Frontend Diffusion: Empowering Self-Representation of Junior Researchers and Designers Through Agentic Workflows

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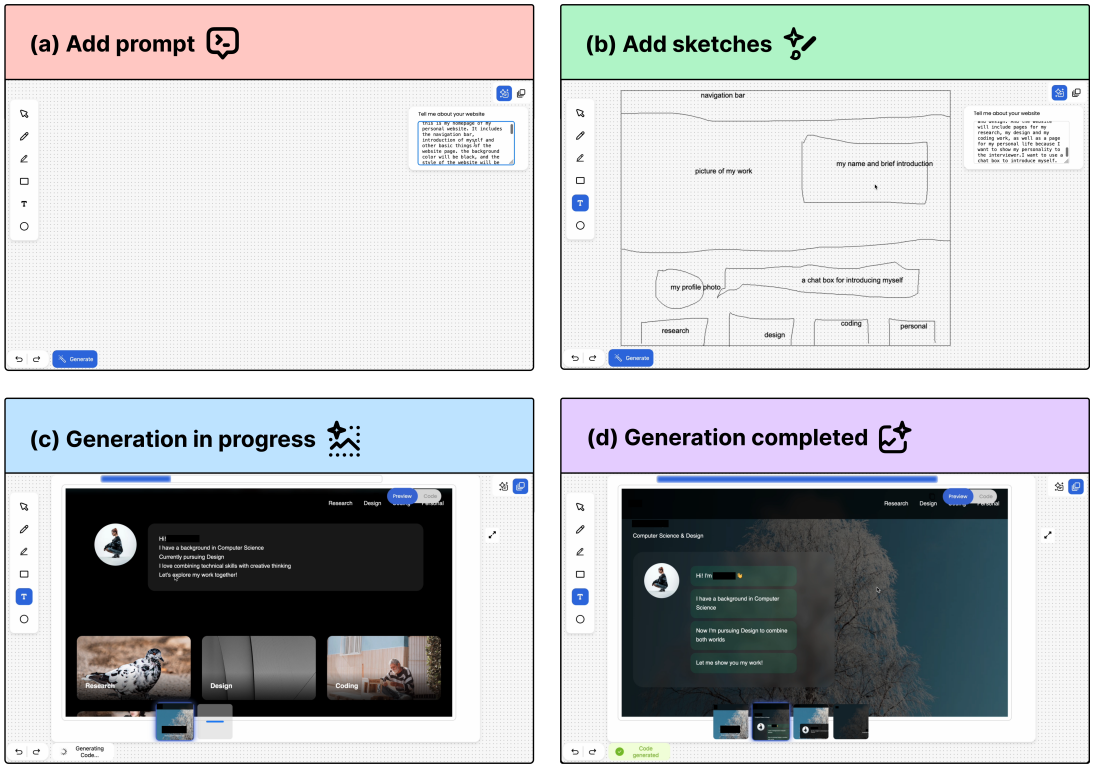

Fig. 1. Website generation workflow: (a) user inputs prompt; (b) user draws layout of the website in sketch; (c) the system generates the first website; (d) the system completes generations four website iterations.

With the continuous development of generative AI's logical reasoning abilities, AI's growing code-generation potential poses challenges for both technical and creative professionals. But how can these advances be directed toward empowering junior researchers and designers who often require additional help to build and express their professional and personal identities? We present Frontend

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Diffusion, a multi-stage agentic system, transforms user-drawn layouts and textual prompts into refined website code, thereby supporting self-representation goals. A user study with 13 junior researchers and designers shows AI as a human capability enhancer rather than a replacement, and highlights the importance of bidirectional human-AI alignment. We then discuss future work such as leveraging AI for career development and fostering bidirectional human-AI alignment on the intent level.

Additional Key Words and Phrases: Creative Workflow, Research, Code Generation

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1 INTRODUCTION

With the rapid advancements in AI's logical reasoning capabilities [8, 19], technical productivity has been enhanced across various domains. In programming, state-of-the-art models have increased the resolution rate of pull requests on GitHub from under 2% in 2023 to over 50% by the end of 2024 [10]. These advancements have not only spurred companies' interest in adopting agentic workflows within software development but have also raised concerns among human professionals about the potential for AI to replace their roles. This anxiety has been particularly pronounced in creative industries, where screenwriters face competition from text-generation models [18] and illustrators contend with text-to-image models [9, 11, 12]. Such realities motivate us to explore a future where humans and AI coexist synergistically. Instead of automating humans out of the creative process, AI can—and should—act as a catalyst for enhancing self-expression, facilitating more effective personal and professional presentation, and freeing up time for higher-level intellectual pursuits.

This vision holds particular relevance for emerging scholars, such as early-career PhD and master's students, who stand at a critical juncture in their academic journeys. For them, self-presentation is intricately tied to personal growth, skill development, and the formation of academic identities. Despite their wealth of new ideas and scholarly potential, junior researchers often face challenges in building their professional brands and achieving online visibility. Creating a professional website—an essential tool for showcasing research, academic networks, and aspirations—can be a daunting task due to technical and time-related constraints. Agentic programming workflows have the potential to address these challenges, not by replacing the researcher's creative authority, but by enabling them to focus on more meaningful pursuits, such as crafting their scholarly narratives and refining their research agendas, ultimately emphasizing their unique academic identities and depth.

To support self-representation through agentic workflows, we developed *Frontend Diffusion*, an end-to-end, model-agnostic frontend development system. Our system employs a multi-stage agentic workflow to transform user-drawn layouts and thematic prompts into iteratively refined website code. We evaluated the system through a user study involving 13 participants with diverse technical backgrounds. The findings revealed that the AI tool functions not merely as a code generator but as a collaborative partner. Participants emphasized two major themes: AI as a Human Capability Enhancer, Not a Replacement, and Bidirectional Human-AI Alignment.

Our contributions are twofold:

(1) **System Development**: we designed and implemented Frontend Diffusion, a system that enables users to generate professional websites by combining sketches and textual prompts in a multi-stage agentic workflow.

(2) **Empirical Study**: we conducted a user study with 13 participants and collected qualitative data through interviews to understand their perceptions of the system as human capability enhancer and its bidirectional Human-AI alignment.

2 RELATED WORK

2.1 Advancements in AI and Agentic Workflows for Code Generation

Since the training process of GPT-3.5 incorporated a substantial amount of code data to enhance the logical reasoning capabilities of language models [2], code generation has become closely intertwined with language modeling. With the emergence of models that place a stronger emphasis on reasoning, these capabilities continue to evolve. According to the SWE-bench benchmark, which simulates human programmers' problem-solving workflows, AI programming performance increased from below 2% in December 2023 [10] to over 60% by February 2025[1].

However, simply reinforcing the reasoning ability of language models primarily advances lower-level software development tasks such as auto-completion and refactoring. To enhance automation in real-world software and system development, researchers have introduced various agentic workflows, including OpenHands [28], an open-source coding agent designed for end-to-end development, and Agent Company, which simulates the operation of a software company [33]. Nonetheless, as of February 2025, even the most sophisticated agentic workflows remain unable to fully realize end-to-end programming[2], let alone organization-level agency[3].

