Supporting Design Reasoning in AI-assisted Interface Prototyping for HCI Research

Eunhye Kim*
gracekim027@kaist.ac.kr
School of Computing, KAIST
Daejeon, Republic of Korea

Minju Yoo*
minjuyoo@kaist.ac.kr
School of Computing, KAIST
Daejeon, Republic of Korea

Jenny C Yang
jenny_yang@kaist.ac.kr
Graduate School of AI, KAIST
Seoul, Republic of Korea

DaEun Choi
daeun.choi@kaist.ac.kr
School of Computing, KAIST
Daejeon, Republic of Korea

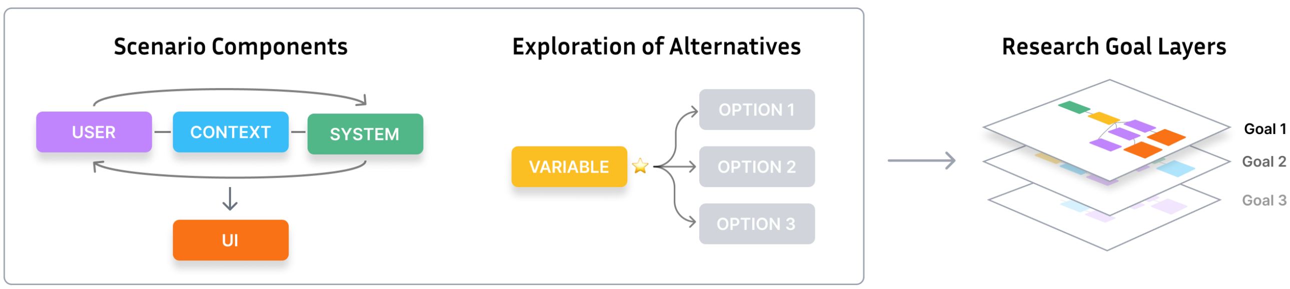

Figure 1: Design Goals of ProtoFlow

Abstract

Recent AI prototyping tools can rapidly generate interfaces from simple prompts, but often collapse the intermediate design reasoning that HCI researchers need—exploring alternatives, weighing tradeoffs, and articulating rationale. To address this, we present ProtoFlow, a node-based prototyping tool grounded in scenario-based design theory. ProtoFlow structures interaction design from scenario components, supports exploration through design variable nodes, and integrates designs across research goals using layers. In a preliminary study with 6 HCI researchers, participants found that scenario components helped bridge high-level intentions and concrete specifications, design variables externalized decision-making rationale, and layers enabled bottom-up design while prompting reflection on goal clarity. We discuss implications including stage-appropriate abstraction, bidirectional iteration between top-down and bottom-up design, and grounding designs in prior research.

CCS Concepts

• **Human-centered computing** → **Systems and tools for interaction design**; **HCI design and evaluation methods**.

*Both authors contributed equally to this research.

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Keywords

AI-assisted prototyping, design reasoning, scenario-based design, UI generation

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1 Introduction

Recent AI prototyping tools (e.g., chat-to-UI workflows [1, 8, 27]) are capable of generating user interface (UI) designs from simple natural language prompts. While these tools enable rapid generation of working prototypes, they risk collapsing intermediate design reasoning into opaque prompt–response interactions or automatically synthesized interfaces [17]. This poses particular challenges for research system prototyping in Human-Computer Interaction (HCI) [13]. In the field of HCI, prototyping is a means of exploration and design reasoning, requiring researchers to explore alternatives, weigh tradeoffs, and articulate the rationale behind each particular design choice [12]. However, current AI-first prototyping workflows provide limited support for these reasoning processes, making it difficult for researchers to engage in them during prototyping [23].

Prior work has explored supporting design reasoning outside the HCI field, through structured scaffolding, such as tools that help designers compose UI elements [16], blend references [5], or visualize design processes [28]. While these approaches successfully externalize the design process, the reasoning they foreground is primarily oriented toward how designs are constructed. In contrast, the prototyping of the research system in HCI requires reasoning anchored in *research goals* [30], where design decisions must be continuously explored and evaluated based on how they support the evaluation of the hypothesis and the implications of the system's structure [19]. As a result, existing approaches provide limited support for reasoning about design decisions as instruments for research inquiry.

