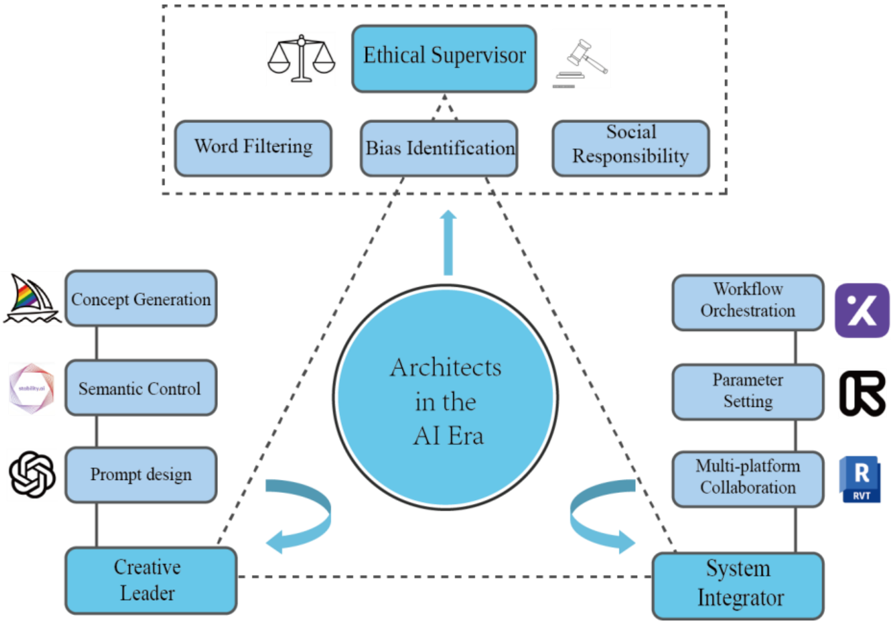


Figure 2. Triple Evolution Path Diagram of the Architect Role

3. Research Methodology

3.1. Research Framework and Methodological Approach

To systematically examine the evolution of architects' professional roles and human-machine collaboration mechanisms within the context of artificial intelligence intervention in architectural design, this study adopts a systematic literature review as its primary research methodology. Compared to conventional narrative reviews, systematic reviews employ explicit search strategies and screening protocols to mitigate researcher bias, rendering them more suitable for structured analysis of cross-technological and interdisciplinary topics. Accordingly, this study adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to establish a structured process for literature retrieval, screening, and analysis.

The primary focus of this study is not a comprehensive evaluation of artificial intelligence algorithms or tech-nical performance, but rather the structural impacts arising from the deep integration of AI within architectural design processes. Specifically, it examines the effects on the architect's role, design responsibilities, and collabora-tive models. Consequently, the literature screening criteria were defined around the interrelationship between ‘technological intervention,’ ‘design stages,’ and ‘architect's role,’ ensuring the research samples align with the pa-per's central argument.

3.2. Literature Search Strategy and Scope Definition

The literature search was conducted using the Web of Science Core Collection database. This database possess-es high academic authority and broad coverage in architecture, engineering, and interdisciplinary research, making it suitable as the primary data source for this systematic review. The search employed a topic-based (TS) approach, constructing a reproducible query by integrating core elements such as AI technology types, architectural design contexts, and the architect's role and collaborative relationships.

The specific search strategy was set as:

TS = (‘artificial intelligence’ OR ‘generative AI’ OR AIGC OR ‘machine learning’ OR ‘large language model’)

AND (‘architectural design’ OR ‘design process’ OR ‘design workflow’)

AND (architect OR ‘professional role*’ OR ‘human–AI collaboration’ OR ‘co-creation’ OR ‘design decision*’ OR ethic*)**

Document types were restricted to Articles and Reviews, with language limited to English. The timeframe was defined as 2019–2025 to encompass generative AI's progression from early exploration to systematic application within architectural design. Initial retrieval yielded multiple records, subsequently processed to eliminate duplicates.

3.3. Literature Screening and Analysis Process

During the literature screening phase, this study adhered to the PRISMA 2020 systematic review protocol, em-ploying a phased, multi-tiered screening methodology to ensure high relevance and theoretical validity of the liter-ature sample to the research topic. Initially, an initial literature sample was obtained through the Web of Science Core Collection. A preliminary screening was conducted at the title and abstract level, focusing on excluding liter-ature types with low relevance to architectural design research. This included studies primarily concerning traffic engineering, energy systems, medical applications, or pure algorithmic performance optimisation. Following this preliminary screening, research related to architectural design, generative artificial intelligence, and hu-man-machine collaboration was retained for the next stage.

Subsequently, full-text reading and eligibility assessment were conducted on the retained literature, further excluding studies lacking substantive engagement with architectural design decision-making processes, architect participation mechanisms, or human-machine collaborative relationships. This screening phase ultimately yielded the core literature sample for systematic analysis. The entire literature screening process and sample size evolution were documented and presented according to the PRISMA 2020 flow diagram (Figure 3), ensuring research reproducibility and methodological transparency.

