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Exploring the Integration of Artificial Intelligence in Co-Design Framework for Designer

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Abstract
This study explores the integration of AI into the co-design process, emphasizing how AI can enhance collaboration between designers and stakeholders. Key areas include autonomous navigation, intelligent systems, and trajectory optimization, which can boost creativity, streamline workflows, and improve decision-making. A literature review of 20 papers reveals that AI can act as a collaborative agent, automating routine tasks, providing real-time feedback, and fostering creative exploration. However, challenges remain in maintaining human-centered design values and preserving designers' agency. Future research should develop AI tools that support co-design dynamics and address ethical concerns in creative fields.

Keywords: Artificial Intelligence (AI); design; co-design

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1.0 Introduction

The rapid development of artificial intelligence (AI) has altered several industries, including design, where it is rapidly being integrated into collaborative frameworks such as co-creation. Co-design, which incorporates the active engagement of designers and stakeholders in the creative process, has traditionally been based on human intuition, creativity, and communication skills (Guo, 2023a). However, advancing AI technologies, particularly in sectors such as autonomous navigation, intelligent systems, and trajectory optimization, opens up new chances to improve and change these collaborative efforts.

AI's position in design has evolved from a tool for efficiency to a collaborator in creativity (German et al., 2019). Autonomous navigation, for example, enables designers to explore large design environments that would otherwise be too difficult or time-consuming to research manually. Intelligent systems, with their ability to analyze vast datasets and deliver real-time insights, can help designers make more informed decisions, eliminating the trial-and-error method that is commonly associated with creative processes (Edmonds,

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2020; German et al., 2019; Tedre et al., 2023). Meanwhile, trajectory optimization provides new approaches for optimizing processes, guaranteeing that design activities are accomplished more precisely and efficiently.

Despite these advances, the use of AI in co-design is still underexplored, notably how AI might assist designers without weakening their creative independence(Hao et al., 2021; Malik et al., 2022). This research addresses this gap by conducting a comprehensive literature review on integrating AI inside co-design frameworks. This study will analyze 20 papers, fifteen from the Scopus database and five from Research Rabbit, to address the fundamental research question: "How is AI integrated into the co-design process for designers?"

This study's findings will help deepen our understanding of AI's potential in co-design and provide insights into how designers might use AI to improve creativity, collaboration, and efficiency while keeping the human-centered character of the design process.

2.0 Literature Review

The design landscape is rapidly evolving with Artificial Intelligence (AI) integration, offering both transformative potential and significant challenges. Co-design, or participatory design, involves stakeholders throughout the design process to create solutions tailored to users' needs (Hussaini et al., 2024; Zhang et al., 2024). AI's role in enhancing co-design frameworks is a growing area of research, providing improved collaboration, feedback mechanisms, and innovative solutions. However, challenges must be addressed to realize AI's potential in this space fully.

AI has transformed industries by automating tasks, improving decision-making, and offering new insights. In design, it has been applied to generative design, UX enhancement, and design validation (Poduval et al., 2024; Yu et al., 2022), enabling designers to explore a broader range of possibilities (D. Chen et al., 2024; Seng & Ang, 2022). AI's data analysis capabilities make it an invaluable tool in co-design and enhancing stakeholder engagement. Additionally, predictive analytics helps forecast user preferences and guide design decisions (Hussaini et al., 2024; Largo & Pino, 2024).