Within code generation and system development, front-end code generation—such as website development—often demonstrates stronger performance than back-end development. Research in this domain has examined reconstructing HTML/CSS structures from UI screenshots using computer vision techniques [25], implementing hierarchical decomposition strategies for interface elements to optimize UI code generation [27], and improving model specialization through domain-specific fine-tuning for UI generation [30]. To systematically evaluate front-end code generation, specialized benchmarks have been developed to assess the quality of HTML, CSS, and JavaScript implementations [24]. To investigate the societal impact of this notable improvement in AI programming capabilities, we focus on the task of website generation, where current AI systems are relatively close to achieving near end-to-end automation.

2.2 Beyond Templates: AI-Powered, User-Centric UI

With the continuing development of AI-driven user interface (UI) generation, users increasingly seek more personalized and diverse expressions rather than relying solely on conventional template reuse. Recent advances have led to adaptive UI generation systems like FrameKit, which allows end users to manually design keyframes and generate multiple interface variants [31]. PromptInfuser goes a step further by enabling runtime dynamic input and generation of UI content [21]. In this context, AI tools have been shown to offer inspiration for professional designers [17]. For instance, DesignAID [1] demonstrates that generative AI can provide conceptual directions and stimulate creativity at early design stages. Misty supports remixing concepts by allowing users to blend example images with the current UI, thereby enabling flexible conceptual exploration [16].

Beyond offering inspiration, AI can also provide real-time design feedback to guide iterative refinement and error correction [5], such as handling CSS styling in simple websites and optimizing specific UI components [13]. It is capable of evaluating UI quality and relevance, offering suggestions at various design stages [29], and even detecting potential

[1]https://www.swebench.com/
[2]https://www.swebench.com/
[3]https://the-agent-company.com/

development or UI issues in advance [21]. Automated heuristic evaluations generated by AI can provide more precise assessments and recommendations, thereby streamlining the iterative process [6]. When combined with traditional heuristic rules, AI has been shown to increase the effectiveness of UI error detection and correction [15]. Integrating prototype-checking techniques into the UI generation workflow can further enhance automatic repair capabilities [32].

2.3 Improving the Creative Workflow with AI

In many creativity workflows, a prolonged progression from ideation, prototyping, and development to iteration is required [20]. Those creative processes are frequently constrained by multiple intricate steps that limit users' expressive capabilities. For example, the complexity and associated costs of developing a personal website often deter individuals from undertaking this process, prompting many to resort to standardized website templates for personal websites. However, GenAI can assist with the creativity workflow from various angles [14, 20, 26]. First, GenAI such as text-to-image generation can reduce the time needed to produce high-fidelity outcomes. This enables creators to focus on refining the gap between the high-fidelity results and their envisioned expectations, rather than expending effort on how to achieve high fidelity in the first place [7]. Besides, AI lowers the cost of experimenting with new ideas, thereby minimizing the psychological barriers to conducting trial and error with unconventional concepts [20]. When users are uncertain about what they want or have only a broad concept lacking specific details, AI can offer inspiration [22]. Moreover, AI can facilitate parallel prototyping by presenting multiple design directions simultaneously, allowing creators to compare and refine a range of diverse design solutions [4].

3 SYSTEM DESIGN

We developed Frontend Diffusion, an end-to-end AI-powered frontend code generation tool as illustrated by Figure 2. Constructing a personal website based on both sketches and textual prompts is inherently complex, given the need to account for not only the content to be displayed (e.g., the type of information) but also the format (e.g., layout, color schemes, and style). Although language models demonstrate capabilities in translating user intentions into code, the initial user inputs—such as a brief sketch and prompt—often leave information gaps relative to the final website. Attempting to fill all details in a single step frequently results in coarse or incomplete outcomes. To address this limitation, we employ a multi-stage agentic workflow, wherein the website creation process is divided into multiple tasks, mainly in two phrases: (1) Sketch-to-PRD generation, (2) PRD-to-code generation and code refinement as shown in Figure 2.

3.1 Phase 1: Sketch-to-PRD Generation

This step transforms the user's visual and textual inputs into a structured document, referred to as the Product Requirements Document (PRD), which serves as a blueprint for the website's development process. Upon completion of the user's sketch and theme input, the user can activate the code generation process via "Generate" button. The system then converts the sketch into SVG format, followed by a subsequent transformation into JPG format. This two-step conversion process was implemented based on empirical evidence from our tests, showing that language models exhibit better performance when processing images in JPG format compared to images in SVG format.

Then we used the JPG formats to generate PRD. To enhance the visual appearance of the generated websites, the system integrates the Pexels API[4] for image retrieval. The language model is specifically prompted to include image