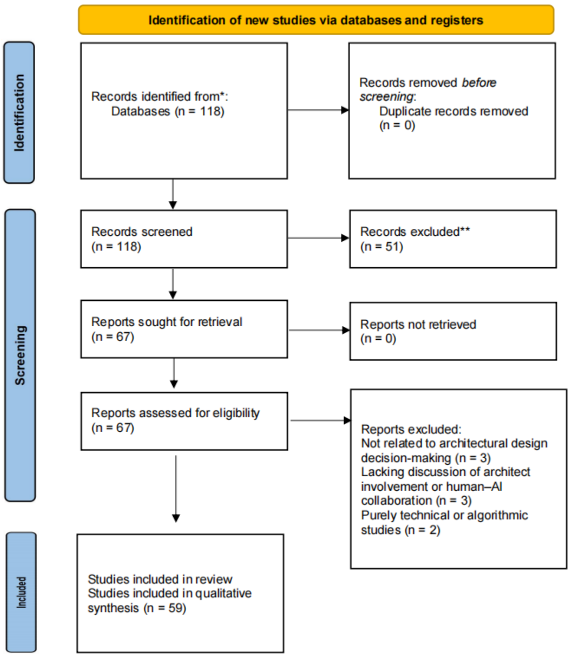


Figure 3. Screening process of literature for review

During the literature analysis phase, this study employed a combination of qualitative induction and structured analysis methods to systematically code and organise the selected literature across three dimensions: (1) the types of stages at which artificial intelligence intervenes in the architectural design process and the underlying technological paradigms; (2) the role positioning, decision-making approaches, and evolving characteristics of architects within AI-assisted design environments; (3) The influence mechanisms of human-machine collaboration models on design value construction, responsibility allocation, and ethical issues. Building upon this, the study further integrates the literature analysis findings with exemplary practice cases to refine and construct a three-tiered structural framework for the ‘AI–Architect Collaboration Model’. This framework elucidates the intrinsic logic underpinning architects' transformation from ‘creative generators’ to ‘system integrators’ and ‘ethical supervisors’ in the AI era.

4. Construction of an AI–Architect Collaborative Workflow

Artificial intelligence is evolving from a peripheral auxiliary tool into a collaborative agent embedded throughout the entire architectural design process. The relationship between architects and AI is no longer a one-way “user–tool” control model, but is gradually developing into a multidimensional “human–machine–task” interaction network, within which role responsibilities, framework logics, and decision boundaries must be clearly defined at each stage. Building on the preceding discussion of the architect’s role reconstruction, and through a synthetic analysis of the key points at which AI intervenes in architectural design, this paper proposes an “AI–Architect Collaborative Workflow Framework.”

4.1 Construction of the AI Collaboration Framework

Starting from the structure of the design workflow, this study constructs the collaborative relationship between architects and AI across three functional layers (Figure 4): (1) Concept Generation and Semantic Control Layer (Prompt Layer):AI is responsible for producing preliminary visual sketches, conceptual texts, and spatial atmospheres that constitute the initial design language, drawing on existing corpora in response to user prompts. The architect’s role is to lead semantic conception and keyword formulation, to steer the cultural orientation, functional appropriateness, and aesthetic coherence of generated images and texts, and to continuously refine prompts (prompt tuning). (2) Logic Integration and Parameter Steering Layer (Logic Layer):AI is tasked with performing functional layout, structural analysis, thermal and energy simulations, and related operations within specific platforms (e.g., Forma, PKPM-AID, Finch), enabling automated multi-scheme iteration. The architect is responsible for inputting decision parameters (such as plot indicators, development objectives, unit-type ratios, ventilation paths, etc.), validating AI’s internal logic, and mediating trade-offs among competing objectives. The architect also leads model selection and the prioritization and scheduling of different computational tasks. (3) Corpus Governance and Ethical Oversight Layer (Ethics Layer):AI is responsible for executing instructions and automatically optimizing generated outcomes, but it has no capacity for autonomous ethical judgment. Architects, by contrast, are responsible for selecting and curating training data sources, monitoring cultural bias, and safeguarding contextual expression. In public projects involving AI, architects additionally bear the responsibility for explanation and communication, and they take the lead in reviewing the legitimacy and reasonableness of value choices embedded in AI-assisted design.

