# SketchComm: A Tool to Support Rich and Flexible Asynchronous Communication of Early Design Ideas

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## ABSTRACT
When designers explain their early design ideas to others, they usually use face-to-face communication along with sketches. In practice, however, sometimes face-to-face meetings are not possible, and designers have to rely on asynchronous communication. Important contextual information that is available in face-to-face meetings often becomes missing in such asynchronous communications, which can lead to confusion and misunderstanding. To address this challenge, we present SketchComm: an enhanced tool to support rich and flexible asynchronous communication of early design ideas. The key of the system is to allow designers to capture and communicate important contextual information to the audience in addition to sketches. A user study with designers and audience demonstrated effectiveness of asynchronous early design communication using SketchComm.

### Author Keywords
Design, asynchronous communication, tool.

### ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

### General Terms
Design; Human Factors.

## INTRODUCTION
Communicating designs to others and getting feedback is a key practice in the design profession. Especially in the beginning of a design process, when designers communicate their early design ideas to others, they usually use face-to-face communication along with hand-drawn sketches. Relatively little effort was needed to draw these sketches, saving considerable work that would otherwise be required if using sophisticated digital tools tailored for later-stage expression of concrete and/or finalized designs, such as Photoshop or 3D Studio. Indeed, the inherent "roughness" of such sketches matches the preliminary, non-specific, and incomplete nature of early design ideas, and serves as a reminder for the audience to focus their attention and feedback on the concept rather than details of the design. All this allowed designers to obtain feedback as early as possible in their design process, which proves to be essential to the design success [4].

However, the casualness and openness of these early sketches usually also means that they have to rely on the designer's personal presence to be understood. The rich contextual information available in face-to-face communication, both provided by the designer themselves and from the physical surroundings, nicely complements the sketches to deliver a holistic message. In practice, however, such face-to-face meetings (or even synchronous telecommunications such as audio/video conferences) are not always feasible due to various constraints such as conflicts of schedule, geographical distances, time differences, or the need to communicate to multiple audiences. In these situations, designers have to rely on asynchronous channels, e.g. sending their ideas through email in the form of digital sketches and/or written descriptions. However, when taken out of the context of face-to-face communication, sketch as a communication tool may become inadequate on its own, precisely because of the reasons that makes it powerful otherwise. The non-specificity and lack of details in early sketches now often leads to confusion and misunderstanding. As a result, designers often set aside asynchronous communication altogether and wait until an opportunity for face-to-face meeting (often too late for early feedback), or have to resort to later-stage design expression tools and lose all the merits of hand-drawn sketches.

To address this dilemma in asynchronous communication of early design ideas, we present SketchComm (Figure 1), a tool that preserves the light weight and flexibility of sketch, while completes the missing contextual information essential in face-to-face communication. This is achieved by allowing the designer to capture such rich information, such as multimodal remarks, real-world references, logical order etc., in ways as lightweight and flexible as drawing sketches themselves, and incorporate and transmit them together with the sketch over asynchronous channels. We conducted a three-stage user study with both designers and audience, demonstrating the effectiveness of SketchComm from both perspectives, as well as how SketchComm was creatively appropriated by users.

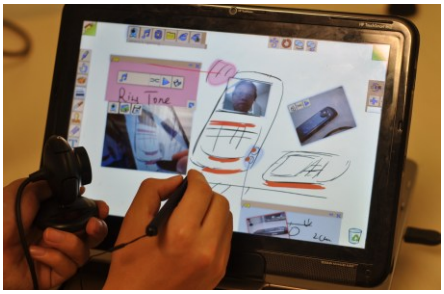

**Figure 1. SketchComm being used by a designer.**

## RELATED WORK
As a classic category of Creativity Support Tools (CST), many researchers have created tools to support the work practice of designers. In particular, given the central role of sketching in design processes, it is not surprising that many systems involved digital sketches. Some of them looked at


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sketching as a flexible input mechanism to create computer representations. Early examples can be dated back to SketchPad [22], a system to create engineering drawings with a light pen. More recently, the Electronic Cocktail Napkin [8] enables people to sketch design concepts and attempts to interpret drawing elements and configurations; and ILoveSketch [1] is a virtual sketchbook that directly supports the sketching of 3D curve models. Some systems go beyond static representations, e.g., SILK [14] and DENIM [15] both allow designers to create interactive user interface prototypes through digital sketching; and K-Sketch [6] supports novice animators in creating kinetic animations through simple sketching. Others have employed freehand sketching and gesturing as a lightweight way to annotate existing designs. For example, Boom Chameleon [24] allows viewing and annotating 3D designs by both touch gestures and voice. Space Pen [13] is a web-based system that allows participants in a design project to "walk-through" the work in 3D and annotate it with location-specific text comments or by drawing directly on the 3D model. We share the same basic rationale with these works in keeping sketching at the center of our tool to retain its light weight and flexibility, but focus on interpersonal communication rather than computer input. Researchers also created systems that aim at fluid design collaborations. For example, Design TeamMate [16] is a system in which individual workstations of designers are fluently integrated with an augmented tabletop and wall display, and Digital Scrapbook [23] is a web tool that automatically aggregates design students' online content for the tutor to oversee their design process. Pictionaire [10] is based on a large-sized interactive table, which supports design groups to integrate physical and digital artifacts using an overhead camera and projector for design meetings. However, so far there has not been research dedicated to asynchronous communication of early design ideas.

Some other domains that often require such enhanced asynchronous communication support include education and business collaboration. For example, MRAS [2] is a web-based system that supports annotation of multimedia lectures. Students can access the website to study, and make shared annotations to discuss. Similarly, Petkovic et al. [19] developed an asynchronous multimedia annotation platform for web-based biology education. MemTable [12] is an interactive tabletop that supports collaborative work, which can capture and asynchronously search and review past meetings during co-located meetings. These focused on communication around pre-generated or recorded information, rather than creative design ideas.