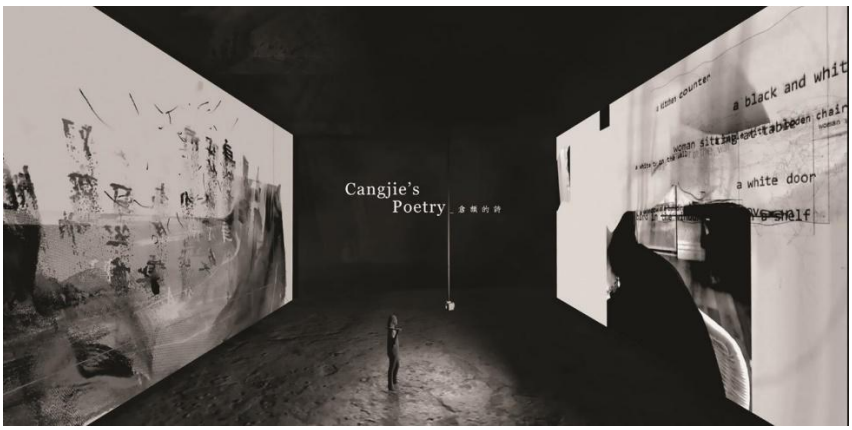

Fig. 1. A gallery mock-up view of the Cangjie's Poetry art installation.
(left) The first projection: Live streaming imagery writes new symbols.
(right) The second projection: Intelligent visual poetry describes surroundings.
(Source: Zhang et al., 2024)

Co-design emphasizes stakeholder collaboration, fostering a dynamic and iterative process. AI integration can enhance these efforts in several ways, enabling real-time collaboration where stakeholders interact with design concepts and provide instant feedback (German et al., 2019; Hao et al., 2021). Tools like Autodesk's Generative Design allow users to input preferences and explore multiple design options, promoting inclusivity and more effective participation (Du et al., 2022; Seng & Ang, 2022).

AI also enhances feedback systems by analyzing stakeholder data to identify patterns and emerging concerns. Natural language processing (NLP) tools can assess qualitative feedback, helping designers respond more effectively to stakeholder needs (D. Chen et al., 2024; Poduval et al., 2024). AI's ability to generate multiple design options supports the co-design's goal of exploring diverse perspectives (Bui & Alaei, 2022; Zhang et al., 2024).

However, challenges arise. Over-reliance on AI might diminish the human empathy central to co-design, while privacy and algorithmic bias issues must be addressed (Guo, 2023a; Tedre et al., 2023). Designers must also adapt to AI tools, requiring new skills and careful integration into established workflows (Malik et al., 2022).

Future research should explore how AI can enhance stakeholder interaction, balance human-centric co-design principles, and create adaptable design systems that respond to real-time feedback (D. Chen et al., 2024; González-Vélez et al., 2021). As AI evolves, addressing ethical concerns while preserving human creativity and collaboration will be crucial to its successful integration in co-design frameworks (Bui & Alaei, 2022; Guo, 2023a).

3.0 Methodology

In accomplishing a complete literature review survey, 76 documents were first discovered from Scopus and 10 from Research Rabbit, with a focus on publications published between 2020 and 2024 in the journal category. Using the search string TITLE-ABS-KEY ("Artificial Intelligence" AND " Arts" (art OR co-design)), the initial pool was reduced to 71 relevant articles.

The selection was then further refined by a comprehensive screening procedure. Articles with irrelevant titles, as well as abstracts and content that was inconsistent with the study's topic, were eliminated. Finally, 20 publications were found appropriate for in-depth analysis.

The articles chosen through this rigorous screening process represent extensive literature within the defined timeframe and conditions. The methodological approach, built on the search string and subsequent screening criteria, guaranteed that only relevant studies were included in the final analysis.

Based on Scopus, a renowned database, this survey approach provides a solid framework for researching the incorporation of artificial intelligence ethics. The refined selection of 27 publications provides a complete picture of the present research landscape, allowing for a nuanced investigation of the junction of artificial intelligence and art within the era chosen.

4.0 Findings

4.1. Autonomous Navigation

Integrating artificial intelligence (AI) into co-design frameworks, especially regarding autonomous navigation, has made notable progress across various fields. AI's ability to enable autonomy and assist human decision-making is a recurring theme. This discussion compares AI's application in spacecraft navigation, microwave filter design, human fall detection, and interactive art, drawing insights for co-design.