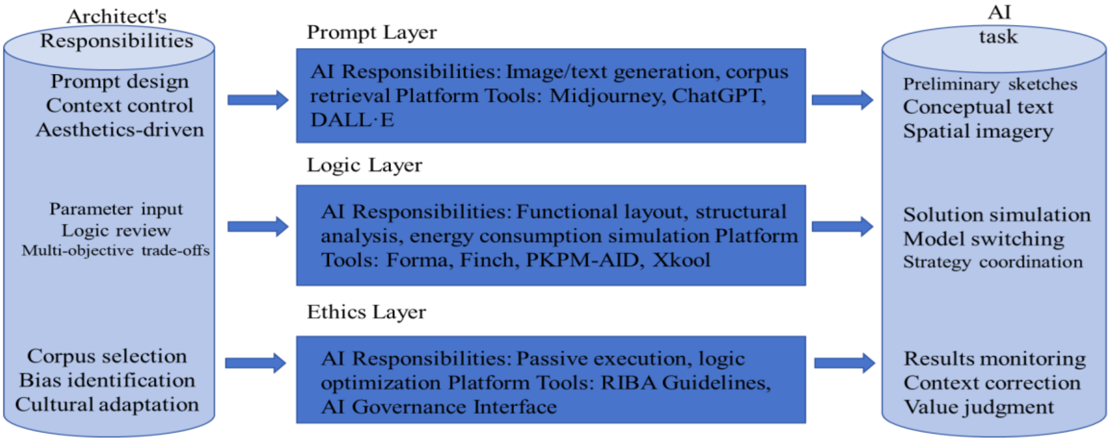


Figure 4. Three-layer architecture of the AI–architect collaborative model

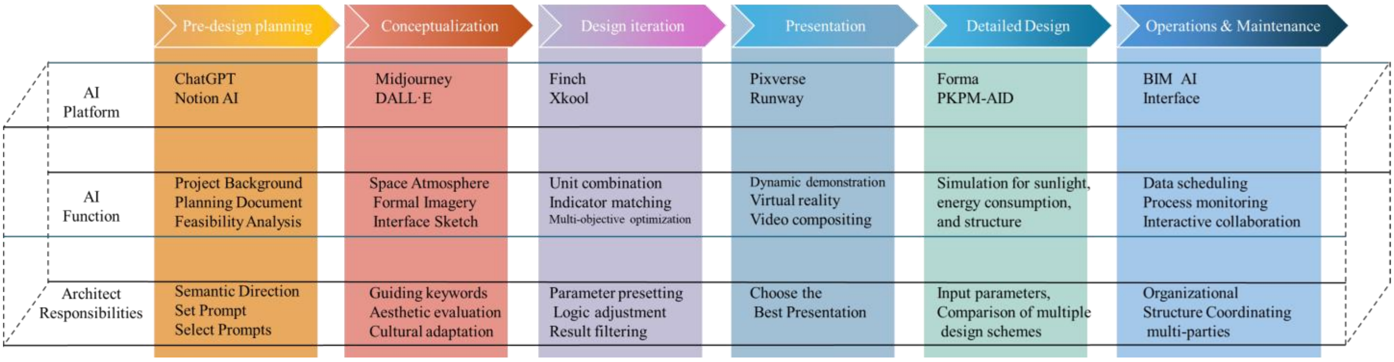
4.2 AI Collaborative Design Workflow

Building on the three-layer framework described above, this study develops an AI-assisted collaborative design workflow that spans early-stage planning, concept generation, scheme iteration, technical development, representational output, and project delivery and management (Figure 5). In the early planning stage, tools such as ChatGPT and Notion AI are introduced to support functional programming narratives, feasibility analyses, and the structuring of project background information. Architects lead decision-making by formulating semantic directions, setting prompts, and selecting valuable AI-generated outputs.

In the concept generation stage, Midjourney and DALL·E are employed to produce spatial atmosphere images, formal impressions, and interface sketches, while architects guide keyword inputs, conduct aesthetic evaluation, and ensure cultural appropriateness. During the scheme iteration stage, multiple scheme-generation tools are used to achieve horizontal comparison among alternatives. For example, Finch and Xkool AI can be applied to unit aggregation, indicator matching, and multi-objective optimization, with architects organizing and managing the evolution of multiple schemes through parameter presetting, logical adjustment, and result filtering.

In the technical development stage, AI-based building performance simulation tools are used to evaluate design performance. Platforms such as PKPM-AID and Forma simulate and recommend schemes based on daylight, energy consumption, and structural performance. Architects are responsible for controlling the input conditions of the simulation models and collaborating with structural and MEP engineers to validate the schemes.

In the representational output stage, AI-driven visual tools enable multiscale and multimodal presentation of design schemes. For instance, Pixverse and Runway can be used to generate dynamic presentations, construct virtual reality environments, and synthesize videos, while architects define representational intentions and select outputs that align with spatial logic and narrative style. Finally, in the project delivery and operation–maintenance stage, BIM–AI interfaces support design data orchestration, construction process monitoring, and collaboration via interactive platforms. In this phase, architects take the lead in configuring organizational structures and coordinating collaborative workflows among multiple stakeholders.



