# Comprehensive Sketching: Exploring Infographic Design Alternatives in Parallel


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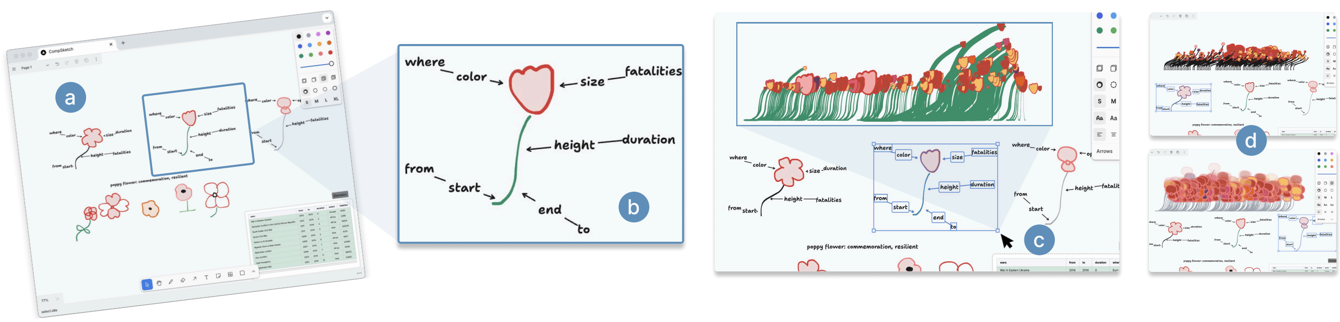


**Figure 1: CompSketch is a sketch-based infographics authoring tool to support early-stage brainstorming and parallel prototyping. (a) A designer can sketch multiple disjoint ideas on a freeform canvas, (b) use arrows to indicate how to bind data attributes to visual channels of the glyph, and (c) and lasso-select a specific area of the sketch for previewing the corresponding visual outcome. The previews is automatically generated by the system with data binding applied, displayed near the selected sketch and disappear upon deselection. (d) By selecting different areas of the sketch on the canvas, designers can intuitively explore and refine multiple design alternatives in parallel.**


## Abstract

Designing effective and memorable infographics requires both aesthetic creativity and strategic data binding decisions, demanding intensive exploration and iterative trials and errors. Although existing sketch-based tools automate the data binding process to support rapid prototyping, they typically rely on serial workflows that limit freeform exploration. To address this, we introduce the concept of *comprehensive sketching* which reimagines sketches as interactive objects for expressing design intent — defining what visuals to use, how to bind data, and where to arrange elements. We implement this idea in a tool named CompSketch. CompSketch features a *freeform canvas* that allows designers to sketch and organize multiple disjoint ideas without assuming every stroke contributes to the final design. An *on-demand preview* lets users control when and how data bindings are applied, facilitating seamless transitions between exploration and refinement. CompSketch encourages the divergent thinking and empowers designers to explore infographic design alternatives in parallel.




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## CCS Concepts

• **Human-centered computing** → *Interactive systems and tools*; • **Applied computing** → *Arts and humanities*.


## Keywords

Free-form Sketch, Infographics, Creativity Support, Design Ideation

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# 1 Introduction

Infographics combine visuals and data to convey insights, communicating the facts behind datasets while also resonating emotionally with audiences through compelling visuals [14]. This dual purpose makes infographics a powerful media for both storytelling and analysis [25], as seen in impressive examples that commemorate deaths in wars (Poppy Field) [9], highlight key moments of the MeToo movement (MeToomentum) [10], and raise awareness of other globally recognized issues [5, 19, 38]. However, designing effective infographics is inherently challenging, as it requires both a keen aesthetic sense and strategic data-binding decisions [35]. Before arriving at a compelling design, designers invest significant time brainstorming and exploring numerous possibilities. As Linus Pauling famously stated, *"the way to get good ideas is to get lots of ideas and throw the bad ones away"* [24].

To develop ideas in the early design stage, designers sketch to think visually [1, 2, 30], externalize abstract ideas onto the paper [18], and coordinate fuzzy thoughts during the iterative divergence-convergence cycles [23]. Designers often begin by sketching as many ideas as possible — ranging from glyph variations to data-binding strategies or layout arrangements [11]. This divergent process is critical for exploring possibilities and fostering creativity. As ideas accumulate, designers compare and refine them, gradually converging on key design choices.

