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UbiSketch: Bringing Sketching out of the Closet

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ABSTRACT

As paper-based communication is being supplanted by digital channels like E-mail, Facebook, and Flickr, so is handwritten and sketch-based expression. We posit that digital pen-and-paper technologies can bring the unique affordances of paper-based communication to social media, providing new channels of expression to those who favor handwriting and sketching. We present UbiSketch, a ubiquitous real-time sketch-based communication tool that supports social communication using natural paper-based interaction. UbiSketch allows people to create drawings, doodles, and text notes with digital pens and paper, and publish them via their mobile phones to online social networks or e-mail. In a 4-week user study, this novel modality successfully brought sketching into the public realm, exhibiting characteristics of digital social media such as rapid authoring and dissemination, while retaining sketching's unique qualities of visual communication. Friend responses to sketches were more numerous and more personal in nature than those to text and photo postings.

Author Keywords

Sketching, interactive paper, real-time social communication

ACM Classification Keywords

H.5.m Information Interfaces and Presentation: HCI

General Terms

Design, Human Factors

INTRODUCTION

Paper has traditionally played an important role in communication, both at a distance and face-to-face. A hand-written letter can express the author's message through the words and style of handwriting; a sketch can quickly express ideas visually; and an artistic drawing can express an aesthetic sensibility. With the emergence and increasing dominance of digital media, the use of paper for communication is being supplanted. As an example, US mail dropped from 213 billion pieces in 2006 to 177 billion in 2009 [30]. More strikingly, there were 330,000 public mailboxes in 2005 – predominantly

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[1]http://www.anoto.com

[2]http://www.facebook.com/press/info.php?statistics

used by individuals – but only 177,000 by 2009: the 153,000 boxes were removed because they received less than 25 pieces of mail a day [28]. This underscores that most of the drop off in the US mails has been in personal communications.

Of course, typed text and digital photos are now widely used in digital communication, as e-mail, mobile phones, and social media like Facebook, Twitter, and Flickr have transformed how we communicate. Yet, while artists continue to draw in sketch books and students doodle in class notebooks, there is no analogous mechanism for sharing. Given the uniqueness of sketching as a means of expression, this is a real loss. As an example of this loss at a personal level, one group of subjects in our user study had given up their sketching practice as adults, for lack of time.

With the advent of technologies for digitizing paper-based input, such as Anoto digital pen and paper[1], we see an opportunity to enable powerful paper-based communication via social networking channels and the mobile connectivity provided by today's smart phones. Facebook alone facilitates sharing more than 30 billion pieces of information each month[2] supporting informal, lightweight, text and photo-based communication at a tremendous scale. We use such tools to keep in touch with family, friends, and colleagues, and to manage our relationships, both strong and weak. Paper-based sketching and writing, with their unique expressive and personal character, hold the promise to expand and enrich these communications.

In this paper we introduce UbiSketch, a lightweight, real-time system for sharing sketches, created with pen and paper using Anoto technology and 3G smart phones. After highlighting the potential interplay between sketching and social networking, we motivate and describe the UbiSketch system. We then present and discuss the results of a 4-week naturalistic field study, in which we observed how participants
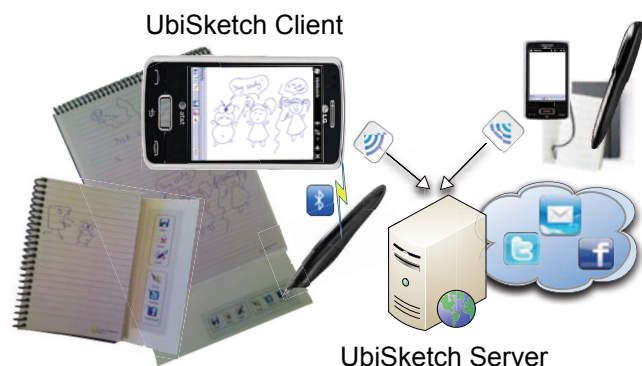

Figure 1. UbiSketch system overview

used UbiSketch for real-time, sketch-based communication with their friends and on Facebook. The study revealed that this novel modality successfully brings sketching into the public realm, exhibiting characteristics of digital social media such as rapid authoring and dissemination, while retaining its qualities of uniquely personal visual communication. Friend-response rates to sketches exceeded those of text and photo postings, and the responses were more personal in nature.

BACKGROUND AND RELATED WORK

Sketch-based communication possesses unique qualities. Like spoken and written language, sketches are a form of communication with self and others, and that externalize ideas for remembering, sharing, discussing, revising, etc. [29]. But uniquely, sketches convey visuo-spatial ideas directly, they map elements and spatial relations in the world to elements and spatial relations on paper [29]. Thus, it is easier to explain thoughts and ideas by sketching them than attempting to verbally describe them. Moreover, Buxton observed that sketches are quick to make, timely (provided when needed), inexpensive, disposable, and show the peculiarities of individuals' handwriting [6]. Sketches can be made on virtually any surface, from napkins, to walls, to printed copies of scientific paper. Sketches give a sense of openness and freedom, and require only minimal detail to render intended concepts. Their ambiguous nature encourages multiple various interpretations and thus serves as a catalyst for conversation.

Accordingly, people sketch to express themselves creatively, to brainstorm, and to share ideas. They sketch individually or collaboratively, for leisure and for work. People sketch to express feelings or relieve boredom, and doodling during lectures or meetings has shown to aid memory and focus [1]. Designers sketch to explore concepts, often iterating between different approaches [6] to make abstract ideas concrete [6, 18]. Artists also often use an iterative process, with final paintings evolving from rough sketches. Sketching creates external representations that play a central role in what Schön terms a *reflective conversation with materials* [23], common to design and integral to artistic cognition [7].

Yet, for all the benefits of sketching, sketches can be difficult to re-access, edit, rearrange, or share [16]. This has motivated the exploration of digital alternatives. Sutherland's Sketchpad was the first system to introduce pen-based user interfaces to support sketching [27]. Following this work, research evolved to explore pen-based sketching through interactive tablets such as the Interactive Worksurface Project [20] or the NPL electronic paper project [4]. Other tools supported sketching through electronic pads, for example SILK [17]. Although these systems enable digital input and interactive feedback, the material properties of a digital tablet or board do not offer the same experience and tactile feedback as sketching on paper, so users often have to adjust their drawing techniques accordingly [11]. Also, digital aids today cannot afford grasping, folding, and carrying as paper can. The many affordances of paper remain unique [24, 19].