	Pre-design planning	Conceptualization	Design iteration	Presentation	Detailed Design	Operations & Maintenance
AI Platform	ChatGPT Notion AI	Midjourney DALL·E	Finch Xkool	Pixverse Runway	Forma PKPM-AID	BIM AI Interface
AI Function	Project Background Planning Document Feasibility Analysis	Space Atmosphere Formal Imagery Interface Sketch	Unit combination Indicator matching Multi-objective optimization	Dynamic demonstration Virtual reality Video compositing	Simulation for sunlight, energy consumption, and structure	Data scheduling Process monitoring Interactive collaboration
Architect Responsibilities	Semantic Direction Set Prompt Select Prompts	Guiding keywords Aesthetic evaluation Cultural adaptation	Parameter presetting Logic adjustment Result filtering	Choose the Best Presentation	Input parameters, Comparison of multiple design schemes	Organizational Structure Coordinating multi-parties

Figure 5. Framework of the AI collaborative design workflow

4.3 Definition and Control of AI Task Boundaries

To prevent the “black-box” intrusion of AI into the logic of architectural creation, this study emphasizes that architects should clearly define three categories of collaborative boundaries:(1) Content boundary: AI may assist in generating images and design suggestions, but it cannot substitute for cultural judgment, ethical choice, or the assumption of social responsibility;(2) Process boundary: AI can accelerate design exploration and option filtering, but the implementation of any scheme still requires empirical validation and final decision-making by architects;(3) Value boundary: AI exhibits a pronounced preference for efficiency and functional optimization, whereas architects must safeguard the publicness of urban space, historical continuity, and social diversity.

In response to these boundaries, architects need to develop three core competencies:(1) Prompt design capability: mastering AI generation logics and the control of keywords in order to construct robust language–space mappings; (2) Process control capability: coordinating across platforms, managing parameters, switching between models, and reviewing outputs;(3) Ethical governance capability: understanding corpus bias, platform mechanisms, and social orientations, and assuming responsibility for the value propositions embedded in AI-assisted design.

Beyond efficiency gains, the reliability and risks of AI-assisted architectural design require critical examination. Practical testing indicates that current generative AI systems often exhibit limitations in geometric accuracy, regulatory alignment, and representational realism, with optimisation-driven generation contributing to design homogenisation. In addition, AI tools may embed latent compliance risks when relying on incomplete or context-insensitive regulatory datasets.From a governance perspective, platform ownership and algorithmic opacity restrict architects' ability to audit decision logic, training data composition, and responsibility attribution in cases of design error. As a result, architectural expertise remains indispensable for validating assumptions, interpreting uncertainty, and mediating between optimisation outputs and contextual, cultural, and social constraints.These limitations underscore the necessity of clearly defined task boundaries within AI–architect collaboration, positioning AI as a probabilistic exploration mechanism rather than an autonomous decision-maker. Sustained human oversight is therefore essential to ensure that technological efficiency does not supersede architectural responsibility.

5. AI-Assisted Architectural Design: Practice Cases

Against the backdrop of deepening generative artificial intelligence technology, the collaborative mechanisms between architects and AI no longer remain confined to replacing single stages or functions, but instead form co-creation mechanisms across multiple process nodes. To further validate the adaptability of the three-tier role model—'Creative Leader—System Integrator—Ethical Supervisor'—this section conducts empirical analysis using representative case studies. Regarding case selection, this paper does not aim for exhaustive coverage of AI-assisted architectural design practices. Instead, it selects representative samples based on the principles of 'role typicality' and 'collaborative mechanism readability'. Specifically, case screening primarily adheres to the following three criteria: (1) AI has substantively intervened in critical decision-making stages within the design process, rather than being used solely for visualisation or post-rendering; (2) Architects retain explicit judgement and control authority throughout AI participation, demonstrating human-machine collaboration; (3) Practices are verifiable through public literature, platform reports, or project exhibitions. Based on these criteria, this paper examines three representative role pathways: experimental explorations by international architectural firms, process-oriented applications by Chinese AI platforms, and collaborative practices applied to real projects.

5.1 Regenerating "Stylistic Cognition" via Deep Neural Networks

The Austrian architectural firm Coop Himmelb(l)au has explored the use of deep neural networks to reconstruct its architectural stylistic language through the "Deep Himmelblau" project, embedding the trained model directly into the conceptual design process. The architects fed the firm's historical design drawings, model photographs, and project texts into a generative network, guiding the AI to produce thousands of sketch-like images, from which they then selected and manually refined a subset of design intentions (Figure 6). This experiment opens up a new pathway for reconfiguring stylistic cognition, transforming AI from a mere imitator of form into a feedback mechanism within the architectural design language generation system.

In this process, the architects act both as guides for prompt input and as interpreters of semantic output. The case demonstrates that architects still occupy the core position of creative control in the AI-based image generation stage, serving as the primary agents of "semantic empowerment" rather than passive followers of machine-driven aesthetics. It is worth noting that the architectural imagery generated by Coop Himmelb using deep neural networks remains highly abstract, such abstract visuals can only serve as reference material for architects during conceptual design, and they still fall far short of commercial-grade architectural renderings.