Yet, sketching alone often falls short in allowing designers to holistically visualize how a design will appear once data is integrated, as humans naturally struggle to mentally simulate the effect of hundreds of data points. Existing digital tools [21, 27, 42] address this issue by automatically binding data to sketches through direct manipulation interfaces and facilitating rapid prototyping. However, these tools simply treat sketches as static visual marks for *creating* a design, rather than reflecting a dynamic *thinking* process to fully explore the design space, as designers traditionally do with pen and paper. Additionally, they adhere to a *serial prototyping* workflow, requiring design decisions to be made step-by-step in a procedural manner. Such an approach overlooks the inherently non-linear and iterative nature of the design process, where decisions are often intertwined and designers frequently explore alternatives and revisit earlier concepts. In contrast, *parallel prototyping* (Figure 2) — creating and exploring design alternatives at the same period rather than one design after another [4, 6, 13] — has been shown to promote divergent thinking and improve design outcomes across domains such as advertisement design [13], interface design [39], shape design [28], and 3D content authoring [15, 20]. Compared to *serial prototyping*, *parallel prototyping* encourages designers to explore a wide range of possibilities, yielding more innovative results and reducing attachment to any single idea [13]. Despite its potential benefits, it remains understudied how to effectively enable parallel prototyping for sketch-based infographic design.

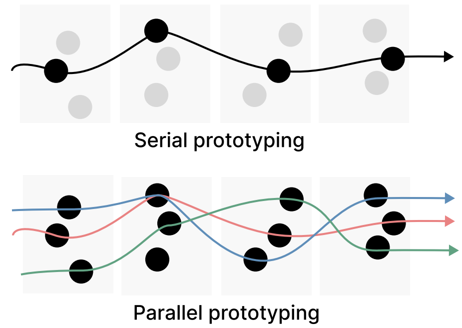


**Figure 2: Comparison of serial and parallel prototyping workflows: in serial prototyping, designers make sequential decisions, finalizing a single prototype (grey circles represent options, black circles indicate the choice). Parallel prototyping retains multiple options, enabling flexible combinations and simultaneous exploration of alternatives.**

To address this gap, we introduce the concept of *comprehensive sketching* which reimagines sketches as interactive objects for expressing design intent — defining what visuals to use, how to bind data, and where to arrange elements. We implement this idea in a tool named CompSketch, which provides a *freeform canvas* that allows designers to create multiple design alternatives, freely explore and organize various design options during the divergence phase, without assuming every design decision necessarily becomes a part of the final design. CompSketch also introduces *on-demand preview*, enabling users to select specific areas of the canvas to visualize designs with bound data. By supporting seamless transitions between divergent exploration and convergent refinement, CompSketch empowers designers to navigate the design space more effectively.

# 2 Related Work

Sketching is a fundamental method for early-stage ideation due to its inherent freeform nature [4, 29, 34], particularly in creative and design domains. It plays a crucial role in visual thinking [40], enabling designers to *"think with their hands"* by concretizing their abstract ideas in mind onto the paper and flexibly coordinating different ideas and thoughts in an unconstrained way [18]. However, in the context of infographics design, integrating data into sketches introduces significant challenges. Designers often find it difficult to mentally simulate how bound data will appear, making it hard to solely rely on manual sketching without external assistance.

To support the sketch-based infographics creation and authoring, previous work focuses on automating the process of binding data to sketched visuals. NapkinVis [7] is a pivotal work that first enables sketch- and gesture-based visualization creation without any programming for quick and informal design needs, using predefined gestures to link the data to visuals. SketchVis [3] extended this by enabling hand-drawn sketches to directly manipulate the simple charts. To further support more diverse and expressive infographics, many tools started to allow users to draw their own personalized visual glyphs. For example, SketchStory [21] and SketchInsight [22] allow designers to sketch glyphs, specify chart types via gestures, and add hand-written annotations with the system completing the data binding process automatically. Focusing on a specific visualization type, TimeSplines [26] focuses on temporal data, enabling users to sketch timelines that are automatically bound to data. DataToon [16] introduces an innovative way to create dynamic network visualizations in the form of comics, blending storytelling with data visualization. DataSelfie [17] supports users to design their own visual vocabulary to represent personal data where users can draw glyphs with visual suggestions in separated design layers.