To support reasoning for research-driven UI design, we take the approach of going back to traditional HCI theory, where we ground our design goals in scenario-based design [3, 4, 10, 20]. Scenario-based design frames system design as the iterative construction of scenarios composed of user actions and system events, enabling researchers to reason about how design choices unfold in concrete situations [2, 4]. This perspective aligns with research system prototyping in HCI, where design decisions must be continuously explored and evaluated in relation to research goals [11]. Accordingly, our design goals focus on supporting researchers in articulating design intentions, exploring alternatives, and examining the interaction within and across scenarios. Our design goals are as follows:

- **DG1: Structuring Interaction Design from Scenario Components.** The system should decompose interaction design into units—user actions, system events, and context—enabling researchers to construct scenarios and interfaces from these building blocks.
- **DG2: Enabling Exploration of Interaction Alternatives.** The system should support structured exploration by making branching points explicit, allowing researchers to generate, compare, and reason about alternative design choices.
- **DG3: Connecting Interaction Design to Research Goals.** The system should support both goal-level design and cross-goal reasoning, enabling researchers to understand how individual goals relate and contribute to a unified interaction design.

Guided by these design goals, we developed ProtoFlow, a node-based prototyping tool that supports researchers in constructing interaction flows and scenarios while organizing design goals as layered structures. ProtoFlow uses LLM/VLMs to generate and expand design elements while making the reasoning process explicit through structured nodes. It supports branch-based exploration through design variables, allowing researchers to explore alternative designs. It further supports cross-layer reasoning by through node reuse across layers and an aggregated view for reflecting on how individual interactions contribute to broader research goals.

To understand how ProtoFlow shapes researchers' experiences with AI-assisted prototyping, we conducted a user study with 6 HCI researchers. We observed that participants leveraged the node-based structure to explicitly specify the interaction flow, and the design variable nodes helped participants articulate their design reasoning and systematically consider the design space. Furthermore, connecting interface artifacts to research goals encouraged participants to reflect on individual interactions and how they relate to one another. Based on these findings, we discuss design implications for supporting research system prototyping and design in the field of HCI.

2 Design Goals

2.1 Structuring Interaction Design from Scenario Components

According to scenario-based design theory, scenarios consist primarily of user actions and system events [3, 20]. *User actions* include actual behaviors as well as the reasons or tasks behind those behaviors, while *system events* illustrate how the system presents information and processes data [4, 29]. *Context* such as user motivation or task environment also provides essential background that influences interaction design [2]. Based on these frameworks, the system should provide these constituent elements—user actions, system events, and contextual information—as the base unit of construction, enabling researchers to construct and explore their scenarios through these components.

2.2 Enabling Exploration of Interaction Alternatives

Scenario-based design requires iterative exploration by considering alternative approaches and addressing discovered trade-offs [2, 18, 21]. For instance, examining scenarios where a particular approach or design decision does not apply can reveal trade-off relationships that worth considering, and questioning what factors should be considered during exploration can help identify key branching points [14, 22]. This aligns with the role of prototyping as a process of filtering possibilities and informing the design space [9, 15]. Therefore, the system should support structured exploration by making explicit which dimensions to explore and enabling researchers to navigate branching points systematically.

2.3 Connecting Interaction Design to Research Goals

HCI research often involves multiple goals with sequential and dependent relationships [2, 19]. To interpret such complex processes, researchers must examine both concrete individual actions and the relationships among more abstract goals [3, 26]. Scenarios serve as a common language that connects research goals to user interfaces, providing an intermediate level of description that captures overall objectives and persistent context [7, 10]. Based on these principles, the system should support designing for individual research goals while enabling researchers to reason about cross-goal relationships and work toward a coherent, unified interaction design.

