

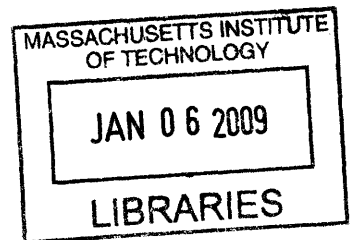
Quickies: Intelligent Sticky Notes

by
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Submitted to the Program in Media Arts and Sciences,
School of Architecture and Planning,
in partial fulfillment of the requirements for the degree of

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Abstract

This thesis introduces 'Quickies', an attempt to bring one of the most useful inventions of the 20th century into the digital age: the ubiquitous sticky notes. Sticky notes help us manage our to-do lists, tag our objects and documents and capture short reminders or information that we may need in the near future. 'Quickies' enrich the experience of using sticky notes by allowing them to be tracked and managed more effectively. Quickies are sticky notes that have a digital duplicate and the ability to remind us about the task we ought to perform or to provide us at the right time with the information we captured in the past. The thesis explores how the use of Artificial Intelligence (AI), Natural Language Processing (NLP), RFID, and ink recognition technologies can make it possible to create intelligent sticky notes that can be searched, located, can send reminders and messages, and more broadly, can help us to seamlessly connect our physical and digital information worlds.

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1. Introduction

“Machines that fit the human environment, instead of forcing humans to enter theirs, will make using a computer as refreshing as taking a walk in the woods.” - Mark Weiser

Tiny, cheap processors with integrated sensors and wireless communications capability, the remote identification and precise localization of devices, flexible displays based on polymers, miniaturization of computing devices, capacitive multi-touch sensing, and electronic ink - it becomes clear that the technological basis for a strange new world has already been created. On the other hand another interesting opportunity lies in linking information to our everyday objects, effectively attaching this information to them, or augmenting our daily life objects in some sense. Instead of creating more devices to interact with the digital realm, we can communicate directly with our clothes, watches, pens, or furniture. As an extension to this idea, they can communicate with each other and with other people's objects. The vision of a future of smart and interacting everyday objects offers a whole range of fascinating possibilities. The foreseeable technological developments can definitely add new quality to everyday objects - these might be able not only to communicate with people and other objects, but also to discover where they are, which other objects are in their vicinity, and what has happened to

them in the past, for example. Objects and devices could thus behave as “smart,” without actually being “intelligent.”

1.1 Motivation

Drawing (including in this definition also the concept of writing) is an essential part of human communicational and intellectual activities. It allows expressing thousands of different types of data; it can be done without paying active attention and it does not require users to be familiar with computers. Therefore, it is not surprising that almost since the beginning of modern computer science, research has been conducted in order to develop interfaces that could enable users to draw. The development of digitizers was an important step, allowing users to input their drawings by writing on a tablet or directly on the screen. However, despite these developments, the use of paper as the primary medium for information organization has far from dwindled, but instead increased steadily. Today, the paperless office is more distant than when it was proposed [9]. Despite the enormous popularity of computers and personal digital assistants, along with improvements in screen technology, mobile computing technology, and navigational and input tools, paper usage in the U.S. continues to increase (see Figure 1.1)¹. Of total paper production, the percentage of paper used for writing and printing increased approximately 13% from 1970–1997. Global paper use increased more than six-fold over the latter half of the 20th century, and has doubled since the mid-1970s.

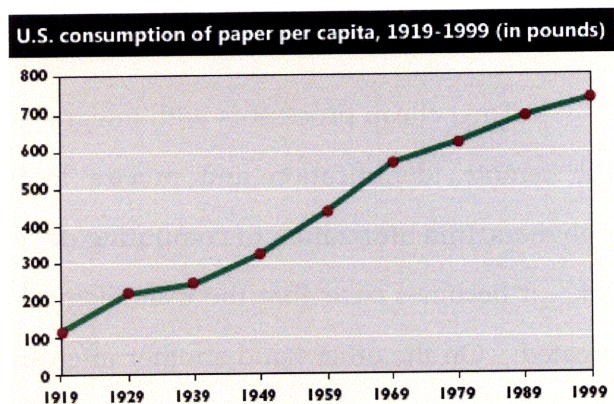


Figure 1.1. U.S. consumption of paper per capita, 1919-1999 (in pounds). *Source*¹

Paper has visual (resolution, contrast, viewing angle) and functional (null power consumption, low cost, portability, small & light weight) features that can hardly be rivaled.

¹ American Forest and Paper Association. 1998 Statistics: Paper, Paperboard and Wood Pulp.

Another important reason is that we, humans, have been using paper and its variants for thousands of years. This has created a psychological attachment of human to paper and its variants. Paper use is deeply rooted in our culture and has had a profound impact on the civilization of our society. As Strassmann noted, paper-based documents will survive as long as institutions deeply rooted in traditions of an agricultural society continue to operate [19].

Support for and augmentation of paper-based routines is an important step in the computerization of human work practices. Several studies [14] have showed that paper objects are very supportive, giving users control, flexibility, and overview of information in ways that are difficult to achieve with computer technology. However, digital benefits such as trace-and-search ability of documents are almost impossible to achieve with solutions based on paper only. Rather than trying to develop solutions that can replace the world of paper, it would be interesting if we can make it possible to use paper as the interface to computers, and augment and link paper-based work processes to our digital world.

Since 3M's introduction of Post-it® Notes in 1980 [1], sticky notes, one of the variants of paper, have become an integral part of our everyday life - accumulating and keeping track of all sorts of information. In an office, sticky notes are often seen on desks as meeting reminders, to-do lists and contact information; on whiteboards as brainstorming devices; and on paper documents as brief notes to the recipient about the content or intended purpose. Sticky notes are also found at home mostly near telephones or on refrigerators as household reminders and messages. Sticky notes are usually seen in books as bookmarks. In addition, we also use sticky notes to tag our assets for personal or social usage. In short, sticky notes are everywhere. Unlike most of our modern digital information devices, sticky notes are portable, low cost and easy to use. As a prognostication to the web, sticky notes offered an easy way to link one piece of information to another in a precise contextual manner. As a forerunner to email, they made informal, asynchronous communication a major part of our modern daily life. They are no short to modern computer-based task-lists, calendars or address books.

However, as written sticky notes accumulate, keeping track of our stickies and the information they contain gets unruly. Desks, whiteboards, refrigerators, telephones and textbooks are inundated with sticky notes. As a result, stickies become lost, hidden or forgotten about. Furthermore, sticky notes have physical limitations; a particular sticky note cannot be in an office and at home simultaneously. Being a passive piece of paper, sticky notes lack the capability of dispatching reminders about upcoming events or deadlines. After scribbling details of a forthcoming occasion on a sticky note, one can still overlook the appointment due to forgetfulness or loss of the sticky note. Like most paper-based media, sticky notes fall short as a medium that can communicate to other, especially digital, information media we use.

1.2 Hypothesis

Given the wide popularity and practical usefulness of sticky notes, we are compelled to bring them along with us into the 21st century. At the same time, given sticky notes' weakness in communicating with our digital information world in a more orderly and active way, we feel the need to augment the features of sticky notes. The Quickies system attempts to bridge the gap between the physical and digital worlds of information, linking hand-written sticky-notes to the mobile phone, digital calendars, task-lists, e-mail and messaging clients. By augmenting the familiar and ubiquitous physical sticky-note, Quickies leverages existing patterns of behavior, merging paper-based sticky-note usage with a user's digital informational experience.

The research started with a set of interesting questions. Can sticky notes be 'intelligent'? More specifically, what if sticky notes can do something more.

Can they (sticky notes) ...

- Alert me at the right time about some appointment?
- Remind me?
- Keep track of my belongings?
- Manage my task-list?

- Remember on behalf of me?

Can they be ...

- Located?
- Searched among?
- Linked to other media?
- Organized the way we want?

These questions motivated me to implement a working prototype of Quickies - Intelligent sticky notes that can be searched, located and can send reminders and messages [11]. Quickies are regular paper sticky notes that have been augmented in a few ways. First, each sticky contains a unique RFID tag, so that stickies can be located in different parts of a home or office. Second, we use a small digitizer, so that while a note is being scribbled, a digital copy is created. Character and shape recognition is used to translate the note's content into machine readable data. Finally, special-purpose knowledge, NLP (Natural Language Processing) and commonsense based AI (Artificial Intelligence) techniques are used to interpret what the content of the note means and what relevant actions should be taken. Subsequently, Quickies updates your electronic calendar with the meeting reminder you wrote down on a paper sticky note; and reminds you 15 minutes before your meeting via an SMS. It Syncs the list of items to buy with your computer based task-list. You can locate documents or books tagged with Quickies in your home or office. To look up some information quickly from your computer, you can use Quickies instead of keyboard and mouse. 'Quickies' is an attempt to link physical and digital informational media and combine the best of both worlds in one seamless experience.

1.3 Contributions

This thesis describes the design and implementation of the Quickies system. The contributions of this thesis include:

- Design and implementation of a system, linking hand-written physical sticky-notes to mobile phones, digital calendars, task-lists, e-mail and messaging clients.
- Design and implementation of software algorithm for identifying and categorizing different types of handwritten sticky notes.
- A modular software system that can capture the paper sticky notes into digital form and can also save, sort, search, filter, organize those digital representations.
- Software modules for sending reminders and messages to a user or user's contacts via SMS and Emails, updating the user's digital calendar and task-lists, printing information requested by user using hand written queries on paper sticky notes.
- Implementation of a system for tracking the physical location of sticky notes and thus user's physical assets in a home or office environment.
- User needs analysis using an online survey (49 users) and qualitative user study to evaluate users' interaction with the prototype system (24 users).

1.4 Outline

This thesis contains seven chapters. The first chapter, **Introduction**, provides a general introduction and motivation behind the project along with the list of major contributions. The next chapter, **Background and Related Work**, starts with a discussion around affordances of paper and one of its variants, sticky notes. The chapter also discusses some of the relevant concepts and research projects related to the project Quickies. Then, in **Design**, we plunge right into the design process of Quickies from user analysis with empirical data to the ideation stage centered around users, and from demonstration of the design theories that Quickies has followed to the design of the prototype. Features and three major applications of the Quickies are listed and explained through user scenarios in the following chapter, **Applications and Features**. A chapter on **Implementation** discusses the detailed implementation process of Quickies system and the design and development of its software system. Next, **Evaluation** reports on the user study experiments along with results gathered through users' direct usage

of the Quickies system. Finally, the last chapter, **Conclusions and Future Work**, presents conclusive remarks of Quickies and also discusses the future possibilities.

2. Background and Related Work

"If it were easy, someone else would do it."

– Art Fry, Inventor of the Post-it Note

This chapter is concerned with addressing the affordances of paper and its variants such as sticky notes as a medium for information organization. It will briefly introduce Mark Weiser's vision of 'ubiquitous computing' that inspired the Quickies project. This chapter will also present a short overview of related concepts and projects in the field.

2.1 Paper and its "affordances"

The relation between digital technologies and paper in our daily life is much more complex than one might think. Often, it seems that the new technologies shift the point at which paper is used rather than replacing its use altogether. We see this in the shift from photocopying to digital printing and how the point at which the printing takes place is altered (previously before distribution; now after it) [17]. In either case, paper is still consumed. We have also seen that new technologies can radically alter office work: sometimes the digital

technologies do away with the need for paper, but other times they create more demand for it. To understand why this is so, we need a better grasp of the reasons that paper supports some kinds of human activities better than the digital alternatives do. We need to understand what it is about the physical properties of paper that make it play into different aspects of the work that people do, and how work practices have evolved along with paper in such a way that paper is woven into the very fabric of work. It is only by looking carefully at people's interactions with paper artifacts, and with the digital technologies they have at hand, that we can hope to predict the circumstances under which they might be willing to give up paper. To some extent, this will be a matter of providing people with better technological alternatives, but it also means being sensitive to their existing work practices so that we can know what their requirements might be and how change can be introduced.

To take this view is to see paper not as a prop in organizational life but as a way of looking at our daily work life. In other words, it is to view paper as a way of understanding the work that people do and the reasons they do it that way. It can help determine which existing digital technologies might support people's work and how digital devices might be better designed to do this.

To help understand these aspects of paper, we will employ a concept called 'affordances.' The notion of affordances can be traced back to the ecological psychologist J. J. Gibson in his seminal book 'The Ecological Approach to Visual Perception [3].' Gibson's theory was that people 'pick up' information about their environment and the objects in it largely by attending to what those objects 'Afford'. An affordance refers to the fact that the physical properties of an object make possible different functions for the person perceiving or using that object. In other words, the physical properties of objects determine the possibilities for action. Consider what Gibson said about tools:

"An elongated object, especially if weighted at one end and graspable at the other, affords hitting or hammering (a club). A graspable object with a rigid sharp edge affords

cutting and scraping (a knife, a hand axe, or a chopper). A pointed object affords piercing (a spear, an arrow, an awl, or a needle). These tools may be combined in various ways to make other tools."

The physical properties of paper (being thin, light, porous, opaque, flexible, and so on) afford many different human actions, such as grasping, carrying, manipulating, folding, and in combination with a marking tool, writing on. These affordances of paper, then, are about what people can do with paper. If paper is used to make different kinds of objects, those objects take on a different set of affordances. For example, bind the pieces of paper together into a book, and it affords flicking through and reading from. Its fixed arrangement of pages affords placeholding and knowing where you are within the book. To be more relevant to this thesis, it is the re-adherable strip of adhesive on the back of a 3 inch square piece of paper which makes a Post-it® note so prevalent and handy.