Also related are tools for active note taking, which share some similar attributes as the design sketching activity. In addition to commercial systems such as Microsoft OneNote [17], there exist several research prototypes. For example, InkSeine [11] is a tablet PC application that interleaves inking, searching, and content gathering. NiCEBook [3] is a prototype paper notebook, which supports taking, structuring and reusing notes in both the physical form and the digital representation. These focused on individual information work instead of communication.

One of the key features of our system was the capturing of real world content. Some creative systems also share the similar feature. This includes CopyCAD [7], a system that allows users to copy 2D shapes form arbitrary real world objects, and then modify them through sketching. The I/O brush [21] is a physical paintbrush with an embedded camera that can pick up color, texture, and motion from the physical environment and paint with them. TellTable [5] is a storytelling system that allows children to take photos of real world objects to create story elements, and use them to tell animated stories on an interactive table. In contrast, we focus on using content captured from the physical world to facilitate asynchronous communication, rather than as raw material for real-time creation.

Finally, some existing works focused on capturing and replaying the design activity. Design Amanuensis [9] is a tool to assist researchers to conduct think-aloud studies of design processes, by capturing the designer's spoken and drawing actions into a replayable and searchable document; Where Were We [18] supports instant video replay of recent events in design brainstorm sessions to facilitate the ongoing design activity; and XNETWORK [20] is an environment for computer network design which captures design discussions into the design artifact itself. These systems target at passively archiving the design activity itself for later reference, while we aim to support the designer to actively find relevant contextual information to capture in order to construct the design communication.

In comparison to these prior works, SketchComm targets at a unique yet common challenge, asynchronous communication of early design ideas, which has not been specifically tackled in the research field. Although SketchComm may indeed share some rationales or features with some of these systems, the contribution of our work is not necessarily in inventing individual interactions and features, but in a holistic solution and a seamless experience that are based on the understanding of and tailored for this particular activity.

## CONTEXTUAL INFORMATION TO CAPTURE

Given the key of our tool is to capture contextual information to be transmitted with sketches, we first sought to identify some of these most common categories of information that are essential in face-to-face communication of design ideas, but missing in current asynchronous channels.

We obtained such information from three sources: informal interviews with four professional designers about how they currently communicate their early ideas face-to-face; observations of three early-stage design meetings in interdisciplinary teams; as well as the own professional experience of the authors (two of the authors were professionally trained as industrial designers themselves). By examining the common practices in face-to-face design communication obtained from these sources, and contrasting them with functionalities of current asynchronous communication channels, we identified the following categories of contextual information that are especially useful, which we propose to capture in our asynchronous design communication tool:

### *Multimodal Remarks*

One of the most powerful attributes of face-to-face communication is that it is inherent multimodal. Although the communication of the design idea is usually centered around sketches, such static representation is constantly augmented by verbal explanations, iconic gestures, dynamic demonstrations, etc. These provide essential additional information for

the audience to understand beyond what is conveyed in the sketches themselves. We sought to capture such freeform multimodal remarks from the designer.

*Real-world References*

A common way to facilitate early design communication, especially when explaining concrete artifacts, is to refer to physical objects in the surrounding. Such real-world references can be used to easily and vividly illustrate many attributes that are difficult to describe through abstract sketch or speech, such as shape, color, size, material, or even sound. In addition, designers often use physical objects as opportunistic props to demonstrate ideas. By enabling capturing such real-world references, we sought to enrich the vocabulary of the designers through our tool.

*Thought Process and Logical Order*

Often time understanding the thought process of reaching the design idea is as important as the resulting idea itself. Seeing the thought process allows the audience not to be overly caught in the specifics of the single design idea, but can better understand the rationale of the designer and provide feedback on a higher conceptual level. This is especially important in the early design stage, when the idea itself is often incomplete and open to redefinition. Equally important is the logical order in the idea representation for the audience to comprehend it, which is often not apparent due to the unstructured nature of early sketches, and relies on the designer to guide the audience through in face-to-face communication. In our tool we sought to provide lightweight mechanisms for designers to record the thought process and indicate the logical order to their audience.

*Communication Context*

Finally, the overall context of the communication session itself, such as topic, time, place, and participants, is not only useful for the audience to understand the bigger picture of the design project, but perhaps also importantly contextualize their memory of the idea and let them recall it more easily. This may be equally helpful for both the audience and the designers themselves. We sought to support capturing such communication context in a rich and flexible manner.

Obviously, this is not meant to be an exhaustive list of all contextual information available in typical face-to-face communication. What we aim for is to include functions to capture the most common categories of information, while keeping them as flexible as possible so that designers can creatively repurpose them to capture other information as they find useful to the communication.

## SKETCHCOMM SYSTEM

Based on the above rationales, we created SketchComm, a software application running on a Windows 7 Tablet PC with both pen and multi-touch input, and connected to a webcam. SketchComm was designed through an iterative process, incorporating feedback from trial usage by real target users (designers and audience) at several stages of the development. In designing the system to capture the four categories of contextual information mentioned above, we maximized richness and flexibility in the expression, both of which later proved essential to the success of SketchComm.

SketchComm consists of two interaction modes: *Creation* mode (Figure 2a), in which the designer creates the content for communicating the design idea using a mixture of sketch and captured information; and *Review* mode (Figure 2b), in which the audience reviews the idea.

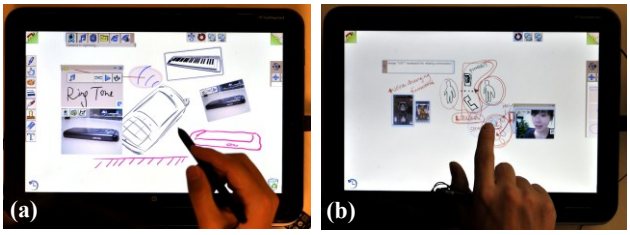


**Figure 2. System Interface. (a) Creation Mode. (b)Review Mode.**

### Creation Mode

In the Creation mode, the designer is provided an infinite blank canvas that can be freely zoomed and moved using two-finger gestures. Interface buttons to trigger additional functions are laid out along the edges of the screen, which can be operated using either the pen or a finger. Similar to other freehand sketching applications, the designer can use the pen to sketch on the canvas with a variety of stroke colors and widths, as well as erase sketches with an eraser function. Additionally they may insert text boxes into the canvas, with which they can input text using a physical or software keyboard, or through onscreen handwriting recognition.