The works most closely related to ours are DataInk [42] and DataGarden [27]. DataInk [42] supports progressively sketching glyphs and specifying data binding through direct manipulation [37], employing a lazy data binding approach at each step. While its early data integration provides immediate feedback, it can prematurely force users into concrete forms too soon, potentially disrupting creative thinking with abstract representations [8, 31, 41]. DataGarden [27], in contrast, uses a template-based workflow where designers first sketch, then define a data schema, and finally bind the complete dataset. This delayed data binding reduces cognitive load but risks mismatches between the envisioned and final design, as integration issues emerge late, increasing revision costs. Our approach bridges these extremes by enabling early previews of data integration to guide design decisions while preserving the flexibility to iterate on abstract representations, balancing creative freedom with practical alignment.

Despite that above-mentioned sketch-based tools provide an effective way for designers to ideate in the early stage, they predominantly follow a serial prototyping workflow where users make design decisions step-by-step, and focus on completing one certain version at a time. In contrast, in this work, CompSketch enables a parallel prototyping workflow to encourage users to explore more design alternatives and foster divergent thinking.

## 3 Design Goals

CompSketch aims to support creative exploration and expressive authoring of infographics without overwhelming authors with tedious data binding efforts. Our approach balances the trade-off between the efficiency of rapid prototyping and the freedom to explore alternative designs, thereby enabling *parallel prototyping* and promoting divergent thinking. Drawing insights from previous literature, we articulate the following three design goals that guided our development:

*DG1: Facilitate a **fluid sketching** experience that captures the entire thinking process with minimal reliance on UI widgets.* When sketching with pen and paper, designers naturally capture their entire thought process, including rough aesthetics, potential data bindings, and other design considerations (Figure 3). Tablet-based digital whiteboards strive to replicate the physical sketching experience as naturally as possible in many different design contexts [36, 43]. However, existing sketch-based tools [21, 27, 42] for infographics authoring fall short in two key aspects: (1) they focus on sketching aesthetics while deferring data bindings to UI widgets, disrupting the continuity of design workflow; and (2) they assume a clean canvas, ignoring the divergent thinking process on the paper where multiple ideas are often explored simultaneously. CompSketch aims to address these limitations by replicating the intuitive, fluid experience of drawing on paper — expressing *all* abstract data visualization plans through sketching without interruptions caused by switching between pen and UI widgets.

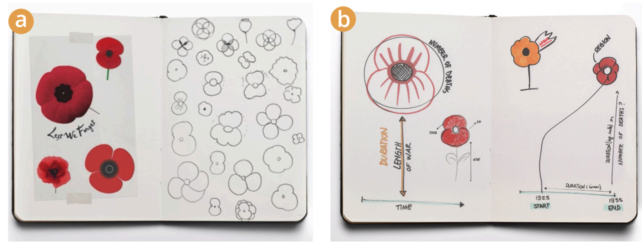


**Figure 3: Traditional pen and paper sketching allows designers to naturally record their entire thought process, including (a) numerous visual mark alternatives and (b) multiple potential data-binding strategies. Source: An online course [12] by Valentina D'Efilippo.**

*DG2: Provide visual, **on-demand feedback** of automatic data binding effects.* Infographic creation often involves a repetitive data-binding process that can disrupt creative flow. While many tools automate such tasks, their varying approaches to *when and how feedback is provided* pose distinct design challenges. For example, DataInk [42] offers immediate data binding, which can overwhelm designers with excessive duplicated visuals. In contrast, other tools like DataGarden [27] delay feedback until all design steps are complete, leaving designers to rely on imagining results in their mind, which largely increases the likelihood of misinformed or suboptimal decisions. CompSketch aims to enable visual feedback *on-demand*, thereby allowing designers to actively control when to see *concrete* data binding results for *converging the ideas* to feasible ones and when to focus on operating on the *abstract* level to promote *diverging thinking*.

*DG3: Enable a **non-linear process** for making, revising, and recombining design decisions.* Design is inherently iterative, with decisions often intertwined. For example, in Figure 3b, the flower sketch binds both how long (`duration`) the war took place and the number of `deaths` to the flower; when instantiated in the final design, each glyph will have a different *length* and *size* depending on the characteristics in the data, which is hard for a user to capture and imagine from the sketch alone (Figure 3b). Traditional tools enforce a *linear* workflow, where each design decision is built on previous ones, making revisions tedious with frequent undo/redo actions. As a result, users have to mentally track decision paths, which becomes impractical with complex data bindings, and cannot skip intermediate steps to revise earlier choices. Additionally, the ability to group and recombine design decisions, a key aspect of flexible exploration [13, 33], is lost in this rigid workflow. CompSketch aims to overcome these challenges by supporting a non-linear way to *make, modify, and recombine* decisions dynamically and holistically, accommodating the compound effects of interdependent choices.