Digital technologies, too, have affordances. A desktop PC, for example, is not light, thin, and flexible, so it does not afford carrying (very easily), folding, grasping, and so on. But because it dynamically displays information, it affords the viewing of moving images. Because it has a keyboard, it affords the creation of regular, geometric, uniform marks. Because it makes use of digital storage, it affords the storing and accessing of large amounts of information. Digital technologies, however, tend to present much more complicated interfaces to their users than most of the physical objects we ever encounter in everyday life. Acting on and interpreting feedback from our actions with devices such as desktop computers often require a great deal of learning and experience. Don Norman has argued in various books [13], that this is because many of the affordances of digital devices are hidden from view, many of their features cannot be perceived and thus are never used.

2.2 Post-it® notes (Aka. Sticky notes)

They are probably all over your computer at work. You use them at home to post the shopping list on the fridge, to leave a telephone message where it will be seen, or to flag a page in a catalog. They stick where you want them to; and unstick when you need them to. The Post-it® note is a piece of paper with a re-adherable strip of adhesive on the back, designed for temporarily attaching notes to documents and to other surfaces: walls, desks and table-tops, computer displays, and so forth. The adhesive has relatively weak stickiness, which allows the user to place, remove, and replace a note many times without leaving marks or residue. The



Figure 2.1. Post-it® notes.

classic Post-it® note is a 3-inch (7.5-cm) square, canary yellow in color. However, the success of the notes has spurred a wide variety of other sizes, colors, and uses. Some pads of notes are also printed with witty comments and illustrations.

The name “Post-it” and the canary yellow color are trademarks of 3M. Accepted generic terms for competitors include “sticky notes” or “repositionable” or “repositional notes.” 3M manufactures other products related to the Post-it® note concept, leveraging the success of the brand. Until the 1990s, when the patent expired, Post-it® notes were only produced in the 3M plant in Cynthiana, Kentucky. Although other companies now produce them, most of the world's sticky notes are still made in Cynthiana.

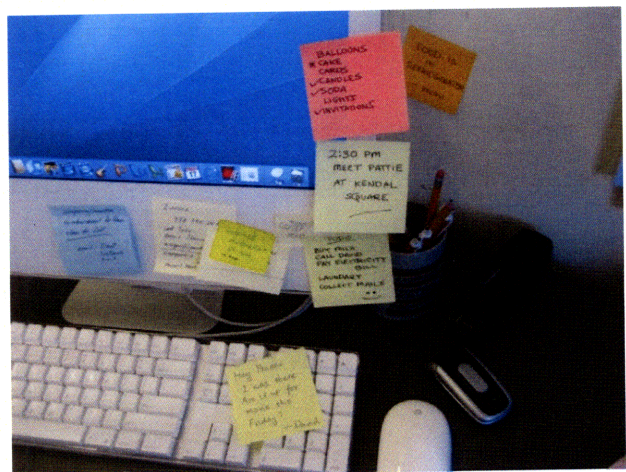


Figure 2.2. Frequent use of sticky notes on the desk.



Figure 2.3. Different kinds of sticky notes available in the market.

The fascinating story of Post-it notes is how they were invented. Ubiquitous in today's office, when they were first created no one had a use for them. Art Fry at 3M searched for uses for a glue, invented by fellow 3M researcher Spencer Silver [1]. Fry used the glue to hold book marks in his hymnal. Others didn't see the utility of this product, so 3M gave samples away. Once office workers discovered their own uses for the notes, they started ordering them and Post-it® notes became a big hit for 3M. According to 3M, the molecules in the Post-it® adhesive are round. This adhesive, containing microsphere molecules, sticks lightly and repositions because the microspheres limit the amount of surface area contact between the adhesive and the substrate. In 1995, 3M was awarded the National Medal of Technology, at least in part due to its invention of the Post-it® note.

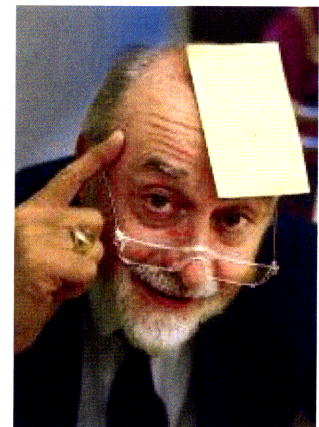


Figure 2.4. Art Fry.

2.3 Ubiquitous computing and smart everyday objects

More than 15 years ago, Mark Weiser, a researcher at the XEROX Palo Alto Research Center, foresaw a development, and described it in his influential article - The Computer for the 21st Century [20]. Weiser coined the term 'ubiquitous computing' referring to the future of omnipresent computers that will serve people in their everyday lives at home and work, functioning invisibly and unobtrusively in the background with the aim of supporting them in their work and activities, and to a large extent freeing them from tedious routine tasks. Whereas his ideas sounded rather utopian at the time, today the large-scale use of tiny computerized devices in everyday life is a reality. Recent technological developments in wireless mobile communications and sensor technology as well as positioning systems and wireless identification systems measuring just a few millimeters are already enabling researchers in development laboratories to realize Weiser's utopia by creating numerous prototypes. The ubiquitous computing project at Xerox PARC served as an exemplar proposal of how computation can be embedded into physical objects and spread throughout a user's environment.

With its orientation towards the public as well as the private, the personal as well as the commercial, ubiquitous computing looks set to accompany us throughout our whole lives, day in and day out. And if the vision of 'invisible computing' actually materializes, we won't even notice any of the underlying technology. The vision of a completely networked future filled with smart everyday objects offers a whole range of fascinating possibilities. Microelectronic devices are becoming so small and inexpensive that they can soon be embedded in almost everything, rendering everyday objects "smart". These smart objects may communicate by wireless means and form spontaneous networks, giving rise to a world-wide distributed system several orders of magnitude larger than today's Internet. The prospects of a world of smart things that virtually talk to each other are fascinating, leading to many new applications and opportunities. Another fascinating possibility is that of virtually linking any sort of information to everyday objects, effectively attaching it to them.

2.4 Related work

Research related to the Quickies project falls into different categories, based upon the different approaches the projects take. I present an overview of the related work landscape first and then discuss some of the most relevant projects in detail later.

Several projects and products have tried to use the metaphor of sticky notes in the digital world. The **Post-it® Digital** [15] of 3M is a computer software program that provides users digital Post-it® Notes. Although Post-it® Digital features searchability, the scope is limited to the boundaries of a computer, isolated from the portable and convenient physical experience that paper sticky notes provide. There are more than a dozen similar software applications available today, all trying to imitate the simplicity and ease of use of physical sticky notes in the digital realm.

Stanford University's **Post-that Notes** [16] project attempts to facilitate both searchability and portability, by creating a mobile phone application which captures regular Post-it® notes as pictures within the mobile phone platform. Inspired by the use of sticky notes on whiteboards and walls during the early stages of a project, the **Designer's Outpost** [7] of the University of California, Berkeley presents a tangible user interface that combines the affordances of paper and a large physical workspace. The Designer's Outpost contains an interactive whiteboard with augmented sticky notes that allow users to collaboratively author website architectures. **Rasa** [10] is a system designed to support situation assessments in military command posts, providing officers the capability of positioning written sticky notes on a paper map with digitizers that simultaneously update a digital database system. **TeleNotes** [23] was one of the first attempts to provide, in the computer, the lightweight and informal conversational interactions that sticky notes provide. Projects such as **HayStack** [4] use sticky notes as a metaphor to provide annotation for the semantic web. Projects such as **TeamWorkStation** [5] and **XAX** [6] were one of the first attempts to integrate traditional paper media with electronic media. **PaperLink** [2] system allows marks made on paper to have

associations and meaning in an accompanying electronic world. **DigitalDesk** [12][21] uses augmented reality to provide an integrated experience of both paper and digital documents. Brief overviews of some of these projects are provided below.

Designer's Outpost

The Designer's Outpost [7] is a tangible user interface that combines the affordances of paper and large physical workspaces with the advantages of electronic media to support information design of web sites. The system is developed to support the practices used by designers during the early phases of information design. Designers will interact with the system by writing on physical Post-it® Notes, arranging them on the digital desk in related groups, and drawing links between them. The system tracks the Post-it® notes and captures links among Post-it® notes and groups. With this system, users collaboratively author website architectures on a touch-sensitive electronic whiteboard augmented with cameras that capture documents placed on the wall. The prototype was implemented as a Java application running



Figure 2.5. Designers' Outpost system.

on a rear-projected 72" diagonal touch-sensitive SMART² Board with a 1280x1024 LCD projector. The Designers' Outpost vision system uses two cameras to provide feedback and high resolution capture. A 640 × 480 pixel video camera mounted inside the whiteboard offers tracking of physical objects placed on the board. A high-resolution digital still camera captures the objects' contents, every few seconds. Users can link

² <http://www2.smarttech.com/st/en-US/Products/SMART+Boards/Rear+Projection/Default.htm>

notes by drawing a line with the electronic whiteboard stylus as well as add ink annotations to a design to convey design rationale. Electronic capture enables replacing physical documents with their electronic images. Users have the same capabilities when content is electronic as when it's physical, thereby retaining physical direct manipulation. Outpost is motivated by the design practice of arranging Post-it® Notes on a large surface such as a wall, table, or desk. Designers write information on Post-it® notes and stick them to the wall. They move the notes into spatially proximate groups representing categories of related information. Groups are labeled and further grouped into hierarchies. The structure of hierarchical groups becomes a baseline for the structure of the final web site. Outpost is a task-centered tangible interface for web site information design.

RASA



Figure 2.6. RASA system.

Rasa [10] is a tangible augmented reality environment that digitally enhances the existing paper-based command and control capability in a military command post. By observing and understanding the users' speech, pen, and touch-based multimodal language, Rasa computationally augments the physical objects on a command post map, linking these items to the digital representations of the same—for

example, linking a paper map to the world and Post-it® notes to military units. Rasa was designed to impact the current work practices of a military command post, in which users already augment objects, like Post-it® Notes, with symbology in order to denote real world objects on the terrain. Rasa understands that symbology, and users' accompanying multimodal (speech/gesture) input, enabling users to create digital representations of the entities with which

they are interacting without even knowing that a computer is involved. Rasa enables a military officer to use paper maps and Post-it notes in support of command and control tasks. During battle tracking, officers plot unit locations, activities, and other elements on a paper map by drawing unit symbols on Post-it notes, positioning them on the map, and then moving them in response to incoming reports of their new locations. With Rasa, each of the pieces of paper is mounted on a digitizing tablet—the map is registered to a large touch-sensitive SMARTboard³, and the Post-its initially rest upon a tablet that supports both digital and physical ink. The user writes a military unit symbol (for example, for an armored platoon) on a Post-it note. The user can also speak identifying information about that unit (for example, “First platoon, Charlie Company”) while drawing the symbol. The computer recognizes both the symbol and the utterance, fusing their meanings. Then, the user places the Post-it onto the paper map, which causes the unit drawn to be recorded in the system’s database, with its location specified by the place it was mounted on the map. The system projects a unit symbol onto the relevant location on the paper map, and distributes the result to collaborating systems. If a report arrives indicating the unit has moved the user needs to pick up the note and put it at the new location on the map. Whereas Rasa enables users to employ paper maps in performing their tasks, the maps still require large, relatively immobile digitizers.

Post-that Notes

Post-that Notes [16] are a digitization of paper notes that users can access through their mobile phones to search and browse. The digital notes are also appended into the mobile calendar to search by date. It uses a Java phone application to access the notes, which are sent to the server from the mobile device as well. Users can post their notes to the server by taking a

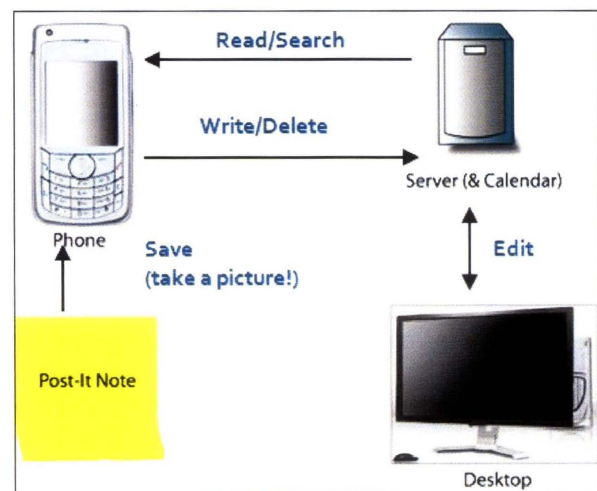


Figure 2.7. Post-That Notes system.

³ <http://www2.smarttech.com/st/en-US/Products/SMART+Boards/Front+Projection/Default.htm>

picture with the camera on their mobile phone and emailing it to a photo-blog server. This project was designed to address the issue of paper versus digital notes. Post-that Notes system does not recognize or interpret the text on the notes.