*Capturing Media Content from the Real World*

At the base of the system, SketchComm provides a generic set of functions to capture various types of media content from the real world. These can be used by the designer for various purposes described later.

Using the webcam and its built-in microphone, the designer can capture a photo, an audio clip, or a video clip of the real world (Figure 3a, b, c). The captured content then appears in the canvas, and can be freely manipulated using single- or multi-touch finger gestures (moving, rotating, scaling) to be positioned together with hand-drawn sketches. Dragging the content into the trashcan in the bottom right corner of the screen deletes it.

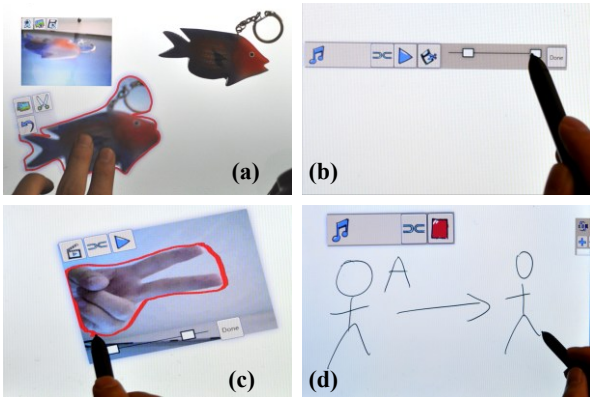


**Figure 3. Captured media. (a) Photo. (bottom left: cropped photo; upper left: viewfinder; upper right: original physical object) (b) Audio clip (being trimmed). (c) Left: Video clip (being cropped). (d) Synchronizing sketch with audio.**

Both photos and video clips can be cropped to arbitrary shapes using the pen so as to show only the region of interest; and both audio and video clips can be trimmed in time using a pair of slider knobs to keep only the segment of interest. The audio and video clips can then be played in place. In the

case of capturing a photo or a video clip, a live on-screen viewfinder is displayed on the canvas to facilitate framing. Similar to captured content, the viewfinder can also be manipulated using finger gestures. These capturing functions allow the designer to easily make references to the real world or incorporate personal remarks.

A common practice of designers in face-to-face communication is to explain verbally in synchronization as they are sketching. This is a perfect example of multimodal communication. In our system, as the designer captures an audio or video clip, they may select the "link with sketch" option, so that they can sketch at the same time and have the sketch strokes recorded together with the clip (Figure 3d). When playing back the clip, the sketches are redrawn in synchronization, emulating the above practice in face-to-face settings.

Aside from directly capturing content from the real world, the designer may also insert media content from secondary sources. This includes image, audio, and video files from a local folder, or from a mobile phone through Bluetooth. The latter especially opens up the space for the designer to capture real world content anywhere and at any time, without being constrained to content near the tablet. In addition, the designer can open an embedded web browser within SketchComm, and capture an interesting portion of its content as a snapshot. This also matches today's common practice of designers searching for reference material online.

*Borrowing Sketching Elements from the Real World*

In addition to using captured media *along with* sketches, the designer may also sample attributes of the real world to be used *in* their sketching. This is made possible by the color picker and texture picker functions, which allow the designer to click any point on the screen to pick its color for sketching, or select any rectangle on the screen to pick the texture inside as the brush pattern for painting (Figure 4a). By picking either from a captured photo or directly from the live viewfinder, the designer can borrow the color and material of real world objects and apply them to sketches. In some sense this can be seen as a software incarnation of the I/O Brush [21], while our functions also provide the further flexibility to sample from purely virtual content such as web pages or existing sketches.

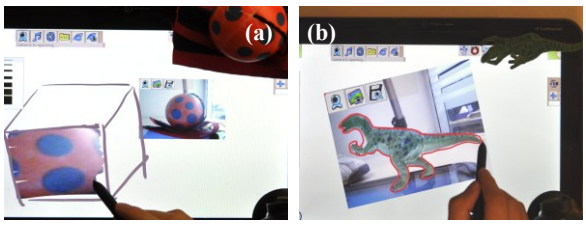


**Figure 4. Borrowing sketching elements from physical objects (top right in photos) (a) Painting a texture. (b) Tracing a shape.**

Another feature that comes "for free" is that the designer may also borrow the shape from a physical object by tracing over it (again either from a captured photo or from a live viewfinder) (Figure 4b). This allows the designer to more accurately depict certain objects when necessary, or simply to complement their freehand sketching skills.

*Multimodal Annotations*

Annotations are a common constituent in most hand-drawn design sketches. Designers use them to communicate additional information regarding specific component of the sketch, usually indicated by visual marks such as callouts and bubbles. With the ability to capture multimodal content, richer and more vivid annotations can be supported. Although it is possible to simply combine hand-drawn marks with captured media to indicate an annotation (e.g., placing an audio clip in a hand drawn callout bubble on the canvas), this solution soon becomes infeasible as the number of annotations increases. The canvas will soon be taken up by annotations, leading to visual clutter (caused by both the annotations themselves and callout marks), less space for the original sketch, and eventually confusions. This is a common challenge in paper sketches, and may be further aggravated in digital sketches given that multimodal annotations such as photos or videos often need to take up considerable screen space to be displayed.

In order to address this challenge, we provide an annotation mechanism that aims to be lightweight, flexible, unambiguous, and scalable. The designer can use a single finger to indicate a canvas region they want to annotate, by either circling the region of interest, or alternatively dwelling the finger on the screen when the region of interest is a single point. Once the system detects a circle or dwell, an annotation icon appears near the finger and follows the finger movement on the screen (Figure 5a). The designer can then move the finger to where they wish the annotation to appear. A rectangular annotation panel appears once the designer releases the finger. The annotation panel functions as a mini canvas. The designer can sketch in the panel, or drag any type of content (e.g., photos, audio/video clips) from the main canvas into it.