We conjecture that the optimal solution is a hybrid system combining paper documents and digital resources. The digital pens based on Anoto technology support this model. This technology is able to track a pen's position on paper doc-

uments. Several pages of handwriting can be captured and stored within the pen before being transferred to a PC via USB connection. Anoto, Hitachi Maxell, and Logitech have released pens that support streaming mode, where position information is transmitted continuously. To support developer access to Anoto technology and offer digital functionality for paper-based interactions, several frameworks such as PADD [13], the iPaper framework [21], and PaperToolkit [35] have been introduced. Anoto has been used in recent years to develop interactive paper applications addressing issues related to paper-digital cohabitation [8, 31], paper-based interactions with digital applications [25], support for field biology work [34], dynamic visual representation of paper interactions [26], or speech therapy [22].

Paper also serves as a medium for informal communication [24]: making short notes to themselves or to others (e.g. with post-its), communicating feelings and emotions (e.g. with a phrase, a doodle or a sketch) or sharing information in local or remote situations (e.g. sharing notes of a lecture or mailing a letter). Yet, because people are constantly on the move and social communities are widely dispersed, there are substantial communication needs that this medium cannot support. To address these issues, a range of digital applications and modalities to support social communication have been introduced. Wellman studied how networked computing systems affect and enable social communication [32], and highlighted the importance of technologies supporting communication over long distances, connecting people with mutual interests regardless of physical location [33]. In recent years, social networking sites (SNSs) emerged as an important tool to support informal communication, with Facebook being the most representative example. Researchers have studied diverse aspects of SNS communication in different settings [14, 3]. Examples range from rural and urban communities [12] to university students [10], or how mobility influences communication within and around the social network itself [2]. Other research has studied how SNSs evolve over time and how people adapt to changes [15], highlighting how important usage pattern emerged either due to changes in the user's social context or the introduction of new features and possibilities. Now, with the increasing functionalities of mobile smart phones, SNSs interactivity are moving from users' desktops into the palms of their users [2].

The overwhelming convenience of digital communication discourages handwriting and hand-drawn sketch-based communication and the unique modes of expression that they afford. Yet, with the emergence of the Anoto pen technology and the mobile networking provided by mobile smart phones, we see an opportunity to bring the affordances of paper-based expression to SNSs. We conjecture that the introduction of paper-based sketching to informal digital communication can drive important changes in the way people communicate with their online social communities.

In the next section we introduce UbiSketch, a mobile digital pen and paper application enabling sketch-based real-time lightweight communication. While Anoto itself was the earliest introducer of a simple form of paper-based communication over mobile phones—the application allowed users to send paper-based notes as MMS messages—to the best of our

knowledge no research has undertaken exploring and studying effects of paper-mediated informal communication and its interaction effects within and around online social networks.

UBISKETCH

UbiSketch is a mixed paper-digital infrastructure that transmits pen and paper sketches in real-time to any desired online service. Users carry an Anoto digital pen, Anoto-Augmented paper for sketching, and a Bluetooth-enabled LG-Expo mobile phone to communicate with the server component of UbiSketch. By exploiting the affordances of pen, paper, and mobile phone, UbiSketch expands the reach of paper-based interaction.

System Architecture

The UbiSketch infrastructure, illustrated in Figure 1, is an extension of the iPaper framework [21] for Windows-based mobile smart phones. Users interact with UbiSketch through paper, imprinted with Anoto dot pattern. Interactive *paper-buttons* are implemented by mapping specific regions of the paper to input events; tapping the pen on a paper button triggers a specific event in the client. Analogous buttons are also provided on the phone UI. Otherwise, any data generated by pen activity is appended to the current sketch. We are using Anoto DP-201 digital pens, which streams data in real-time over Bluetooth to the mobile phone's UbiSketch client while the user is sketching. The mobile phone client processes and temporarily stores the streamed information. The UbiSketch client is implemented in C# on Windows Mobile 6.5, on .NET Compact Framework 3.5, and runs on the LG Expo phone.

The user shares a sketch by tapping the appropriate paper or phone button. This event triggers the UbiSketch client to forward stored information, augmented with supplementary data (current GPS position, and ID of the phone, digital pen, and paper document used), to the UbiSketch server. The server further processes the recorded pen strokes and supplementary data to fit the requirements of the specified communication channel, generating a JPEG image, and then pushes the sketch to the desired publication channel(s). In most respects, the shared sketch rendering faithfully captures the paper sketch, except that the digital lines are of uniform width.

The UbiSketch server has a plug-in architecture that enables development and deployment of extensions to support new publishing channels. The existing plug-ins support Facebook (through the *SketchBook* application and the *facebook-java-api*[1]), Twitter (with the *SketchTweet* application and the *Twitter4J*[2] library) and email (to the sketcher for subsequent for-

Figure 2. SketchBook / SketchTweet / Diary

warding, as well as the researchers) over a *Diary* channel. SketchBook posts user's sketches to an album dedicated to UbiSketches on the user's Facebook profile. Subsequent social interactions, such as comments or "likes", are directly supported by Facebook's interface. *SketchTweet* provides similar functionality for Twitter.

Exploratory Pilot Study

To inform the design of the paper user interface (UI) and elicit early feedback on UbiSketch, we ran an exploratory study in a controlled environment with 11 participants (6 women and 5 men, age 22 to 55, avg. 32). We asked participants to draw one or more sketches and tap on *paper-buttons* to upload them via SketchBook.

The outcome of this study was informative. The published sketches, despite being created in a laboratory setting, led to conversations and social interactions on the Web and in person. After interacting with the provided UI prototypes, participants expressed these preferences: (1) The sketching area should be maximized and the digitized sketch should faithfully capture the details of the original, (2) The paper UI should be portable, simple, and easy to use, (3) The primary interface should be the paper (minimizing phone interaction), and (4) The phone UI should be employed to provide feedback and status. These preferences were fed into the final design, described below.

Paper User Interface

The sketching area is maximized, utilizing the entire page. To balance size and portability, we offered two different paper formats, small (15cm x 10cm), and large (22cm x 28cm) notebooks. The paper-based control panel was printed on sticker paper. We placed one control panel sticker on the outer "flap" of each notebook, easily accessible from any page, and provided additional stickers that users could place in convenient locations. As shown in Fig. 3, the control panel allows users to: save a sketch on the phone, clear the current sketch from the phone, load a previously-saved sketch, or share a sketch to Facebook, Twitter, or to the Diary channel. Loading a previously-saved sketch means tapping the load button and then tapping the area on the paper of a previously-saved sketch.