XAX

XAX [6] from XEROX PARC was one of the very early attempts to bridge the gap between the paper and electronic world by introducing a paper user interface technology. The system retrieves and processes the documents written or printed on a paper form and faxed to/from a server. The XAX system uses conventional office equipment in conjunction with pencil & paper. The XAX-Form is a piece of paper with machine readable marks on it. The marks are also human readable. The user can also make new marks on the XAX form. The

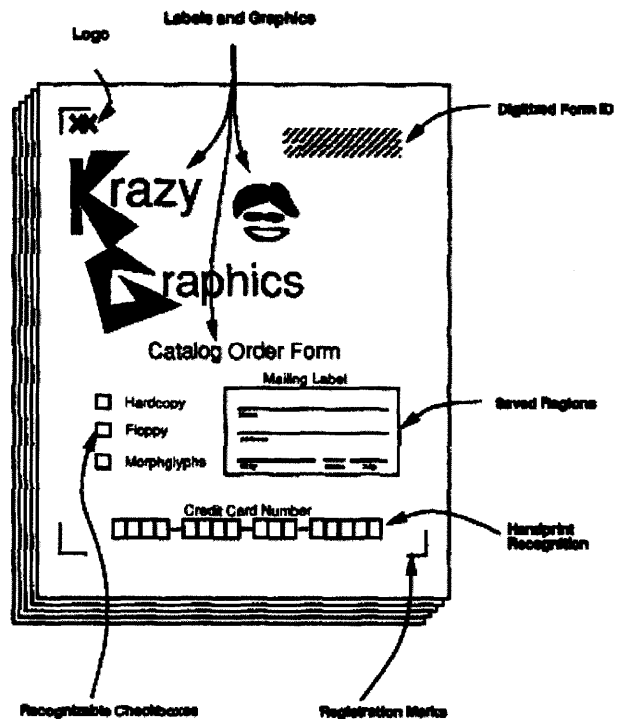


Figure 2.8. XAX Form.

XAX-Server interprets the documents arriving from a scanner or a fax. The server then looks for “glyph” information to determine identity, locates what actions need to be carried out, processes the image, clipped regions, and checkboxes. Later the information is passed along to appropriate storage. XAX attempted to move the user interface beyond the workstation and onto the paper itself.

DigitalDesk

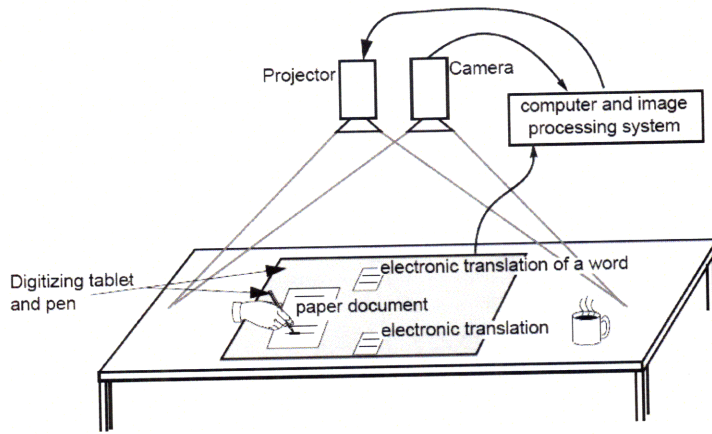


Figure 2.9. DigitalDesk system.

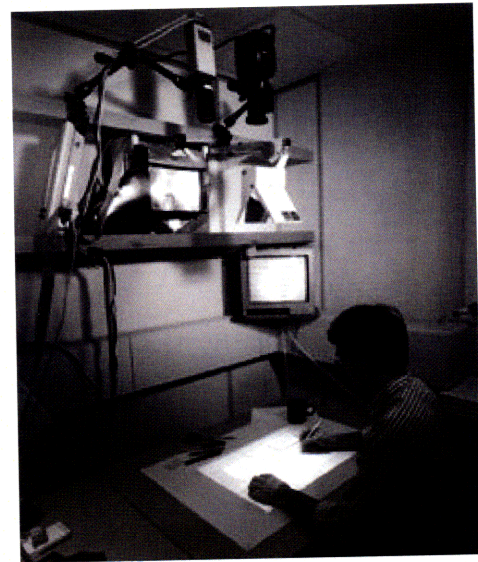


Figure 2.10. Prototype of DigitalDesk.

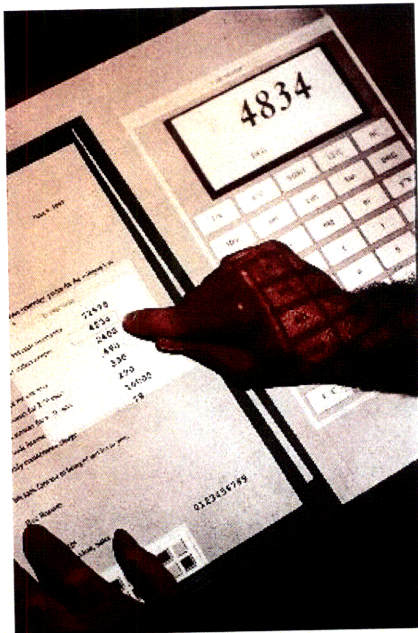


Figure 2.11. Calculator application on DigitalDesk.

The DigitalDesk [12][21] is built around an ordinary physical desk and can be used as such, but it has extra capabilities. A computer display is projected down onto a desk and video cameras pointed at the desk uses image-analysis techniques to sense what the user is doing. The system projects electronic images down onto the desk (onto paper documents), responds to pen-based interactions as well as finger gestures, and can digitize paper documents placed on the desktop. The DigitalDesk merges a physical desktop with paper documents and electronic documents. Using computer vision techniques, the system can also recognize command icons drawn on small pieces of paper. The command icons are more interesting as they are dedicated physical commands which can be spatially arranged and offer space-multiplexing input. Nevertheless, the DigitalDesk is a great example of how well we can merge physical and electronic artifacts, taking advantage of the strengths of both media. The idea of using cameras

and projectors together to form an interactive desk-top system was first proposed by Pierre Wellner [22]. He began his PhD work by considering the potential benefits of using video in the office environment. This quickly led to the conclusion that the desk-top was the most important focus of office work and that there was great potential for any system that eased the transition between paper and electronic information. The idea was tested in a project that used video scanning to translate selected foreign words from paper documents lying face-up on the desk.

Designer's Outpost [7] and **Rasa** [10] are designed for the specific needs of web developers and military officers, respectively, and as such are not generic systems. In addition, both **Designer's Outpost** and **Rasa** require heavy hardware infrastructure and are targeted towards usage of Post-it notes in collaborative environment. They do not address the use of sticky notes by individuals for the information management task. **TeleNotes** [23] and **HayStack** [4] only use the metaphor of features of physical sticky notes in our digital information world. **TeleNotes** attempts to provide the lightweight and informal conversational interactions that sticky notes provide. **HayStack** use sticky notes as a metaphor to provide annotation for the semantic web. **Post-it® Digital** [15] and **Post-that Notes** [16] attempt to bring the familiarity and features of sticky notes to digital world. Rather than linking the physical and digital, they are confined and limited to computers and mobile phones respectively and thus loses the affordance and intuitive interaction of physical paper sticky notes. **DigitalDesk** [12][21], **TeamWorkStation** [5] and **XAX** [6] are great inspiration for Quickies project in devising integrated experience of both paper and electronic media. **PaperLink** brings the concept of hyper-linking to physical world by allowing marks made on a paper to have associations and meaning in an accompanying electronic world. Although **PaperLink** links electronic world and paper, it is limited to hyper-linking. There remains a need for having an integrated system which combines the qualities and affordances of physical sticky notes – portability, adhesiveness, low-cost – with the positive attributes of digital notes – effective information management and organization, automatic reminders and compatibility with the rest of the digital world. Provided their usage can be made as intuitive and efficient as that of

regular stickies, the merger between physical and digital stickies can definitely be an added convenience to our fast-paced environment.

3. Design

“The world we have created is a product of our thinking. It cannot be changed without changing our thinking.” - Albert Einstein

I and My adviser Prof. Pattie Maes are frequent users of sticky notes. The project started with a simple question in an informal talk with my adviser, ‘what if sticky notes can be intelligent?’, ‘what if they can remind us about our meetings or be in sync with our digital information world’. I started with an exploration of why and how people use their physical and digital information media in their daily life.

3.1 The process

A formative design process was followed throughout the project. Amalgamation of various design concepts and processes contributed to the overall design process that followed. The basic process of Define - Design - Refine was without doubt at the core. The six step process followed throughout the project can be illustrated as shown in Figure 3.1.

A comprehensive user analysis helped me understand how people use sticky notes. In parallel, I also educated myself on the start-of-art of the field using different media such as books, published research papers and related projects and products. The ideation step followed with some early interaction prototypes. Ideation step was followed by the system (architecture) design and construction of the working prototype. Architect and Build steps are explained in chapter 5 – the Implementation. The Evaluation is the subject of chapter 6. Individual design steps are explained in detail in the following three sections – Usage of sticky notes, User analysis and Ideation.

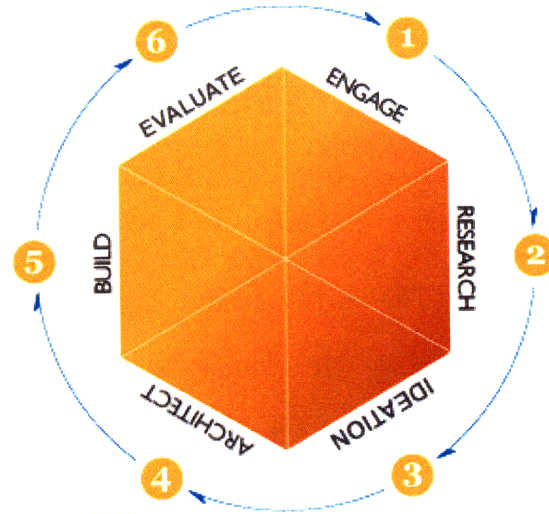


Figure 3.1 Research methodology

3.2 Usage of sticky notes

Small in size and light in weight, sticky notes have nonetheless proved their undeniable influence through their omnipresence in people’s everyday routine. The sticky notes have infiltrated in every corner of our offices and homes. I have found sticky notes in refrigerators for tagging food items and also found them in corporate offices on discussion boards. Surprisingly, I have found people using this quick medium for making artwork and for requesting their dorm-mates not to clean their shoes in basin. Sticky notes are quick memory. They are handy tags and for some they are their calendars, task-lists or address books. The various usages of sticky notes that I have found are illustrated in Figure 3.2.



Figure 3.2 Various usages of sticky notes

3.3 User needs analysis

By employing the notion of affordance discussed in the previous chapter, I began to concentrate on what a sticky note, as a physical artifact, makes possible for the people who use it and for the kind of work they do. The physical properties of sticky notes make many actions possible and many activities achievable that other physical or digital information media do not. I compared and contrasted these affordances of sticky notes with those of existing digital devices. In order to better understand and analyze how people use sticky notes and other physical and digital information media in their daily activities, a quantitative user study has been conducted. These equipped me to reason about what kinds of changes will be necessary before people will favor new technologies over their old tools and artifacts. More interestingly, it helped me to think about what kinds of devices or systems might be constructed that would make new kinds of activities possible or better support the kinds of work that people are trying to accomplish. This section describes the process of the study, the format and content of the survey questionnaire, and also reports on the results obtained from the respondents.

In order to reach more respondents of varied age, culture, countries, ethnographies and professional backgrounds, the user study was conducted using an online survey. The survey questionnaire was divided into four major parts, with each part corresponding to a particular focus. The first part gathers the respondents' background information, such as social role, age, gender, and common work location. The second part surveys the respondents' usage of sticky notes and affinity to other related physical tools such as paper and notebooks. In particular, the respondents are asked the frequency with which they use sticky notes, the main location where they obtain/use sticky notes, the purposes for which they use sticky notes, the surfaces where they usually stick these sticky notes, and what other non-digital media they use for similar purposes as they use sticky notes. The third part intends to find out the respondents' affinity to the digital tools. In particular, the respondents are asked to rank the frequencies with which they use different digital tools for daily information management. They are also asked the purposes for which they use different digital tools. In the last part of the survey, the

respondents are asked to compare the frequency of their usage of digital tools and that of physical tools for different purposes. In an attempt to bridge the physical world and the digital world in a more meaningful and practical way, the respondents are also asked what automatic processes or digital functions they wish to see happening following their usage of sticky notes. The survey was posted online, open to people from all aspects of the society and all countries in the world. People were also informed that their participation in this survey was absolutely voluntary and anonymous. Within two weeks, I gathered a satisfactory amount of meaningful responses among which I randomly selected 45 of them. In the following, I will show some of the results from the 45 responses, accompanied by a corresponding analysis. The complete Survey Questionnaire is provided in Appendix A.

Among the 45 selected respondents, 11 are students, 27 are professionals, 5 are business people, and 2 are housewives; 16 of them are between age 15 and 25, 29 are between age 25 and 45, and no respondent below age 15 or above age 45, which is probably due to less internet activity or less interest in online surveys about technology. In addition, 26 of the respondents are male, and 19 are female; 5 work mainly at home, 38 work mainly at school or in an office, and 2 divide their time evenly among these locations. In the second part of the survey where the usage of sticky notes is of concern, it was found that among the 45 respondents, 17 people use sticky notes every day, 14 people use sticky notes several times a week, 5 people use sticky notes several times a month, and 9 people use sticky notes rarely; additionally, 21 people use sticky notes at home and school/office, 20 people use sticky notes only at school/office, and 4 people use sticky notes only at home. According to the responses, people most frequently stick their sticky notes on surfaces such as computers, documents, books, walls, doors, and refrigerators. The responses also helped me identify the most common usages of sticky notes: to-do lists, reminders of a meeting or an appointment, contact information, messages/notes to another person, and labels/tags on objects and documents.

