Social-Technical Tools for Collaborative Sensemaking and Sketching

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Abstract. Sensemaking is a deliberate effort to understand events or information, and a sketch is an exploratory graphic composition of a concept or observation. Within the architecture domain, sketching is employed during pre-design phases to create a shared understanding among clients and stakeholders. While sensemaking is highly collaborative, sketching is usually a solitary activity. This paper describes the design and evaluation of two prototype social-technical tools to support collaborative "same time, same place" sketching and sensemaking: (1) a software environment (SketchBook) that allows users to quickly generate and capture ideas; and (2) a wireless, scalable, multi-user pen interface (FireFly). When used together, these tools support simultaneous sketching, diagramming, and annotation within the same work space without traditional bottlenecks of "turn taking" by passing a single pen. This paper presents the motivation for sensemaking and sketching, and findings from a preliminary evaluation involving a design charrette with architecture students.

Keywords: design, sketching, architecture, collaborative interfaces, sensemaking.

1 Introduction

Sensemaking has been described at several levels: at the individual level, one is constantly making sense of new information encountered in life as we move through space and time [1]; sensemaking is also an ongoing, collective activity that takes place within organizations [2, 3]. While sensemaking is often a collaborative activity that involves exploring and sketching ideas, concepts, and relationships [4], sketching tools are typically designed to support individuals. This research is focused on designing tools that allow individuals to simultaneously interact, collaborate and create a collective awareness by sharing information through the process of sketching.

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Sketching is a useful and powerful construct during sensemaking activities because it empowers individuals to collaboratively express and share concepts through informal drawing representations. A sketch also serves as a powerful tool of both thought and communication [5]. Sensemaking and sketching are used in a variety of domains: television sportscasters often sketch over "video replays" to help audiences understand what happened in an athletic competition or to describe nuances of team tactics that might otherwise go unnoticed; weather forecasters sketch on maps to explain how changing meteorological data could impact a geographical region. Law enforcement and military staffs likewise sketch on maps to collaborate and create a shared understanding of what has happened in assigned areas, summarize activities, and develop courses of action.

1.1 Sketching, Sensemaking and Design in Architecture Pre-design

Architects use sketching to support sensemaking during pre-design activities as they explore and document issues, constraints and goals with client and stakeholders [6]. During the pre-design phase, architects iteratively work to synthesize information from clients and stakeholders and create meaningful spatial and conceptual relationships through sketches [7].

Pre-design processes. The pre-design phase is characterized by the following collaborative processes:

- *diagrammatic reasoning through sketching*: informal representations are generated to facilitate flexible thinking and rapid conceptualization of abstract and global specifications.
- *generative brainstorming*: there is a rapid production of multiple usage scenarios.
- *collaboration and social learning*: there is an exchange of ideas and information between stakeholders, clients and designers.
- *record of salient information*: values, priorities, goals, and design rationale are captured through a process of imaging and visualization.

Architects use sketching to support sensemaking during predesign activities as they uncover and document client and stakeholder issues [6]. Through the sketches, designers create external artifacts to support a shared understanding about the problem space between themselves, clients and stakeholders [7].

According to Schön's notion of "reflection-in-action", professional practice is an interleaved process of thought and action, and sketching allows a designer to "have a reflective conversation with the materials of a design situation" [8]. By generating (sketching) and interpreting their representations, the designer(s) may change their view of the current design. This is a powerful duality, and it raises the question of what might be possible if *design communities* (e.g. designers, clients, stakeholders, etc.) could have an interface to easily interact in the sketching process.

Design charrettes. An architectural practice for engaging in sensemaking activities in a democratic process with all constituency groups is a *design charrette* [9, 10, 11]. During a design charrette, stakeholders and designers come together to participate in an intensive workshop for the purpose of creating consensus about the vision and direction for a design process by creating graphic documentation of their ideas and explorations. A charrette is participatory in nature; all parties share their unique perspectives and information about project goals.

1.2 Other Computational Environments for Sketching

Several computational sketching approaches have previously been developed and investigated including: (1) personal sketching and modeling environments, such as SketchUp [12] and Skencil [13]; and (2) on-line, multi-user sketching environments, such as iSketch [14] and SwarmSketch [15]. Other approaches for supporting collaborative sketching include computational whiteboard designs such as multi-touch table top environments [16], and electronic multi-touch whiteboards [17].