The annotation panel is connected to the annotated region, which is visualized as a translucent halo, through a curved line. Each annotation is automatically assigned a color code upon creation, reflected by the panel, the halo, and the connection line. The opacity of the halo is reversely proportional to its area, so that smaller annotated regions appear more prominent than larger ones, allowing them to be easily distinguishable in the case of nested annotated regions.

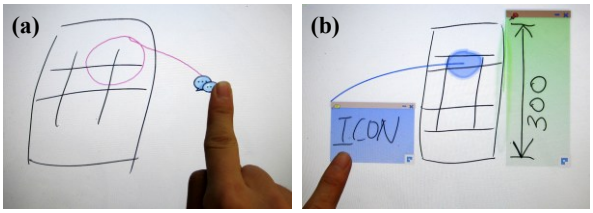


**Figure 5. Annotations. (a) Creating an annotation. (b) Floating (left) and fixed annotations (right).**

Depending on the designer's need, an annotation panel can be set to be floating or fixed (Figure 5b). A floating panel can be freely moved and resized using the finger, while a fixed panel remains static. The former is particularly useful when the designer needs to lay out multiple annotations or avoid occluding content on the canvas, and the latter is suited for annotations whose meaning is dependent on their positions, such as length markings.

Each annotation panel can be individually hidden or shown by tapping on the corresponding halo. The halo remains visible in either case as an indication of an existing annotation. This allows only showing annotations that the user is currently interested in, and avoids visual clutter. The user can

also hide or show all annotations at once, so that they can choose to see content on the canvas only or have an overview of all annotations. Dragging an annotation into the trashcan deletes it.

Combining multimodal content both on the canvas and in annotations, the designer may describe their design idea in a much flexible and vivid way. The following example illustrates how this may be achieved (Figure 6). The designer wants to communicate his idea about a mobile phone design. He sketches the basic shape of the phone, and captures a photo of his face to be placed in the phone screen to illustrate a video call. He uses the texture picker to select a wooden texture from his desk and paint the bottom of the phone with it to illustrate a wooden shell. Around the sound wave icon near the phone, he adds an audio annotation, recording knocks on the desk as the ringtone. He adds another annotation around the charging socket on the phone, this time combining sketches and a cropped photo of a mango to show the idea of charging the phone using a fruit battery. Finally, he adds a video annotation around the entire phone, demonstrating his hand holding a real mobile phone and using different gestures to pick up and hang up the phone, along with his verbal explanation.

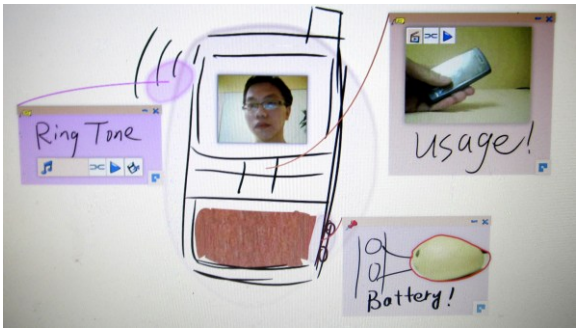


**Figure 6. An example of multimodal content and annotations.**

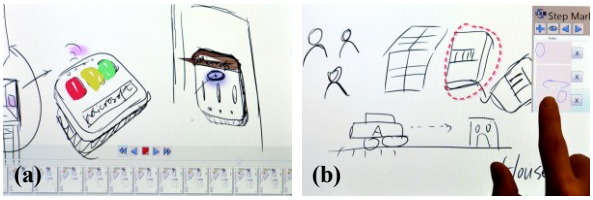


**Figure 7. Captured thought process and logical order. (a) Timeline (bottom). (b) Step mark (dotted circle).**

*Recording Thought Process*

To capture the thought process of the designer, the system automatically records a timeline of the entire interaction history, such as sketching, adding annotations, capturing content, canvas manipulation, etc. This allows others to review the process through which the designer has reached the final presentation. The timeline can be accessed through an interface button, and is represented by a series of canvas thumbnails (Figure 7a). It can be replayed at various speeds and in both directions, to be viewed in the main canvas area. The designer can also directly return to a specific point in the timeline, after which they can start further interaction from that point. In our current implementation this overwrites the rest of the timeline, whereas in the future we plan to offer the option of saving as a different version of the design idea to allow branching explorations.

One thing we should note here is that the system is capturing the thought process of generating the communication material, and not necessarily that of generating the design idea itself. However, in practice these two processes often overlap to some extent, and the former can often provide insights into the latter.

*Indicating Logical Order*

Due to the nature of early stage design communication, the communication material generated by the designer may often appear less planned and structured. In order for the designer to indicate a logical order after the material has been created, they can create "step marks" that highlight certain regions of the canvas (Figure 7b). This is done by selecting the "add step mark" button and then circling the region in question with a finger. The step marks panel on the right lists all step marks in the order of creation. Using the arrow buttons on the panel the user can display each step mark in the order indicated, or click a specific mark in the list to jump to that step.

The step marks act as a lightweight suggestive viewing path for the audience to guide understanding, yet is by no means binding. Different from the timeline which is an objective capturing of the creation process, the step marks convey the subjective understanding of the logical structure by the designer.

*Capturing Communication Context*

To convey the overall context of the communication session, the designer can open the "Communication Context" screen, which includes four fields: Topic, People, Time, and Location. Each field is simply a blank canvas in itself, and similarly the designer can fill it with a combination of sketch and captured content to convey the according communication context in a flexible and vivid way (Figure 8).