Besides using sticky notes, it appears that people also tend to use pocket-size diaries, notebooks, or simple, foldable plain paper for similar tasks. 16 of the 45 respondents have

mentioned that they have either seen or used digital sticky notes which are shown on a computer screen. At the same time, many of the respondents commented on their reasons of preferring the regular paper sticky notes, stating that sticky notes are important *“for capturing information that is temporary and is likely to be discarded in a short amount of time,”* that they like to *“use [sticky notes] to write phone numbers and keep them in their wallet,”* and that they *“use them extensively to leave messages for others, keep reminders for themselves, sometimes even just for fun. Making a list on a sticky is good so that I remember it, coz it can be stuck to any surface.”*

In the third part of the survey that focuses on the usage of digital tools, the majority of the 45 respondents indicated that using Emails for correspondence, making to-do list, setting meeting reminders, using contact book and messaging are among the top purposes for which computers and mobile phones are used in their everyday life. Thus, we can see a common pattern of usage between digital tools such as computers and mobile phones and physical tools such as sticky notes. However, when being asked to rank the frequencies of usage of computers, mobile phones, and sticky notes for the same tasks, almost all respondents ranked computers as their top choice, followed by mobile phones and lastly sticky notes and other tools. I believe this ranking preference is a result of lack of synchronization of the physical sticky notes with the digital tools, in a modern world infiltrated with digital information. My speculation can be further confirmed through the responses to the fourth part of the survey, where the respondents have described various processes they wish to see happening automatically following their usage of sticky notes. Some of the automatic processes include adding the note to a computer database, sending the sticky note message to intended recipients through digital media such as e-mail, and giving second time reminders from a digital source even after the sticky note has been discarded or lost. In short, the results in the last part of the survey indicate a strong wish for synchronization and connectivity between the familiar physical tools of information management and the popular digital tools - computers and mobile phones. The responses and suggestions from 45 respondents proved to be design considerations or important factors for the design of the functionalities of the Quickies.

One of the limitations of the methodology used for the user needs study is that the group of respondents was self-selected. Therefore, it was not entirely a representative group of users as all the respondents were users who use the internet. A second limitation is that the users were self-reporting about their habits, which is known to result in incorrect data: people's beliefs about their habits are different from their actual habits.

3.4 Ideation

Ideation is the process of forming and relating ideas by creating design sketches, designing user interaction, and generating various paper prototypes. Here I mainly concentrate on the user interaction and user experience part of the project. The studies of the usage of regular sticky notes helped me to identify some recurring cases of notes. Some of the most common cases of sticky notes I recognize are:

- To-do lists
- Reminders of a meeting or an appointment
- Contact information
- Messages/notes to another person
- Labels/tags on objects and documents

I have built a prototype system to recognize these various types of notes and decided based on the user analysis what the relevant actions are for the 'intelligent' quickies to take in those cases [11]. For example, in the case of a to-do list, the preferred action is to merge it with the computer-based to-do list; in the case of a note about an upcoming meeting, the preferred action is to add the appointment to the user's calendar and send a reminder 15 minutes beforehand; in the case of a note to another person, the preferred action is to look up that person's name in the address book and send him/her an SMS or email message with the same contents. The system should also allow the user to alter these default automated actions according to their preferences. The following chapters explain in detail what Quickies: intelligent sticky notes are and how they work. Sketches from the Quickies' ideation process are reproduced in Figure 3.2.

4. Applications and Features

This chapter, through user scenarios, discusses three major applications of the Quickies system followed by the complete list of features that the Quickies system supports. Quickies are sticky notes that offer portability, connectivity to the digital information world, smart information organization, ability to be findable (searchable as well as locatable) and ability to send reminders and messages. These are just examples, but Quickies can do a lot more. The following usage scenarios present some common problems or tasks that Quickies offers a better solution for than today's paper or electronic solutions.

- Imagine you scribbled a sticky note about an upcoming meeting with a colleague; you placed the note on your desktop. Unfortunately, you overlooked the note, completely forgetting about the meeting and went for lunch with a friend. Luckily, your intelligent sticky note added the meeting to your online

calendar system and reminds you about the meeting via a friendly text message on your mobile phone 15 minutes before the meeting.

- You write down a person's name and phone number on a sticky note while talking on the phone. That new contact information is automatically entered in your computer address book.
- You create a grocery list or to-do list on a paper sticky note. This list is automatically synchronized with the task-lists in your mobile phone and computer. Now, your mobile phone has a list of the things you noted down to buy, which comes in handy when you are at the grocery store.
- You use a sticky note to bookmark a section about the 'Platypus Paradox' in Peter Morville's 'Ambient Findability' book. Several weeks later, a discussion about the 'Platypus Paradox' arises and you remember bookmarking Morville's explanation. You can now use Quickies' graphical interface to search for the keywords 'Platypus Paradox'. As the system is keeping track of all your notes in digital form, it shows all the relevant notes you have created in past. The system also helps you locate that note (and hence the book) in the house.
- It is Saturday and you are at home. You forgot some important information that you noted down on a sticky note while in office on Friday. You ask the Quickies graphical interface to show the notes located at your office. Your computer screen shows you all the notes located at your office. There are many. You filter them by selecting 'notes created on Friday'. You get the particular sticky note and information you were looking for.
- You are in a hurry to get to a doctor's appointment. You ask Quickies system the address of 'Dr. Smith' by writing down on a sticky note (or a piece of paper) 'Address of Dr. Smith' followed by a '?' mark. In just a few seconds, a small printer prints out the address along with the driving directions to Dr. Smith's clinic.

- Your mom prefers using paper rather than mobile phones and computers. She leaves a message for you on a sticky note when leaving for the market. The note recognizes that this is a message to you; looks up your mobile number in the contact-list and sends you her message as an SMS.

All of these features and uses of the Quickies system can be categorized into three major application areas:

1. **Paper as an I/O interface**
2. **Tag & track**
3. **Brainstorming**

We discuss each of these in more detail below followed by the complete list of features that the Quickies system supports.

4.1 Paper as an I/O interface

Since its invention millennia ago, paper has served as one of our primary communication and information organization media. Despite of the enormous advantages of the digital information organization media and technologies, paper and its variants are still indispensable for us. Paper's inherent physical properties make it easy to use, transport, and store, and cheap to manufacture. On the other hand, digital media provide features such as sorting, searching and linking and connectivity to other digital media.

Writing a meeting reminder on sticky notes is intuitive and still preferred compared to setting up a reminder with mobile phone and computer based calendars. But, In spite of writing down, we still forget to look at those meeting reminders. Whereas, mobile phones and computer based digital calendars can provide timely reminders, at the appropriate time. Although both paper and digital information media coexist, there remains a need to connect these two in a more intuitive way such that we can use the affordance of paper media and still have advantages provided by the digital tools.

The system of Quickies allows paper to be used as an interface to the digital world of information. 'Quickies' enriches the experience of using sticky notes and bridges the gap between the physical and digital information worlds, linking hand-written sticky-notes to the mobile phone, digital calendars, task-lists, e-mail and instant messaging clients. By augmenting the familiar and ubiquitous physical sticky-note, 'Quickies' leverages existing patterns of behavior, merging paper-based sticky-note usage with the user's informational experience. As shown in Figure 4.1 (A), the user writes down a reminder for a meeting with a friend. 15 minutes before the meeting, at 2:15 PM she receives a message on her mobile phone reminding her about the meeting (see Figure 4.1 (B).) The Quickies system provides a sticky note interface to the user's digital information world. The user can use the familiar physical sticky notes to manage the user's information world. The Quickies system reminds the user at appropriate time or remembers things on behalf of the user. The system is also configurable according to the user's personal preferences so that the user can decide what she wants the system to do in

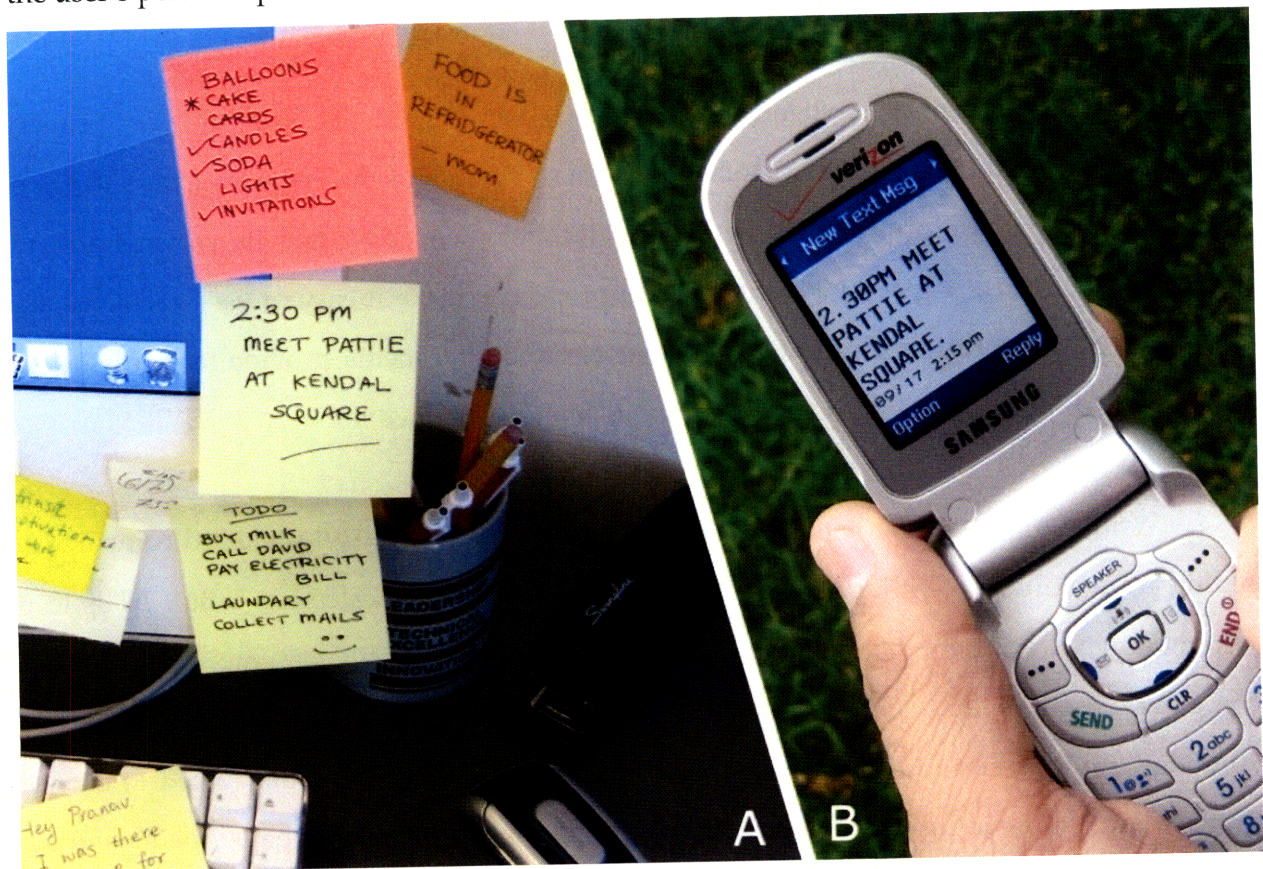


Figure 4.1. (A) Sticky notes at user's desk (B) Example of a reminder sent to a user's mobile phone.

particular situations. For example, if she has a habit of putting a star (“*”) in front of important notes, she can configure the system to interpret accordingly. She can also configure to receive email reminders instead of SMSs.

With Quickies system, sticky notes (or paper) can be used not only as an input but also an output medium. As shown in the Figure 4.2 (A) the user writes down a query “? The address of Dr. Smith” on a sticky note. As shown in the Figure 4.2(B) a small handheld printer prints out Dr. Smith’s address from the user’s address book in the computer. It also prints out the driving direction to Dr. Smith’s clinic from the current location.

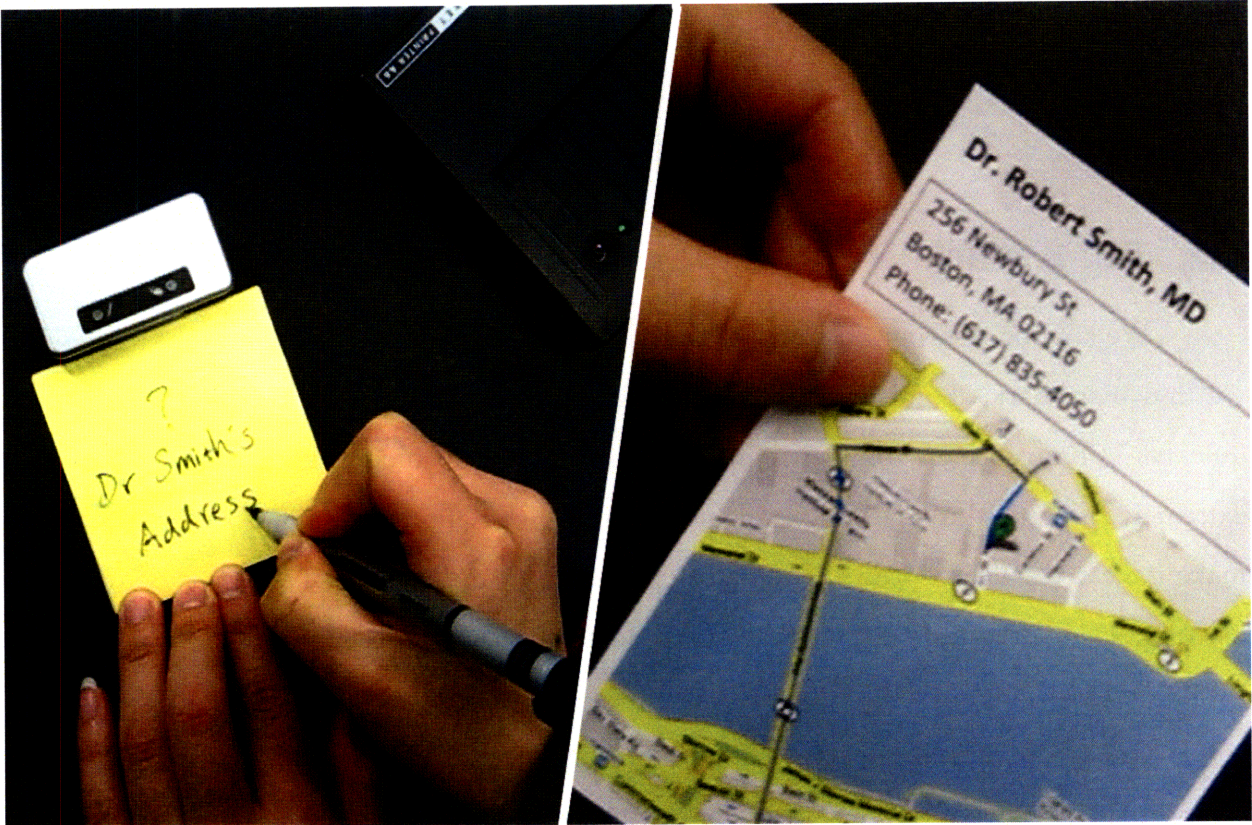


Figure 4.2. (A) User writes a query on a sticky note (B) A handheld printer prints out the requested address and driving directions.