Figure 3. UbiSketch paper-based control panel

Mobile Phone User Interface

The mobile phone UI is intended to be secondary to the paper UI, providing optional visual feedback. As users sketch on paper, the phone UI automatically displays a rendering of the sketch, in the same color ink as the pen's, in horizontal or landscape mode. During the evolution of the sketch, the rendering is dynamically resized so that the screen's real estate is best used. The phone's UI also contains a control panel, identical to the paper control panel, and a status bar that displays

feedback regarding events triggered via the paper or phone control panel. For example, after a user taps the paper button to publish a sketch to Facebook, the status bar indicates that the sketch is being published, and then whether it was successfully published.

USER STUDY

We conducted a user study to learn how Ubisketch's unique modality of sketch-based communication shape the interplay of sketching and social interaction. Specifically: 1) How do participants use and experience UbiSketch, and incorporate it into their lives? 2) How and why do participants use UbiSketch to communicate, and how is this communication shaped by UbiSketch? 3) How does using UbiSketch impact participants' social interactions and relationships, and how does this influence participants' sketching?

To observe naturalistic usage practices, we ran a 4-week field study. We conducted pre-study training sessions and interviews to assess participants' existing sketching and social networking habits. We then conducted weekly follow-up interviews regarding their experiences, published sketches, and subsequent social interactions. At the end study, we conducted a final interview to investigate participants' sketching, communication, and social practices, presenting their own sketches and those of their group-mates to ease recall and elicit discussion.

Participants

We recruited 10 participants, 4 female and 6 male, ages 22 to 46 (avg = 31.9), who enjoyed sketching, were interested in sharing their sketches, and used Facebook. To explore usage in different social structures, we recruited 1 individual, 3 pairs, and a group of 3. The participants' Facebook friends also indirectly participated through Facebook interactions around the published sketches. We identify groups as follows: a unique letter (A–E), followed by group size (1–3). We identify participants by their group ID followed by a "–" and a digit (1–3).

In group A3, A3-1 and A3-2 are a married couple, who moved from [US city] to [US city] during the study, and A3-3 is a close friend living in [a distant US city]. A3-1 (male, age 26) is a chef/photographer, A3-2 (female, age 27) is a seminary graduate student, and A3-3 (female, age 27) is a computer science graduate student.

Pair B2 consists of two brothers who live an hour's drive apart in [US metropolitan area]. One is an artist / teacher (B2-1, male, age 43), and the other is a salesperson / holistic health instructor (B2-2, male, age 46). C2 is a pair of friends who live near each other in [US metropolitan area]: an artist/teacher (C2-1, male, age 37) and a computer programmer (C2-2, male, age 36). Pair D2 consists of undergraduates, friends and classmates who live nearby in [US city] and see each other regularly (D2-1, male, age 24) and (D2-2, female, age 22). Individual E1 (female, age 31) is a stay-at-home mom and jewelry artisan living in [US city].

Sketching and Sketch-Sharing Practices

All participants regularly doodled and hand-wrote notes on paper, while drawing practices varied: 7 participants drew regularly, 2 drew occasionally, and 1 never drew. Participants occasionally shared sketches face-to-face but rarely online. The members of group A3 occasionally mailed each other paper sketches, the 4 students sometimes showed their doodles to classmates, and C2-1, an artist, had posted photos of his paintings on his website. Two participants had, infrequently, scanned sketches, edited them in Photoshop, and posted them on Facebook.

All participants used Facebook as their primary online social networking tool. Eight have between 132 and 219 friends, and 2 have larger social networks (651 and 1419 friends). Five read content throughout the day, and the remaining 5 read it once or twice a day. Two participants post content at least 3 times a day, while the remaining 7 post weekly or less. They primarily post status updates or comments, and they occasionally post photos, links or events. Participants accessed Facebook in a variety of ways, depending on the context: 6 sometimes used mobile phones, 7 sometimes used laptops, and 4 sometimes used desktops.

Methods

With each participant, we conducted a pre-study interview and training session, in which we defined the study task—sketch as they would normally, but using UbiSketch, for 4 weeks. We also conducted weekly mid-study interviews and a post-study interview, to which we asked participants to bring their original paper sketches. All interviews were audio-recorded and transcribed. We provided each participant with an LG-Expo smart-phone, an Anoto DP-201 digital pen, and two notebooks (small and large) containing Anoto-augmented paper. Throughout the study, we collected the published, digitized sketches and the resulting interactions (e.g., Facebook comments and *likes*).

Analysis

We logged UbiSketch usage on the client, server, and—with the consent of the participants and their Facebook friends—we retrieved the Facebook interactions attached to published sketches. The collected data was analyzed qualitatively and quantitively. We used elements of grounded theory [9] to analyze the interviews, the published sketches, and the Facebook conversations that arose from them. Quantitative analysis was performed on data, logged by the UbiSketch server (published sketches and associated metadata), and on related data obtained from Facebook regarding subsequent interactions. In the next section we detail the results of our analysis.

RESULTS AND DISCUSSION

The analysis of the 4-week user-study data allows us to classify UbiSketch usage, and Ubisketch's impact in users' communication within and around their social environment. Our analysis breaks down into four broad categories in the following subsections: *UbiSketch Usage and Social Activity, Archetypal Users, The Sketching Experience*, and *Sketching to Communicate*.

i

UbiSketch Usage and Social Activity

We analyzed the usage of UbiSketch over the 4 weeks of the study in terms of the total number of sketches published

by our participants on the different channels. A total of 241 sketches was published through UbiSketch and every user uploaded between 3 and 55 sketches (avg=25, stdv=18.9). Facebook was the most used channel (78%).

Participants used UbiSketch in a variety of locations (home, work, school, a cafe, a friend's home, outdoors, and in motor vehicles) and contexts (in class, in transit, while cooking, at work, at church, during leisure activities, while simply drawing, and even walking). They sketched on a variety of surfaces, including a table, a bed, the floor, lap, knees, or in the hands. Nine out of 10 participants typically kept Ubisketch's phone out while sketching, periodically referring to it for visual feedback: to see how the digital sketch looked or to check the application's status (e.g., to monitor publication progress, to troubleshoot). The remaining participant, D2-1, kept the phone in his backpack while sketching. A3-1 kept her own smart phone out, in addition to the UbiSketch phone, so that she could tag people in the sketches on Facebook. Eight participants exclusively interacted with the paper UI (control panel), while 2 sometimes used the phone's UI as well. Six participants exclusively used the small notebook, 2 exclusively used the large one, and 2 used both. They carried the equipment in pockets, purses, or backpacks. Six participants always drew spontaneously, 2 always thought about what they wanted to sketch in advance, and the remaining 2 participants' sketches were sometimes spontaneous and sometimes planned. B2-1 sometimes pencilled sketches on the Anoto pad first, then penned the final sketch in. He explained, *"I almost always draw with a pencil and then ink it in"*.