Hao et al. (2021) present a vision-based guidance, navigation, and control (GNC) system for spacecraft, emphasizing AI's role in real-time decision-making. AI enables spacecraft to navigate autonomously in unpredictable environments, reducing reliance on human control using deep learning (DL) and probabilistic modeling. In contrast, Yu et al. (2022) explore AI-driven automation in microwave filter design, which uses data-driven optimization to handle complex, dynamic conditions. Though these fields differ, both demonstrate AI's capacity to automate tasks traditionally managed by human expertise.

Bui and Alaei (2022) further illustrate AI's role in optimization by utilizing virtual reality (VR) to generate training data for fall detection algorithms, enhancing AI performance in data-scarce environments. This parallels AI's use in autonomous navigation, optimizing complex systems. Zhang et al. (2021) explore AI in interactive art, where AI autonomously writes and interprets poetry, symbolizing AI's potential in co-design. AI can collaborate creatively with designers, offering new ideas through autonomous interpretations.

These studies show AI's transformative potential in enabling real-time, autonomous decision-making, from spacecraft navigation (Hao et al., 2021) to electromagnetic filter design (Yu et al., 2022). However, full AI autonomy remains a challenge. Hao et al. (2021) note that fully autonomous space systems are still years away, and Guo (2023a) highlights designers' concerns about AI's ambiguous role in creativity, which could complicate co-design processes.

In conclusion, AI's integration into co-design frameworks aligns with broader trends in enhancing autonomy and optimizing complex tasks. The future of AI in co-design lies in balancing human creativity with AI autonomy, making AI a co-creation partner rather than a replacement. Ongoing research will continue to shape how designers work with AI, fostering collaboration between human and machine creativity.

4.2. Intelligent Systems

Integrating Artificial Intelligence (AI) into co-design frameworks transforms design by enhancing decision-making, optimization, and efficiency. Research highlights how intelligent systems empower designers and engineers in complex domains, particularly in cloud and edge computing. This paper synthesizes key ideas from various studies to explore the implications of AI for co-design.

Seng and Ang (2022) discuss the growing complexity of AI installations in cloud and edge devices, where embedded intelligence (EI) supports automation in IoT and mobile applications. This approach emphasizes adaptability and scalability, especially in Industry 4.0 environments. Similarly, Du et al. (2022) examine the computational efficiency of AI in deep learning tasks using Deep Learning Processing Units (DLPUs), achieving a significant speed boost and energy savings, thus optimizing tasks requiring high computational power and real-time decisions.

Zhang et al. (2024) introduce ReCollection, an AI-powered art installation that fosters non-linear storytelling and community memory through visual inputs, emphasizing empathy and inclusivity in the design process. This contrasts with more technical applications by focusing on emotional and social engagement in co-creation.

The comparison of these studies underscores AI's adaptability across various applications. While Seng & Ang (2022) focus on real-time processing in edge devices, Du et al. (2022) highlight performance improvements in deep learning, and Zhang et al. (2024) explore AI's impact on creativity and communal connections in design.

Though these applications differ—from industrial to artistic frameworks—AI consistently emerges as an enabler of efficiency, creativity, and collaboration. However, the autonomy and flexibility of these systems vary, with Seng & Ang (2022) focusing on distributed, high-performance systems, while Zhang et al. (2024) explore AI's role in enhancing human-machine interactions.

AI's co-design success relies on its ability to support creativity, optimize workflows, and enable real-time decision-making. Seng & Ang's (2022) EI approach emphasizes real-time processing in constrained environments, but integrating these systems into established frameworks poses scalability challenges. Du et al. (2022) highlight the performance benefits of DLPUs, but their specialized nature may

limit their use in smaller teams. Meanwhile, Zhang et al. (2024) argue that AI can foster deeper emotional and community connections in the design process.