The major features of Quickies system as 'Paper as an I/O interface' can be listed as below. Quickies system:

- Adds the meeting reminder written on a sticky note to user's digital calendar and also sends reminder via an SMS or Email, 15 minutes before the meeting.
- Adds or updates user's address book with the contact details written on a sticky note.
- Syncs to-do items written on sticky notes with user's digital task-lists.
- Sends user's message, written on a sticky note, to the intended person by finding out her mobile phone number or Email address.
- Prints out the required information from user's computer based address book, calendar, mailbox or task-list, when queried by writing on a sticky note.
- Provides a simple graphical interface to browse, search, and sort all of the created by the user.

4.2 Tag & track

We tag our assets or documents in order to remind ourselves the context of them when we find them back. Sometimes, the act of tagging also helps finding them back easily and quickly. In our office environments, filled with important documents and artifacts, it becomes extremely important to tag the documents or objects with appropriate information in order to make it clear what the document contains or what to do with that. Although tagging is very useful, tracking or locating the tagged items remains an unsolved issue.

One of the most interesting features Quickies provide is 'findability'. The user can use physical sticky notes to tag her assets or documents and later can locate that tag, hence the tagged object, at home or in the office using the Quickies graphical interface. At the back of each of the Quickies is a unique RFID tag, which makes it possible to locate Quickies in the house or office. As shown in Figure 4.2 'A' and 'B', the user uses a Quickie to tag the book given to her by a friend with that friend's first name. Some weeks later when the user wants to

return the book to her friend, she uses the Quickies graphical user interface (Figure 4.2 'C') to search through all the notes she has created. By searching for her friend's name she sees all the notes that mention her friend's name. She can see the digital version of the note saying "PATTIE'S BOOK", which she used to tag the book. As shown in the Figure 4.2 'D', the note has an RFID tag on the back that gets picked up by one of the many RFID readers positioned in the house so that the book can be located. The computer program also provides other information such as when the user created the note, and all the different locations where that RFID tag (and so forth the book) has been detected in the past.

Tracking the location of handwritten sticky notes enables many interesting scenarios. With Quickies system the user can not only find the location of a particular tag, but also query the system for multiple notes located at particular locations. For example, the user can ask for all the notes, of the type 'To-do list', located at his office desk, while he is at home. Sometime, if the user doesn't remember exact words on the note but by remembering the location, where he placed the note, he can still find the note and the content on it.

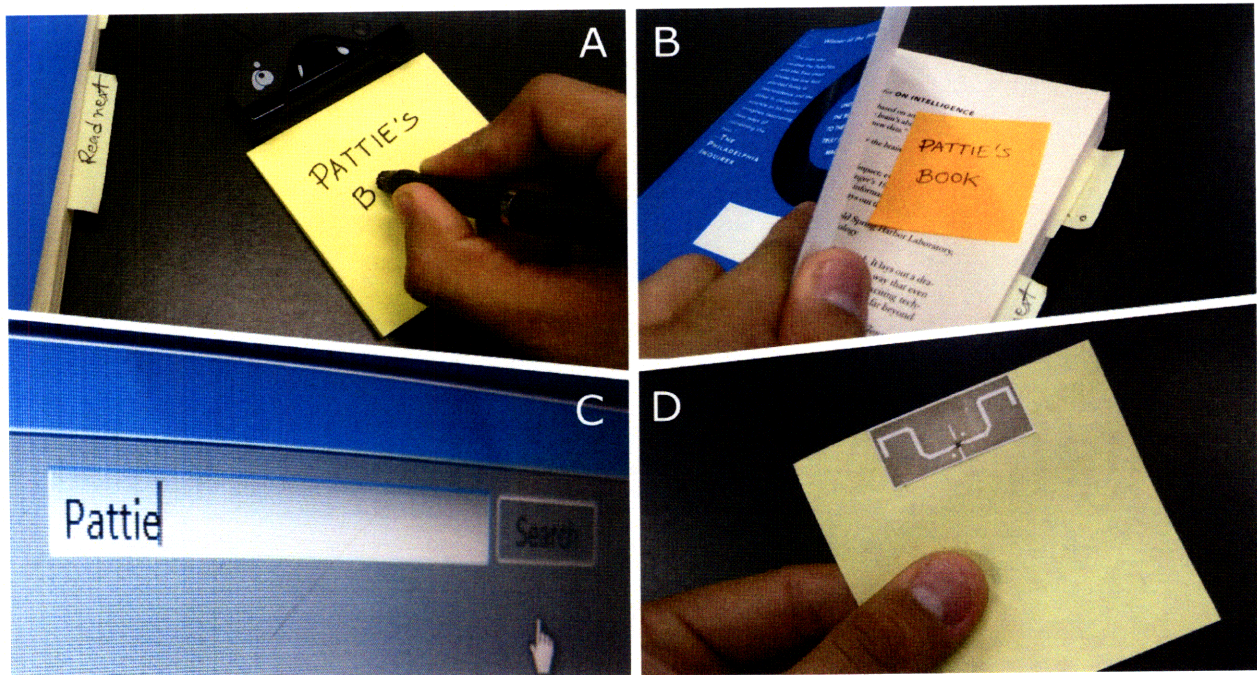


Figure 4.3. (A) User writes on a sticky note (B) User tags a book with the sticky note (C) User searches notes related to the word 'Pattie' (D) A sticky note with the RFID tag on back.

4.3 Brainstorming

Sticky notes have also proven its importance as a useful tool in the process of brainstorming in design studios as well as in the corporate world. The features of Quickies can definitely elevate the use of sticky notes as a brainstorming tool. The Quickies system captures the content written on each note; it can also automatically create a digital representation of the current state of the ideation/brainstorming. RFID based tracking or a computer vision system can be used to track the positions of individual sticky notes and thus can help determine the proximity and grouping. Quickies can also be helpful in remote multiuser brainstorming. The physical sticky notes and the virtual (digital representation) of the sticky notes of the remote place can be shown on the same surface using a projector or large size digital display screen. In this case, the physical sticky notes of one end will act as virtual sticky notes at another end. (Note: Because of the limited timeframe of this research work, this feature (Brainstorming) has only been ideated but not been implemented yet.)



Figure 4.4. (A) Brainstorming using physical sticky notes (B) Digital representation of the brainstorming.

4.4 Features of the Quickies system

This section discusses features and functionalities supported by the Quickies system. The Quickies system consists of a digitizer hardware (pad + pen) device, a software program and physical sticky notes. Optionally, the system can also include a handheld printer, RFID readers and RFID tags. These components and how they work together as a system are explained in detail in chapter 5 - Implementation.

The user uses the digitizer pad-pen hardware to write on the paper sticky notes. All the handwritten notes created by the user are captured and the digital representations of the notes are saved in the note database. The system also interprets the note content and categorizes the notes into one of many possible types of notes. At present, the Quickies system can categorize notes into following types: To-do list, Meeting reminder, Message, List of items, Contact, Payment, Query, and Tag. The Quickies system provides a highly visual interface to browse

these digital representations of the notes. The software interface can let the user sort, filter or search for one or more specific notes by keywords, date created, physical location of the note and type of the note. The system also performs a set of operations according to the type of the note. The note types and operations performed by the Quickies system after the recognition of the type of the note are explained below.

- **To-do list note:** A list of one or more to-do items is recognized as a “to-do list” note. The system identifies total number of to-do items from the handwritten note and separates them. Individual to-do items are added to the user’s digital task-list (for example, Tasks in Microsoft Outlook.)
- **Meeting reminder note:** A note with a time entity, a task or subject of meeting and/or a location is recognized as a “meeting reminder” note. The system is capable of extracting elements such as time of the meeting, place of the meeting, name entities and the subject/purpose of the meeting from the user text. The system also updates the user’s digital calendar (for example, Microsoft Outlook, Google Calendar) with the meeting at the particular time and place, if any, mentioned in the handwritten note.
- **Message note:** A note with a message directed to a person is considered as a “message” note. The system identifies who the message is directed to and also finds out his/her mobile phone number or email address from the user’s address book. The system also sends the message written on the note to the recipient via an SMS or an Email.
- **List of items note:** A note with list of items such as list of names of people, list of grocery items is recognized as a “list of items” note. The system adds the lists to user’s digital lists and lets the user retrieve them when needed.
- **Contact note:** A note with contact information such as a name and a mobile number and/or an email address is recognized as a “contact” note. The system extracts phone numbers, email addresses and street address from the contact information note and updates or adds the new contact in the user’s address book (for example, Contacts in Microsoft Outlook.)

- **Payment note:** A note with a pay request with a payee name and an amount is recognized as a “payment” note. The system identifies the payee name and the amount from the payment note. It is capable of processing and performing money transaction on the user’s approval, a signature of user. The system can also print out the physical check with the specified amount and payee name with the information written on the “payment” note.
- **Query note:** A note starting or ending with a question mark (‘?’ symbol) is recognized as a “query” note. The system is capable of processing user’s query on the user’s address book, calendar, mailbox or task-list. The system prints out the information requested using a handheld printer.
- **Tag note:** A note which cannot be recognized as any of the above types is considered by the Quickies system as a “tag”. The text written on the “tag” note can be searched or filtered with a specific word using the graphical interface. The quickies system also shows the location of the specific “tag” note that has an RFID tag on the back of it. In order to identify the location of the “tag”, the note must be augmented with an RFID tag as well as be within the proximity of at least one of the readers.

It is difficult to process some types of notes for the Quickies system. Composite notes and notes with multiple (but of similar type) information entries are such notes.

- **Composite notes:** Composite notes are the notes that can be categorized into more than one type or the sub-content of the note can be categorized as some type other than the type of the note. A to-do list that contains a to-do item that is a meeting reminder is an example of composite notes. At present, the Quickies system is not able to process such notes correctly.
- **Notes with multiple (but of similar type) information entries:** Note with more than one contact information or more than one meeting reminders falls into this type of notes. Although the system is able to process multiple to-do items on one note, it is not able to process notes with multiple contact information or multiple meeting reminders, at present.

Although the user needs to follow specific rules in order to make the handwritten notes to be processed by the Quickies system, the system can be customized according to the user's preference. The 'Settings' section of the Quickies software interface lets users customize the system's behaviors for each type of the notes. For example, the user can customize that he wants to receive reminders about a meeting 30 minutes before the meeting, not 15 minutes (default) before the meeting. The user can set that he would like the system to consider to-do items with a '✓' mark in front of them as 'important' items. Alternatively, the user can use the simple method of 'special marks' to customize the operations performed by the system for a single note. The user can place a specific symbol at the top right corner of the note as a command to the system stating what to do with the note. For example, when the user wants to send the message written on a sticky note to the recipient via an e-mail instead of an SMS, the user can place a '@' symbol at the top right corner of the message note. This will instruct the system that it needs to ignore the default behavior of sending the message as an SMS and send the message as an e-mail. Consequently, the system will search the recipient's e-mail address from the user's address book and sends the message on the handwritten note as an e-mail to the recipient. The user can place a 'X' symbol on the top right corner of the paper sticky note to instruct the system that the user does not want the system to perform any automatic actions for the particular note. Although, such symbology can be expanded to instruct the system according to the user's preferences, at present the system supports limited number of symbols that can be recognized as one of the special symbols supplied in a standard font.

5. Implementation

“Design is not just what it looks like and feels like. Design is how it works.” - Steve Jobs

This chapter explains how Quickies work and discusses the system design and implementation details of the project. The chapter provides an overview of major technical components involved. A brief description on individual key software and hardware components of the Quickies system is given in the end.

