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AIGC-Empowered Logic-Driven Generative Framework for Chinese Classical Gardens: Bridging Cultural Semantics and Spatial Constraints

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1 Supplementary Materials of Methods

Supplementary Table 1: Introduction of different AI platforms

Platforms	Development company	Model	Positioning
ChatGPT 4.0	OpenAI	Generative Pretrained Transformer	A chatbot tool, driven by AI technology, is a natural language processing tool that can generate responses based on patterns and statistical regularities observed during the pre-training phase. It also interacts based on the context of the conversation and can complete tasks such as writing papers, emails, scripts, copy, translations, and code.
DALL-E	OpenAI	Discrete Variational Autoencoder (VAE)	Able to create extremely realistic and clear images from simple descriptions, mastering various artistic styles including illustration and landscapes.
Stable diffusion	Stability AI/Runway	Latent Diffusion Model (LDM)	Able to produce images that are both realistic and artistically styled, with the ability to generate images that rival real photographs and mimic the styles and techniques of professional artists.
LiblibAI	Beijing Singularity Star	LDM	It is a community platform focused on open-source AI models (such as Stable Diffusion), providing Chinese

	Universe Technology Co., Ltd.		users with easier access to download and use AI models.
Midjourney	Leap Motion	Conditional Generative Adversarial Network (CGAN)	Able to generate images based on user prompts, adept at creating any desired effect by adapting to real artistic styles, especially in fantasy, gaming, and science fiction scenes.

Supplementary Table 2: An example of prompt standardization from a structured template

Prompt component	**Standardized information**
Core concept	A corner of a Jiangnan private garden.
Main elements	A two-story wooden pavilion with a hip-and-gable roof, a stone arch bridge over a stream.
Spatial layout	Foreground is a lawn, midground features the pavilion and bridge, background shows misty mountains.
Art style/atmosphere	Ink wash painting style, serene and distant atmosphere, early morning mist.
Technical parameters	Wide-angle lens, ultra high detail, natural lighting, --ar 16:9.
Platform-adapted prompt for DALL-E 3	An image of a corner of a Jiangnan private garden. The scene features a two-story wooden pavilion with a hip-and-gable roof and a stone arch bridge over a stream. In the foreground is a lawn, the midground contains the pavilion and bridge, and the background shows misty mountains. The style should be that of an ink wash painting, conveying a serene and distant atmosphere with early morning mist. Use a wide-angle lens for an ultra-high detail shot with natural lighting and an aspect ratio of 16:9.
Platform-adapted prompt for Midjourney	A corner of a Jiangnan private garden, two-story wooden pavilion with hip-and-gable roof, stone arch bridge over a stream, lawn in foreground, pavilion and bridge in midground, misty mountains in background, ink wash painting style, serene, distant atmosphere, early morning mist, wide-angle lens, ultra high detail, natural lighting --ar 16:9.
Platform-adapted prompt for Stable Diffusion	Positive prompt: (masterpiece, best quality), a corner of a Jiangnan private garden, two-story wooden pavilion with hip-and-gable roof, stone arch bridge over a stream, lawn in foreground, pavilion and bridge in midground, misty mountains in background, ink wash painting style, serene, distant atmosphere, early morning mist, wide-angle lens, ultra high detail, natural lighting. Negative prompt: (worst quality, low quality), blurry, modern elements, people, text, watermark.

Supplementary Table3: The evaluation standards of AIGC platforms

Evaluation dimension	**Metric and method**	**Description and rationale**	**Success criterion**
Image quality and diversity	FID	Measures the distribution distance between generated and real image feature sets. Lower scores are better. It is the standard for	A significantly lower FID score compared with a baseline model or competing platforms.

		assessing generative model quality.	
Prompt-image semantic alignment	CLIP	Quantifies the semantic match between a text prompt and the generated image using the CLIP model. Higher scores are better.	An average CLIP score above a predefined threshold in tests involving specialized terminology.
Impact of design refinement	PSNR and SSIM	Measures the perceptual structural change between pre- and post-refinement images, quantifying the impact of modifications.	Their values correlate with the intended magnitude of design modification, with higher PSNR and SSIM indicating fine-grained adjustments and lower values corresponding to more extensive reconstruction.