Personal sketching environments present collaborative limitations similar to those found in other "personal" applications, such as MS Word. When using "personal applications", participation takes place in a solitary, parallel modality and products must be "merged" into a final product. This methodology is not supportive of the highly fluid and collaborative workflows used in fields such architecture.

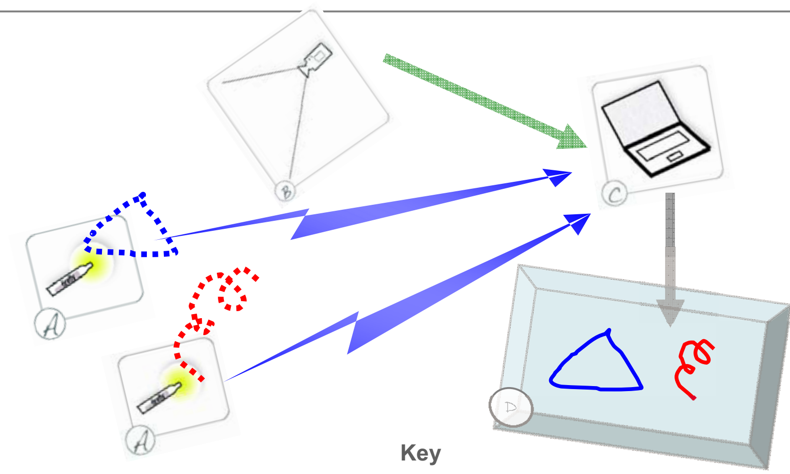
On-line, multi-user sketching environments (similar to SwarmSketch) may also be considered for "same time, same place" collaborations. However, when these systems are used in an on-line "groupware" modality, they may create problems with participant focus and communication as co-located collaborators attend to their personal computer while listening to others who are sketching, drawing, or presenting ideas on a shared space.

1.3 Research Focus

Given the previous approaches toward on-line and personal sketching environments, our research focused on the design of computational sketching tools that support the creation of a *shared understanding among co-located collaborators* engaged in sensemaking activities. "Same time, same place" collaborations are very desirable for situations involving ambiguity and incomplete information since participants engage in face to face communications while presenting ideas.

Within the architecture domain, analog "whiteboards" are often used to capture and organize collaborator concepts, sketches, photos and other related information about the project at hand. Computational whiteboard and tabletop systems share many affordances of analog systems – as well as limitations:

- *accessibility issues:* when computational whiteboard and tabletop systems are used as collaboration environments, all output "real estate" must be visible and physically accessible to all participants. This creates obvious problems for people with physical or mobility disabilities who would desire to annotate, highlight or sketch to express their ideas. It also presents problems if there is a single user input device since a facilitator is needed to interpret and represent ideas on the system.
- *proximity issues*: as with traditional analog whiteboards, digital whiteboard systems [Perceptive Pixel 2008] typically require that users work in close proximity to a projected image space. If the projected image is large, it may be difficult for the sketcher to obtain a holistic view of the entire design space, and the image can become hopelessly obscured if several people are interacting in front of a digital whiteboard.



Key

A – multiple **FireFly pens**, each with a light emitting diode (LED), on-board sensors, and wireless digital data communications with computer

B – standard video camera to transmit video images to computer for tracking pen positions

C – computer running **FireFly interface software** and **SketchBook environment** with wireless digital data communications to pen and data communications to video camera

D – computer or projection screen display output from FireFly pens.

Fig. 1. Overview of FireFly and SketchBook architecture

2 System Overview

Two key components were designed to support collaborative sketching and sensemaking:

- ***a software environment*** that allows users to quickly generate and capture ideas *(SketchBook),* and
- ***a wireless, scalable, pen interface*** *(FireFly*) that allows multiple users to simultaneously sketch, diagram, and annotate within the sketching environment (SketchBook).

When used together, these tools support simultaneous sketching, diagramming, and annotation within the same work space without traditional bottlenecks of “turn taking” by passing a single pen (Figure 1). The software environment (SketchBook) and interface were designed as independent components to support comparative evaluations between different software environments (SketchBook vs. SketchUp, etc.), as well as different interface treatments (SketchBook with FireFly, tablet stylus, or mouse interface).