5.1 Overview

In this section, I will discuss the operation of the Quickies system using a concrete case scenario. A high-level overview of how, in the meeting reminder scenario (as explained in the Applications and Features chapter), a reminder of a meeting appointment was sent to the user’s mobile phone (see Figure 5.1) is shown in Figure 5.2. When at the desk, the user writes a meeting reminder on a physical sticky note. The information is simultaneously captured and

stored as a digital note in the computer. A digital-pen hardware device enables this capturing. A computer program processes the digital note, recognizes and converts the hand-written text into digital text and applies computational methods to understand the intended purpose and the content of the note. Since in the given scenario the note was about a meeting appointment, the computer program updates the user's calendar and also reminds him of the scheduled appointment at the appropriate time via a text-message on his mobile phone.

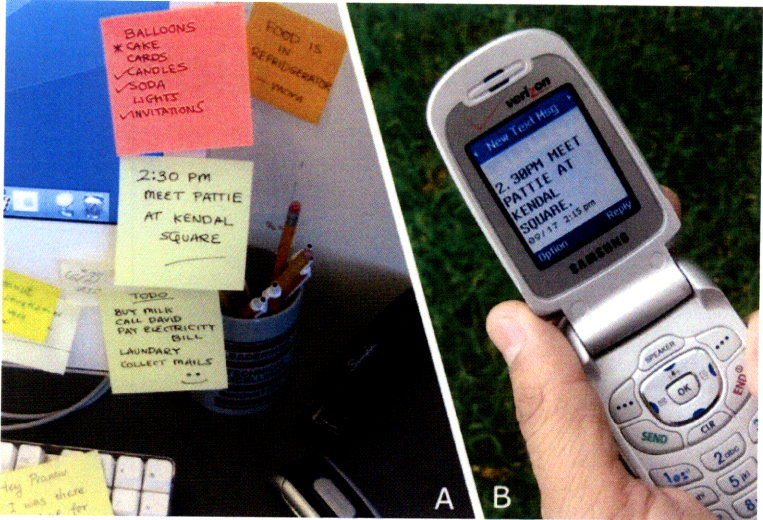


Figure 5.1. (A) Sticky notes at user's desk (B) Example of a reminder sent to the user's mobile phone.

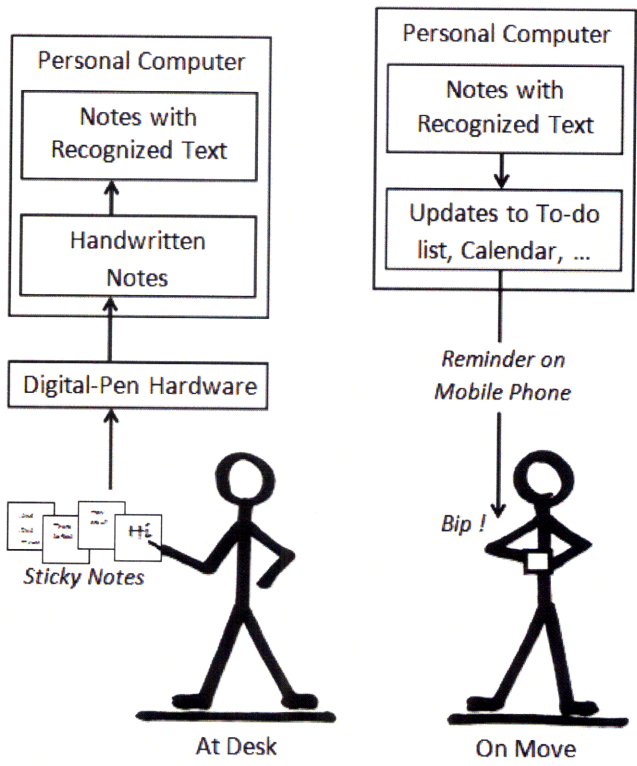


Figure 5.2. Overview of how Quickies work.

5.2 System design

Figure 5.3 presents a more detailed explanation of how Quickies work. Physical sticky notes are captured and stored in the computer using commercially available digital-pen hardware, which captures the movement of the pen on the surface of a sticky note. The digital-pen hardware used in the prototype uses an ultra-sound wave sensing mechanism. Two

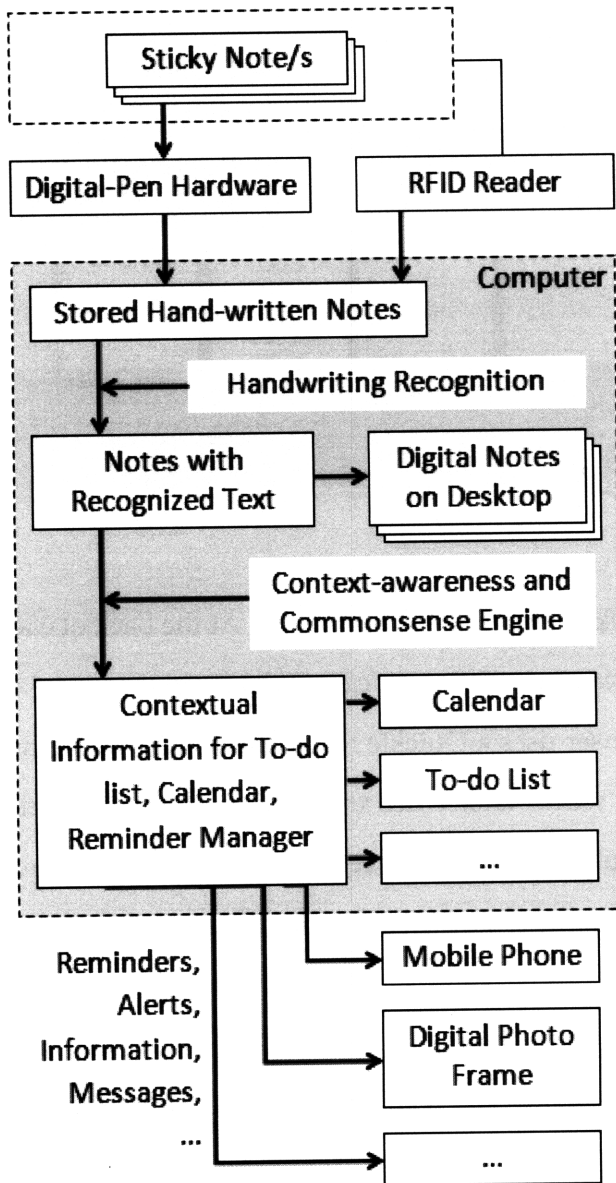


Figure 5.3. System design of 'Quickies'.

stationary sensors receive ultra-sound waves that are emitted by a transmitter placed at the tip of the pen. The device measures the location of the pen tip on the paper based on the calculation of receiving-time differences of the signals received by the two stationary receivers. A software program stores the handwritten notes as images/strokes and converts the stored hand-written notes into computer-understandable text using handwriting recognition algorithms.

As shown in Figure 5.4, the computer program also provides a highly visual user interface for browsing or searching all of the user's notes based on keywords. The user can also use the 'Advanced Search' feature for searching notes at created at particular time or located at a place in office. For example, the user can search for all the Quickies on the user's desk at work that contain the word 'Urgent'?

The recognized text is processed using a commonsense knowledge engine which is based on NLP and

ConceptNet [8]. This process provides the note database with contextually rich information. Later, the computer program uses its understanding of the user's intentions, content and the intended purpose of the notes to provide the user with reminders, alerts, messages and just-in-time information.

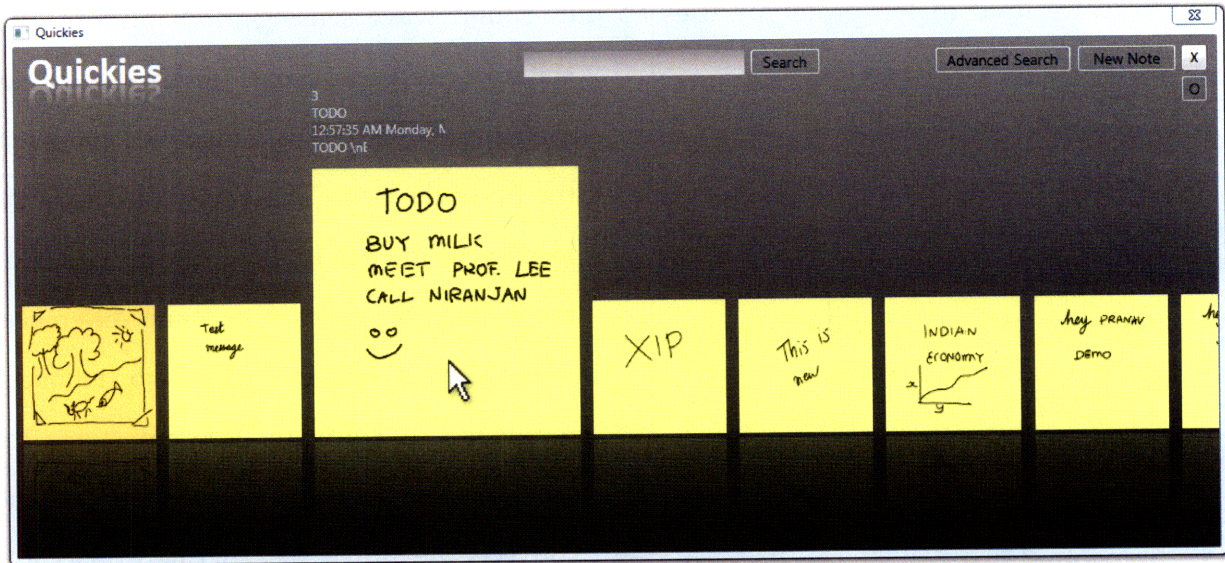


Figure 5.4. Graphical user interface of the 'Quickies'.

One of the most interesting features Quickies provide is 'findability'. At the back of each of the Quickies is a unique RFID tag, which makes it possible to locate Quickies in the house or office. As shown in Figure 5.5 'A' and 'B', the user uses a Quickie to tag the book given to her by a friend with that friend's first name. Some weeks later when the user wants to return the book to her friend, she uses the Quickies graphical user interface (Figure 5.5 'C') to search through all the notes she has created. By searching for her friend's name she sees all the notes that mention her friend's name. She can see the digital version of the note saying "PATTIE'S BOOK", which she used to tag the book. As shown in the Figure 5.5 'D', the note has an RFID tag on the back that gets picked up by one of the many RFID readers positioned in the house so that the book can be located. The computer program also provides other information such as when the user created the note, and all the different locations where that RFID tag (and as such the book) has been detected in the past.

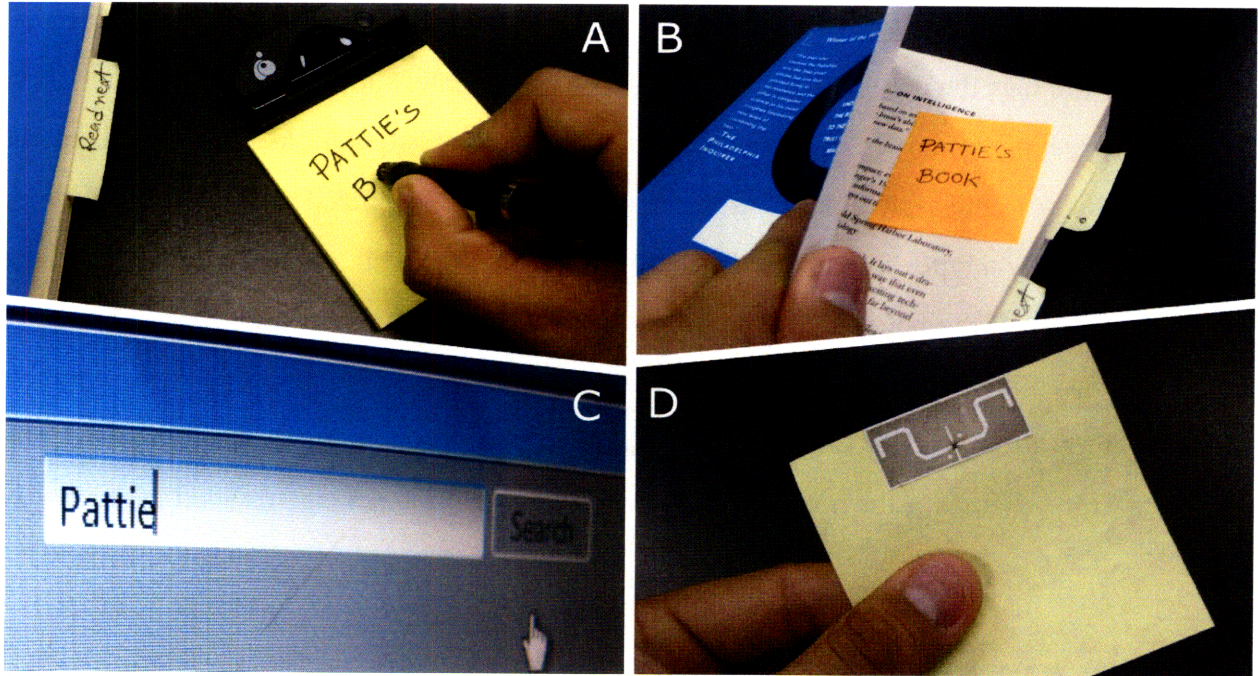


Figure 5.5. (A) User writes on a sticky note (B) User tags a book with the sticky note (C) User searches notes related to the word 'Pattie' (D) A sticky note with the RFID tag on back.