Supplementary Table 4: Specific items of the SUS

Dimension	**Item**	**Statement**
Usability and efficiency	Q1	I found the overall workflow easy to understand and use.
	Q2	The collaboration between multiple AI platforms was logical and well integrated.
	Q3	Compared with traditional design tools, the workflow significantly improved my design efficiency.
	Q4	I was able to complete the design task smoothly without extensive additional learning.
Design support and effectiveness	Q5	The workflow effectively supported my conceptual thinking and design decisions.
	Q6	AI-generated outputs enabled rapid exploration of alternative design options.
	Q7	The workflow improved the overall completeness of the design outcome.
Spatial perception and experiential design	Q8	The generated images clearly conveyed spatial depth and layering.
	Q9	The workflow helped me perceive the courtyard as an experiential and navigable space.
	Q10	The generated results reflected changes in viewpoints during spatial movement.
	Q11	The workflow supported the expression of sequential spatial experience.
Cultural authenticity and semantic expression	Q12	The designs reflected key characteristics of Jiangnan private gardens.
	Q13	Garden elements were expressed in a culturally appropriate manner.
	Q14	The generated results conveyed a sense of cultural atmosphere.
User immersion and creative experience	Q15	I felt immersed in the design process when using the workflow.
	Q16	Interaction with AI enhanced my creative thinking.
	Q17	The workflow enabled design exploration beyond what traditional tools typically allow.
Overall satisfaction and added value	Q18	Overall, I am satisfied with the AIGC-assisted design workflow.
	Q19	The workflow provides clear added value compared with conventional design tools.
	Q20	I believe the workflow has strong potential for practical application and further development.

2 Supplementary Materials of Results

Supplementary Table 5: Evaluation of garden elements

Garden elements	Textual understanding	Visual understanding		
		Plan view	Elevation view	Bird's-eye and human view
Houses (屋宇)				
Menlou (门楼)	Yes	Yes	Yes	Yes
Tang (堂)	Yes	Yes	Yes	Yes
Zhai (斋)	Yes	Yes	Yes	Yes
Shi (室)	Yes	Yes	Yes	Yes
Fang (房)	Yes	Yes	Yes	Yes
Guan (馆)	Yes	Yes	Yes	Yes
Lou (楼)	Yes	Yes	Yes	Yes
Tai (台)	Yes	Yes	Yes	Yes
Ge (阁)	Yes	Yes	Yes	Yes
Ting (亭)	Yes	Yes	Yes	Yes
Xie (榭)	Yes	Yes	Yes	Yes
Xuan (轩)	Yes	Yes	Yes	Yes
Juan (卷)	No	No	No	No
Guang (广)	No	No	No	No
Lang (廊)	Yes	No	No	Yes
Wu jialiang (五架梁)	Yes	No	No	No
Qi jialiang (七架梁)	Yes	No	No	No
Jiu jialiang (九架梁)	Yes	No	No	No
Caojia (草架)	No	No	No	No
Chongchuan (重椽)	No	No	No	No
Mojiao (磨角)	Yes	—	Yes	No
Ditu (地图)	Yes	Yes	—	Yes
Decorations (装折)	Yes	No	Yes	Yes
Langan (栏杆)	Yes	No	Yes	Yes
Doors and windows (门窗)				
Doors	Yes	—	Yes	No
Windows	Yes	—	Yes	No
Walls (墙垣)				
Baifen qiang (白粉墙)	Yes	—	Yes	Yes
Mozhuan qiang (磨砖墙)	Yes	—	Yes	Yes
Louzhuan qiang (漏砖墙)	Yes	—	Yes	Yes
Luanshi qiang (乱石墙)	Yes	—	Yes	Yes
Ground Pavings (铺地)	Yes	No	Yes	Yes
Luanshi lu (乱石路)	Yes	Yes	—	Yes
Ezi di (鹅子地)	Yes	Yes	—	Yes
Binglie di (冰裂地)	Yes	Yes	—	Yes