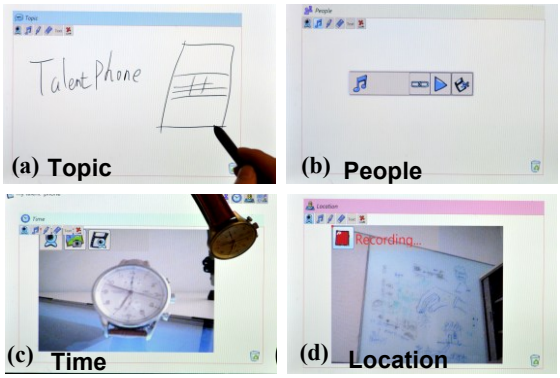


**Figure 8. Captured communication context. (a) Topic (here represented by sketch). (b) People (here represented by an audio clip of their verbal greetings). (c) Time (here represented by a photo of a wristwatch. (d) Location (here represented by a video sweeping through the meeting room).**

All the material created by the designer is stored in a project folder, which can be then transferred to the audience through file share or other channels. The audience can then open the project in the Review mode.

**Review Mode**

The Review mode is a read only mode of the application. It includes all viewing, navigating, and replaying functions as in the Creation mode, but does not allow adding or modifying content. This allows the audience to review the commu-

nication material created by the designer to understand the design idea being expressed.

Although our current system design targets at a one-way communication model with passive audience, one can also imagine the audience using the Creation mode to provide feedback or further develop on the idea, especially if the audience themselves are also designers. We will leave this scenario for future explorations.

## USER STUDY METHOD

We conducted a user study in order to understand how effective SketchComm is in supporting asynchronous communication of early design ideas from both the designers and the audience perspective, as well as how the system is appropriated by the users to suit their needs.

### Procedure

The study included both designers and viewers (to avoid confusion, from now on we use "viewer" to refer to the individual participants who reviewed the designers' ideas in our study, and "audience" to refer to this general user population). It consisted of three stages: the designer expressing the design idea using the tool; the viewer reviewing the idea through the tool and then describing their understanding and feedback; the designer evaluating the viewer's understanding and feedback.

All participants used the same HP TouchSmart 2 tablet PC for the study, saving the step of transferring the material between users.

#### *Stage 1: Designer Expressing Ideas*

Each designer was asked to express two design ideas, one using SketchComm, the other using an alternate tool (to be explained later). These ideas were generated by the designer to address two design problems of their choice from a list of five open-ended problems we provided:

(a) A design to remind people to get better nutrition;
(b) A design to urge office workers to do more exercise;
(c) A design to cheer people up when they are depressed;
(d) A design to keep people in closer contact with former classmates;
(e) A design to help people stick to their schedule.

These problems were chosen for their generalizability and familiarity to everybody, so that both the designers and the viewers can directly relate themselves to them. Given that SketchComm is targeted at the stage of communicating early design ideas, neither generating the idea itself (the stage before) nor communicating a complete design (the stage after), we decided to inform the designer of the design problems two hours before the study started. This allowed the designer to have some ideation and come to the study with an early idea, while not to the point of having a complete design. In particular, the designer was told not to pre-prepare any material for the communication.

When the designer came to the study, they were given a demonstration of the functionalities of SketchComm, after which they were asked to explore and familiarize with the tool using a simple example design problem. Then they used the tool to express the design idea they generated before the study.

Since SketchComm is addressing an activity that had not been supported by existing tools, it is in principle unnecessary and infeasible to include a baseline comparison. Nonetheless, in order to gain some insights on how and why SketchComm is effective, we decided to offer a variety of related alternative tools that might be reused for this purpose, from which the designer could choose one or a combination that they felt comparably most feasible to complete the same activity. These included OneNote (a freehand sketching and note taking tool with basic audio/video recording functions), PowerPoint and Word (often used for asynchronous communication between information workers), Photoshop (the most common visual design tool), and InkSeine [11] (a tool combining active note taking and in situ search and gathering). We should note again that none of these tools had been designed or widely adopted for asynchronous communication of early design ideas. Therefore the comparison with them in our study should not be taken as a rigorous experiment, but a conduit to better understand the usage of SketchComm. A tutorial was given to the designer for tools they were not already familiar with. After the designer made the choice, they followed the same procedure as with SketchComm to explore and familiarize with the alternate tool and then express the idea using it.

#### *Stage 2: Viewer Reviewing Ideas*

Each viewer reviewed two design ideas, one expressed using SketchComm (reviewed using the Review mode), one using the alternate tool chosen by the designer. These two ideas were from two different designers, to prevent the viewer from becoming overly familiar with a certain design style. The viewer followed a similar procedure as the designers did: For each idea, they were first demonstrated the functions of the respective tool, and then allowed to explore and familiarize with the tool with an example design idea created from a pilot study. They then reviewed the idea generated by the designer. Afterwards, they were asked to describe their understanding of the idea via two mutually complementary channels: a written form and a verbal description. The written form consisted of the following questions:

1. What is the idea about?
2. Who is it used by?
3. In what situation is it used?
4. How is it used?
5. What is its innovating/distinguishing feature?
6. What did I not understand about the idea?
7. Any comments or suggestions to the idea.

And the verbal description, which was video-recorded, allowed the viewer to describe the idea in spoken language and provide any feedback to the design as they wished.

In both Stage 1 and 2, the order of using SketchComm and the alternate tool was counterbalanced between participants, and they took a short break between the two.

#### *Stage 3: Designer Evaluating Viewers' Understanding*

Finally, the designer was presented the viewers' descriptions and feedback (written form and video recording of verbal description) for each of their ideas, and judged accordingly how well the viewers understood their ideas and how valuable the feedback was.

### Participants

Eight people, aged 23-26, participated in the study, who were interns and contractor workers at the China office of an IT company. The design problems used in our study were unrelated to their work.

*Designers*

Four of the participants (1 female, 3 male) were professionally trained as industrial designers, and currently working on user experience design projects. They acted as the designers in the study (D1-D4). In terms of sketching skills, according to self report, one was proficient, two were average, and one was below average by designer standard. Two of them had experience sketching on a digital tablet. All were familiar with common computer-aided design tools. They all had collaborated with people from other disciplines, mostly with engineers, and in some cases with people from management and psychology backgrounds.