5.3 Construction

Following a thoughtful system architecture, a fully working prototype of 'Quickies' was implemented. Hand-written note capturing is performed by the Pegasus PC NoteTaker digital pen hardware. The ultrasonic sensing mechanism provides the system with X and Y coordinates of the pen tip ($X(t)$ and $Y(t)$). The spring mechanism at the tip of the pen picks up pen-up/pen-down switching. Detailed specifications of the NoteTaker hardware are provided in Appendix B. Time sampling of X and Y coordinates of pen tip ($X(t)$ and $Y(t)$) are captured in strokes. These strokes (also known as digital ink) are passed to the handwriting recognition engine. On-line handwriting recognition algorithms convert the pen strokes of text into digital text. The engine also analyses layout of the written text and primitive shapes, if any, on the sticky note. The output of the handwriting recognition engine with added information of layout and graphical shapes is passed to the interpretation engine that uses ConceptNet [8], Natural Language Processing (NLP) and some other computational methods in order to

support categorizing and understanding the intended purpose of the notes. This engine categorizes and tags the note with its type. The system currently supports following categories: to-do list, meeting reminder, message, list of items (not a list of tasks), contact, payment reminder, query to the system and tag. If the strokes are unrecognized or not text, such notes are represented by a type, 'unknown'. Each note is saved in an XML database. Along with the content and type of the note, for each note the system also captures extra information such as the note ID, creation date and time, author of the note, etc. The actual graphical representation of the note is also saved as an image file and also referenced in the XML database. The complete XML schema for the note database along with a sample note is provided in Appendix C.

According to the type of the note, the system also performs some extra actions. For instance, the system updates the user's digital calendar with the 'meeting reminder', by adding the entry for the event at the specified date and time. It can also remind the user about the meeting via an SMS or an Email. For notes of type 'message', the system looks up the contact information of the person that the message is written for in the address book and sends that person an SMS or an Email with the message. The to-do lists get synced with the user's digital task-lists and new contacts are updated in the user's address book, even though they are written on sticky notes. The system is also capable of processing simple queries on the user's address book, email clients or digital calendars. Notes of type 'query' are replied to with requested information on the computer screen or on a printout. A Brother MW-260 Portable Mobile Printer is used as an output medium for printing out answers to the user's queries in the prototype. Please find the detailed specification in Appendix E. The most important feature of the Quickies system is that the user can customize what he or she wants the system to do in different cases or in case of different types of notes. In order to make the Quickies trackable at home or in office, each sticky note contains a unique RFID tag on the back. Multiple RFID readers keep track of the availability of the individual RFID tags in their vicinity. UHF (902-928 MHz) RFID readers and EPC Gen 2 tags are used in the prototype system. This mechanism provides sticky notes unique IDs and links the IDs to content. Specifications of the RFID reader

and tags used in prototype are provided in Appendix D. The user can use the Quickies graphical interface to browse, search or filter particular notes he is interested in. The user can also find the location of a note and hence the object he has tagged with the note at home or in office. The RFID tracking mechanism enables this feature. The software program of Quickies system is built on Microsoft.NET platform using C# and C++. The graphical interface of Quickies is built using Windows Presentation Foundation (WPF). Primitive handwriting recognition is achieved using Microsoft.Ink. SharpNLP (a C# port of OpenNLP) is used for processing the text content of sticky notes. ConceptNet is used in conjunction with some computational methods to classify the notes into different types and understand the intended purpose of the note. There are many SDKs and APIs that are used in order to achieve such level of integration with user's digital information media such as mobile phone, digital calendars, task-lists, and email and messaging clients. Individual software and hardware components of the Quickies system are explained in the next section.

5.4 Software components

Handwriting Recognition and Ink Analysis

Handwriting recognition is the ability of a computer to receive and interpret intelligible handwritten input. The movements of the pen tip may be sensed in real-time using an ultrasonic digital pen. Alternatively, the image of the written text can also be sensed offline from a sticky note by optical scanning (optical character recognition). The handwriting recognition engine of Quickies principally entails character recognition. However, the system also handles formatting, performs correct segmentation into characters and finds the most plausible words. In addition to recognition of handwriting that allows for the conversion of digital Ink into standard text strings, the engine with its Ink analysis capability adds spatial interpretation to the mix to apply further semantics. Ink analysis helps to retrieve more information from Ink beyond its simple text representation. The system divides Ink into individual segments, such as words or paragraphs. It also captures the layout of the note based

upon the placements of the words on it. One example is that Quickies recognizes special instructional symbol written at the top right side of a sticky note and processes that as a special user instruction for that particular note. This sort of functionality requires the recognition of primitives, such as lines, circles, triangles, or rectangles, and recognition of the spatial relationship. Microsoft's handwriting recognition API, Microsoft.Ink, is used as primary handwriting recognition of Quickies. I extended the system with added algorithms to perform advanced recognition specific to the research. Some of the added features include recognition of primitive shapes and symbols, layout recognition and correction recognition.

ConceptNet

ConceptNet [8] is a large semantic network of commonsense knowledge suitable for making various kinds of practical inferences over text. It is a freely available commonsense knowledge base which supports many practical textual-reasoning tasks such as topic-gisting, analogy-making, and other context oriented inferences. ConceptNet captures a wide range of commonsense concepts and relations like those in Cyc⁴, while its simple semantic network structure provides it an ease-of-use comparable to WordNet⁵. The data in ConceptNet was collected from ordinary people who contributed it over the Web. ConceptNet represents this data in the form of a semantic network, and makes it available to be used in intelligent user interfaces. The basic nodes of ConceptNet are concepts, which are aspects of the world that people would talk about in natural language. Concepts correspond to selected constituents of the common-sense statements that users have entered; they can represent noun phrases, verb phrases, adjective phrases, or prepositional phrases. In the semantic network, concepts are the nodes and the edges are predicates, which express relationships between two concepts. Predicates are extracted from the natural language statements that contributors enter, and express types of relationships such as IsA, PartOf, LocationOf, and UsedFor. AnalogySpace [18] is a way of representing a knowledge base of common sense in a multidimensional vector

⁴ http://www.cyc.com/cyc/technology/whatis_cyc

⁵ <http://wordnet.princeton.edu/>

space. It uses dimensionality reduction to automatically discover large-scale patterns in the data collected by the common-sense knowledge resource ConceptNet. Please visit <http://conceptnet.media.mit.edu> and <http://analogyspace.media.mit.edu> for more information about ConceptNet and AnalogySpace.

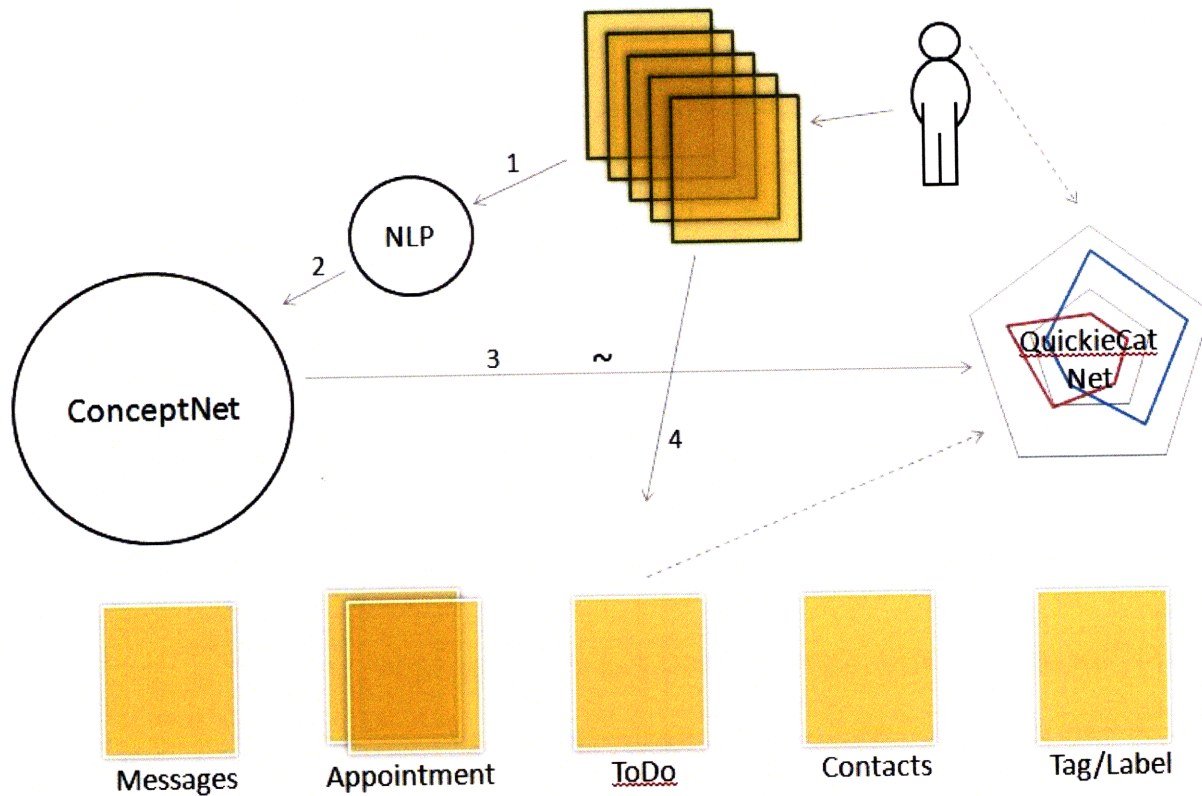


Figure 5.6. Use of ConceptNet to categorize different types of notes.

The Quickies system uses ConceptNet primarily for categorizing the Quickies into different types in order to process them on the basis of their types. Figure 5.6 provides an overview of how the handwritten notes are categorized. The handwritten notes are converted to digital text using handwriting recognition engine. This text is passed to the 'Quickies Categorizer' - a special purpose categorizer engine of Quickies that uses NLP and ConceptNet. First, the engine performs sentence detection and also tokenizes the sentences into phrases and words. In the next step, the parser provides a detailed grammatical structure of the text. This structure is used to determine which of the phrases or words should be passed to the ConceptNet. The system also provides a graphical tree structure of the parsed text. Later, the

selected phrases and words are passed to the ConceptNet and are compared to a special purpose database - QuickieCatNet. QuickieCatNet is a relatively small database of concepts that are relevant to and tagged with different note types. The engine uses the AnalogySpace [18] in order to compare a word using ConceptNet and QuickieCatNet. The result of this comparison is used in scoring the types of the note. Figure 5.7 shows a screenshot of the Quickies Categorizer application. The parsed text of the sample note is depicted by a graphical tree structure in the bottom left section, whereas the bottom right section shows the scoring of the note. (Note: The chosen example note shown in figure 5.7 is a composite note. It is a to-do list; but the first to-do item in the list is a meeting reminder. Although the Quickies Categorizer is able to process the note as a composite note on basis of the scores of the note, at present, the Quickies system is limited and does not process composite notes correctly.)

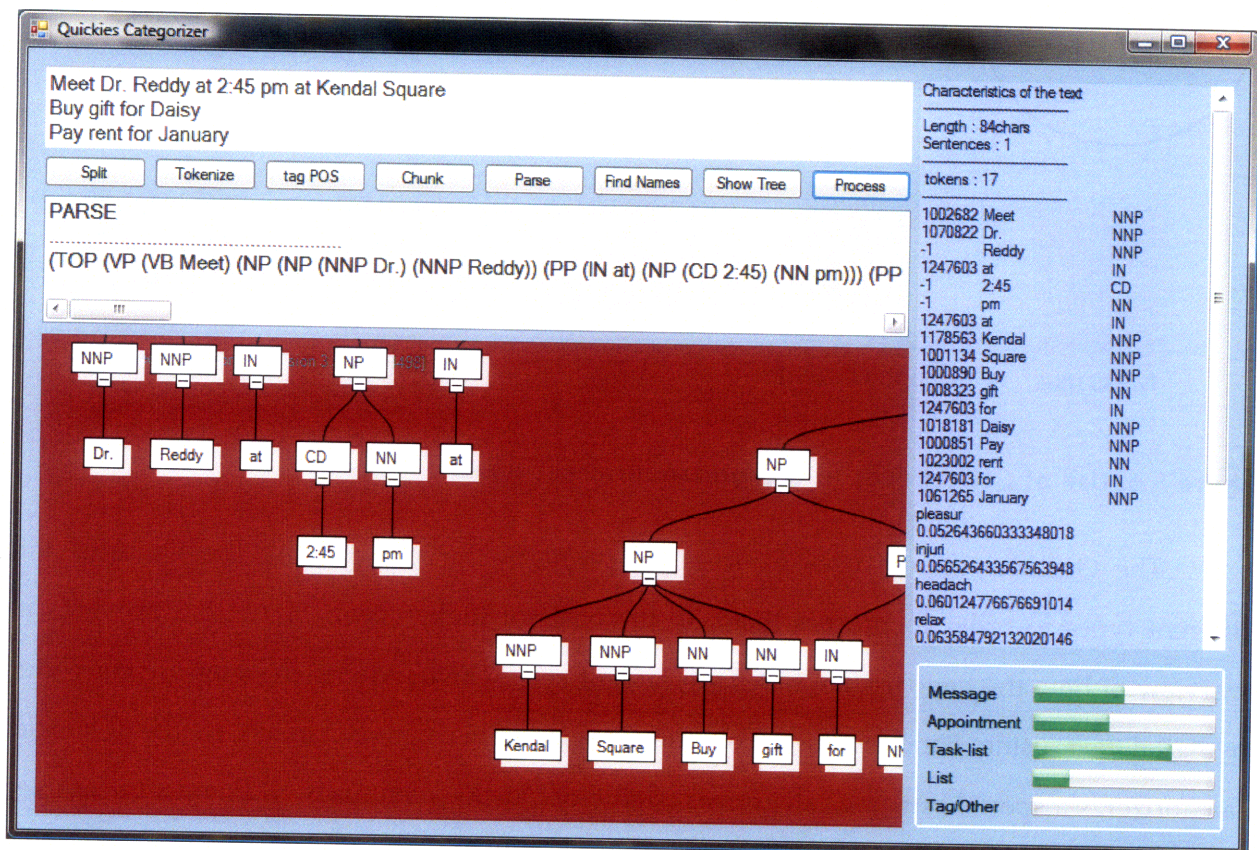


Figure 5.7. Quickies Categorizer - sample application showing how Quickies system processes text on sticky notes and categorize it using ConceptNet.