[4]https://www.pexels.com/api/

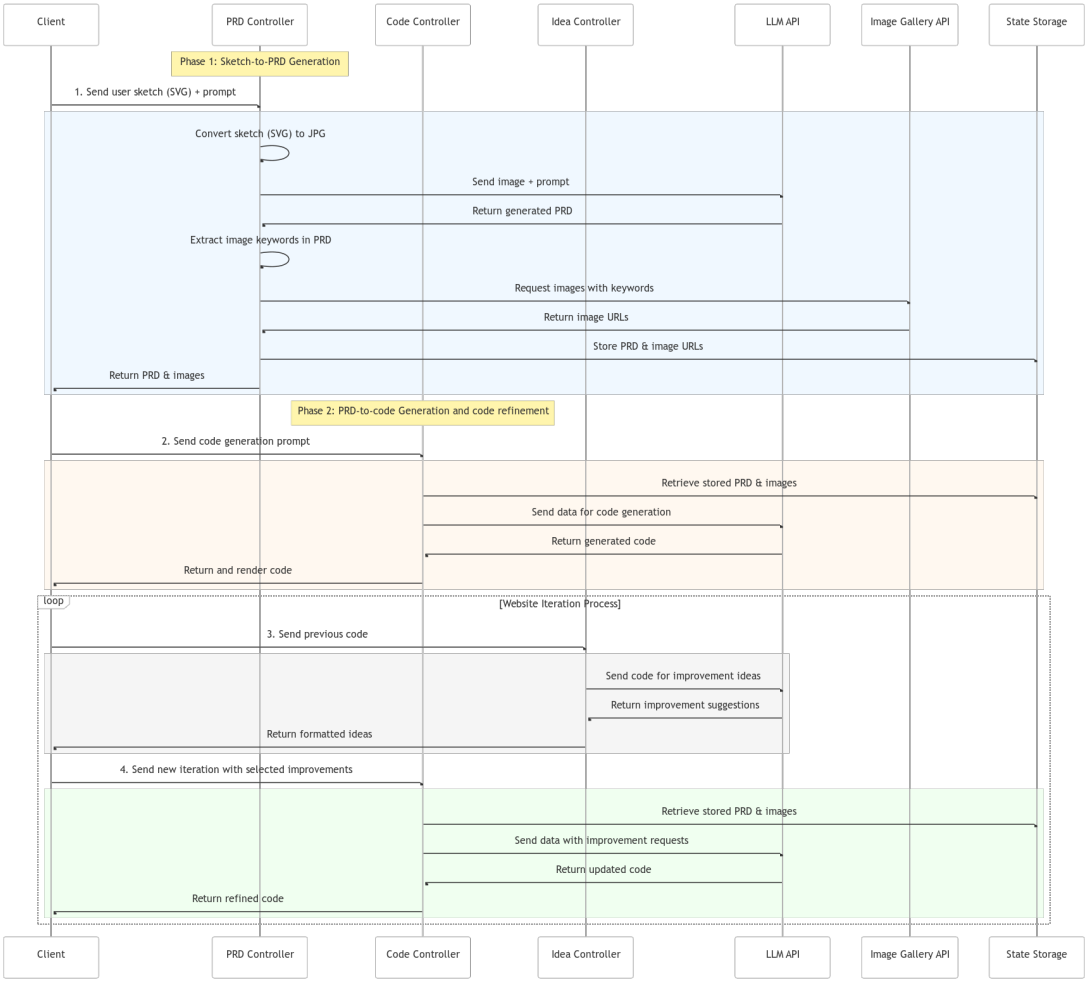

Fig. 2. Agentic workflow of frontend code generation system: (1) Sketch-to-PRD generation, (2) PRD-to-code generation and code refinement. The prompts for PRD, code and idea generation are attached in Appendix B.

terms and size descriptions (e.g., [school(large)]). These descriptors are subsequently utilized to query the Pexels API, which returns relevant image URLs for incorporation into the PRD.

3.2 Phase 2: PRD-to-code Generation and Code Refinement

The phase 2 of the system consists of two steps: (1) PRD-to-code generation: the system utilizes the generated PRD and the original user prompt as inputs for code generation; (2) code refinement: the system implements an iterative refinement process to automatically enhance the generated website with richer functionality and reduced flaws. This process involves analyzing the initial code to generate optimization suggestions, merging these suggestions with the original theme, and utilizing the enhanced theme along with the previously generated PRD to regenerate the code. The system executes this iterative refinement process multiple times (by default, n=4). Users can navigate between

iterations by selecting preview thumbnails displayed at the interface's bottom, and can access or copy the generated code for each version.

All the generation steps utilize the Claude 3.5 Sonnet language model (claude-3-5-sonnet-20241022)[5], one of the most advanced language models for coding as of December 2024[6]. We also anticipate rapid developments in LLMs, so the task transition techniques described herein are designed to be model-agnostic, ensuring their applicability to future, more advanced LLMs. The project code will be open-sourced after the paper's anonymity period ends.

4 STUDY DESIGN

The experiment lasted approximately 45 minutes and consisted of three parts: a 5-minute participant onboarding, a 20-30 minute user study, and a 15-20 minute post-study interview. First, participants read and signed the consent form, granting permission for screen recording. Next, the researcher demonstrated how to use it by creating one website page. Participants then created between 1 to 5 personal website pages depending on participants' needs. These pages could showcase either professional content, such as research or design portfolios, or personal interests, such as an image gallery or reading list. After completing the user study, the researcher conducted a 15-20 minute post-study interview, following the protocol outlined in Section 4.2.

4.1 Demographic Information

In the pre-study survey, we collected demographic information, including participants' age, gender, educational level, experience in web development, design, and research, as well as whether they had a personal website (Y/N). Table 1 summarizes this information. Among the 13 participants, there were 4 master's students, 5 first-year Ph.D. students, and 4 third- or fourth-year Ph.D. students. Regarding website development experience, 6 participants reported having a personal website. Overall, the group represented a relatively diverse range of website creation backgrounds.

	Demographic			Experience (in yrs)			Website	
PID	Age	Gender	Edu	Dev	Design	Research	Prev. Website	Pages created
1	25	F	Yr-1 PhD	0	0	3	N	5
2	25	F	Yr-1 PhD	0.1	0.2	4	Y	3
3	23	F	Yr-1 master	1	3	0.5	Y	3
4	23	F	Yr-2 master	0.5	3	3	Y	2
5	28	F	Yr-3 PhD	1.5	4	5.5	Y	4
6	31	M	Yr-3 PhD	0.5	1	10	N	5
7	29	M	Yr-1 PhD	0	0	4	N	3
8	23	F	Yr-1 master	1	0	1	N	5
9	31	F	Yr-4 PhD	0	1	8	N	4
10	24	F	Yr-1 PhD	0.5	0	3	N	1
11	23	F	Yr-1 master	3	1	0	Y	5
12	29	M	Yr-3 PhD	1	0	4	N	4
13	27	M	Yr-1 PhD	2	3	3.5	Y	3

Table 1. Participants demographic information, including age, gender, educational level, experience in web development (dev), design, research, having personal website (Y/N), and number of pages (each page has 4 iterations) created in the study.

[5]https://www.anthropic.com/news/claude-3-5-sonnet
[6]https://www.swebench.com/

4.2 Post-Study Interview Protocol

Following the completion of the website creation task, we conducted semi-structured interviews with each participant to gain insights into their experiences, perceptions, and overall satisfaction with the tool. The interviews took place immediately after the hands-on sessions, ensuring that participants' impressions and feedback were fresh and accurately captured. Each interview lasted approximately 20–30 minutes and was audio-recorded, with participants' consent, for subsequent transcription and thematic analysis.

The interview protocol was designed to explore three main dimensions: (1) User Experience, (2) Improvement and Recommendation, and (3) Broader Impacts and Perceptions. While the interviewer maintained flexibility to probe further into interesting responses, all participants were asked the same core questions to ensure consistency. The interview outline was as follows:

- **User Experience**
  - **Process:** Did you find the process of using the tool to generate a personal website smooth? Were there any steps that were particularly time-consuming or challenging?
  - **Result:** Did the final website meet your expectations? Do you think the tool accurately understood your intent between sketch input and the generated website? Why or why not?
- **Improvement and Recommendation**
  - Are there any features you would like the tool to add or improve? Did you feel the need for more interaction or guidance from the tool?
  - Would you recommend this tool to your peers? Why or why not?
- **Broader Impacts and Perceptions**
  - Does this tool increase or decrease your interest in frontend development, or even research?
  - Do you think this tool enhances human abilities or replaces them? Why?

5 RESULTS

We identified two major themes in our results. First, participants consistently viewed AI tools as augmenting human abilities rather than replacing them. Second, the interaction between users and AI revealed a process of bidirectional human-AI alignment. The result overview is shown in Figure 3.

5.1 AI as A Human Capability Enhancer, Not a Replacement

All participants consistently viewed AI tools as enhancing rather than replacing human capabilities in frontend development and design. Participants found these tools served as a starting point and source of inspiration, with humans still needed for refinement and final decision-making. Participants described that this tool heightened people's desire for a more robust digital presence: "Without this tool, maybe very few people would have their own website; but once it's available, everyone might want one as a digital business card… With such tools, everyone can become a designer, frontend developer, or product manager, thereby driving the creation of more interesting products." (P3)

The frontend generation tool's ability to implement unconventional requests while maintaining user agency was valued by P9: "it's actually picking up intention… it's not going to try to second guess me," while P10 emphasized the irreplaceable role of humans as requirement providers, noting that "even the user doesn't have a standard perspective. The users are like the client, and this tool is like the contractor."