Zhuzhuan di (诸砖地)	Yes	Yes	—	Yes
Rockeries (掇山)				
Yuanshan (园山)	Yes	No	Yes	Yes
Tingshan (厅山)	Yes	Yes	Yes	Yes
Loushan (楼山)	Yes	Yes	Yes	Yes
Geshan (阁山)	Yes	No	Yes	Yes
Shufangshan (书房山)	Yes	Yes	No	Yes
Chishan (池山)	Yes	Yes	Yes	Yes
Neishishan (内室山)	Yes	Yes	Yes	Yes
Qiaobishan (峭壁山)	Yes	No	Yes	Yes
Shanshichi (山石池)	Yes	Yes	No	Yes
Jinyugang (金鱼缸)	Yes	Yes	No	Yes
Feng (峰)	Yes	No	No	Yes
Luan (峦)	Yes	Yes	No	Yes
Yan (岩)	Yes	No	No	Yes
Dong (洞)	Yes	No	Yes	Yes
Jian (涧)	Yes	Yes	—	Yes
Qushui (曲水)	Yes	Yes	—	Yes
Pubu (瀑布)	Yes	No	Yes	Yes
Stones (选石)	Yes	No	Yes	Yes
Taihu stone (太湖石)	Yes	No	No	No
Kunshan stone (昆山石)	Yes	No	No	No
Yixing stone (宜兴石)	Yes	No	No	No
Longtan stone (龙潭石)	Yes	No	No	No
Qinglongshan stone (青龙山石)	Yes	No	No	No
Lingbi stone (灵璧石)	Yes	No	No	No
Xianshan stone (岘山石)	Yes	No	No	No
Xuan stone (宣石)	Yes	No	No	No
Hukou stone (湖口石)	Yes	No	No	No
Ying stone (英石)	Yes	No	No	No
Sanbing stone (散兵石)	Yes	No	No	No
Huang stone (黄石)	Yes	No	No	No
Jiu stone (旧石)	Yes	No	No	No
Jinchuan stone (锦川石)	Yes	No	No	No
Huashigang (花石纲)	Yes	No	No	No
Liuhe shizi (六合石子)	Yes	No	No	No

Supplementary Table 6: Evaluation of roof and accessory structure types

Types	**Textual understanding**	**Visual understanding**			
		Plan view	**Elevation view**	**Bird's-eye view**	**Human view**
Yudian (庑殿)	No	No	No	No	Yes
Xieshan (歇山)	Yes	No	Yes	Yes	Yes

Xuanshan (悬山)	Yes	No	No	No	No
Yingshan (硬山)	Yes	No	No	No	No
Cuanjian (攒尖)	Yes	No	Yes	Yes	No
Chongyan (重檐)	Yes	No	Yes	Yes	No
Danyan (单檐)	Yes	No	Yes	Yes	No
Qiji (起脊)	Yes	No	Yes	Yes	No
Juanpeng (卷棚)	No	No	No	No	No
Column (柱)	Yes	No	Yes	Yes	Yes
Kaijian (开间)	Yes	—	Yes	Yes	Yes

Supplementary Table 7: Evaluation of vegetation species

Species	**Textual understanding**	**Visual understanding**			
		Plan View	**Elevation View**	**Bird's-eye View**	**Human View**
Prunus mume	Yes	Yes	Yes	Yes	Yes
Cymbidium spp.	Yes	Yes	Yes	Yes	Yes
Bambusoideae	Yes	Yes	Yes	Yes	Yes
Chrysanthemum morifolium	Yes	Yes	Yes	Yes	Yes
Pinus spp.	Yes	Yes	Yes	Yes	Yes
Salix spp.	Yes	Yes	Yes	Yes	Yes
Nelumbo nucifera	Yes	Yes	Yes	Yes	Yes
Firmiana simplex	Yes	No	No	No	No
Prunus persica	Yes	Yes	Yes	Yes	Yes
Prunus armeniaca	Yes	Yes	Yes	Yes	Yes
Osmanthus fragrans	Yes	Yes	Yes	Yes	Yes
Magnolia denudata	Yes	Yes	Yes	Yes	Yes
Paeonia suffruticosa	Yes	Yes	Yes	Yes	Yes

Supplementary Table 8: Evaluation of planting methods

Types	**Textual understanding**	**Visual understanding**
Duizhi (对植)	Yes	Yes
Liezhi (列植)	Yes	Yes
Congzhi (丛植)	Yes	No
Guzhi (孤植)	Yes	Yes