*Viewers*

All 8 participants acted as viewers. Besides the 4 designers mentioned above who doubled as viewers ("designer viewers", again D1-D4) for other designers' ideas, the other 4 viewers ("general viewers", G1-G4) were from other disciplines. This allowed us to observe the effectiveness of SketchComm for both audience who were designers themselves, and audience from a general background. Although in our case the 4 general viewers (2 female, 2 male) were all from a computer science education background, and currently working on research or development in computer technology, we considered them qualified as general viewers since the design ideas were not directly related to computers. Among the 4 general viewers, three had experience discussing with designers, and two directly collaborated with designers.

As a result, each design idea was reviewed by two viewers: one general viewer and one designer viewer. And in turn each designer evaluated understanding of their two ideas by four different viewers. The assignment of the ideas from the designers to the viewers was counterbalanced using a Latin Square.

On average, D1-D4 each spent 5 hours for the study (Stage 1: 2 hours; Stage 2: 1 hour; Stage 3: 2 hours), and G1-G4 each spent 1 hour (Stage 2).

### Data Collection

We collected both qualitative and quantitative data during the study. As mentioned earlier, the fact that SketchComm was the first tool to specifically support this activity means that the rich behavior and subjective feedback from our participants would provide more insights than necessarily quantitative comparison with a different tool appropriated for this purpose. This was the rationale behind our relatively small participant pool but more extensive study process, so as to gain richer insights from each participant. Nonetheless, we collected quantitative ratings to compare the effectiveness of SketchComm with the alternate tool in order to ground and strengthen the qualitative findings. To reduce potential bias, it was clearly stated to the participants that SketchComm was a work-in-progress prototype, and we were looking for most objective feedback in order to improve it.

*Quantitative Data*

In order to evaluate how well the design idea was communicated from both perspectives, both the viewers and the designers were required to fill a rating form for each design idea they reviewed/created:

In Stage 2, the viewer filled the form after they finished reviewing each idea. The form consisted of the following dimensions in terms of the clarity of the communication, each to be given a rating on a 7-point scale, with 0 being the worst, and 6 the best:

VQ1: Clarity of the overall idea;
VQ2: Clarity of the target population;
VQ3: Clarity of the target situation;
VQ4: Clarity of the usage;
VQ5: Clarity of the innovating/distinguishing feature.

Similarly, in Stage 3, the designer filled the rating form after they were presented the viewer's description for each of their own ideas. The form consisted of the following dimensions, mainly in terms of how well the description matched the original idea, with one additional question DQ6 on the value of the viewer's feedback:

DQ1: Match of the overall idea;
DQ2: Match of the target population;
DQ3: Match of the target situation;
DQ4: Match of the usage;
DQ5: Match of the innovating/distinguishing feature;
DQ6: Value of the viewer's feedback.

*Qualitative Data*

At the end of each stage, we conducted a semi-structured interview with the participant, each with a slightly different focus. In Stage 1, we focused on the designer's general impression of SketchComm, how it met their need for expression, etc.; In Stage 2, we focused on how and why the viewer found the idea expression clear or confusing, their preference between different forms of expressions, etc.; and in Stage 3, the focus was on the designer's reflections on the feedback from the viewers. Where applicable we also asked them to compare to the experience using the alternate tool. In addition, we probed about some general questions, e.g., how they saw the value of communication in the early design stage.

We also actively observed and video-recorded the participants throughout the study, aiming to understand how SketchComm was used by them, and to identify creative usage of the system.

## USER STUDY RESULTS

All participants finished the study as planned, resulting in 8 different design ideas, reviewed 16 times in total. Interestingly, all designers chose OneNote as the alternate tool, quoting InkSeine as being "overly informal" and other tools (PowerPoint, Word, Photoshop) as being too time-consuming for early ideas, whereas OneNote seemed the right compromise point for them. On the other hand, the set of functionalities of OneNote was most similar to paper sketches, therefore we may also consider its effectiveness for asynchronous communication to be somewhat representative of that of paper sketches, the most common apparatus used in face-to-face early design communication. Each idea took 30-45 minutes to express, and 10-15 minutes to review. This time frame was similar for both SketchComm and OneNote. Where the expression involved handwritings and voice recordings, they were mainly done in Chinese, with a few cases mixing with English. All the designers agreed that communicating their early design ideas to other was necessary for getting valuable feedback: "*the earlier we communicate, surely the better for my idea*" (D3).

We now report how SketchComm supported asynchronous communication of the design ideas in our study, comparing

to OneNote where appropriate. As will be seen throughout this section, richness and flexibility in the expression, supported by the SketchComm capturing functionalities, were the two key contributing factors reflected in all its usage.

### Style of Expression

When the designers communicated the ideas, they adopted distinct styles of expression using SketchComm and OneNote (see Figure 9 for examples). Unsurprisingly, with SketchComm the designers incorporated a rich mixture of multimedia content, both on the canvas together with the sketches, and as multimodal annotations. This resulted in a more vivid visual style in SketchComm. Comparatively, with OneNote the expression was mostly restricted to plain sketch and text (some handwritten and some typed). As apparent in Figure 9b, there was a heavy reliance on textual descriptions/annotations in OneNote (637 words in total for 4 ideas): "*With OneNote, I had to write a lot to express clearly*" (D3). The majority of the text (367 words, 57.6%) was detailing the usage of the design, often the most cumbersome to describe with text given its dynamic nature. The rest was spent on the overall description (152 words, 23.9%), target situation (72 words, 11.3%), and target population (46 words, 7.2%) respectively. In comparison, the use of text was largely alleviated in SketchComm (319 words in total for 4 ideas) by replacing them with multimodal content and annotation. In an extreme case, D2 wrote 176 words with her OneNote design, but did not include any text in her design with SketchComm. Instead, she used a single audio clip synchronized with sketch to explain the usage scenario. Where the designers did use text in SketchComm, the text can be similarly categorized into describing the usage of the design (130 words, 40.8%), overall description (109 words, 34.2%), target situation (80 words, 25.1%), but not target population (0 words, 0%). Compared to OneNote, these were considerably reduced in all categories except one (target situation). This exception could be explained that while other categories of information can be easily illustrated or acted out using nearby physical references, target situation by nature often involves a different physical environment that is difficult to directly refer to in the designer's physical context.