Fig. 2. Exterior view of current FireFly prototype with light emitting diode, power and momentary switches. CPU, power supply, and wireless communication components fit into a dry marker package and a user "draws" by pressing the momentary switch while moving the pen.

2.1 Description of the Prototype Firefly Multi-user Interface

FireFly is a wireless "smart pen" with a light emitting diode (LED) on the pen tip. Each FireFly pen communicates with the SketchBook environment via two communication channels:

- ***optical tracking*****:** A standard VGA video camera optically tracks multiple FireFly pens as users draw in a virtual space. Using the camera video image (see Figure 1), movements of FireFly pens are mapped to the SketchBook drawing space.
- ***digital commands:*** each FireFly pen contains a CPU, switch sensors, and wireless communication technologies to detect and send commands to the SketchBook.

Current pen commands include detecting "mouse down" and "mouse up" using a small momentary switch (see Figure 2) and recording personalized "gestures" that can be mapped to application menu commands. FireFly users sketch by moving the pen in space (A in Figure 1), while a video camera (B in Figure 1) located above the computer screen optically tracks each pen position. A standard VGA video camera with manual exposure controls (aperture, contrast, and shutter speed) provides a flexible way to detect the LED on a FireFly pen tip in a wide range of ambient room lighting conditions. Since each FireFly pen transmits a unique initialization "handshake" upon power up, multiple pens can be detected and simultaneously tracked using the video image data.

When a FireFly user wants to draw "ink" in the SketchBook environment, the sketcher presses a small momentary switch, indicating a "mouse down" command. Since each FireFly pen contains a CPU to process on-board sensor data, the pen could also detect subtle user gestures that may not be visible to the video camera, such as pressure changes, or rotational changes. Once detected, pen commands are interpreted and wirelessly transmitted the computer running the SketchBook environment. Since each pen is tracked and analyzed in its own software thread, one FireFly pen can be drawing, while another is making a menu selection (changing line color, undo, etc.).

2.2 Description of the Multi-user SketchBook Environment

SketchBook, a multi-user sketching environment, currently supports two FireFly pens and a mouse, allowing multiple users to simultaneously engage in free-form sketching, annotation, and diagrammatic reasoning (Figure 3). SketchBook provides a minimal menu set to present a simple and informal “paper and pencil” interface motif. Menus choices include line color and thickness, as well as “clear”, “undo” and “erase”. Whenever a user performs a potentially destructive operation (e.g. “clear”, “undo” or “erase”), a “thumbnail sketch” appears to the right of the collaborative sketch space to preserve ideas that were under consideration (Figure 3). In this way, SketchBook allows users to quickly get their ideas out without the worry of losing previous work, and without the overhead of naming and saving files.