UbiSketch was heavily used throughout the study. Figure 4, highlights how the novelty effect played a role in the first week of the study. After week 1 we experienced technical problems due to the increasing complexity of the sketches being posted by our participants. The complexity of the sketches increased the volume of information being transmitted, which in turn induced long transmission times, creating time-out problems. As a consequence, complex sketches could not be published. We released a fix that our participants installed during week 2 or 3. During week 4 the usage increased.
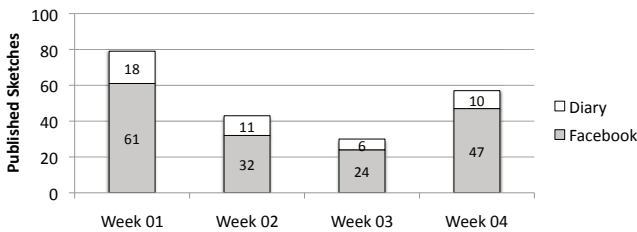

Figure 4. UbiSketch publication statistics

Data collected from users' Facebook profile was analyzed to conceptualize how a UbiSketch is perceived by the social environment of participants. Fig. 5(a) compares, per sketch versus per photo, the average number of comments, *likes*, and the number of friends that commented or liked. To avoid the perturbance of sketches on photo behavior, we used the 48 weeks of photo data preceding the study. UbiSketch drove substantially more attention and social interaction than photos.

Fig. 5(a) suggests that perhaps sketches allow people to be more personal than "just" a photo. To gain insight on this
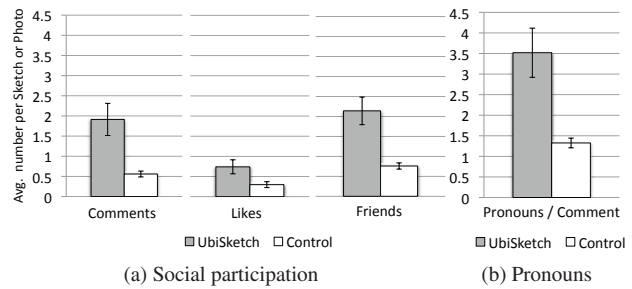

(a) Social participation   (b) Pronouns

Figure 5. Social Interaction: UbiSketch vs. Photos on Facebook (error bars show 95% confidence interval of the mean)

idea, we ran an additional analysis on the contents of the comments on the photos and UbiSketches. Building on previous work [5], we quantified the personalness of UbiSketches and photos by counting the number of specific personal pronouns such as 'I', 'we' and 'you'. Figure 5(b) highlights how UbiSketch comments on average, contain markedly more personal pronouns than regular Facebook photos.

These quantitative analyses, all told, suggest that the sketches provide unique communication affordances when made available in the Facebook milieu. In the subsequent subsections, we discuss the qualitative aspects of sketching with UbiSketch to gain a greater understanding of why this is so.

Archetypal Users
Based on our analysis of the published sketches and the performed interviews, we outline three archetypal users that can be considered as a representative example of how the study-participants used UbiSketch. These help to inform the results presented in the subsequent subsections.

The Artist
C2-1 is an artist with a regular sketching practice. He sits in a cafe and draws in a sketchbook for an hour every day. His sketchbooks are private and he rarely shows them to anyone. In his work he uses certain recurring shapes and visual themes, which he describes as a visual language that he uses to express himself. His sketches tend to be abstract, energetic, and highly aesthetic.

With UbiSketch, C2-1 has continued his existing practice of sketching in a cafe, simply swapping his ordinary sketchbook and pen with those we provided. He shares all of his sketches on Facebook, and enjoys the new experience of publishing his sketches rather than keeping them hidden. He gets lots of feedback from friends and family, who comment on and like his sketches, and enjoys hearing from people with whom he would not ordinarily share or discuss art and people with whom he does not ordinarily connect on Facebook. He has changed the content of his sketches somewhat since he began publishing them online, shifting from a purely aesthetic style to a more expressive, storytelling style. He thinks more about what he wants to tell people, rather than just drawing for practice, just for himself. For example, he has expressed his feeling of being overwhelmed as the father of a newborn, his discomfort during hot weather, and, concerns about his upcoming surgery, as shown in Fig. 6(a). His sketches never contain words, yet he adds a title or comment to each sketch on Facebook, in a post-publishing step, to hint at the signifi-

cance of the sketches' often abstract contents. The UbiSketch interface has also impacted his drawing style. He likes how the simple nature of the drawing interface constrains his sketches to be relatively simple, small, and quickly drawn. He also enjoys that he cannot erase or undo pen strokes, since this frees him from dwelling on details.

The Doodler

D2-1 is an undergraduate student who doodles in his notebook during class. Doodling helps him stay alert in early morning classes and provides a creative outlet to pass the time when he's bored. He rarely shares his sketches, except sometimes with friends who are sitting near him in class. He believes that he is not good at drawing, yet he doodles prolifically.

With UbiSketch, D2-1 continues to doodle in class. He brings his UbiSketch notebook and his ordinary class notebook, and uses the Anoto pen to sketch in one and to take notes in the other. He prefers to organize the material in separate notebooks and simply moves his hand back and forth between them. His doodles, such as Fig. 6(b), consist primarily of handwritten text accompanied by quirky cartoonish drawings, which together tell a rambling, stream-of-consciousness story in words and pictures. He describes his dreams, his past and recent experiences, his current feelings, and the adventures of fictional characters he makes up. His sketches generally contain the implicit message that he is bored during class and is reaching out to his friends. He enjoys getting feedback on Facebook from his friends, and uses UbiSketch as a sort of diary that talks back. Because he typically creates quick, simplistic doodles, UbiSketch has not greatly impacted D2-1's sketching style.

The Socializer

A3-1 is a graduate student with a long history of sharing comic strips with her old friends, A3-2 and A3-3, a married couple who live in a distant city. Years ago, they created a set of comic cartoon characters (avatars) to represent each of them, and they periodically draw comic strips portraying their real and fictional adventures and mail them to each other. When they get together in person, for vacations or holidays, they draw these comics together. Hardly anyone else knows about their comics, except for close friends and family members who have seem the comics at their homes.