Another notable difference was the level of structure in the content. With OneNote the designers' sketches were usually organized in a clear linear structure, both visually and logically, which required a fair level of preplanning. In contrast, with SketchComm the sketches were usually freeform and did not follow an obvious visual structure. This evidenced a more ad hoc and casual expression process: "*Actually I did not think it over when I started drawing. I just thought as I drew, so my sketch is a bit messy.*" (D2) This was made possible largely thanks to the infinite canvas and the flexible annotation function, which made pre-budgeting of the screen real estate unnecessary for both sketch and annotations. As important were the step marks, which allowed the designer to apply a logical order to unstructured sketches *after* they have been drawn (a feature used by all the designers). Such flexibilities are particularly suited for early design ideas that are still in the process of forming.

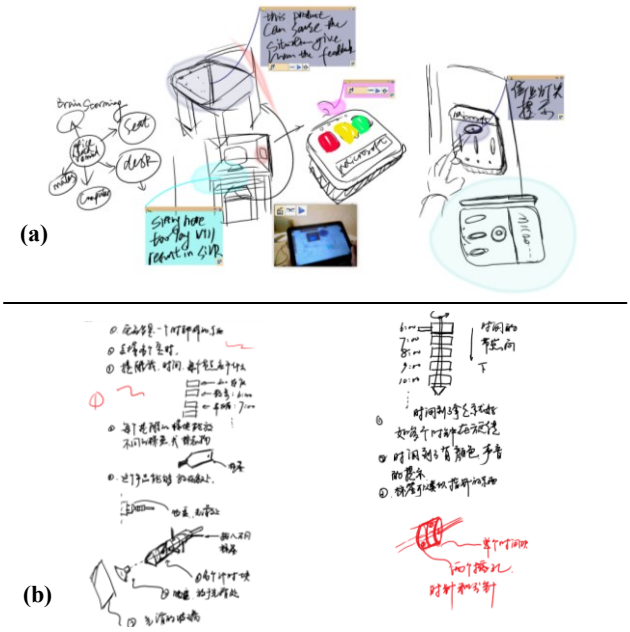


**Figure 9. Examples of ideas expressed by participants using: (a) SketchComm. (b) OneNote.**

Interestingly, both the reduced amount of text (thanks to richness in expression) and the unstructured nature of sketches (thanks to flexibility in expression) in SketchComm resemble hand-drawn sketches used in face-to-face communication (whereas the OneNote style represents more how paper sketches might be used asynchronously). This demonstrated how SketchComm helped converge the asynchronous communication experience towards the in person communication experience.

### Effectiveness of Communication

We now examine the effectiveness of communication using both tools at two levels: understanding of the designer's idea, and the feedback generated by the viewers. The former indicated the information the viewer gained through the communication, and the latter indicated the reward that the designer gained through the communication.

#### *Understanding the Idea*

The ratings from both the viewers (VQ1-5) and the designers (DQ1-5) reflected how well the design ideas were understood by the viewers (Table 1). We see a general trend that SketchComm were rated higher than OneNote in all dimensions except one, suggesting that SketchComm facilitated the understanding better. In particular, the two overall ratings: Clarity of the overall idea (VQ1) and Match of the overall idea (DQ1), were highly correlated ($r^2 = 0.843$), showing a general agreement between the viewers and the designers on how well each idea was understood. The only exception (VQ4) where OneNote was on par with SketchComm regarded how the design should be used. As we reported previously, this was what the majority of the written notes in OneNote were focused on, in order to achieve a similar level of comprehensibleness as SketchComm. However this was at the cost of sacrificing clarity of other information. And even so, DQ4 revealed that the viewers' understandings of the usage through OneNote did not necessarily match with the designer's original idea as well as with SketchComm.

| Category | Question | SketchComm | | OneNote | |
|---|---|---|---|---|---|
| | | Mean | Std dev | Mean | Std dev |
| Clarity of Expression | VQ 1 (Overall idea) | 4.75 | 0.463 | 4.375 | 0.744 |
| | VQ2 (target population) | 4.5 | 1.414 | 4.25 | 0.886 |
| | VQ3 (target situation) | 5.125 | 0.834 | 4.5 | 1.069 |
| | VQ4 (usage) | 4.25 | 1.035 | 4.25 | 1.488 |
| | VQ5 (innovating/ distinguishing feature) | 4.75 | 1.035 | 4.125 | 1.246 |
| Match between viewer's description and original idea | DQ 1 (Overall idea) | 5.75 | 0.463 | 5.25 | 1.165 |
| | DQ2 (target population) | 5.875 | 0.353 | 5.5 | 0.535 |
| | DQ3 (target situation) | 5.625 | 0.518 | 5 | 1.414 |
| | DQ4 (usage) | 5.625 | 0.518 | 4.875 | 1.356 |
| | DQ5 (innovating/ distinguishing feature) | 5.25 | 0.707 | 5 | 1.069 |
| Feedback from viewer | DQ6 (value of feedback) | 5.75 | 0.463 | 5.25 | 1.165 |

**Table 1. Ratings from participants.**

We now look at places where the viewers found the idea unclear. Some of these were caused by the designers not having thought of or concretized certain aspects of the idea, which should not be considered a failure in communication, but rather opportunities for audience feedback. Others were specifically related to the communication channel. For example, with OneNote there were two instances where the viewer could not recognize the handwriting of the designer, which directly resulted in misunderstanding of the idea, and in one case failing to identify the innovating feature. A similar situation happened with SketchComm where the viewer could not recognize a handwritten annotation, however he was able to recover the information by listening to the linked audio clip. The rich multimodal remarks in SketchComm provided redundant information that helped enforce and disambiguate the communication, again similar to what happens in face-to-face communication.