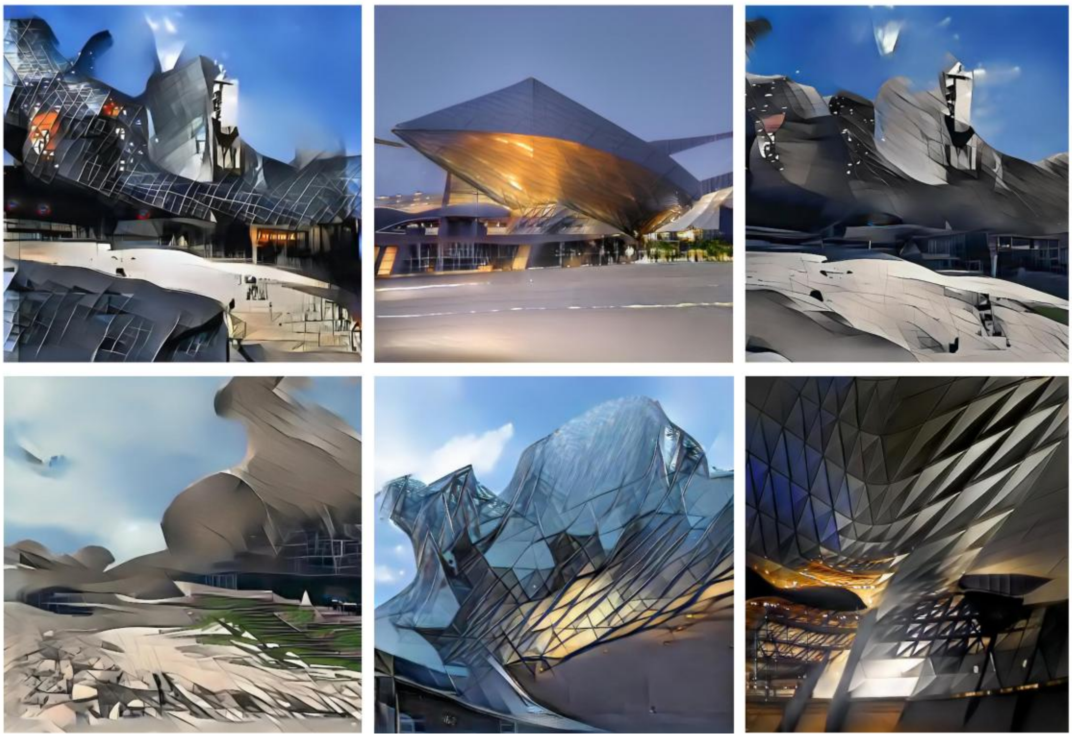


Figure 6. Research example of artificial intelligence applied to façade design: Coop Himmelb(l)au (source:[31])

5.2 Workflow Optimization and Human–AI Co-Creation under a Gray-Box Mechanism

As a representative example of the intelligent transformation of China's architectural design industry, the Xkool AI platform has developed a human–AI co-creation model based on a "gray-box mechanism." In real projects, architects input parameters such as plot indicators, development constraints, and unit types, upon which the system automatically generates multiple functional layout schemes and unit-aggregation configurations. At the same time, the platform retains access to intermediate variables and adjustable parameters, enabling architects to modify logical rules at any time and "back-trace" the generation pathways.

Taking residential district design as an example, Xkool AI assists in multiple rounds of scheme iteration, including unit-type adaptation, circulation optimization, and daylight simulation (Figure 7), while architects maintain primary decision-making authority by filtering system outputs and steering semantic intent[32]. This case shows that AI is no longer merely an "assistant" to the designer, but a "co-creator" within a collaborative ecosystem formed together with architects. In addition, by visualizing its generative logic, the platform endows architects with a structured capacity to control–interpret–reconfigure the system, thereby concretely embodying the practical transformation toward the role of "systems integrator." However, Xkool AI's outputs may still exhibit a degree of solution homogenization and "template-like" bias under similar constraints, and code compliance and constructability typically require substantial manual verification and refinement.