UbiSketch brings A3-1 and her friends A3-2 and A3-3 longstanding practice of sketching cartoons for each other to Facebook. A3-1's sketches frequently contain her triad's avatars, as outlined by Fig. 6(c), along with avatars for other friends and family members, as well as fictional characters. Her sketches usually contain some hand-written words, used to label elements of the scene or clarify the activities being depicted. Post sketch-sharing on Facebook, she usually tags people depicted in the sketch, so that they'll be notified of sketches intended for them—using sketches to send "thinking of you" messages to particular friends. Those friends, and others, often respond with comments or likes. In addition to sending messages to friends, A3-1 uses UbiSketch as a visual blog, to update friends on how she is feeling (stressed, happy) and what is going on in her life (an impending deadline, a fun vacation, an outing with friends). A3-1 sketches in many different contexts, including work, home, in transit, and

out with friends. She sometimes sketches collaboratively with friends and family: letting them draw, drawing together, and incorporating their suggestions into her drawings. Because she can publish sketches easily immediately with UbiSketch, she shares more short vignettes, and fewer lengthy stories. In the past, there were many comics she never got around to finishing or sending to her friends. In a similar vein, she appreciates the fact that she cannot erase or undo ink strokes with UbiSketch, it prevents her from getting caught up in striving for perfection.

The Sketching Experience

Naturalness, immediateness, informality

All participants said using UbiSketch felt natural, like using an ordinary pen and paper. Although two participants thought the pen was too wide, and many complained about its ambiguous vibratory feedback: *"Sometimes the pen buzzes and I didn't know why"* (A3-1), they appreciated the feeling of using pen and paper. A3-2 valued the paper's tactile feedback, *"when you're trying to draw without the feel of actual resistance that the paper gives you, it's like you're ice skating with a pen."* C2-1 enjoyed the familiarity: *"it's not like I'm drawing on a computer screen, you have that natural feeling of paper and pen, which we all know."*

Many participants remarked that using UbiSketch felt direct. E1-1 said, *"UbiSketch just does what you want it to do, and what you're used to do. There's not that interface between doing what you want to do and doing what it's actually doing."* A3-2 described his and his wife's (A3-3) initial surprise at UbiSketch's directness: *"When we saw the [control panel] stickers ... we were like, pushing on the paper, like mocking, 'What is this supposed to do?' And then you touch the pen to it, and [your sketch] is on Facebook. You're like, 'Whoa ... this is unreal'."*

UbiSketch's immediacy was a crucial factor in sharing sketches. C2-1 explained, *"I really like being able to draw something and have it immediately on a digital image, and then be able to immediately post it. To have to make a drawing and then scan it at home and then email it to Facebook – I would never do that."* A3-2 concurred, explaining, *"without [UbiSketch], I definitely would not have ever published any of those sketches online. I don't even know if I would have sketched them at all."*

Managing technical constraints

Participants adapted their drawing styles to UbiSketch's technical constraints. For example, lines always had the same thickness, shading did not render well: *"After a couple experiments with more intricate sketches, I pretty much stuck to little cartoon bubble drawings"* (A3-2). B2-1 complained that the pen's digital coordinates had higher resolution than ink on paper: *"[The lines] don't always meet up the same way,"* so he tried to draw lines in continuous strokes. B2-2 described his attitude toward the inability to erase, saying, *"Whatever hits the paper is there, and so you have to kind of be in acceptance."* The phone's memory limitations led A3-2 to simplify his sketches, which helped him communicate: "It gets the point across a lot better when it's simpler because everybody is so used to expressing *"This is how my day went"* in 170 words or less."
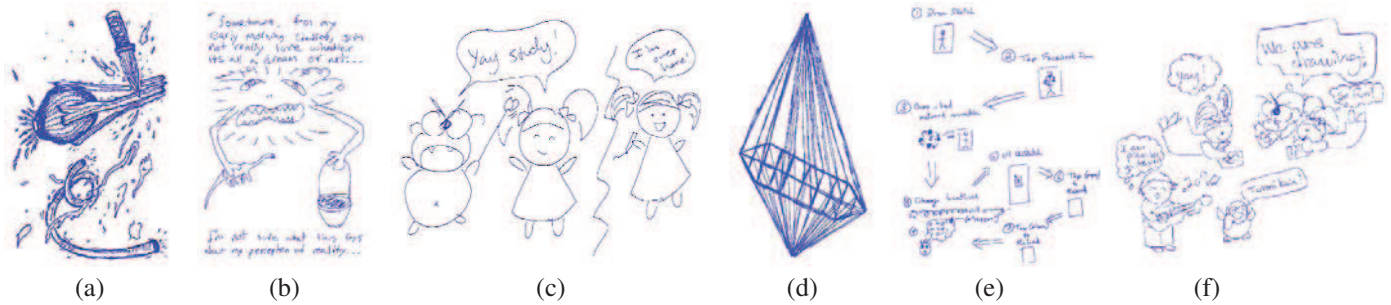
Figure 6. Participants UbiSketches (1 of 2)

UbiSketch vs. photos and scans of sketches

We asked participants to explain how UbiSketch was different than sharing scans or photos of sketches. B2-2 appreciated that UbiSketch captures only the ink: *"you don't end up with grayscale in the back of your drawing...you don't have a bunch of artifacts that are really in the way."* A3-1 remarked that with her camera-phone, photography might not be feasible because it cannot focus close up and lacks a flash: *"it would have been impossible to take a picture...I was using the phone's light to draw the picture."* For C2-2, UbiSketch had a conceptual advantage: *"The [UbiSketch] technology inherently suggests sharing drawings. I wouldn't typically even think to take a picture of a sketch."* Indeed, only B2-2 had ever shared a photo of a sketch.

Sketching to Communicate

The synergy between paper-based digital sketching and a semi-public channel like Facebook created a dynamic ecology, affecting how and what participants sketched, who commented on the sketches, even impacting face-to-face interactions.