3 ProtoFlow

3.1 Features

3.1.1 Node-based Interaction Design Construction (DG1). ProtoFlow decomposes prototype construction into finer-grained interaction units, represented as four node types: **context, user action, system action, and UI** (Figure 2-B). Each node supports two input modalities—structured and unstructured—and ProtoFlow automatically generates the counterpart when users select either version

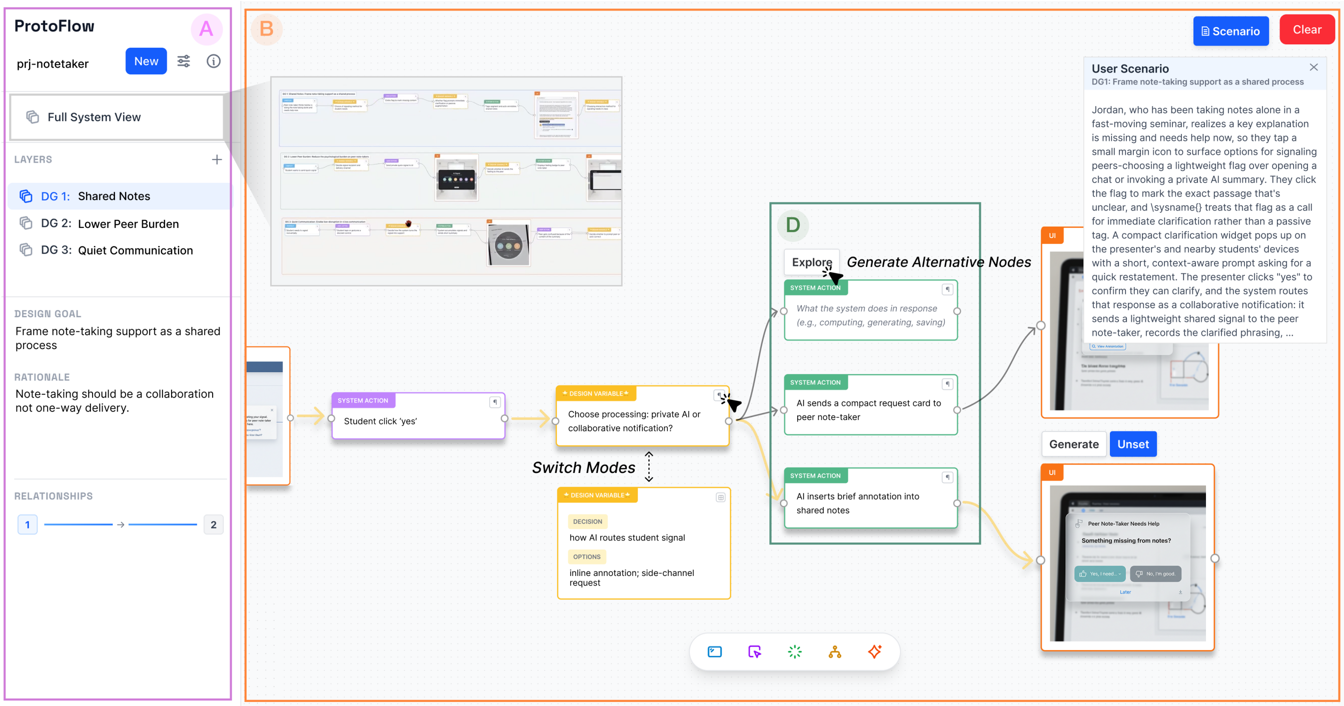

Figure 2: Overview of ProtoFlow.

(Figure 2-C)(Appendix A.1). By connecting nodes, users define sequential flows; by branching, they specify alternative paths. Users can attach a UI node to generate an interface representing the preceding flow, or iteratively revise an existing UI by modifying upstream nodes and regenerating. When a user designates a flow as final for a design goal, the system generates an integrated scenario (Figure 2-E).

3.1.2 Exploration of Interaction Alternatives (DG2). Exploring multiple alternatives for the same interaction step and evaluating how well each aligns with design goals is a core part of HCI practice. ProtoFlow supports this through dedicated *design variable* nodes, which represent explicit axes along which an interaction can meaningfully branch (Figure 2-D). When a user clicks explore on a node, ProtoFlow inserts a design variable upstream and generates multiple variants. ProtoFlow also scaffolds an initial layer with multiple nodes containing at least one variant by default. Users can also manually define a design variable by selecting specific fields in a structured node and creating sibling variants.