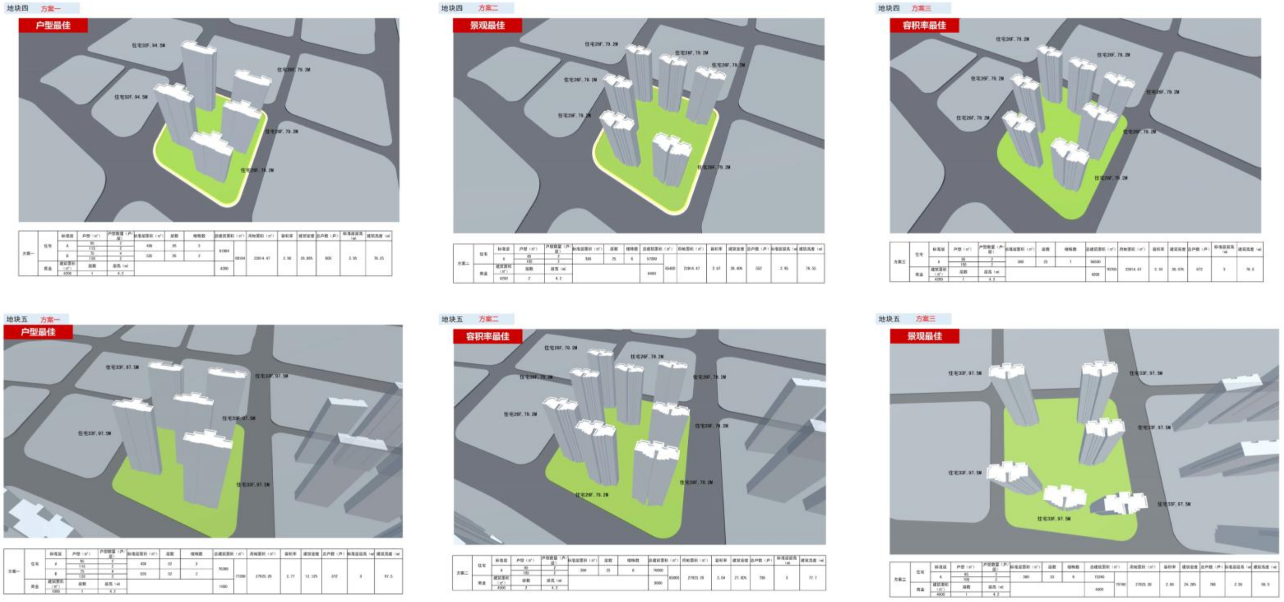


Figure 7. Xkool Design Cloud: An integrated intelligent cloud platform for architectural design (source: https://www.xkool.ai/)

6. Discussion: Architectural Education and Institutional Responses in the AI Era

The deep embedding of artificial intelligence into architectural design workflows poses structural challenges to existing systems of architectural education and professional regulation. At present, most architecture schools still organize their curricula around the traditional triad of "aesthetics," "function," and "safety," with architectural design studio at the core, while failing to systematically incorporate key competencies such as AI tool operation, understanding of algorithmic logic, and ethical awareness. To respond to this transformative trend, it is urgently necessary to develop a comprehensive strategy along three dimensions: the restructuring of curricula, the construction of new collaboration mechanisms, and the strengthening of ethical codes and governance frameworks.

6.1 Curriculum Restructuring: Integrating Technology and Design Logic

At the curricular level, architecture programs should establish interdisciplinary course modules that promote deep integration between AI tools and the architectural knowledge system. Specifically, Prompt Engineering can be introduced as a foundational course, focusing on how to craft prompts with clear spatial semantics and stylistic orientation in order to effectively control AI-generated outputs. Building on this, a course on AI and Spatial Logic may be offered to analyze the coupling between AI and architectural composition from perspectives such as site semantics, architectural language, and corpus bias, thereby helping students understand the spatial logics and technical mechanisms underlying generative results.

In parallel, a Multimodal Design Tools Studio could incorporate coordinated use of platforms such as Midjourney, ChatGPT, Forma, Finch, and Runway into a unified teaching framework, strengthening students' capacity for "human–machine co-operation" across different tools. In addition, a course on AI Data Literacy and Ethics should guide students to engage with issues such as dataset provenance, bias identification mechanisms, and algorithmic transparency, enhancing their sensitivity to the boundaries of technological application and its broader social impacts.

Through the coordinated construction of these course clusters, a triadic pedagogical system of "algorithmic understanding–spatial control–ethical governance" can be formed, thereby supporting the transformation of architectural education toward a composite talent model that integrates technical proficiency, strategic thinking, and value-oriented judgment.

6.2 Construction of Collaboration Mechanisms: Institutional Embedding of AI Usage Norms

At the level of collaboration mechanisms, rules governing the use of AI should be systematically embedded into professional standards and institutional frameworks, so as to construct a supervisory mechanism for AI–architect collaborative workflows. First, it is necessary to clarify, at the regulatory level, the ownership of design outcomes produced within AI-assisted workflows and the allocation of responsibility for AI-generated content, thereby defining the rights and obligations of different stakeholders when using AI tools. Second, an "AI–human collaboration" review mechanism should be established in architectural assessment procedures, specifying who has interpretive authority over AI-generated results and how much weight human intervention carries, so as to ensure that critical judgments remain in the hands of professionally qualified architects.