Representational devices: avatars, text labels, & beyond

Five participants used cartoon avatars to represent themselves symbolically within sketches, leveraging their existing paper-based sketching practices: B2-1 used Snoopy, D2-2 used a "creepy cat creature", and group A used cute cartoon characters they created. Participants also used symbols to convey other kinds of information. For example, C2-1 drew on recurring visual themes, explaining, *"It's like a language."* He described a sketch (Fig. 6(d)): *"This is an image that I've drawn many times before, and it takes on different meanings...I was feeling really worn out and stretched thin."*

Participants typically combined images and hand-written text in their sketches: 4.8% of sketches contained only text, 30.7% contained only images, and the remaining 64.5% contained both text and images. In 46.3% of sketches, text was used to label elements within the sketch or to clarify its meaning, as A3-2 explained: *"I'm not cool enough to be able to express everything I want to in just pictures, so, I'll draw word bubbles with people talking."* In 29.4% of sketches, text conveyed a specific message (e.g., "Happy Birthday"). For most participants, text was *"only to back up the drawings"* (B2-1), however for D2-1 text was often primary. One participant (C2-1) titled his sketches, explaining *"I always title my larger artwork, but in terms of sketches in a sketchbook I don't...since I'm posting to Facebook I've been feeling the need to give them all titles."*

Participants often told sequential stories within a single sketch. For example, B2-1 detailed his day at the beach, and C2-2 sent the researchers "a bug report" (Fig. 6(e)) .They also published sketch sequences, telling comic-strip style stories or showing the process of a sketch's creation. Participant C2-2, published a steganographic sketch in 4 parts, intended to be superimposed in viewers' minds.

Feedback

Participants received a lot of feedback, usually encouraging, sympathetic, or funny. Because A3-3 posted more than previously on Facebook, she got more feedback: *"Being able to post the sketches, I ended up having a lot more interaction with people... Now, I actually have comments and conversations going back and forth with people."* E1-1 also received many comments on her children's drawings, e.g. the children's grandmother expressed her enjoyment (*"oh Grandma Just loves your pitcher"*). Participants were usually encouraged by the feedback they received, as evinced by B2-2's remark: *"It made me really want to draw more."* Unfortunately, they sometimes felt frustrated when viewers misinterpreted sketches. B2-1 related, *"I don't feel like I really made communication with them"*, adding that he sometimes hand-wrote words to *"add information to a sort of ambiguous drawing."*

Participants wanted more friends using UbiSketch, and their friends didn't want to be left out. D2-1 wanted to distribute the conversation more evenly, explaining, *"It shouldn't just be one person drawing and everyone commenting on that person. It's more fun if everyone's drawing and you can comment on each other or build off of the stuff."* Participants' friends also expressed interest. For example, E1-1's friend commented, *"I love this!! I wanna draw, now!"*, and A3-1 said that her friends wanted to to respond to her with sketches of their own.

Participants also received feedback through various channels, including email, phone calls, or face-to-face conversations. D2-1 typically spoke to his friend D2-2 in person, explaining, *"Usually I would just face-to-face comment."* E1-1 emailed some sketches to her grandfather, and related, *"he didn't actually write me back, but he called."* And despite B2-2's Facebook privacy settings, which restricted comments, his friends encouraged him through email and private Facebook messages. He related, *"a bunch of people said they want to comment on my drawings, like 'Wow. I can't comment on your things, but your drawings are cool'."*

Participants created sketches in response to feedback from friends, or posted sketches and comments intended to influence others' sketching. For example, B2-1 responded to his friend's comment (*"Curse you right-handed butter knives"*),
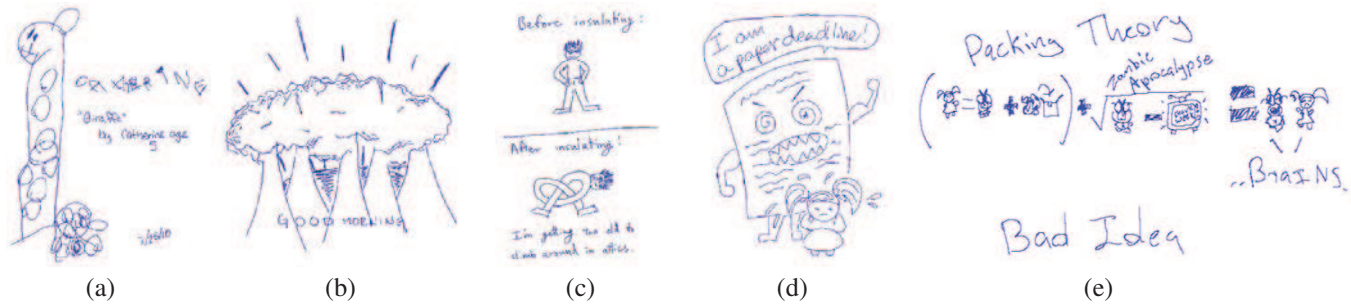
Figure 7. Participants UbiSketches (2 of 2)

on a drawing of a knife slicing butter, with one of a left-handed butter knife. Also, A3-1 tried to inspire A3-2 and A3-3 to publish more sketches by depicting them drawing in a sketch of her own (Fig. 6(f)), and on another occasion, wrote a comment (*"CARTOON!"*) to encourage A3-2 to elaborate on his Facebook status (*"just saw a pig give birth"*). She related, *"the [UbiSketch] picture showed up later, and I was very happy."*

The Synergy of Ubisketch and Facebook
UbiSketch's real-time, mobile publication *enabled* participants to quickly share context-dependent information such as locale. Facebook's newsfeed and the common practice of posting about contemporaneous events *encouraged* it, creating a powerful synergy.

The lightweight nature of UbiSketch and the inherent informality of sketching encouraging many participants to share more sketches. D2-1 explained, *"I don't really show my sketches digitally 'cause they're nothing to write home about. So why would I make an effort to show people?...But if it's automatic then there's not really no cost to [sharing them], so...It's kind of a casual thing."* The simplicity of using Ubisketch allowed A3-3 to express a lighter side of her personality: *"It allowed me to be more playful. Some of my friends think I'm too serious, so I think it helped [them see] that I wasn't just this formal type of person that they knew but someone who could enjoy telling something funny through a sketch."* It also relieved participants from worrying about viewers critiques: *"no one's really judging it very heavily...[there's] nothing serious about it, so I don't really think that I was too worried about what people would say"* (2B-1). It also lowered communication barriers, as E1-1 described: *"I had my kids use it because all of my family lives far away...often they'll draw little stuff and I'll save it, and mean to mail it to my mom, and I never do it... [with UbiSketch] it was done, and I sent it, and it's saved."*

Betraying a Facebook mindset, A3-3 explained why real-time publication was critical to convey certain types of information: *"It was such an in-the-moment kind of a thing that once a day passed, there was no point in posting it up. It just wouldn't have the same meaning to me. It wouldn't have the same meaning to people looking at it."* The real-time nature of UbiSketch allowed participants to micro-publish, sharing *"just really small snapshots... trying to capture just the moment"* (A3-3). A3-2 explained the importance of UbiSketch's mobility: *"If it's small and...portable and we take it with us, it's all about living in the moment and using it when it's opportunistic. It's really important to be able to publish it in that same context."*