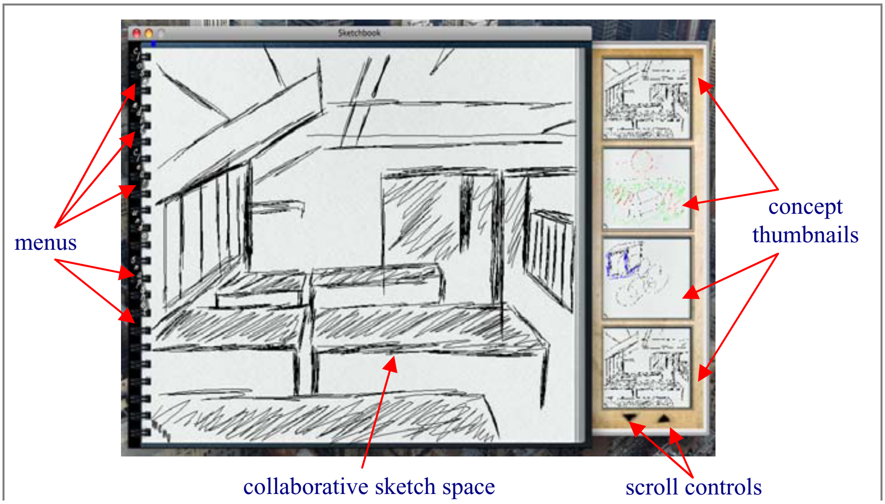


Fig. 3. SketchBook, a multi-user sketching environment

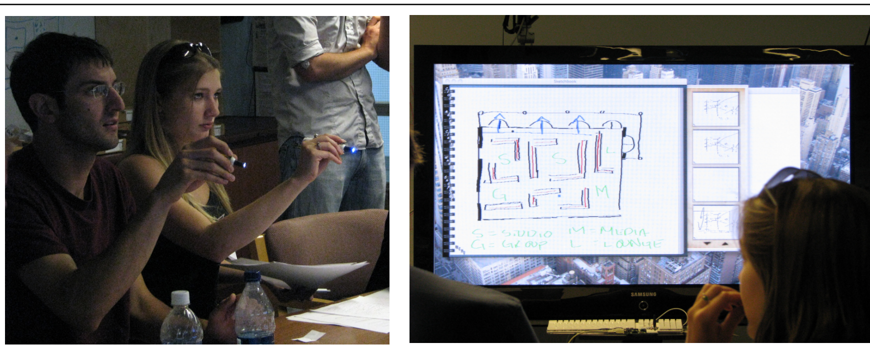


Fig. 4. A student design team sketching in a pilot design charrette [Lennertz et. al 2008] with FireFly and Sketchbook prototypes on a large display screen

The SketchBook environment runs on a PC, Tablet PC, Macintosh, and Linux. The environment supports simultaneously drawing on a scalable range of output displays including notebook, large screen displays or projected images (see Figure 4). In addition to the prototype FireFly interface, the SketchBook application can also be used with a PC mouse, stylus pad, or track pad. This design permits evaluations of the software environment with a variety of interface treatments.

3 Evaluation Studies

Evaluation studies were conducted to (1) understand how the prototype Sketchbook application and FireFly interface support collaborative sensemaking and pre-design processes within architecture design groups; and (2) identify potential improvements for the prototype application and interface. User studies were situated within a "design charrette". The design charrette started with an open-ended design problem requiring group ideation, brainstorming, and establishment of design goals.

Once a goal was established, the group created conceptual designs and prepared a presentation to communicate key design concepts and design rationale. Following group presentations, each participant completed an anonymous survey providing feedback about (1) the overall design experience and (2) the tools used. Data from presentation outputs and surveys were aggregated and analyzed to identify refinements in the technologies and/or the design problem.

3.1 Evaluation Task

Twenty-one architecture student volunteers were divided into design teams of five or six members in a design studio style exercise [18]. Each team was provided background materials about a real-world design task involving a large studio space in a campus environmental design building (Figure 4). Teams could choose between focusing on macro-level issues (layout of the overall studio) or micro-level features (team work areas and desk space design). Each team was instructed to create a conceptual design and prepare a group presentation summarizing their findings and design recommendations.

Each group had a laptop computer as well as paper and pencil. Students were instructed to focus on the design task, not critique the prototype tool. One member of each group was randomly designated as a team leader as responsible for overall time management and group participation, while another acted an internal "observer" and took notes anytime the team either reached an impasse or had a problem with the prototype tools.

Since one large screen and two prototype FireFly pens were available, teams rotated between the following interface treatments and software: (1) the FireFly and SketchBook application on a large screen; (2) SketchBook on a tablet PC and a stylus; and (3) SketchBook on laptops with a mouse or track pad. Teams were also permitted to use paper and pencil to represent any conceptual sketches, diagrams, or annotations that were difficult to represent using the assigned tools.

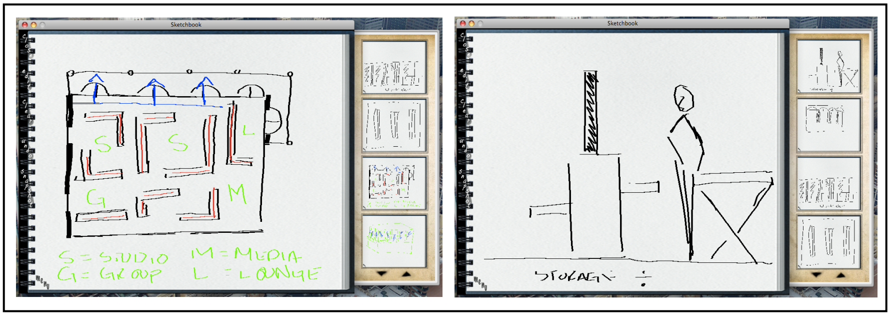


Fig. 5a (left) and 5b (right). Groups were provided a real world design task and asked create concepts focusing on macro-level floor plan design considerations or micro-level workspace issues.