At the same time, large firms and design platforms should be encouraged to implement AI operation transparency logs, recording and archiving key operations and decision nodes to make collaborative workflows traceable and auditable. On this basis, the effectiveness of AI use can be incorporated into architectural quality evaluation systems—for example, by adding indicators such as the "reasonableness of AI decision pathways" under the dimension of technological innovation—to assess the combined performance of design outcomes in terms of technical application and decision transparency. Such institutional arrangements help safeguard architects' "decision sovereignty" within the design process and promote the standardized development of AI-assisted collaborative design under a controllable and regulable framework.

6.3 Strengthening Ethical Codes: Guiding Value-Oriented Innovation

At the ethical level, particular attention should be paid to the value-related and risk-related issues accompanying the application of AI in architecture, so as to prevent the apparent "neutrality of technology" from obscuring its potential negative impacts. We recommend that professional associations take the lead in formulating Ethical Guidelines for AI Use in the Architectural Profession, setting out operational and enforceable standards of conduct. On the one hand, such guidelines should clarify mechanisms for disclosing the sources of AI corpora and the processes of model training, thereby enhancing the transparency of data and algorithms through information disclosure. On the other hand, they should strengthen early-warning and corrective mechanisms for algorithmic bias and for the formal homogenization driven by image-oriented generation, preventing AI from amplifying existing prejudices or weakening architectural diversity and local specificity.

At the same time, it is necessary to establish an evaluative framework for the value implications of AI in public-building design, incorporating cultural, social, and ecological dimensions into technical assessment systems, so as to prevent technological logics from overriding public interests and environmental needs. In this process, architects should be encouraged to consciously assume the professional responsibilities of "cultural gatekeepers" and "social translators" when using AI, situating technological innovation within an explicit value orientation. Through institutionalized ethical safeguards, architects can be supported in simultaneously acting as technology users, collaborative mechanism designers, and guardians of values in the AI era, thereby guiding architectural innovation toward more responsible and sustainable directions.

7. Conclusion

Based on systematic retrieval from the Web of Science Core Collection database and standardised screening according to PRISMA guidelines, this paper systematically reviews research progress on AI intervention in architectural design within defined temporal parameters and explicit inclusion criteria. It conducts a comprehensive analysis centred on the transformation mechanisms of the architect's professional role. The study first traces the evolutionary trajectory of AI technologies in architectural design, subsequently proposing three directions for the architect's role redefinition amidst deep AI integration. further constructing an ‘AI–Architect Collaborative Model’ across three dimensions: collaborative architecture, design processes, and task boundaries. The model's practical applicability was validated through case studies of exemplary implementations.

Findings indicate that artificial intelligence has not supplanted architects' professional standing, but rather catalysed a structural transformation of their role within the reconfigured design process. Architects are transitioning from “creative labourers” centred on drawing production and form generation towards composite knowledge entities possessing strategic construction, systemic organisation, and value judgement capabilities. Whilst generative AI, parametric platforms, and intelligent collaborative systems significantly enhance design efficiency and reshape design logic, architects retain irreplaceable leadership in critical domains such as contextual understanding, cultural expression, value balancing, and ethical decision-making.

Furthermore, the proposed ‘AI–Architect’ collaborative framework demonstrates that architects' professional functions in the AI era can be synthesised into a tripartite system comprising ‘Creative Leader,’ ‘System Integrator,’ and ‘Ethical Supervisor.’ This role structure is not a linear substitution but dynamically manifests through collaborative embedding across different design phases. Case studies demonstrate that this framework possesses reasonable explanatory power and operational feasibility in real-world projects, providing empirical support for understanding the redistribution of architectural decision-making authority under human-machine collaboration. It should be noted that while the aforementioned case studies provide a relatively clear illustration of the evolving role of architects within AI-assisted design, their analysis inevitably carries a degree of subjectivity and selective bias. On the one hand, the cases predominantly originate from publicly showcased or experimental, cutting-edge project practices, where collaborative outcomes and role divisions are to some extent influenced by the researcher's interpretative perspective. On the other hand, variations in AI application depth, organisational structures, and institutional environments across different practices, platforms, or project types may result in more complex or overlapping manifestations of the architect's role. Consequently, the three-stage role model summarised herein should be understood as an ‘analytical framework’ grounded in existing literature and practice, rather than an exhaustive description of all AI-assisted architectural design practices. Future research may further test the applicability and boundary conditions of this model through empirical investigations, interviews, or quantitative analyses involving larger sample sizes.

Building upon this, the study contends that architectural education and industry systems urgently require corresponding adjustments. Architectural education should systematically incorporate the cultivation of AI-collaboration competencies, including prompt control, cross-platform coordination, and ethical evaluation literacy. At the industry level, governance should shift from singular tool usage regulations towards institutional frameworks focused on collaborative mechanisms and responsibility allocation, thereby establishing an intelligent design ecosystem that balances technological efficiency with value orientation.