Enhancing Social Interaction
UbiSketch helped participants and their friends maintain a sense of awareness of, and connectedness with, each other. For example, B2-1 shared his activities, explaining one sketch as *"everything that happened to me that day."* And A3-2 kept up with A3-1's life without having to ask, explaining *"How many times do you forget to say, 'How's your Gung Gung?', which is her Grandpa. So, you see the sketch, he's there and he's smiling, [and you think], 'Oh, he's okay. That's good'."* Also, drawing pictures depicting themselves together (see Fig. 6(f)) helped Group A, who lived in distant cities, to feel connected: *"we can't take [photos] together when they're that far away, but we can still draw pictures where we're all together"* A3-1. UbiSketch led to increased social interaction, both in-person and online. D2-1 related, *"There's more social interaction for both places...with online-only friends and then here-friends that also look on my Facebook."* For example, Group A rekindled their sketch-sharing practice, which they had become too busy to maintain as adults. A3-3 recounted, *"it was really emotional 'cause it's been a while since we've communicated in this way...and sketching is just so much a part of how we've communicated in the past."*

Participants also sketched collaboratively with friends and family. Over 13% of the published sketches were created by *guest-artists*, in collaboration with 7 participants. Remarkably, 10% of all sketches were created by children (Fig. 7(a)); three of the participants' young children (ages 3-6) sketched under their parents' supervision. Participants' friends also collaborated indirectly, suggesting what to write or draw. What these behaviors suggest is that the digital sharing of sketches—at least when untethered from the computer—creates social interactions in the physical world as well.

Many participants noticed that UbiSketch strengthened weaker ties. D2-1 expressed surprise, remarking, *"my close friends, yeah, I expected that ... but random [people] I wouldn't have expected."* A3-3 appreciated the interaction that strengthened weak ties: *"to have even a five or six-line comment back and forth with them was way more interaction than we'd had in years."* In another example, C2-1 forged a connection with his brother-in-law, relating, *"To have him see my work and comment on it and seem interested–it was gratifying to connect with him. He's not someone I connect with in any way."*

Private to Public
With UbiSketch, participants shared more sketches, and consequently shared information that they might not otherwise share. A3-3 posted more about her life, explaining, *"I didn't really post many updates to Facebook before UbiSketch...I*

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could let people into what was going on with me because drawing was so much more fun than saying, 'Hi, I'm having a good day'" (Fig. 7(b)). C2-1 also shared more of his drawings, which helped reduce the isolation of his work: *"A lot of my work just ends up being hidden away in a sketchbook or in my studio...One thing that's really good for me as an artist is...to think about how to connect with people through my work, because my work can be kind of a solitary thing."*

Some participants adjusted their sketching for public presentation. D2-1 explained that instead of *"random doodle stuff"*, he tried to draw *"something that other people would possibly be interested in"* and that would tell *"some sort of story."* A3-2 said, *"just like you would filter out things that you would say over a social network, you filter out the things that you would draw."* C2-1 created more "diaristic" and "personal" sketches for Facebook, relating, *"I figured, 'Well, it's my Facebook page, I suppose I should be doing things about me'."*

UbiSketch enabled users to communicate things that they could not express, or would not feel comfortable expressing, through words or photos. E1-1 related, *"There's certain things you just can't type up with words. I do a lot of photography, and that's still not the same thing as drawing something."* A3-2 used UbiSketch *"whenever words wouldn't do something justice, or you could put a funny spin on something that was just pathetically mundane."* D2-1 added, *"In this kind of format, I feel like it's socially okay for me to say whatever it is that I'm feeling...But if I actually write it out as a status thing...then it's just kind of awkward."*

Participants were able to express their feelings by sketching. E1-1 described some of her sketches as *"like emotional state, almost like a diary entry,"* and C2-2 sketched himself bent into the shape of a pretzel to illustrate how he felt after helping a friend install insulation (Fig. 7(c)). A3-1 felt that her sketches, about an impending paper deadline (Fig. 7(d)), were easier to relate to than a status update, explaining, *"It's easier to see yourself in that [situation] and think 'I've been there'."* C2-2 used humor to make light of his concern about an upcoming surgery in a sketch, highlighted in Fig. 6(a), titled "Strabismus Massacre Feared Dead": *"The title is showing you the over-the-top silliness of the fear of this surgery. I'm sure it will be fine and not a big deal, but in my mind it's this horrible thing."*

UbiSketch gave sketch viewers additional insight into authors' thoughts and feelings. For example, it eased understanding between A3-3 and her husband. She related, *"normally, he's trying to verbally describe his thoughts to me and I get so lost...the picture makes a lot more sense"* (Fig. 7(e)). She consequently paid more attention to sketches than to her friends' other online updates, explaining *"The sketches just expressed a whole lot more."* For example, one of A3-1's sketches expressed her sadness that her friends were moving farther away, and A3-3 related, *"There's just no better way, and I knew exactly how she felt."*

CONCLUSION
When other media went online, sketching was left behind, effectively silencing a unique form of visual communication for the typical sketcher. In seeking a remedy to this problem, we explored real-time sketch-based communication by using mobile phones to connect digital pens and paper to online social networks like Facebook. We created a working prototype system called UbiSketch and conducted a 4-week field study to observe participants' usage, experiences, communication practices, and social interactions.

Our results show how UbiSketch brought sketching from the privacy of paper notebooks and sketchbooks into the public domain of social networks, meeting an otherwise unmet need for informal communication. (Indeed, as of this writing, four of our participants still publish on Facebook daily and a new user has started to exploit the system, a sibling of one of the participants.) Several factors enabled UbiSketch to bring sketching back into the public realm.

- *It enabled participants to express things that they could not or would not otherwise express.* Participants expressed feelings like happiness, boredom or pain through sketches that were not possible to effectively communicate over photos or text.

- *Its direct interface and instantaneous publication preserved the quality of prevailing social media.* Slow sketching combined with fast-paced online social media would have resulted in an impedence mismatch. Participants could express themselves quickly and naturally on paper and share in-the-moment information, fitting the practices typical of today's of social media applications.

- *It broadened and deepened social interactions.* Compared with prior photo practices, participants posted more on Facebook, their sketches received more comments, and a larger group of friends responded. The sketches and comments were also more personal. UbiSketch created unique social interactions within the participant groups and across their social networks, with friends actively participating in the social existence of the published sketch.

All in all, the affordances offered by UbiSketch enable the digital medium to embrace an additional form of communication, bringing it one step closer to fulfilling the promise of capturing the full spectrum of human experience.