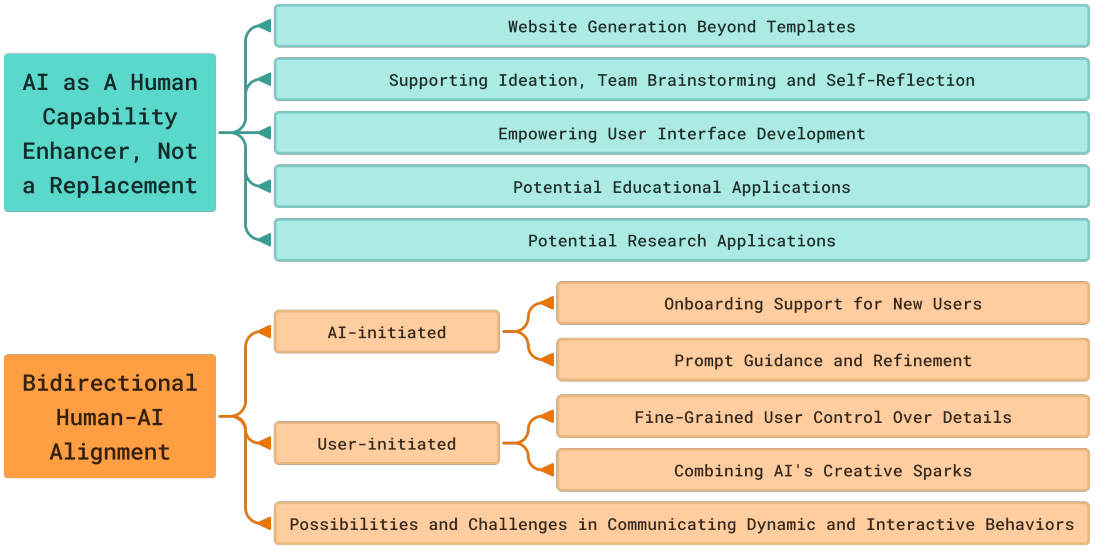

Fig. 3. Overview of the results section: 1) AI as a human capability enhancer, not a replacement 2) bidirectional human-AI alignment.

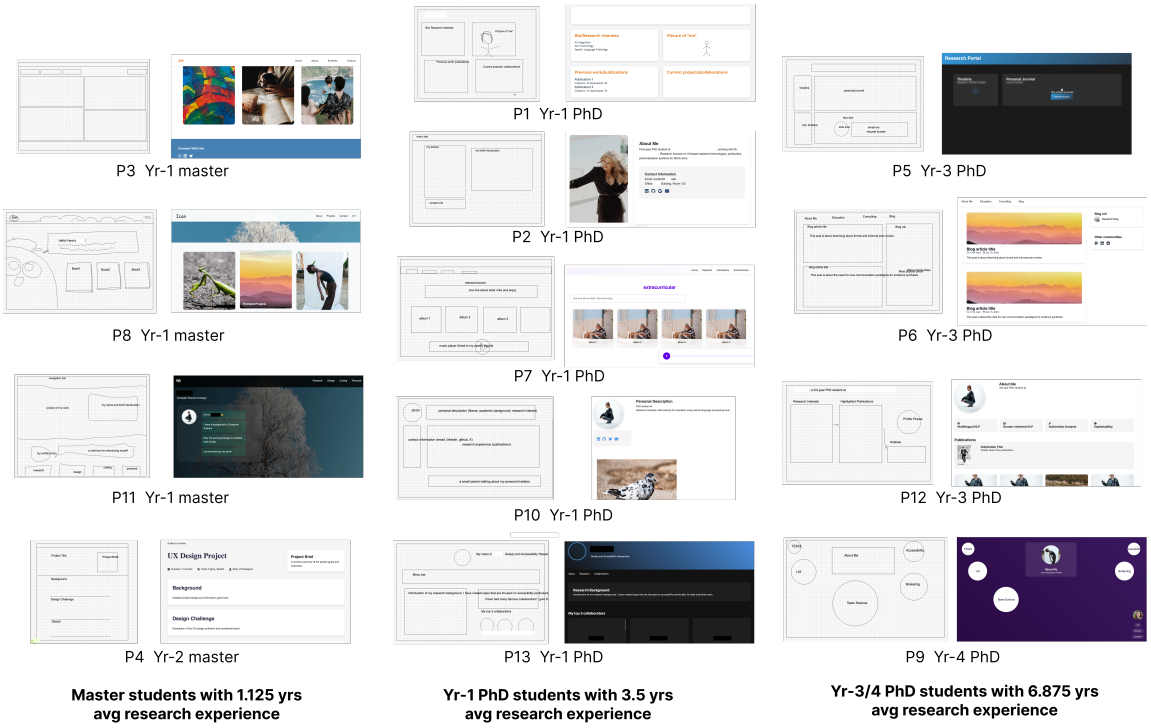

Fig. 4. Website examples created by researchers and designers grouped by education level.

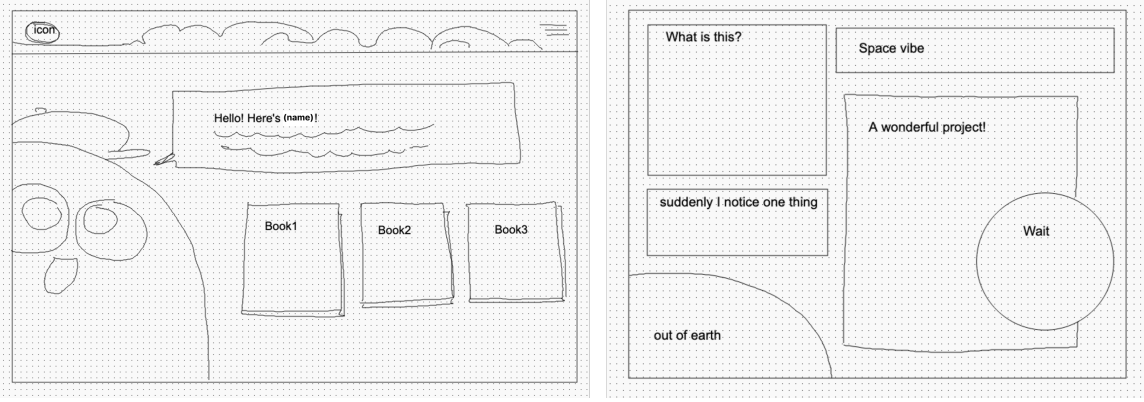

Fig. 5. Examples of participant's sketch (P8) on the system for brainstorming of the homepage personal website.