3.1.3 Goal-based Layers and Cross-goal Integration (DG3). ProtoFlow organizes interaction design around research goals while making their relationships explicit (Figure 2-A). Each research goal is represented as a separate layer, and a full-system view aggregates flows across goals(Figure 2-F). Because goals often have dependencies and shared constraints, users can import and export nodes and sub-flows across layers, enabling reuse when one goal builds on another or when multiple goals require consistent interaction logic. ProtoFlow also surfaces cross-goal relationships (e.g., prerequisites, shared constraints, overlapping steps) and suggests a coherent development order.

3.2 Implementation Details

ProtoFlow was implemented with React, and the node-based visualization was implemented using React Flow[1]. For the generation of nodes, scenarios and exploration, `gpt-5-mini-2025-08-07` model was used. For UI image generation, `gemini-2.5-flash-image` model was used. For generating or re-generating images, the initial nodes were changed into a system scenario, and given into the prompt. The prompts for triggering the first exploration node flow, creating variants, and generating UI images are included in Appendix A.2.

4 Experience Evaluation

To investigate how users prototype HCI research systems with ProtoFlow, we conducted a 90-minute user study with six HCI researchers (3–5 years of research experience) who had completed at least five prior prototyping projects and had experience using AI tools for design or prototyping. After a 10-minute introduction and tutorial, participants spent 60 minutes prototyping an HCI project they brought using a think-aloud protocol. The session concluded with a 20-minute semi-structured interview about their design process and outcomes. Participants were compensated $20 USD. The study was approved by our institution's IRB. Across all participants, 264 nodes were created (M=44.0 per user), with 54.5% AI-generated and 45.5% user-created. All participants utilized all

[1] https://reactflow.dev/

five node types, and participants created an average of 2.7 design goal layers each, with 16.5 nodes per layer.

4.1 Scenario Components Support Structured Interaction Design (DG1)

Participants found that interaction-unit based scenario construction aligned well with HCI design practice. Several participants noted that they previously thought at a high level of abstraction (P2) and, while they could envision broad functions, struggled to specify the detailed system actions that would realize them (P3). ProtoFlow's node structure helped participants think through the system's interaction logic (P6), enabling them to move from function-level thinking to concrete specifications (P2). P3 observed that AI helped bridge high-level design decisions and low-level actions, a gap that was difficult to navigate manually. Notably, system-processing nodes were the most frequently created (32%), suggesting that participants actively engaged with specific system behavior. Participants also valued how scenario construction supported early-stage research reasoning. Regarding the structured input format, participants identified a tradeoff. Compared to freeform prototyping tools where high freedom sometimes led to uncertainty about what to specify and whether the LLM understood correctly (P2), ProtoFlow's explicit structure made it easier to direct the AI. While this reduced flexibility, it allowed participants to verify whether the AI's outputs aligned with their intended flow (P2).

4.2 Design Variables Facilitate Structured Exploration (DG2)

Participants used the design variable node to explore alternatives for the same interaction step and to navigate the design space more systematically. Across all participants, 23 design variables were actively used, with an average of 3.09 branches per variable. All explorations continued to a depth of 2, suggesting participants developed alternatives beyond initial branching. The design variable helped users externalize their decision-making by articulating why they made particular choices (P1). P1 noted that this fits HCI research well, where explaining the rationale behind design decisions is essential; ProtoFlow's design variables enforced this reasoning step explicitly. Participants leveraged design variables in different ways: P2 used them to control the scope of exploration—fixing certain elements while leaving others open for alternatives. P3 used the explore function to generate multiple system action options aligned with their goals, then selected the ones that best fit their needs.

4.3 Research Goal Layers Facilitate Goal-level and System-level Design (DG3)

Dividing the design process into layers based on research goals helped participants engage in bottom-up interaction design. Participants noted that they typically design with a top-down approach, but separating layers allowed them to focus on individual goals independently (P2, P4) and better clarify the sub-goals each layer should address (P5). P3 appreciated being able to consider relationships between layers while keeping them conceptually separate. The layer structure also prompted reflection on goal clarity. P2 observed that the generated results for two design goals appeared unexpectedly similar, revealing unintended overlap; this led them to refine their goals to be more distinct. Participants also noted the importance of integration support. P2 mentioned the importance of connecting the separate layers, suggesting that supporting organic connections across layers is an important system role. P2 and P4 also expressed a need for visualizing relationships and sequencing between design goal layers.