In the future we plan to expand UbiSketch to explore further sketching practices. For example, currently users and viewers see the sketch in its final static form. What if we show the dynamic evolution of the sketch or some of its hidden properties? We will explore visualization techniques to provide additional information about the publisher's context and mood, e.g., expressing the location, speed, and force of sketching, through static (color, stroke thickness) and dynamic (animation, replay) representations.

REFERENCES
1. J. Andrade. What does doodling do? *Applied Cognitive Psychology*, 24(1):100–106, 2009.

2. L. Barkhuus and J. Tashiro. Student socialization in the age of facebook. In *Proc, CHI '10*, pages 133–142, 2010.

3. D. Boyd and N. Ellison. Social network sites: Definition, history, and scholarship. *Journal of Computer Mediated Communication*, 13(1):210, 2007.

4. E. R. Brocklehurst. The NPL Electronic Paper Project. *International Journal of Man-Machine Studies*, 34(1):69–95, 1991.

5. L. Brothers, J. Hollan, J. Neilsen, S. Stornetta, S. Abney, G. Furnas, and M. Littman. Supporting informal communication via ephemeral interest groups. In *Proc. CSCW '92*, pages 84–90, 1992.

6. B. Buxton. *Sketching User Experiences*. M. Kaufmann, 2007.

7. A. Clark. *Mindware: An introduction to the philosophy of cognitive science*. Oxford University Press, Oxford, UK, 2001.

8. K. Conroy, D. Levin, and F. Guimbretière. ProofRite: A Paper-Augmented Word Processor. Technical Report HCIL-2004-22, CS-TR-4652, Human-Computer Interaction Lab, University of Maryland, USA, May 2004.

9. J. Corbin and A. Strauss. *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Sage Publications, Inc, 2008.

10. N. Ellison, C. Lampe, and C. Steinfield. Social network sites and society: current trends and future possibilities. *interactions*, 16(1):6–9, 2009.

11. C. H. Faber. Digital Drawing Tablet to Traditional Drawing on Paper: A Teaching Studio Comparison. In *Proc. IASDR '09*, pages 2485–2492, 2009.

12. E. Gilbert, K. Karahalios, and C. Sandvig. The network in the garden: an empirical analysis of social media in rural life. In *Proc. CHI '08*, pages 1603–1612, 2008.

13. F. Guimbretière. Paper Augmented Digital Documents. In *Proc. of UIST '03*, Vancouver, Canada.

14. E. Hargittai. Whose space? Differences among users and non-users of social network sites. *Journal of Computer-Mediated Communication*, 13(1):276–297, 2007.

15. C. Lampe, N. Ellison, and C. Steinfield. Changes in use and perception of Facebook. In *Proc. CSCW '08*, pages 721–730, 2008.

16. J. A. Landay and B. A. Myers. Interactive sketching for the early stages of user interface design. In *Proc. CHI '95*, pages 43–50, 1995.

17. J. A. Landay and B. A. Myers. Interactive Sketching for the Early Stages of User Interface Design. In *Proc. CHI '95*, pages 7–11, 1995.

18. Y. Li, J. A. Landay, Z. Guan, X. Ren, and G. Da. Sketching informal presentations. In *Proc. ICMI '03*, pages 234–241, 2003.

19. P. Luff, C. Heath, and D. Greatbatch. Tasks-in-interaction: paper and screen based documentation in collaborative activity. In *Proc. CSCW '92*, pages 163–170, 1992.

20. G. Martin, J. Pittman, K. Wittenburg, R. Cohen, and T. Parish. Sign Here, Please (Interactive Tablets). *BYTE*, 15(7):243–251, 1990.

21. M. C. Norrie, B. Signer, and N. Weibel. General Framework for the Rapid Development of Interactive Paper Applications. In *Proc. CoPADD 2006*, pages 9–12, 2006.

22. A. M. Piper, N. Weibel, and J. D. Hollan. Introducing Multimodal Paper-Digital Interfaces for Speech-Language Therapy. In *Proc. ASSETS '10*, Orlando, FL, USA, October 2010.

23. D. Schön. *The Reflective Practioner: How Professionals Think in Action*. Basic Books, 1983.

24. A. J. Sellen and R. H. Harper. *The Myth of the Paperless Office*. MIT Press, 2003.

25. B. Signer and M. C. Norrie. PaperPoint: A Paper-Based Presentation and Interactive Paper Prototyping Tool. In *Proc. TEI '07*, Baton Rouge, USA, February 2007.

26. H. Song, T. Grossman, G. Fitzmaurice, F. Guimbretiere, et al. Penlight: combining a mobile projector and a digital pen for dynamic visual overlay. In *Proc. CHI '09*, pages 143–152, 2009.

27. I. E. Sutherland. SketchPad: A Man-Machine Graphical Communication System. In *Proc. AFIPS '63*, pages 329–346, 1963.

28. The Washington Post, Brigid Schulte. So Long, Snail Shells: Mail Volume Expected to Decline; U.S. Postal Service Adapts by Pulling Collection Boxes. *http://www.washingtonpost.com/wp-dyn/content/article/2009/07/24/AR2009072403857.html*, July. 25, 2009.

29. B. Tversky. What do Sketches say about Thinking. Technical Report SS-02-08, AAAI, 2002.

30. US Postal Service. Facing Greatest Mail Volume Drop in History, Postal Service Begins Contract Negotiations with Rural Letter Carriers. *http://www.earthtimes.org/articles/press/negotiations-rural-letter-carriers,1457366.html*, Sept. 13, 2010.

31. N. Weibel, A. Ispas, B. Signer, and M. C. Norrie. PaperProof: A Paper-Digital Proof-Editing System. In *Proc. CHI '08*, pages 2349–2354, 2008.

32. B. Wellman. An electronic group is virtually a social network. *Culture of the Internet*, pages 179–205, 1997.

33. B. Wellman, A. Quan-Haase, J. Boase, W. Chen, K. Hampton, I. de Diaz, and K. Miyata. The social affordances of the Internet for networked individualism. *Journal of Computer-Mediated Communication*, 8(3), 2003.

34. R. B. Yeh, C. Liao, S. R. Klemmer, F. Guimbretière, B. Lee, B. Kakaradov, J. Stamberger, and A. Paepcke. ButterflyNet: A Mobile Capture and Access System for Field Biology Research. In *Proc. CHI '06*, 2006.

35. R. B. Yeh, A. Paepcke, and S. R. Klemmer. Iterative Design and Evaluation of an Event Architecture for Pen and Paper Interfaces. In *Proc. of UIST '08*, Monterey, USA.