## 4 CompSketch System

We built CompSketch on top of the open-source *tldraw*[1] framework. Accessible on both laptops and tablets, CompSketch allows users to draw freely using a mouse or pen. CompSketch integrates

[1] https://tldraw.dev/

three main components: a drawing toolbox for essential design functionalities, a data table displayed at the bottom right corner of the canvas for referencing datasets, and a freeform canvas for ideation and experimentation. In this section, we introduce the main features in CompSketch.

## 4.1 Sketch as an Interactive Object to Express Ideas

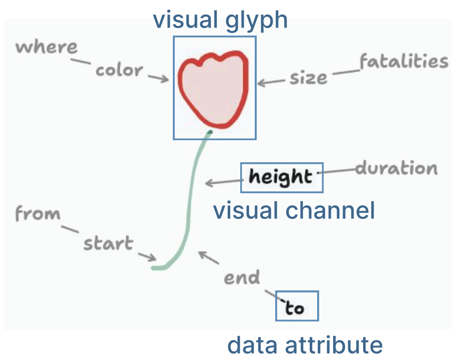


**Figure 4: *Abstract* representation of design intent, consisting of the *visual glyph*, arrows for binding *data attributes* to the glyphs with the specification of *visual channels*.**

In CompSketch, designers can use the pen tool to draw glyphs; designers can then annotate them with arrows to indicate the data bindings for different visual channels, closely mimicking how ideas are naturally communicated on paper (**DG1: fluid sketching**). The "sketch" (Figure 4) refers to the collection of hand-drawn glyphs, arrows, and textual annotations, collectively treated as *an interactive object that visually represents design intent.* Every element within a sketch is fully manipulable, allowing designers to move, resize, and recombine glyphs, arrows, and annotations to test different data-binding strategies dynamically (**DG3: non-linear process**). For instance, users can easily reattach arrows to different glyphs or data attributes to explore design alternatives (Figure 5.b).

This design provides two significant advantages. First, the sketch serves as the *abstract* representation of the design intent, distinct from the resultant visualization in "*concrete*" form. While the concrete form reflects finalized designs with all data bound to visuals, often resulting in many duplicated glyphs, the abstract form consolidates all design decisions in one place. For example, Figure 4 shows five data bindings to the flower with separate visual channels, offering a clear overview of the design choices. This abstraction makes it easier for designers to understand and analyze the relationships between elements, which may be obscured in the concrete form, where only the resultant appearance is visible. Second, the abstract representation allows users to revise any design decision freely, without adhering to a specific sequence. In the traditional workflow reliant on UI widgets, revisions often require sequential changes, binding data one attribute at a time. In contrast, CompSketch's flexible approach enables designers to adjust any part of their sketch at any time, providing a fast way to test multiple alternatives.

## 4.2 A Freeform Canvas for Exploring Divergent Ideas

The canvas in CompSketch is intentionally designed to be *freeform*, offering a flexible space for open-ended exploration. Unlike existing sketch-based tools, where the canvas is rigidly tied to the final design, CompSketch separates the sketching process from the final outcome, allowing multiple, disjoint ideas to coexist — much like sketching on paper (**DG1: fluid sketching**). This separation allows designers to explore multiple ideas simultaneously and evaluate them collectively. The canvas is infinite, with no fixed size, offering sufficient space for designers to freely sketch, zoom, pan, and scale as needed. Users can dynamically group, rearrange, or delete strokes to organize their ideas as they evolve. This freeform design mirrors the messy and iterative process of ideation, encouraging *divergent thinking* by enabling the exploration of a variety of ideas before consolidating them into more refined ones.

## 4.3 On-Demand Preview for Converging Ideas to Feasible Ones

Previewing the resultant design with data bound is critical for infographics, as data patterns can significantly influence the final visual effect, for example, Figure 5.a vs.Figure 5.c. While CompSketch allows designers to work in an abstract, exploratory space, it also provides the ability to selectively preview how designs look with integrated data. This feature, tailored to the freeform canvas, enables users to control *when* and *what* to preview (**DG2: on-demand feedback**).