### *Feedback Generated*

Since the major motivation of communicating early design ideas is to get early feedback from the audience, the value of the feedback generated is also an important criterion for the effectiveness of the communication. As shown in Table 1 (DQ6), the designers felt the feedback from viewers using SketchComm to be more valuable than those using OneNote. This rating was grounded by more closely examining the feedback the viewers had given. Through the written form and video recording, 12 pieces of feedback in total were provided by viewers for the 4 ideas expressed using SketchComm, as opposed to 7 pieces for those using OneNote. The feedback mainly focused on the target situation, the usage, and the underlying mechanisms of the design idea. In addition to the quantity of feedback, SketchComm also resulted in better quality. For example, after watching the timeline and seeing the designer's thought process, G3 was able to provide a great deal of good feedback, far surpassing the designer's expectation for feedback from a general viewer.

### Subjective Preference

When asked about preference between the two tools, 5 of the participants preferred SketchComm (D1, D3, G2, G3, G4), 1 preferred OneNote (D4), and 2 said they did not care which tool to use (D2, G1).

For designers who preferred SketchComm, they felt that it matched their practice and satisfied all their needs in early idea communication. The various capturing functions in SketchComm was said to result in less effort and less skills required from the designer, hence easier expression: "*I feel it is hard work to use OneNote to express my idea, since I need to write down a lot of things. Your system (SketchComm) is much better.*" (D3)

The flexibility in SketchComm was again emphasized on by the designers. As mentioned earlier, this flexibility meant the designers did not require preplanning in terms of visual structure or screen real estate. Furthermore, the flexibility in expression through the variety of modalities also resulted in high error tolerance: "*There is a trial-and-error process when you learn any new software. When I use SketchComm, although I do make mistakes, I can achieve what I want in whatever way.*" (D3)

The richness in expression was also highly appreciated, especially by the viewers. They saw this as being very effective in attracting the audience's interest. All the viewers felt that reviewing the idea through SketchComm was an enjoyable activity, while reviewing OneNote felt more an assigned task. Some general viewers even stated strong interest to use SketchComm to express their own ideas after the study.

Only one designer (D4) preferred OneNote because of its simplicity. He was a proficient sketcher and very comfortable with sketching with pencil and paper, thus he felt OneNote was sufficient for his need, particularly for the relatively simple design problems in our study. However he then added "*If I were to express a sophisticated idea or multiple solutions, I would use your tool (SketchComm)*", again testifying for its rich expressiveness.

### Creative Usage

The participants actively used all the functionalities in SketchComm, in ways mostly consistent with our anticipations. However, we also observed many creative usages. Such creative re-appropriations of the functionalities were the best testimonial for the flexibility supported by SketchComm. Below are merely a few interesting examples:

The video capture function was often used in a 3rd person perspective to capture objects. One designer wanted to demonstrate usage of a phone she designed. Instead of looking for a real phone, she noticed the voice recorder used for our user study and picked it up for its similar appearance, then pointed the webcam to her hand to capture the demonstration (Figure 10a). This repurposing of physical objects as ad hoc mockups is also common in face-to-face communication. The same designer, however, when sketching to further explain the idea, pointed the webcam to capture her own face and talked as she sketched, creating a 2nd person perspective to allow the audience to feel as if they were communicating face-to-face (Figure 10b). And in another example, a design-

er asked the experimenter to help hold the webcam to shoot over his shoulder and capture his hand sketching on the tablet, resulting in a 1st person perspective to directly guide the audience's attention (Figure 10c).

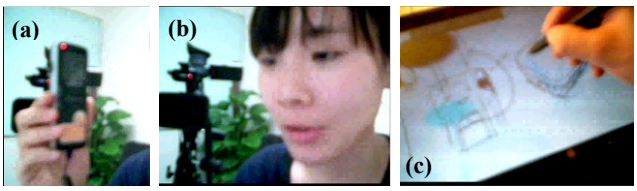


**Figure 10. Videos captured in different perspectives. (a) 3rd person view. (b) 2nd person view . (c) 1st person view.**

Although SketchComm was designed for communication, it became clear that some designers were also using it to facilitate ideation. One designer had a rough idea of a hybrid device between a wristwatch and a mobile phone but was unsure what it should look like. So he wrote down these words on the canvas, and started using the embedded web browser to search for such images. As he saw more images his idea started to concretize, and finally he used a combination of these images along with handwriting, sketch, and audio to express his idea. This blurring between design ideation and design communication may point us to new opportunities to design tools that seamlessly support both.

Also interesting was the usage of the timeline. In addition to using it to follow the thought process of the designer, some viewers simply watched the timeline for fun: "*I find watching the timeline a very enjoyable experience, and would not mind how much time I have to spend on it*" (G3). Some general viewers learned about the user experience in the Creation mode that they were not aware of, simply by watching the timeline: "*It must be extremely convenient for the designers to use this*" (G2), or felt a more intimate connection with the designers' practice after watching: "*I always felt the designers can draw everything so well, but after watching…, I realize designers have to draw things step by step, too.*" (G2) On the other hand, the timeline was also creatively repurposed by the designers: after erasing and redrawing her sketches several times, D2 happened to replay the timeline and was excited to see her sketches became "animated". She decided that next time she would plan the timeline to purposely create animations.

## CONCLUSION

We presented SketchComm, an asynchronous communication tool that allows designers to capture rich contextual information in addition to sketches for communication of early design ideas. Our user study demonstrated that SketchComm enhanced the effectiveness of such communication, enabled rich, flexible, and creative expression. Our work is a successful exploration in addressing a realistic challenge that has not yet been tackled before.

In the future, we plan to further improve SketchComm based on our findings. Most importantly, we would like to design for the audience to provide feedback through the tool, e.g. for iterative design and brainstorming scenarios. We are also interested in exploring specialized hardware designs for the camera and the tablet to enable a more comfortable and flexible capturing experience. Finally, we plan to explore how SketchComm might be appropriated and adapted to support other creative user groups beyond designers.

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