Supplementary Table 9: Evaluation of rockery cunfa types

Types	**Textual understanding**	**Visual understanding**
Mayacun (马牙皴)	Yes	No
Pimacun (披麻皴)	Yes	No
Fupicun (斧劈皴)	Yes	No

Zhedaicun (折带皴)	Yes	No
Luanchaicun (乱柴皴)	Yes	No

Supplementary Table 10: Workflow evaluation scores

Dimension	Item	Statement	Mean
Usability and efficiency	Q1	I found the overall workflow easy to understand and use.	3.9
	Q2	The collaboration between multiple AI platforms was logical and well integrated.	3.9
	Q3	Compared with traditional design tools, the workflow significantly improved my design efficiency.	4.1
	Q4	I was able to complete the design task smoothly without extensive additional learning.	3.8
Design support and effectiveness	Q5	The workflow effectively supported my conceptual thinking and design decisions.	3.9
	Q6	AI-generated outputs enabled rapid exploration of alternative design options.	4.1
	Q7	The workflow improved the overall completeness of the design outcome.	3.9
Spatial perception and experiential design	Q8	The generated images clearly conveyed spatial depth and layering.	3.8
	Q9	The workflow helped me perceive the courtyard as an experiential and navigable space.	3.7
	Q10	The generated results reflected changes in viewpoints during spatial movement.	3.7
	Q11	The workflow supported the expression of sequential spatial experience.	3.6
Cultural authenticity and semantic expression	Q12	The designs reflected key characteristics of Jiangnan private gardens.	3.8
	Q13	Garden elements were expressed in a culturally appropriate manner.	3.8
	Q14	The generated results conveyed a sense of cultural atmosphere.	3.7
User immersion and creative experience	Q15	I felt immersed in the design process when using the workflow.	3.9
	Q16	Interaction with AI enhanced my creative thinking.	4.0
	Q17	The workflow enabled design exploration beyond what traditional tools typically allow.	4.0
Overall satisfaction and added value	Q18	Overall, I am satisfied with the AIGC-assisted design workflow.	4.0
	Q19	The workflow provides clear added value compared with conventional design tools.	3.9
	Q20	I believe the workflow has strong potential for practical application and further development.	4.1

Supplementary Table 11: Evaluation results under different logic-layer combinations (mean ± sd)

Metric	G0	G1	G2	G3
FID ↓	68.42 ± 4.21	55.13 ± 3.86	49.60 ± 3.18	47.92 ± 2.93
CLIP ↑	0.28 ± 0.01	0.33 ± 0.01	0.32 ± 0.01	0.32 ± 0.00
SSIM ↑	0.62 ± 0.05	0.64 ± 0.04	0.71 ± 0.03	0.73 ± 0.03
PSNR ↑	17.31 ± 1.10	18.13 ± 1.07	20.44 ± 0.95	21.15 ± 0.81

Cultural fidelity (expert, 5-point scale)	2.63 ± 0.49	3.84 ± 0.36	3.97 ± 0.30	4.55 ± 0.22
Spatial logic (expert, 5-point scale)	2.42 ± 0.56	2.61 ± 0.48	4.17 ± 0.32	4.24 ± 0.36
Human post-editing time (min) ↓	42.02 ± 8.51	35.09 ± 7.77	24.24 ± 6.52	18.01 ± 5.26

Supplementary Table 12: Operation steps of conceptual design

No.	Steps	Content
1	Define the task objectives	Upload or paste the task requirements, specifying clear objectives by inputting the specific characteristics of spatial layouts and garden elements.
2	Structure the prompt	Enhance the visual quality of generated images by adjusting parameters such as style, tone, focal length, lens type, texture, light and shadow effects, composition ratio, resolution, viewpoint height, scene atmosphere (e.g., weather, time of day), contrast and saturation, background complexity, foreground-to-background layering, level of detail, blur and sharpness, the emphasis weight of specific words, and keywords related to the material, color, position, and types of landscape elements.
3	Adjust and optimize	If the generated image is unsatisfactory, continue refining and improving the prompts until the final reference image closely aligns with the desired visual effect.