5.1.1 Website Generation Beyond Templates. The AI-powered generation approach demonstrated advantages over traditional website templates. P2 argued that the tool proves more efficient than searching through templates, which often requires trial and error: "With templates, you spend time reviewing different options, and even after selection, you must understand their code structure. This tool generates clean, targeted output without unnecessary elements." P5 observed that website templates can constrain thinking: "Using a GitHub framework means starting with an existing template, which influences how you present yourself. This tool removes that template-imposed limitation on creative thinking."

P7 compared it favorably to website builders: "For those without UI design experience who struggle with platforms like Wix - which has numerous options requiring drag-and-drop interactions and color decisions - this tool streamlines the process by handling color schemes automatically. When I needed a floating music player, instead of searching through component libraries, the tool generated one directly with multiple variations."

The tool showed promise in creating personalized academic websites. P5 critiqued current academic websites: "Existing personal websites often appear standardized in style, structure, and content. Many researchers' sites follow similar templates without reflecting their interdisciplinary backgrounds and interests. For interdisciplinary researchers, websites should be more comprehensive, demonstrating engagement across different domains rather than merely listing publications and projects." They mentioned that for researchers working with VR, AR, or multimodal content, traditional flat presentations prove insufficient. Future tools should support more immersive and diverse presentation methods to fully communicate research domains, methodologies, and outcomes.

5.1.2 Supporting Ideation, Team Brainstorming and Self-Reflection. The tool effectively facilitated both collaborative ideation and individual reflection processes. In team settings, it enabled efficient prototyping and concept exploration. As P8 described, "I wasn't anticipating a perfect prototype generation, but during the sketching phase, it serves as an instrumental aid in my brainstorming process" (as shown in Figure 5). They elaborated on its collaborative applications: "It provides accessibility and facilitates communication. In group projects, team members can individually contribute through text or sketches, collectively evaluate outcomes, and iteratively build upon selected concepts - making it particularly suitable for brainstorming sessions."

For UI/UX practitioners, the tool expedites concept visualization. P2 observed: "It proves especially valuable for designers because when they can articulate their intentions precisely or have an initial draft, they can visualize outcomes promptly without frontend development dependencies. While the output might approximate 60-70% of the final implementation, it accelerates idea communication in both upward reporting and general presentations."

The tool extends beyond external presentation to function as a medium for self-reflection. P5 elaborated on this fundamental aspect:

> "From my perspective, a personal blog's essential function lies in its capacity to aggregate and synthesize existing knowledge. This utility isn't necessarily directed toward public consumption - it may serve primarily as a tool for self-examination, illuminating the processes of my internal thought world… The act of presenting to oneself necessarily precedes external presentation to the broader audience." (P5)

The tool's rapid prototyping capabilities support this introspective process. As P5 explained, "It facilitates the clarification of how one wishes to present their professional identity and understand it internally. Subsequently, with a defined target audience, one can appropriately adapt this self-presentation for integration into the social context." This capability particularly benefits creative professionals, as P12 noted: "I have some art friends. A lot of their portfolios are pretty creative. I probably recommend it for that." They emphasized its accessibility for non-technical creators to generate initial design frameworks without requiring direct HTML/CSS implementation.

5.1.3 Empowering User Interface Development. For experienced developers, AI code generation serves as a powerful accelerator in the development process. P8, P10, P11, and P13 emphasized that users with foundational web development knowledge can effectively leverage and modify AI-generated code to achieve sophisticated results. As P11 noted, "You need to understand the basic components of a webpage, like its structure. This helps you achieve your desired results more quickly." This knowledge becomes particularly important for implementing complex or innovative designs, where users must articulate requirements using appropriate technical terminology. P8 elaborated on this point:

> "To achieve more specific outcomes, some UI/UX knowledge is essential. For instance, when implementing complex animations like a rotating solar system, rather than using general descriptions, I would specify technical requirements like 'I want one sphere rotating around another sphere.' The AI tool can then better interpret these technical terms like 'rotate' to generate the appropriate code." (P8)

For novices and those less experienced with frontend development, the tool serves a different but equally valuable purpose - providing emotional support and reducing the stress typically associated with web development. P13 highlighted this benefit:

> "Frontend development can be very frustrating for some people. It can be very painful. People might literally pull their hands up. So this can certainly be a great stress elimination… I prefer back-end programming. I like writing algorithms… I'm not a big fan of frontend development. And when I was learning front, when I was trying to write frontend code for the first few times, I found it very frustrating." (P13)

The tool is particularly empowering for those without UI design experience, acting as a bridge to overcome their limitations in visual design. P7 described how the tool compensates for their lack of design expertise while boosting their confidence in website creation:

> "As a non-design person, it enhances and complements my poor sense of color and form. It helps design a website I like based on my needs… I don't need to find third-party paid platforms anymore. Now I can

> design a website I like through such simple operations… It has greatly enhanced my capability and desire to showcase myself through a website." (P7)

5.1.4 Potential Educational Applications. The tool demonstrated educational value by enabling users to learn through observation and experimentation. P11 emphasized how examining the generated code facilitated learning: "By studying the code it generates, one can understand how the page is constructed… When I cannot envision certain animations, it provides exemplary solutions that I can learn from regarding how such effects are created."

P6 conceptualized the tool as an educational mentor rather than a replacement, noting that it removes mundane implementation tasks while serving as a learning platform. They envisioned it as guiding users toward professional standards through demonstration and instruction, rather than simply automating the design process. This mentorship extends to providing role-based feedback, with P6 suggesting that the tool could act as different professional personas (like recruiters or UX directors) to critique the website's design and content: "Because I want to see what recruiters and consultants want… if there's a way that the AI can advise me, not just with the visual, but just with the overall look and feel and content of it. Let's say you're a business looking at my UX research portfolio or description of my career, then is this an OK page for that kind of thing?" The tool also proved effective at overcoming procrastination barriers. As P6 explained:

> "And for a first pass, I think it does fairly well in helping you. Like I said, I wanted to do a website for a long time, and I haven't done it. So just to kind of break the barrier of getting something down and start thinking about it, this would be pretty helpful… The tool should help me learn by taking a model of a professional designer and how they would think about things, and then nudge me towards doing some of the more professional stuff." (P6)

5.1.5 Potential Research Applications. The tool demonstrated value for research applications. For researchers working with specific user groups, the tool's ability to generate accessible code was beneficial. As P2 explained:

> "My users are blind users, so I need the frontend to be sufficiently simple for screen readers like Voiceover to work effectively. If it can generate HTML that is both simple and well-structured, it would enhance my productivity." (P2)

The tool also exhibited promise in expediting research prototyping processes. P7 described its utility in experimental settings: "It proved immensely helpful when we needed to create an audio recording experiment website. Previously, we spent extensive time trying to build it with Wix… In 2020, it took me an exceptionally long time to set it up. This tool makes it much simpler - just designing the interface saved me substantial time, especially for components like the music bar and audio elements."

The tool's flexibility and accessibility encouraged researchers to explore diverse presentation formats. As P7 noted, "Instead of being limited to basic presentations, this opens up more channels. Why not create an HTML report? It's not restricted to personal websites - it could be a report format as well."

Looking toward future developments, participants expressed optimism about the tool's evolving capabilities. P4 observed, "This tool has room for growth. As it becomes more powerful, it will become increasingly compelling."