It should be noted that, constrained by systematic review methodologies and data sources, this analysis primarily draws upon peer-reviewed journal literature. While supplemented by representative practice cases, it does not comprehensively incorporate rapidly proliferating industry reports and non-peer-reviewed materials. Consequently, conclusions remain subject to limitations imposed by sample scope and literature selection. Future research may integrate larger-scale cross-database datasets, quantitative metrics analysis, or long-term project tracking studies to conduct more in-depth validation of the dynamic evolution of AI–architect collaboration mechanisms.

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Informed Consent Statement: Any research article describing a study involving humans should contain this statement. Please add "Informed consent was obtained from all subjects involved in the study." OR "Patient consent was waived due to REASON (please provide a detailed justification)." OR "Not applicable." for studies not involving humans. You might also choose to exclude this statement if the study did not involve humans.

Written informed consent for publication must be obtained from participating patients who can be identified (including by the patients themselves). Please state "Written informed consent has been obtained from the patient(s) to publish this paper" if applicable.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

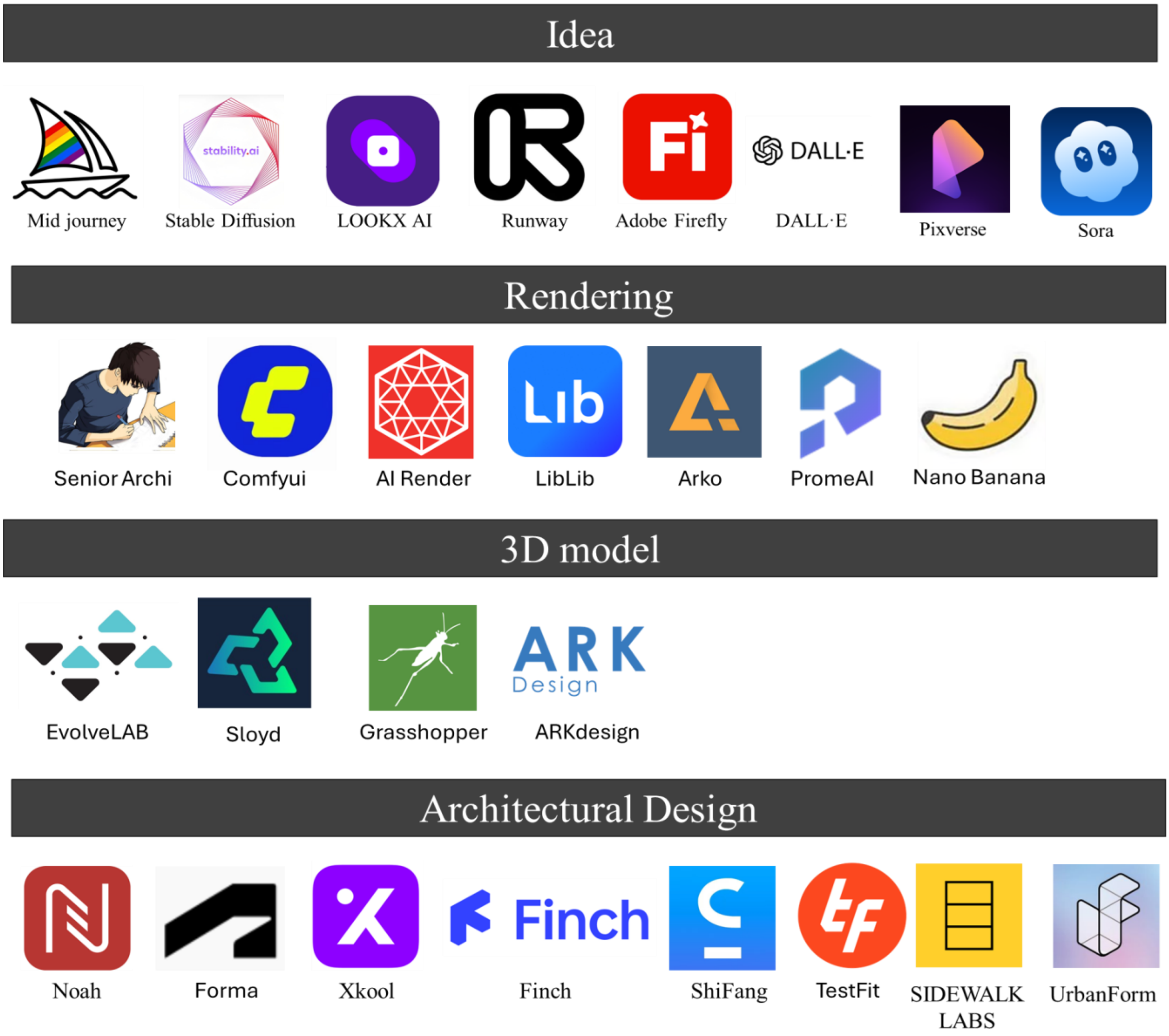

Figure A1. AI platforms related to architecture

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