To trigger a preview, both data and sketch must be selected, though the order of selection does not matter. The entire dataset can be selected by clicking the "select/deselect" button on the data table, or users can refine the selection by clicking on individual rows. Sketches are selected using the lasso-select tool to indicate which data bindings the system should apply to the sketch (Figure 6). Once both data and sketch are selected, the system will integrate the selected data and display a preview directly adjacent to the selected region. The preview is temporary and disappears when the user clicks elsewhere, maintaining a clean workspace. If users lasso-select a sketch without selecting any data, the system interprets the selection as an action to move elements. Similarly, if the selected sketch lacks data bindings (arrows) specifying intent, no preview will be displayed. Unlike traditional tools that update visualizations in real time, this *on-demand* preview approach separates sketching from rendering, supporting thoughtful exploration and refinement while preserving the flexibility of the freeform canvas.

# 5 Exemplar Scenario

In this section, we illustrate how designers can use CompSketch through an example scenario (Figure 7). Imagine Stella, a visual designer, wants to create an infographic to commemorate deaths in wars. Her dataset includes details such as `start` and `end` years, `fatalities`, `where` the war happened, and `duration`. Inspired by the poppy flower's symbolic meaning i.e., remembrance and resilience, Stella chooses it as the central visual theme.

*Exploring and making the design decisions.* She begins by uploading the dataset to CompSketch. Reflecting on the symbolism of the poppy, she starts sketching multiple variations of poppy flowers

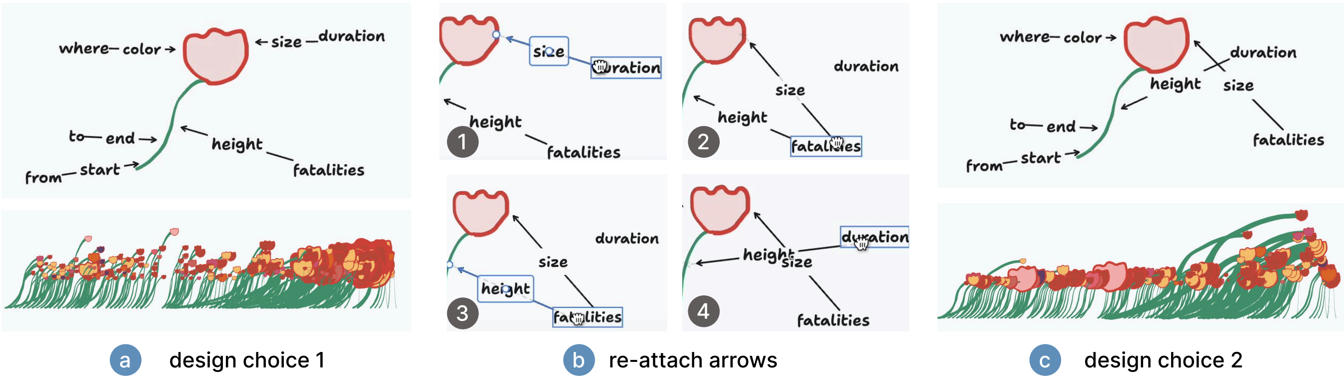


**Figure 5: Starting with the initial design choice (a), users can (b1) drag the end of an arrow, (b2) reattach it to a different data attribute, and repeat the process for other data bindings (b3-4) to explore an alternative design choice (c).**