5.2 Bidirectional Human-AI Alignment

We observed a bidirectional human-AI alignment process in the user interview: *AI-initiated alignment* (from AI to human), which includes onboarding support for new users and prompt guidance and refinement, where AI helps

facilitate more explicit user expression of ideas; and *human-initiated alignment* (from human to AI), which includes fine-grained user control over details and harnessing and combining AI's unexpected creative sparks, where users communicate their expectations and aesthetic preferences through interactions with AI. Within these interactions, there exist both possibilities and challenges in conveying dynamic and interactive behaviors, as well as requirements for multimodal inputs to enhance AI's understanding and anticipation of user intent. Users acknowledged the importance of understanding this bidirectional alignment process: "It's not like a steep learning curve. It's not super challenging. But it's interesting to learn how the system thinks and then trying to match what you're thinking to it." (P9)

5.2.1 AI-initiated Alignment: Onboarding Support for New Users. While users expressed optimism about AI tools' potential, P1, P10, P11, P12 emphasized the necessity of educational guidance such as example websites (P1, P12), demo videos (P10), tutorials of website components (P11, P12). They can help users better comprehend tool capabilities and feasibility, indicating users need to establish appropriate mental models and operational habits for effective utilization.

P1 described the challenge of structuring website content without prior planning: "I do think another thing that was challenging was coming up with a certain format for the website, just because I don't have one yet and I don't really know what a website, or what a grad student's website should entail at this point." P12 emphasized the value of concrete examples: "Even a tutorial or an example of, like, hey, this is what one person put and this is what - this is all the different images that came out from it. This is an example of what AI can do in this context. I think having that as a reference point for me to look at and say, okay, so the AI can develop - can be this creative even when given this."

5.2.2 AI-initiated: Prompt Guidance and Refinement. P3 and P6 identified prompt formulation as a key challenge requiring time and effort. P6 explained: "The little bit of challenge comes with figuring out how to prompt it, because sometimes you need to have some prior experience to know what to expect to minimize the number of iterations. So I didn't know whether I should use certain key terminology, like cards or models or something like that."

P9 and P10 suggested incorporating interactive guidance: "Do you know Clippy? The little guy that pops up and tells you things. So if you had Clippy, like, oh, did you think about adding colors? Did you think about specifying? So the poking you to do more." (P9)

Moreover, P2, P3, P9, P10, P11 and P12 expressed a preference for iterative refinement capabilities rather than one-time generation. They sought to continuously adjust, replace, and combine advantageous elements from different versions to arrive at a satisfactory final product. In other words, these AI tools should function as partners for ongoing dialogue and evolution, rather than providers of one-off solutions.

For example, P2 and P9 advocated for more direct manipulation capabilities: "It modularizes everything so I can directly manipulate it in the graphical interface, adjust it to what I want… If I'm 70% satisfied with the current version, I can reorganize it further." (P2)

The participants also emphasized that AI should engage in clarifying dialogues with users when faced with uncertainty, rather than making assumptions. P1 noted: "I definitely think that it should ask maybe follow-up questions when generating the response… Like, follow up questions to maybe prompt the user to specify what they want." P8 suggested that the tool could enhance iteration efficiency by posing confirmatory questions during generation, such as whether the output meets expectations or if users would like to explore alternative styles.

5.2.3 User-initiated: Fine-Grained User Control Over Details. Users expressed a need for more granular control over intent expression. P2 noted that the current system only allows high-level requirements specification without detailed control over individual page elements; if the users are able to provide more precise parameters or specific regions,

the generated pages would better align with user requirements. Similarly, P6 advocated for hierarchical prompting for different page sections: "I wonder if you can have a general prompt and then prompt also in the specific section with a little tag." For minimalist design practitioners, precision in visual elements emerged as crucial. P10 elaborated: "For those who pursue minimalism, attention to detail is paramount" - emphasizing the importance of granular control over typography, color schemes, and element properties like border radius.

As another way of fine-grained user control, the participants also wanted to preview intermediate steps before generating the whole website: "And I would like to add, one feature that I would like to add is give me a choice of colors. If I'm specifying Indian vegetarian cuisine, it has automatically assumed orange, yellow, green, all those colors… I would like to see some variations before, some color recommendations before the website is generated. If I can also view some image suggestions… So we can automatically obtain a set of images that I can view before generating the website." (P13)

As the capabilities of smaller size language models improve, P2 suggested that language models running on local devices could conduct "last-mile" tweakings such as importing personal infromation: "Some users may be hesitant to share their materials directly with AI systems. They might prefer generating just the structure, then populating it with their information locally… You could have a large model generate an overall template that's sophisticated and well-structured, clearly indicating where user information should go, then use a local small model to input the personal content without uploading sensitive materials to servers." Another method of fine-grained control is "hierarchical prompting" mentioned by P8, where user requirements could be specified in multiple layers. For example, users could specify the overall layout and then specify the details of each section.

5.2.4 User-initiated: Harnessing and Combining AI's Unexpected Creative Sparks. P3 and P11 found the AI-generated outputs exceeded user expectations by incorporating unanticipated design elements and dynamic effects:

> "The AI's knowledge base may exceed humands, potentially offering unexpected ideas… It introduces dynamic effects that I hadn't considered when creating static sketches… For a personal website, having these animations automatically incorporated is quite valuable." (P11)

Based on the creative pieces generated by AI as "serendipitous sparks", P4, P6, P11 and P13 expressed interest in features that would enable combining elements from multiple generations: "With three or four versions, I might appreciate certain design elements from each. How could we combine them? Perhaps through editing capabilities, comments, or drag-and-drop functionality? (P4)" And P6 proposed a "remix" feature based on previously generated or community-shared designs.

5.2.5 Possibilities and Challenges in Communicating Dynamic and Interactive Behaviors. The communication of dynamic interactions and complex behavioral logic through static sketches and text presented both possibilities and challenges. P7 noted how textual descriptions enhanced design specifications of dynamic interactions: "While my color instructions were minimal, the system comprehended that I wanted vibrant colors and a clean design. Although my sketch was static, it understood which elements should be dynamic, such as the floating music player that follows page scrolling - an option I hadn't explicitly requested but found valuable." On the other hand, P12 tried to indicate toggling function with lines but failed: "The underlines here aren't actual content but rather elements meant to be toggled - expressing such toggle requirements in sketches poses a challenge." This revealed current limitations in AI tools' ability to comprehend complex interactive intentions, suggesting the need for new methods such as flowcharts or state transition diagrams to convey complex interaction patterns in websites. Moreover, the AI tool needs to provide

examples of what the website could achieve for dynamic interactions: "As technology evolves, the AI tool may support more dynamic effects, though this remains an area of uncertainty for us." (P5)

5.2.6 Requirements of Multimodal Inputs. Individual difference were demonstrated in participants' preferences of expressing their design intent through sketches and text. Some found value in an iterative process combining both modalities. As P7 who preferred a text-based expression explained: "As someone without design experience, I find expressing ideas through text more direct than drawing", and "I typically begin by writing to establish a general idea, then create sketches to visualize it, followed by textual elaboration to capture details that sketches cannot express." P7 elaborated on their workflow with this tool: "I find the workflow effective - starting with sketching, then adding textual descriptions. Since sketches are static, it's challenging to convey aspects like draggable elements or fixed components. The text allows me to specify which parts should be fixed and which should be dynamic."