5 Discussion and Future Work

We discuss the implications of ProtoFlow for supporting research system prototyping and future work.

5.1 Adapting Abstraction and Fidelity to Design Stage

Participants expressed a need for adaptive levels of abstraction and fidelity across different design stages and flow depths. Initially, generated options tended to be abstract, but participants wanted lower-level and concrete options as the flows progressed (P1). This need was especially pronounced for interface representations. During early exploration, participants found single-view image mock-ups sufficient for quick feasibility evaluation and variants comparison (P4, P5). However, when examining flows in greater detail, merging multiple flows into one interface (P1), or generating text-based scenarios (P3, P4), participants wanted higher-fidelity and interactive prototypes to evaluate whether the interface could support those flows and to understand the hierarchy among multiple views.

This need for stage-wise fidelity aligns with previous findings and approaches for creativity support, where low-fidelity representations support divergent exploration, while higher fidelity aids convergent refinement [6, 24]. Future versions of ProtoFlow should support adaptive fidelity selection to match the iterative nature of HCI prototyping.

5.2 Enabling Bidirectional Design Iteration

Participants valued the bottom-up approach that ProtoFlow provides, which allowed them to focus on individual design goals and scenario components before integrating them into a unified system view or a comprehensive user flow (P2, P4, P5). However, HCI design is inherently iterative—designers often revisit earlier decisions after seeing later outputs [9]. Participants requested bidirectional support: when a final UI or scenario is edited, the underlying node flow should update accordingly, and vice versa (P4). This would enable flexible movement between bottom-up construction and top-down revision. To support this iterative cycle, future versions of ProtoFlow should enable synchronization across interaction flows, scenarios, and UI artifacts, aligning with the findings of prior work on research support tools [19, 25].

5.3 Grounding Interaction Design in Prior Research

Participants requested the ability to import reference papers and extract reusable design elements into scenario components. P5 noted that when a reference paper shares similar goals, its context, user actions, and design variables could serve as useful starting points—rather than the low-level system actions. P3 suggested that ProtoFlow could break down reference interactions or incorporate reference images during UI generation. P1 emphasized that from a researcher's perspective, being able to trace and cite such references would also support paper writing and grounding. Supporting this kind of reference decomposition could help ProtoFlow better serve HCI researchers in grounding their designs in prior work.

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A Appendix

A.1 Node Structures

Node Type	Structured Fields	Description
Context	`situation, goal`	The situational trigger for the interaction (e.g., user's goal or intent, system event, or surrounding conditions).
User Action	`trigger, input`	The observable behavior from the user (e.g., clicking, typing, uploading, selecting, hovering).
System Action	`does, shows`	What the system does in response (e.g., computing, retrieving, generating, validating, saving).
Design Variable	`decision, options`	A point where multiple design directions are possible (e.g., alternative flows, response styles, interface options).
UI	-	What the user sees: interface state and visual presentation.

Table 1: Node types used in our interaction trace representation and their associated structured fields.