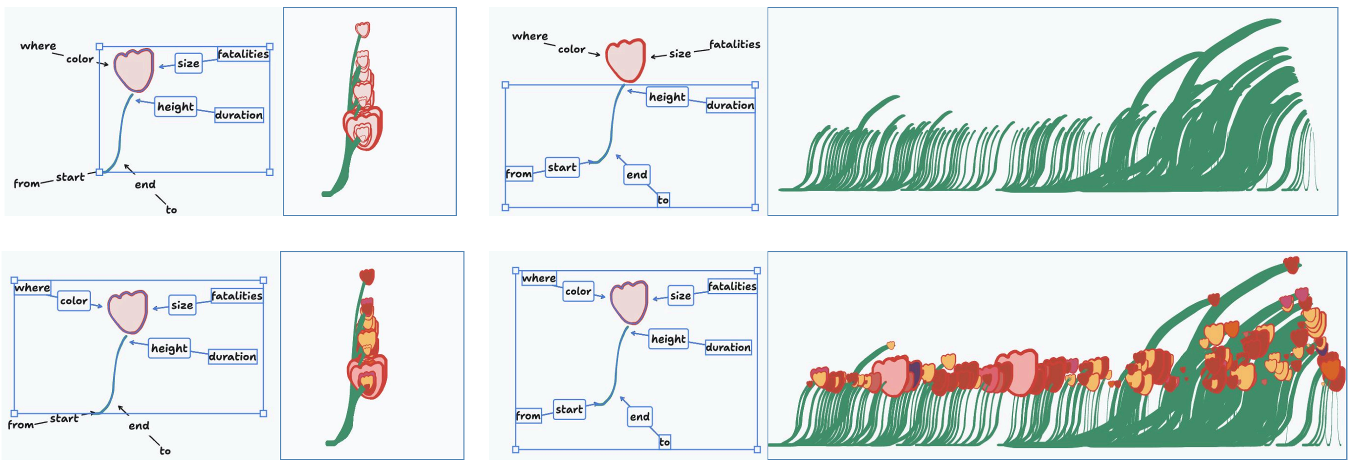


**Figure 6: Demonstration of *on-demand preview*: Users can lasso-select any part or the entirety of a design. When data is selected in the data table, the system generates and displays the corresponding preview, which disappears when deselected.**

on the freeform canvas (Figure 7.1). Stella then selects one of her poppy designs as the foundation to build the rest of the design, leaving unused poppy flower designs as alternatives for future reference. She then begins to bind data onto the sketch, starting with when the war starts (`from`) and the number of `fatalities`. To represent this, she maps `fatalities` to the `height` of the flower's stem and binds the attribute of `from` to the `start` position of the stem (Figure 7.2), imagining a visual representation similar to a bar chart. Using CompSketch's lasso-select tool, Stella previews the stem with the integrated data to ensure it aligns with her desired design outcome, as shown in Figure 7.3. Next, Stella moves forward with incorporating additional data attributes into her design (Figure 7.4). She assigns `where` the war happened to the petal `colors`, ensuring each hue reflects a specific region or country, and maps the `duration` of the wars to the `size` of the petals. Using the preview feature again, she examines how these bindings appear individually and in combination.

*Revising design decisions.* As Stella reviews the simulated preview, she notices a visual imbalance—one data point has a significantly longer stem, reflecting the large number of `fatalities`. Upon checking the data table, she identifies this as World War II. However, its petal appears disproportionately small, as the war's duration was relatively short compared to others, making it less prominent than it should be. To resolve this, she re-assigns `fatalities` to the `size` of the petals instead and `duration` to the `height` of the stem by redirecting (Figure 5) the data mapping arrows (Figure 7.5). This adjustment creates a more balanced and visually harmonious representation of the data (Figure 7.a). She decides to revisit the flower petal design to compare variations and determine which works best. To experiment, she duplicates the composition and replaces only the petals with a new variation (Figure 7.6), keeping most of the arrows intact. After several attempts, she identifies the most suitable design (Figure 7.b).

*Recombining design decisions.* Later, a new idea strikes her: *"what if I use the* `opacity` *of the petal to encode the* `duration` *of the war to highlight the longest-lasting wars?"* Thus, she sketches a new petal, binds the relevant data attributes to it, and combines it with the original stem, copying its associated bindings from the first version of the design (Figure 7.7). Reviewing the result (Figure 7.c), she reflects, *"well, this doesn't seem to work as I hoped."* After exploring multiple design alternatives, Stella confidently finalizes a design