As a comparison, P11 noted that sketch input enhanced the tool's comprehension of user intent: "Compared to pure textual descriptions, sketches enable the tool to better capture spatial layouts and component relationships, leading to more accurate representations of user requirements."

Besides sketches and text descriptions, users expressed interests in leveraging more diverse input methods and modalities, including uploading galleries (P8, P10) and screenshots (P11), and referencing existing websites (P11). This addresses a potential direction for future AI design tools to support multimodal inputs to accommodate users' varied creative sources and generate designs closer to users' expectations.

Several participants advocated for enhanced graphical capabilities. P2 observed that the current drawing and editing functionalities are more constrained compared to professional design tools like Figma, with limited graphical elements and customization options. P3, P10 and P12 suggested expanding beyond basic shapes (rectangles, circles, lines, text) to include additional elements like triangles and rounded rectangles.

6 DISCUSSION

6.1 Summary and Implications of Findings

In this paper, we introduce a novel system, Frontend Diffusion, and present findings from a user study involving 13 junior researchers and designers, supported by in-depth interview results. The task of AI-assisted frontend development spans multiple stages of creative work, including ideation, prototyping, iteration, and development. Consequently, the insights gained from this study are broadly applicable to a wide range of open-ended and creative workflows.

When supporting the self-representation of junior researchers and designers, AI has the potential to enhance human capabilities by alleviating the cognitive and technical burden of repetitive tasks. This enables users to dedicate more time to higher-level ideation and reflection. Furthermore, we observed a bidirectional human-AI alignment [23]: AI-initiated alignment (from AI to human) includes onboarding support for new users and prompt guidance and refinement, while human-initiated alignment (from human to AI) involves fine-grained user control over details and the ability to harness and combine AI's unexpected creative sparks. Additionally, we identified key possibilities and challenges in communicating dynamic and interactive behaviors, as well as the need for multimodal inputs to improve AI's ability to understand and anticipate user intent.

6.2 AI as A Human Capability Enhancer: AI Career Advising and Planning

With technological advancements—especially in AI and robotics that exhibit certain human capabilities—the pace of societal change is accelerating. Consequently, individuals' career trajectories may experience more frequent transitions.

In this inevitable trend, AI can also function as an enhancer assisting individuals in navigating these transitions—from the creation of personal websites to career planning and advising. As noted by P6 in the interview, there is an interest in employing AI to role-play as a recruiter, thereby providing guidance on personal websites. Moreover, AI could enable advise seekers to "try on" career scenarios of interest by having the AI role-play as clients or colleagues within those scenarios, thereby enabling low-cost experimentation during career transitions. While AI provides career advising and planning, potential challenges must also be considered—for example, how to preserve human agency, such as personal interests, passion, and self-efficacy, rather than yielding an AI-optimized career path. This approach helps avoid an overreliance on AI-driven career optimization that could lead to homogenized trajectories and ultimately aims to build a user-initiated career ecosystem—one in which AI offers data-driven insights while humans retain the final decision-making power over non-linear, interest- and passion-driven career narratives.

6.3 Bidirectional Human-AI Alignment: Alignment on Intent Level

Currently, when executing complex tasks with AI, it is necessary to employ an agentic workflow that decomposes high-level human intents into executable steps. For example, in this study, the agentic workflow decomposes the intent to create a personal website into specific tasks such as generating a product requirements document (PRD) based on a sketch and prompt, performing image searches, generating code, and so forth. As AI's logical reasoning capabilities improve [8, 19], it is becoming feasible for AI to autonomously break down human intents into concrete steps through reasoning. For instance, in answering a user's query, AI can determine the various perspectives that need to be considered. It is foreseeable that, in the future, many human–AI interactions will occur at the intent level.

This introduces new opportunities and challenges for human–AI alignment. For instance, when reasoning about complex problems, it could be time-consuming for reasoning models to generate the final outcome; users prefer to examine and adjust intermediate steps such as chain-of-thought, prior to generating the final output (e.g., the "sketch then generate" approach [34]). In future research on human-AI interaction, greater emphasis should be placed on aligning intermediate steps as intent-AI interaction [3].

6.4 Limitation

There were several limitations in the current study that warrant further investigation. First, the user sample was relatively narrow, as the study exclusively involved 13 junior researchers and designers—primarily master's and doctoral students. This limited sample did not encompass a broader demographic, such as participants from non-academic backgrounds or professionals from interdisciplinary fields. Consequently, the generalizability of our findings to a more diverse user population remained uncertain. Second, this study leveraged publicly available online image repositories[7] when generating website content to avoid direct use of participants' personal images. This approach resulted in the selection of images that participants perceived as irrelevant or misaligned with their personal or professional identity, potentially impacting the overall user experience.

6.5 Future Work

Future research could aim to address these limitations while exploring new directions. Regarding privacy and security, subsequent work might investigate localized solutions for handling sensitive data. One potential avenue is local

[7] https://www.pexels.com

deployment of open-source language models [8]. These approaches could enable localizing the processing of personal information and other sensitive data.

In addition, future work might consider expanding the application of AI in career development as discussed in Section 6.2. Potential directions include career planning and advising agents and virtual career environments. Moreover, it is important to examine the long-term impacts of these AI tools on self-expression and career development. Longitudinal studies could provide insights into how AI-assisted systems influence users' academic identities and digital brand building over time, thereby offering insights on the broader social and career implications of integrating AI into personal development strategies.

7 CONCLUSION

This paper introduced Frontend Diffusion, a multi-stage agentic system designed to support junior researchers and designers in self-representation through website generation. We conducted a user study with 13 junior researchers and designers who used the system to generate personal websites. The results indicated that rather than replacing human abilities, AI enhances them by streamlining technical tasks, thereby allowing users to focus more on ideation and identity-building. The interview results also underscored the importance of bidirectional alignment between humans and AI. We also identified opportunities for further development such as leveraging AI for career development and bidirectional human-AI alignment on the intent level.

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A APPENDIX A: RESEARCHERS PROMPT EXAMPLES

Below we provided researchers prompts examples, age and research experience (Exp), grouped by education level.