A.2 Prompts

A.2.1 Prompt for Triggering First Exploration Node Flow.

```
You are an expert HCI researcher specializing in creating
      interaction
traces and flow diagrams for research prototypes.

Your task is to generate a QUICK-START trace flow that helps the
researcher ideate and explore interactions for THIS DESIGN GOAL
      ONLY.
This is intentionally a rough sketch to spark ideas - not a
      comprehensive
or perfect flow.

IMPORTANT CONSTRAINTS:
1. This trace is ONLY for "[designGoalName]" - do NOT include
      information
   from other design goals or broader system flows
2. Keep it SIMPLE and FOCUSED - this is meant to spark ideation,
      not be
   exhaustive
3. Use 3-5 nodes (suggest a realistic but concise flow)
4. MUST include at least ONE design-variable node that creates
      branching
   - A design-variable node should branch to 2-3 nodes of the SAME
        TYPE,
     each representing a different approach to that decision
   - Each branching node should have a slightly different label/focus
     based on the design choice
   - Do NOT branch to different node types - only variants of the
        same type

PROJECT CONTEXT:
[projectContext]

DESIGN GOAL: [designGoalName]
RATIONALE: [designGoalRationale]

Node Types Available:
- context: What initiates this interaction (user goal, system
      state, trigger)
- user-action: What the user does (clicks, types, uploads,
      navigates)
- system-processing: What the system does (validates, processes,
      generates)
- design-variable: A KEY DESIGN CHOICE or branching point
- ui: Visual interface state the user sees

Guidelines:
- Keep descriptions concise (1-2 sentences)
- Make it imperfect and rough - it's a starting sketch
- Design-decision nodes should cause visible branching in the flow
- UI nodes should appear where visual states matter
- Focus ONLY on this design goal, not the broader system

STRUCTURED DATA REQUIREMENTS:
For each node, provide type-specific structured fields:
- context: { situation, goal }
- user-action: { trigger, input }
- system-processing: { does, shows }
- design-variable: { decision, options }
- ui: { elements, state }

Return ONLY valid JSON with nodes and edges arrays.
```

A.2.2 Variant Creation Prompt.

```
You are an expert HCI researcher specializing in exploring different
interaction scenarios and design alternatives.

Your task is to generate [numberOfVariants] DIFFERENT variations of
      a
node based on an existing design decision that has been established.

PROJECT CONTEXT:
[projectContext]

DESIGN GOAL: [designGoalName]

EXISTING DESIGN DECISION:
Label: [designDecisionLabel]
Description: [designDecisionDescription]

NODE TO CREATE VARIANTS FOR:
Type: [nodeType]
Label: [nodeLabel]
Current Description: [nodeDescription]

PRECEDING NODES (what comes before this):
[List of preceding nodes with type, label, description]

FOLLOWING NODES (what comes after this):
[List of following nodes with type, label, description]

EXISTING SIBLING NODES (other variants from the same design
      decision -
AVOID OVERLAPPING WITH THESE):
[List of sibling nodes with type, label, description]

Instructions:
1. Generate [numberOfVariants] Variants: Create different versions
      of
   this node - each variant should represent a different answer to
        the
   existing design decision.
2. Respect the Design Variable: Your variants must directly address
      the
   existing design decision.
3. Avoid Overlapping: Do NOT create variants that overlap with
      existing
   sibling nodes.
4. Contextual: Ensure variants fit logically with the preceding and
   following nodes.

LANGUAGE STYLE:
```

```
- Use simple action verbs: clicks, types, shows, loads, displays,
      selects
- Be direct and specific, not abstract or verbose (3-8 words per
      field)
- Describe the interaction, not explain it

STRUCTURED DATA (type-specific):
- context: { situation, goal }
- user-action: { trigger, input }
- system-processing: { does, shows }
- ui: { elements, state }
- design-variable: { decision, options }

Return ONLY valid JSON with variants array containing label,
      description,
fullDescription, structuredData, and entities for each variant.
```

A.2.3 UI Image Generation Prompt.

```
Create a UI mockup for this interaction.

PROJECT: [projectContext]

DESIGN GOAL: [designGoalName]

INTERACTION FLOW:
1. [NODE_TYPE] Node Label
    Node description
2. [NODE_TYPE] Node Label
    Node description
...

PREVIOUS STEP UI REFERENCE (if available):
The image provided above shows the UI design from the previous step
      in
the interaction flow. Your task is to create a UI design for the
      CURRENT
step that naturally follows from this previous design. Maintain
      visual
consistency with the previous design's style, color scheme,
      typography,
and UI patterns - but progress the interaction to show the next
      step in
the user's journey.

Requirements:
- Show ONLY this specific component/screen - not the full
      application
- Use realistic placeholder content
- Clean, simple design with clear visual hierarchy
- Show the UI in a state that demonstrates the interaction

Generate a focused UI mockup image.
```

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