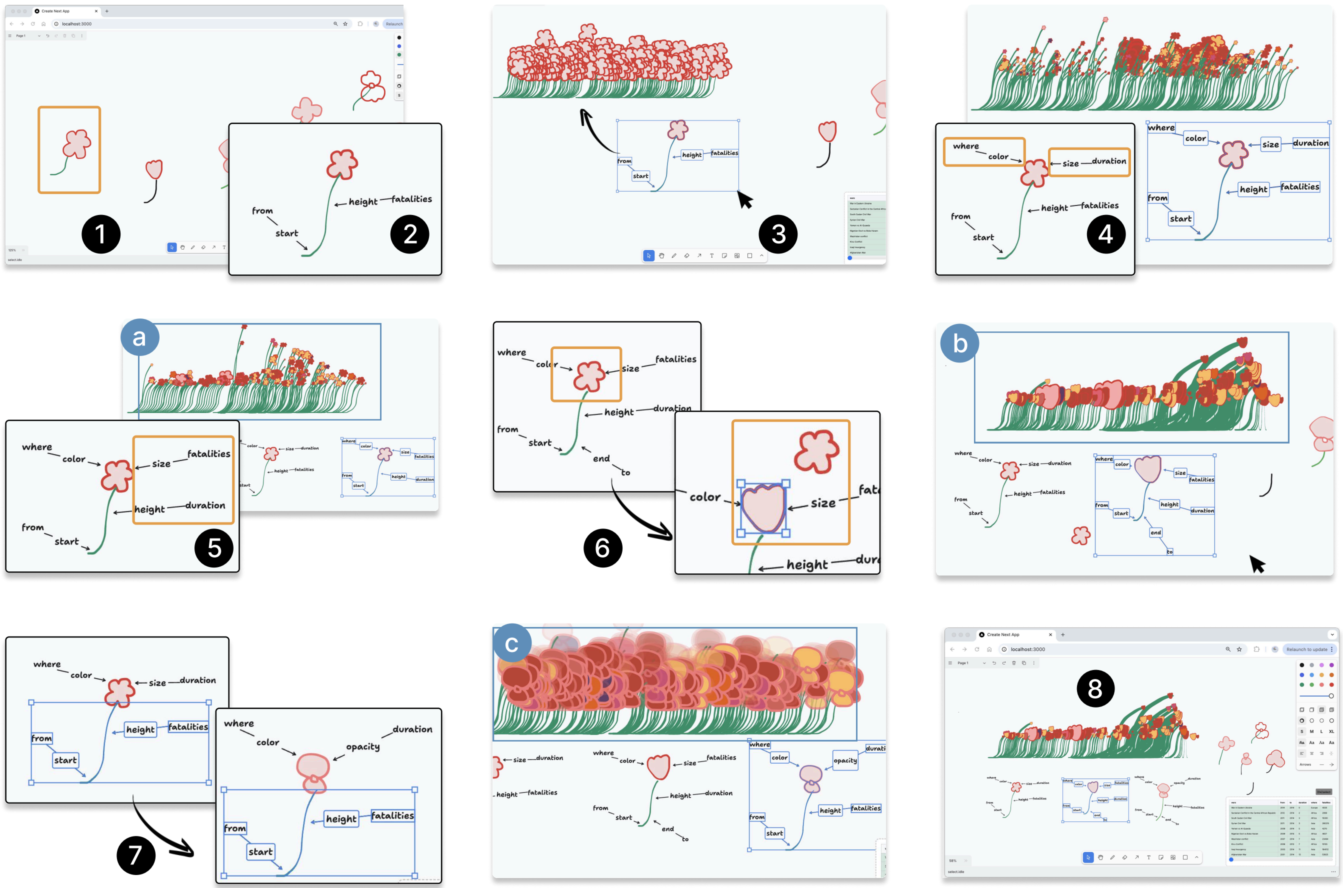


**Figure 7: An exemplar usage scenario in CompSketch: a designer (1) sketches multiple visual glyph options, (2) selects one and binds data to the stem, (3) lasso-selects the design to preview the effect, (4) adds data bindings to the petal and checks the preview, but feels the strategy could improve, (5) swaps the bindings of the stem and petal to test a different encoding and finds it better, (6) experiments with another glyph, (7) explores using `opacity` for encoding while reusing previous designs, and (8) finalizes with several alternatives on the canvas, ultimately choosing the design in the middle.**

(Figure 7.8) that effectively communicates the tragic magnitude of war fatalities and sets the stage for creating a high-fidelity version.

## 6 Design Limitation

While CompSketch aims to replicate the fluidity of sketching on paper, its current design has some limitations. One challenge is the data binding process, which requires users to add arrows and specify visual channels and data attributes. This can potentially disrupt sketching experience, particularly for web users who need to type these details rather than handwriting them as tablet can. Future improvements could incorporate more intuitive sketching gestures, recognizing hand-drawn arrows, and provide automated suggestions for visual channel bindings. Multi-modal input, such as speech commands (e.g., DrawTalking [32]), could also streamline this process, especially for annotating bindings. Another limitation is the lack of flexible annotation methods. Designers often reply on visual cues like color or bolding to differentiate parameters from sketch elements. CompSketch could support more flexible and visually distinct annotation methods to improve clarity on component roles and readability. These enhancements could better align the tool with traditional sketching practices while improving overall fluidity.