PID	Description	Prompt Example
Master Students		
P3	Yr-1 Master Age: 23 Exp: 0.5 Yrs	I'm [anonymized] with 2 years of design experience, I fuse data, user insights, and business objectives to craft empowering user experiences, one interaction at a time. I am interested in VR/AR and accessibility. I want to build a portfolio website focused on research projects. This website's color is based on orange and blue.
P8	Yr-1 Master Age: 23 Exp: 1 Yrs	My name is [anonymized], I'm a first-year Human-Computer Interaction Master student. I studied Computer Science and Psychology, also really like cognitive science and drawing. I especially like comics, so I want my website to have some American comics styles. I want a personal website to display my front-end projects, my drawing works, and my research. Each project category will be a book (Book1, Book2, Book3...), when I click on the book, it will deliver me to the specific project page.
P11	Yr-1 Master Age: 23 Exp: 0 Yrs	This is my homepage of my personal website. It includes the navigation bar, introduction of myself, and other basic things of the website page. The background color will be black, and the style of the website will be simple but also creative. My name is [anonymized], I used to study computer science, but now I changed into a design major. I think my website can show both of the knowledge about coding and design. The website will include pages for my research, my design, and my coding work, as well as a page for my personal life because I want to show my personality to the interviewer.
P4	Yr-2 Master Age: 23 Exp: 3 Yrs	I'm [anonymized], a second-year master student of the human-computer interaction program. I studied psychology before and have some research projects related to that. I worked as a UX design intern in a few places. I'm graduating in May 2025 and want to apply for UX designer jobs.
Yr-1 PhD Students		
P1	Yr-1 PhD Age: 25 Exp: 3 Yrs	My name is [anonymized], and I'm a first-year PhD student at [anonymized] and a practicing speech-language pathologist. My research interests include AI integration when developing communication tools for AAC users.
P2	Yr-1 PhD Age: 25 Exp: 4 Yrs	My name is [anonymized]. I'm now a first-year PhD student in [anonymized], working with Dr. [anonymized]. I have an education background in both electrical engineering and design. My research now focuses on AI-based assistive technologies, especially personalization systems for blind users.
P7	Yr-1 PhD Age: 29 Exp: 4 Yrs	My website should showcase my current affiliation and my research publications. I wish it to be of vibrant color but with simplistic design. There should be different tabs to hold various content.

P10	Yr-1 PhD Age: 24 Exp: 3 Yrs	Name: [anonymized] Academic background: PhD student [anonymized] Research interest: Data science for education using natural language processing tools Personal hobbies: drawing, piano, cooking (pictures of dishes I cooked) Style: minimalism Base color: white
P13	Yr-1 PhD Age: 27 Exp: 3.5 Yrs	My name is [anonymized], and I am an accessibility and UX researcher. I use he/him pronouns. I want to create an accessibility and data visualization portfolio website. I want to have a dark background with white text. The font size of the text should have high contrast and be very readable.
Yr-3/4 PhD Students		
P5	Yr-3 PhD Age: 28 Exp: 5.5 Yrs	I am [anonymized], a PhD student starting my third year in [anonymized]. My work is at the intersection of Human-Computer Interaction, Aging and Accessibility, and Personal and Health Informatics. My research focuses on investigating technologies for collecting and sharing personal health information among underrepresented populations, including older adults and people with mild cognitive impairment and dementia. Recently I have been working on supporting older adults in the data labeling process for training their personalized activity trackers. My work informs strategies that engage older adults as end-users in machine learning.
P6	Yr-3 PhD Age: 31 Exp: 10 Yrs	This is my homepage for a website that I can use to showcase my credentials, blogging, and consulting work. I am [anonymized] and would like to introduce myself as a broadly trained social/behavioral scientist now working at the intersection of metascience and human-computer interaction.
P12	Yr-3 PhD Age: 29 Exp: 4 Yrs	I want to build a research website showcasing my interests and publications. I am a 3rd year PhD student named [anonymized], my pronouns are [anonymized], and my research interests are broadly in multilingual NLP, human-centered NLP, authorship analysis, and explainability.
P9	Yr-4 PhD Age: 31 Exp: 8 Yrs	I want the circles to be interlinked like a network and when you click on one I want it to expand and highlight more information and the rest to pull back to the sides. I would want to group them thematically with an overarching team science page. Each bubble you click on opens. The top right about corner would be static.

B APPENDIX B: PROMPTS FOR AGENTIC PIPELINE

B.1 Prompt for PRD generation

```
Please generate a Product Requirements Document (PRD) targeting the creation of a modern
    and user-friendly personal website for Junior Researchers based on the following
    user's sketch (the picture I sent you) and prompt.
User's prompt: ${userPrompt}
In the PRD, specify what images are needed and where they should be placed (e.g., hero
    image, profile image, etc.) using the format: [term(size)], please use concrete
    keywords like [(profile-picture)medium] instead of vague descriptions like
    [image1(small)].
There are 3 keywords for the size (small, medium, large, landscape, or portrait).
    Remember this only applies to images; for icons, you can just define them without
    the expected format.
Example: [portfolio-preview(landscape)]`
```

B.2 Prompt for website code generation

```
You are a design engineer tasked with creating a user interface for junior researcher
    based on a user's wireframe sketch. Prioritize the user's considerations as design
    preferences while ensuring the design adheres to these principles:
1. Apply shadows judiciously enough to create depth but not overly done.
2. Use the Gestalt principles (proximity, similarity, continuity, closure, and
    connectedness) to enhance visual perception and organization.
3. Ensure accessibility, particularly in color choices; use contrasting colors for text,
    such as white text on suitable background colors, to ensure readability. Feel free
    to use gradients if they enhance the design's aesthetics and functionality.
4. Maintain consistency across the design.
5. Establish a clear hierarchy to guide the user's eye through the interface.
Additional considerations:
2. Utilize a CSS icon library Font Awesome in your <head> tag to include vector glyph
    icons.
3. Ensure all elements that can be rounded, such as buttons and containers, have
    consistent rounded corners to maintain a cohesive and modern visual style.
Based on the following Product Requirements Document (PRD) and User Prompt.
Product Requirements Document (PRD): ${storedPRD}
User's prompt: ${userPrompt}
Please incorporate the following images as specified:
${imageInsertionInstructions}
```

```
Please provide your output in HTML, CSS, and JavaScript without any explanations and
    natural languages(only code),with an emphasis on JavaScript for dynamic user
    interactions such as clicks and hovers.`;
```

B.3 Prompt for code iteration idea

```
Based on the previously generated code, generate 3-5 ideas to improve the website design:
Previously Generated Code:
${previousCode}
Based on the previous design, please provide optimizations and enhancements focusing on:
1. Visual Consistency: Ensure a cohesive look and feel across the entire interface.
2. Unique Imagery: Suggest diverse and non-repetitive images that align with the theme
    of each section.
3. Component Refinement: Enhance the details of each UI component, considering:
- Button designs (hover states, shadows, etc.)
- Input field styles and interactions
- Card layouts and information hierarchy
4. Layout Improvements: Propose better ways to organize content for improved readability
    and user flow.
5. Color Scheme: Refine the color palette to improve contrast and visual appeal.
6. Typography: Suggest improvements in font choices, sizes, and text formatting for
    better readability.
7. Responsive Design: Ensure the layout adapts well to different screen sizes.
8. Interaction Design: Add subtle animations or transitions to improve user experience.
9. Accessibility: Suggest improvements to make the design more inclusive and easier to
    use for all users.
10. Performance Optimization: If applicable, propose ways to optimize the code for
    faster loading and rendering.
Please provide concise, innovative ideas that could enhance the user experience, visual
    appeal, or functionality of the website. Consider the existing code and suggest
    improvements or new features.`
```