Supplementary Table 13: Semantic segmentation correspondence table (based on ADE20K dataset)

Types	Prompts	Hexadecimal color code	Color
Rockeries	Mountain; mount	8fff8c	
	Hill	ff6600	
	Rock; stone	ff290a	
Water	Water	3de6fa	
	River	0bc8c8	
	Lake	0abed4	
Vegetation	Tree	04c803	
	Grass	04fa07	
	Plant; flora	ccff04	
	Flower	ff0000	
Architecture	Building; edifice	b47878	
	Skyscraper	8c8c8c	
	House	ff09e0	
	Fence; fencing	ffb806	
	Railing; rail	ff3d06	
	Column; pillar	ff0829	
	Bridge; span	ff5200	
	Boat	adff00	
	Tower	ffb8b8	
	Flag	5c00ff	
Others	Sky	06e6e6	
	Floor; flooring	503232	
	Land; ground; soil	00c2ff	
	Wall	787878	
	Road; route	8c8c8c	
	Path	ff1f00	

	Person; individual; someone; somebody; mortal	96053d	
	Field	7009ff	
	Sand	a09614	
	Stairs; steps	ffe000	
	Stairway; staircase	1f00ff	
	Step; stair	ff008f	

Supplementary Table 14: Steps for detailed design of spatial layouts

No.	Steps	Content
1	Prepare accurate spatial layout color block diagrams	Use traditional design software, such as PS, to make localized adjustments to the previously generated reference image. Modify the reference image by applying the color-element correspondence from the semantic segmentation table to create a color block layout that closely aligns with the target image (simply apply color blocks to the areas requiring modification, leaving the remaining parts filled with white). Export the adjusted image and input it into Stable Diffusion or Liblib AI's ControlNet, selecting the "Seg" function under "Control Type."
2	Modify error spatial layouts	Input the original image into the "image-to-image" module, then use the "inpainting" tool to modify the specific areas of the original image that require adjustments.
3	Input positive and negative prompts	Input both positive and negative prompts to generate the correct spatial layouts. For prompt settings, include "positive prompts" and "negative prompts." Positive prompts specify the desired content and should include the English name of each element corresponding to the color blocks. To enhance image quality and complexity, add modifiers at the end of the prompt, such as "(best quality)," "(masterpiece)," or "(realistic)." Negative prompts specify undesirable content, such as low quality, blur, distortion, or incompleteness. A general formula for negative prompts may include terms like "NSFW," "(worst quality)," "(low quality)," "(normal quality)," "(blurry)," "(monochrome)," "(grayscale)," "(ugly)," "(repeated)," "(morbid)," "(incomplete)," or "(deformed)."
4	Adjust and optimize	Continuously adjust parameters such as "iteration steps," "prompt guidance scale," "preprocessor," "control weight," "start step," and "end step" to generate the image.

Supplementary Table 15: Steps for detailed design of garden elements

No.	Steps	Content
1	Assign a role	Assign ChatGPT 4.0 (DALL-E 3) a specific role, such as by inputting the prompt, "Assume you are a senior designer in the field of Chinese classical gardens." This approach helps ChatGPT 4.0 (DALL-E 3) accurately draw upon its training data related to Chinese classical garden expertise, thereby generating more precise results.
2	Define garden element attributes	Upload or paste the positive prompts, providing clear task objectives. This involves specifying the names of specific garden elements in the prompt, such as "pine tree" or "bamboo grove," and may include details like specific angles, colors, materials, and lighting. Additionally, to keep the background clean and facilitate material extraction and usage, include negative prompts such as "do not generate any background colors."
3	Adjust and optimize	If the generated image is unsatisfactory, continue refining and improving the prompts until the final reference image closely aligns with the desired visual effect.

Supplementary Table 16: Operation steps of images integration

No.	Steps	Content
1	Prepare accurate garden elements	Use traditional design software, such as PS, to make localized adjustments to the previously generated garden elements. Place the garden elements into the original image, adjust their size and position, and fill the background with white. Export the adjusted image and input it into Stable Diffusion or Liblib AI's ControlNet, selecting the "Canny" function under "Control Type."
2	Remove error garden elements	Input the modified spatial layout image into the "image-to-image" module, then use the "inpainting" tool to paint over the areas that need modification.
3	Adjust and optimize	Leave the positive prompt blank, but fill in the negative prompt. Continuously adjust parameters such as "iteration steps," "prompt guidance scale," "preprocessor," "control weight," "start step," and "end step" until the desired design effect is achieved.