## 7 Future Improvements

We reflect on the design of CompSketch and discuss future directions to enhance its usability and creative potential.

### 7.1 Multi-Preview for Parallel Comparison

Currently, CompSketch allows users to preview only a single design on the canvas at once. To compare multiple alternatives, users must mentally retain transient previews, as side-by-side comparisons are not supported. To better support design comparisons and enable designers to converge more efficiently on a final design, future iterations of the system could provide more flexible selection mechanisms. For example, enhancing the lasso-selection functionality to support multiple independent selection boxes would allow designers to isolate and compare distinct design variations directly on the canvas. Additionally, current previews are temporary and disappear once the selection is deselected. Users might benefit from a feature to save previews for future reference. For instance, users could create snapshots of previews, store them in a gallery or history, and even restore saved designs back onto the canvas. This functionality would improve the management of design alternatives and better support iterative exploration.

## 7.2 Preview Interactivity and Customization

The current preview is static and relies on a default scaling algorithm to render design outcomes. This lack of user control can sometimes lead to visual clutter and the potential misinterpretation of designs, making it challenging for users to evaluate and refine their visualizations effectively. To address these issues, we plan to enhance the preview with interactivity and customization features. For example, users could employ sketching or touch gestures to adjust data point spacing, reducing overlap and improving readability. Additionally, we plan to introduce interactive exploration features, such as filtering, aggregating, or viewing subsets of data to better support handling large datasets. These improvements will enable dynamic customization of the preview, supporting a more flexible and insightful exploration process, and helping users better assess the quality of their designs.

## 7.3 Allowing Uncertainty in Sketch

CompSketch currently assumes that sketches contain complete and precise information, i.e., the triplet of a visual glyph, its associated visual channel, and require at least one data attribute to generate deterministic previews. However, in practice, designers may face uncertainty or ambiguity, such as not knowing which visual channel is appropriate for binding the data attribute. To address this, the future improvement of CompSketch could support incomplete or uncertain sketches, allowing users to intentionally leave parts of a design undefined. For example, users could draw an empty arrow without specifying the visual channel. The system could handle these uncertainties by generating multiple possible solutions and presenting them as ranked previews based on suitability. It would also accommodate varying levels of design expertise — giving experts the flexibility to specify concrete data binding ideas, while allowing novices to benefit from system guidance.

# 8 Plans for Evaluation

Demonstrating our core concept of *comprehensive sketching*, CompSketch shows promise as a sketch-based infographic authoring tool supporting parallel prototyping during the brainstorming stage. However, as a work in progress, the system has not yet been evaluated through a formal user study. Our next step is to conduct a comprehensive user study to evaluate CompSketch's effectiveness with designers. In particular, a key focus is to understand how parallel prototyping with CompSketch can influence design divergence, outcome quality, and creative experience. Additionally, we plan to analyze usage patterns to understand how designers interact with the system, such as their strategies for organizing the canvas, managing design alternatives, and utilizing on-demand preview feature throughout their design journey. In particular, we will examine the pattern of users toggling the preview on and off at different design stages to better understand the need for on-demand versus real-time previews. Through the user study, we aim to better understand how user needs evolve and gather insights to shed light on future research to support early-stage design explorations.

# 9 Conclusion

In this paper, we introduce the concept of *comprehensive sketching* to facilitate the parallel design alternatives exploration — treating *sketching as an interactive process to express ideas*, in which users can draw visual glyphs, specify visual channels, and bind data attributes directly with sketches. To exemplify this idea, we developed CompSketch. The *freeform canvas* in CompSketch allows multiple divergent design alternatives to coexist, while the *on-demand preview* feature enables users to visualize the selected design with integrated data, facilitating convergence on feasible final designs. Moving forward, we aim to enhance CompSketch with intelligent support for broader scenarios and improve the usability, and evaluate it with designers. We believe this work can offer insights to guide future research on effective interaction mediums for early-stage design across diverse fields.

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