3.2 Evaluation Data

Complementary quantitative and qualitative data were obtained through final team presentations, sketch artifacts, post-task individual surveys, and observer notes. These data provided multiple ways to triangulate on system strengths, weaknesses, and potential improvements through collective and individual assessments.

3.3 Key Findings

Concept sketches were analyzed to assess high level goals, and how well the FireFly interface and SketchBook application allowed users to draw and communicate their designs. User surveys also illuminated what interfaces were preferred, features subjects found most useful and usable, and recommendations for improvements.

Support for high level goals and expressiveness. All groups elected to use the SketchBook application for sketching ideas during the design phases. Figure 5a highlights a design that focused on “macro-level issues” including floor space layout, exterior wall, and lighting issues, while Figure 5b illustrates a design created by a group that elected to focus on “micro-level” design issues including workspace, desk, and group cubicles.

Application interfaces used. All four groups elected to use the FireFly interface to make design presentations, and all groups extensively used the “snapshot” functionality in SketchBook to present issues considered and the evolution of their designs. Two groups used the FireFly interface to sketch during their presentation and one also used a mouse interface as a pointer. One group elected to use the mouse as the primary interface, and used the FireFly interface as an augmentation to highlight key design features.

Usability and usefulness. In post-task surveys, users were asked to rate the SketchBook applications with different interfaces (FireFly, tablet stylus, and mouse) vs. paper and pencil, a traditional sketching tool. In rating the usefulness in sketching and representing key aspects of the design, the SketchBook application with a tablet interface was rated as a close second to paper and pencil (9.0 vs. 9.2 on a subjective scale of 1 to 10, with 1=poor and 10=excellent). The mouse/track pad and FireFly interfaces were a distant third and fourth (5.8 and 4.1 respectively). In rating usability to represent key aspects of design, the SketchBook application with a tablet was again rated as just below pencil and paper (8.7 vs. 9.2 respectively), followed by mouse or track pad, and FireFly (5.4 and 3.8 respectively).

Overall impressions. Users were asked to provide overall ratings about the SketchBook application and FireFly interface using the same 1 to 10 subjective interface. The most highly rated features in SketchBook included the ability to import external pictures (9.9), simplicity (9.4), and the ability to keep track of design revisions and changes (9.1). These ratings were followed by the ability to share ideas (8.7) and flexibility (7.8). The FireFly interface was most highly rated for its usefulness in presenting ideas (7.7), ability to change drawing colors/thickness (7.5), simplicity (6.8), and usefulness to simultaneously sketch with more than one person (6.4); less well rated was the ability to annotate and draw (3.9 and 3.0 respectively).

4 Summary and Future Work

These preliminary studies illuminate both the potential and shortcomings of this prototype application and interface. While users exploited the simple yet powerful collaborative dimensions of the SketchBook application, the tracking resolution of FireFly prototype is currently not sufficiently accurate for creating detailed free hand sketching and annotations. Despite these shortcomings, it is remarkable that the FireFly prototype pens were selected by all teams during design presentations. When making presentations, members interactively “tag teamed” between speaking and highlighting sketch design features, often while another member was speaking. This type of collaborative presentation is not usually seen when there is a single speaker and mouse interface.

Future plans for the FireFly interface will explore the use of high resolution tracking cameras and smoothing algorithms to improve drawing performance. We will also explore the use of advanced pen sensors to support the detection, interpretation, and mapping of user-defined gestures to application commands, a strategy for enabling additional application functionality, while preserving the highly rated simplicity of the SketchBook interface and supporting meta-design [19]. In response to survey suggestions, we will also consider extending the SketchBook application to support import and export of a broader range of graphics files, allowing the rough sketches created in the SketchBook application to be further used and refined in other drawing applications.

In summary, multi-user environments offer the promise of greater collaboration and participation in domains where barriers to participation are restricted by system models that assume a single user. Sketching is a powerful and natural activity that occurs when people gather to communicate concepts and ideas, and computational systems for sketching and collaboration should likewise be designed to support simultaneous parallel communications and exchange of ideas. While additional work is needed to improve the tracking resolution of the FireFly wireless pen interface, this research provides a proof-of-concept that a multi-user interface and application can support creative group collaborations.

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