AI's incorporation into co-design offers significant potential for enhancing technical and creative aspects. From embedded intelligence to DLPUs, AI systems boost efficiency, decision-making, and creative collaboration. However, careful consideration is needed to balance scalability, platform constraints, and the human elements of design. As AI evolves, co-design frameworks must ensure designers retain agency while leveraging AI's transformative power.

4.3. Trajectory Optimization

Trajectory optimization, a key focus of artificial intelligence (AI), is crucial in enhancing the efficiency of physical, digital, and operational systems. Its applications span diverse fields such as engineering, communications, cybersecurity, and environmental research. This article synthesizes AI-based trajectory optimization across these sectors, emphasizing its impact on co-design frameworks.

In J. Chen et al. (2023), AI optimizes well trajectories for directional drilling by evaluating the entire geological profile through a new metric, the Formation Evaluation Score (FES). This method enhances hydrocarbon extraction while balancing engineering constraints, offering a more comprehensive approach to trajectory design in complex geological settings.

Poduval et al. (2024) focus on AI-driven trajectory optimization in 6G communication networks, specifically for IoT devices. Their solution improves data transmission reliability and reduces energy consumption, showcasing AI's potential to optimize pathways in highly connected, noisy environments, vital for future networks like 6G.

J. Chen et al. (2023) also explore AI in network security through Generative Adversarial Imitation Learning-based Penetration Testing (GAIL-PT). This framework automates attack path generation, making vulnerability testing faster and more efficient than manual methods, underscoring AI's utility in optimizing cybersecurity.

In ecology, González-Vélez et al. (2021) demonstrate AI's ability to predict wildlife-vehicle collision hotspots using AI algorithms, geographic information systems, and multispectral imaging. This application shows AI's effectiveness in spatial trajectory optimization for environmental and conservation efforts.

Across these sectors, AI enhances trajectory optimization by improving efficiency, reliability, and decision-making. From geological well trajectories and communication networks to cybersecurity and wildlife conservation, AI's capacity to streamline design processes is transformative. As AI continues to evolve, its role in co-design frameworks will lead to more advanced, efficient systems across industries.

5.0 Discussion

AI in co-design frameworks has significantly increased autonomous navigation, allowing systems to function autonomously in complex and dynamic situations. AI-driven decision-making has become critical in many applications, from satellite navigation to digital simulations, enabling more efficient and real-time job optimization. By automating operations that formerly required human intervention, AI enables systems to adapt and respond to unexpected events, improving overall functionality and reliability.

In addition to its role in navigation, AI is important in intelligent systems that optimize designs and make decisions. These technologies, incorporated in cloud and edge computing, enable real-time processing and scalability, giving designers the tools to improve productivity in both technical and creative activities. AI contributes to more effective design outcomes by employing dedicated hardware for deep learning and other computationally demanding processes while also significantly improving speed and energy consumption.

Trajectory optimization is another crucial area where AI shows its value in co-design frameworks. Whether optimizing physical paths in industries such as drilling and network security or forecasting environmental patterns in wildlife research, AI allows for more exact and effective route design. AI refines these processes by examining broader factors and situations, improving overall system efficiency across multiple applications. This capacity to optimize paths within complicated, interconnected systems demonstrates AI's transformational influence in design and issue solutions.

6.0 Conclusion and Recommendations

To summarize, using artificial intelligence in co-design frameworks transforms the landscape of design and optimization across multiple disciplines. AI's ability to navigate autonomously, make intelligent decisions, and optimize trajectory improves efficiency and enables real-time adaptability in difficult surroundings. By automating formerly manual procedures, AI enables designers and engineers to do complex jobs with increased precision and speed. As AI evolves, its function as a collaborative tool in co-design will allow for more sophisticated and creative solutions, ensuring a future in which human inventiveness and machine intelligence operate seamlessly together.

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Paper Contribution to Related Field of Study

This paper advances design research by highlighting how AI enhances co-design processes while addressing challenges in maintaining human-centered values and ethics.

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