Natural Language Processing (NLP)

Natural Language Processing (NLP) is a subfield of Artificial Intelligence (AI) and computational linguistics. It studies the problems of automated generation and understanding of natural human languages. Natural-language-understanding systems convert samples of human language into more formal representations that are easier for computer programs to manipulate. OpenNLP is both the name of a group of open source projects (<http://opennlp.sourceforge.net>) related to Natural Language Processing (NLP), and the name of a library of NLP tools written in Java (<http://sourceforge.net/projects/opennlp>) by Jason Baldridge, Tom Morton, and Gann Bierner. SharpNLP is a C# port of the Java OpenNLP tools, plus additional code to facilitate natural language processing. SharpNLP provides the following NLP tools:

- a sentence splitter
- a tokenizer
- a part-of-speech tagger
- a chunker (used to “find non-recursive syntactic annotations such as noun phrase chunks”)
- a parser
- a name finder
- a coreference tool
- an interface to the WordNet lexical database

All of these tools are driven by maximum entropy models⁶ processed by the SharpEntropy⁷ library. Quickies system uses SharpNLP to parse the user’s written text on the sticky notes. Because of the maximum entropy models provided in SharpEntropy library, the system is also capable of finding names and time or location instances in the parsed text. Maximum entropy modeling is a general-purpose machine learning technique originally developed for statistical

⁶ http://en.wikipedia.org/wiki/Maximum_entropy

⁷ <http://www.codeproject.com/KB/cs/sharpentropy.aspx>

physics, but which has been employed in a wide variety of fields, including computer vision and natural language processing. It can be usefully applied whenever there is a complex process whose internals are unknown but which must be modeled by the computer. Like any statistical modeling technique, it relies on the existence of a data sample that shows, for given sets of input, what output the process generates. This sample is analyzed, and from it, a model is generated, encapsulating all the rules about the process that could be inferred from the sample. This model is then used to predict the output of the process, when supplied with sets of input not found in the sample data.

C#, WPF and Microsoft Visual Studio

C# is an object-oriented programming language developed by Microsoft as part of the .NET initiative and later approved as a standard by ECMA (ECMA-334) and ISO (ISO/IEC 23270). Anders Hejlsberg leads development of the C# language, which has a procedural, object-oriented syntax based on C++ and includes influences from aspects of several other programming languages (most notably Delphi and Java) with a particular emphasis on simplification. The major part of the software infrastructure of Quickies is built using C#.

The Windows Presentation Foundation (or WPF), formerly code-named Avalon, is a graphical subsystem in .NET Framework 3.0 and is directly related to XAML. It provides a consistent programming model for building applications and provides a clear separation between the UI and the business logic. A WPF application can be deployed on the desktop or hosted in a web browser. It also enables rich control, design, and development of the visual aspects of Windows programs. It aims to unify a host of application services: user interface, 2D and 3D drawing, fixed and adaptive documents, advanced typography, vector graphics, raster graphics, animation, data binding, audio and video. WPF is used to develop the highly interactive visual interface of the Quickies system.

Microsoft Visual Studio is an Integrated Development Environment (IDE) from Microsoft. It can be used to develop console and graphical user interface applications along with Windows Forms applications, web sites, web applications, and web services in both native code as well as managed code for all platforms supported by Microsoft Windows, Windows Mobile, .NET Framework, .NET Compact Framework and Microsoft Silverlight. The Quickies system is developed using Visual Studio 2005 and Visual Studio 2008.

5.5 Hardware components

Pegasus NoteTaker

The Pegasus NoteTaker is a digital note taking system that lets the user take notes on regular paper, using simple digital pen technology which is based on ultrasonic positioning mechanism. This technology utilizes ultrasonic transmission, from the tip of the pen, and measures the time duration since the pulse has left the pen until it reaches the receiver. Pegasus has two product lines in this category: PC NoteTaker and Mobile NoteTaker. As the name implies, the latter is a mobile version of the PC NoteTaker. The Quickies prototype works with both versions of NoteTaker. There are many similar products available in the market from other manufactures. The Quickies system is compatible with most of such digital pen hardware. Detailed specifications of Pegasus NoteTaker are provided in Appendix B.

Comparison of input mechanisms

In recent years, a new generation of pen devices, which can be used to capture data by directly writing on real paper, has been attracting increasing attention. With this approach, we can have the advantages of online recognition (segmentation of the data from the background, speed, storing space requirements, preservation of the temporal data) and at the same time preserve the features of paper (existence of physical copy, look and feel). Because users can see what they are writing on the paper, there is no need to have a computer constantly connected to

the device, which drastically increases portability. These digital-pen devices consist of two elements: a pen device and a positioning system. There are several types of these devices, each with its own set of advantages and disadvantages. From a design point of view, they can be broadly divided into two groups.

1. Patterned Paper

A typical patterned paper input device consists of a pen pointer equipped with a camera that reads a barely visible pattern on the paper to determine its position and obtain contextual information of the document such as document type and page number. The pattern is written in black carbon ink, while all the other elements of the document (figures, text) have to be written in another color. Thus, the idea that lies behind the patterned paper is to integrate the positioning system (the pattern) within the paper document. This has some advantages: it is portable, accurate and the paper can be moved freely while writing. However, the use of this pattern has several drawbacks. The pen cannot capture data from documents that do not have this pattern. Moreover, the document has to be in color and high resolution, so it cannot be copied using a standard copy machine. In addition to this, for each type of document the pattern has to be licensed. Consequently, the production cost is high unless a huge amount of copies of the same document is needed. That makes it a poor choice for small-scale applications, or applications that need to use a number of different documents (for example exams or exercises). Examples of this kind of input devices include Logitech io2 Digital Pen, LiveScribe, Fly. These devices use digital paper and pattern decoding technology developed and licensed by Anoto.

2. External sensor

In this approach, the guiding system is integrated in a device external to the pen pointer. This can be an ultrasonic device attached to the paper, a camera above the user, a laser device in the pen or any other device than can track the pen movements. Therefore, we can write on a normal, black and white document. Thus, the cost of an input-enabled document is the same as that of a normal paper. For this reason, this approach is far more flexible than the previous one, especially for applications that need many different document types which require only a small

production of copies, or for fast development applications. The problem is that most of these devices do not include a system to determine the orientation of the paper or detect the paper edges. At present, the Quickies system uses this kind of input mechanism (external ultrasonic sensing) that makes it easy to use any off-the-shelf sticky notes.

RFID readers and tags

The TagSense Micro-UHF RFID Reader is a small-profile, low-power, low-cost RFID reader with a USB interface suited for embedded applications, such as handheld readers, printers, laptops, or smart shelves. An external antenna can be connected via an SMA connector. Multiple TagSense Micro-UHF RFID Readers are used at North American UHF frequencies (902-928 MHz) in the prototype. EPC Gen 2 tags are used in the prototype system. The Quickies system uses RFID based tracking mechanism to find the location of specific sticky notes and subsequently the objects tagged with those notes. Please find detailed specifications of the TagSense Micro-UHF RFID Reader in Appendix D.

Brother MW-260 Portable Mobile Printer

The MW-260 printer is the newest addition to Brother's successful MPrint mobile printer product line. With 300 dpi printing on A6 size notepaper and carbon copy paper, the MW-260 printer provides professional-looking output and is mainly used for printing sales receipts, customer invoices, price quotes, etc. In the Quickies system a Brother MW-260 Portable Mobile Printer is used as an output medium for printing out answers to the user's queries in the Quickies prototype. However, any printer can be used in place of MW-260; Quickies uses it because of its portability and Bluetooth based wireless connectivity. Please find the detailed specifications of MW-260 in Appendix E.

6. Evaluation

The development of the Quickies system began with a meticulous but formative design process followed by the actual technical implementation and later, iterations of refine and redesign cycles based upon user feedback. During the first phase of the development, i.e. the design phase, the users' current practices and desires were given foremost consideration, since, according to Donald Norman, a user-centered system design approach "stresses the need to fully explore the needs and desires of the users and the intended users of the product" (Norman, 1986, *User-Centered System Design: New Perspectives on Human-Computer Interaction*). As such, a planned schema for the design criteria had been carefully laid out. Information such as users' background, expertise, and current work practices of information management was gathered as the basis for the design process. The user needs analysis phase was discussed in detail in chapter 3 – Design. After the second phase - the implementation of the Quickies system was completed, a second round of user study - evaluation - was performed in order to test the usability of the Quickies system and identify areas of change and improvement. This

section discusses that evaluation process, the experiment and results of the user evaluation. The evaluation process was performed through direct contact with the users. The interaction between every user and the Quickies system was carefully watched and recorded. Detailed information on each of the evaluation steps and some of the empirical responses are provided in this section.

6.1 Experimental Method

The evaluation process involved 24 users in total, among whom 17 were males and 7 were females. In addition, 14 of the users were the type of people who use both digital and non-digital means equally for their daily information management and communication tasks. However, due to the disconnection between their physical tools and digital tools, these users have to constantly switch back and forth between the two disjoint worlds. They are still attached to physical tools because of the familiarity and intuitiveness ingrained in the usage of these tools. The remaining 10 users who participated in the evaluation process were the type of people who primarily use non-digital means for their daily information and communication tasks. They frequently use physical tools such as paper and pencils for making to-do list, leaving a message, or creating grocery list. Although most of these users had never used a computer before, they use mobile phones only for communicating with their friends and relatives. They expressed interest in the advantages that digital media provide. However, because of either technical difficulties or language barrier, or other similar problems, these users have been largely restrained within the boundary of traditional physical media for information management.

Upon taking consideration of the background of all participating users, I decided to discard a generic questionnaire evaluation format and to execute the entire evaluation process in four steps. First, each round of evaluation began with an informal interview through which I understood the particular user's usage of sticky notes and his or her familiarity with different types of digital media, hence the level of technical skills. Second, the user was provided

explanations of the Quickies system, such as what it does and how it works, in order to achieve a basic understanding of the system and how to use the system. Next, the user started interacting with the Quickies system while I was observing and recording the progression details. The process always took place at either the user's home or office, in order to cultivate natural interactions. The time duration of the evaluation process with each and every user ranged from two hours up to two days, during which period the user was asked to perform four or five predetermined tasks, such as making a to-do list, messaging a friend, adding a contact to digital contact book, and obtaining physical address of someone through queries to the Quickies system; following the predetermined tasks, the user was left to explore the system himself or herself if other aspects were of any interest. In the fourth and last step of the evaluation, I interviewed each and every user again for feedback on the experience of using Quickies system. I asked the users of any confusion or difficulty encountered suggestions of improvement on the existing elements, and new ideas of other possible usages or features.

6.2 Results

It proved to be a thrilling experience of field study to me. All the users seemed fascinated by the unique technology medium that facilitated them to accomplish many digital processes without using mouse and keyboard, or even learning their usage. Their strong curiosity and deep interest could be easily detected through many questions the users asked me about Quickies. Frequently they asked me about the cost and availability of the product such as where they could buy it and how they could buy it. A couple of them asked me if they could keep the experimental product, as they wished to continue using it. One male user who has been using a personal laptop yet still prefers writing by hand became so involved in experimenting with Quickies that, after finishing the predetermined tasks given by me, he took the opportunity of the two-day limit to populate his digital address book with Quickies. While all users were happy to complete the predetermined tasks such as to-do list, messaging, adding contact to digital contact book, and giving queries to Quickies, a number of them were interested in keeping the system for more time for independent exploration. In the particular

case of messaging, different users have shown different preferences. The users who are used to both digital and physical tools seemed to be equally interested in sending messages through Email on a computer and through SMS on phone. However, most of the users who have lived in a purely physical world seemed to prefer SMS to Email. This is probably due to the wider availability and usages of phone over that of computer, given the technological advance and economic conditions of different societies. This second group of users also expressed relief upon seeing a product like Quickies, which enabled them to write on paper instead of pressing keys, as they complained about troubles with sending SMS through phone in the past. The customization feature of Quickies received warm embraces from all the users who were happy to know that they could set the method of sending messages (Email or SMS), the amount of time before which they wanted to receive meeting reminders, and the number of times they wished to receive reminder about a particular event. The users also found it easy and intuitive to use Quickies' graphic interface for browsing all the sticky notes and for searching particular notes created.

The interactions between the users and Quickies system all proceeded in English in this evaluation. Currently Quickies can support five languages: English, Japanese, Chinese, French, and Spanish. Many of the users mentioned that they wished to write in their native or local languages such as Hindi and Gujarati on sticky notes, should they use Quickies in the future. A few users pointed out that sometimes they forgot to attach the digitizer when writing on sticky notes, and consequently they had to rewrite the note. They were wondering if it would be possible to eliminate the necessity of always attaching a digitizer to the sticky notes when using Quickies. In one case, the system was not able to perform handwriting recognition. Even though the user had the digitizer attached to the sticky note, none of the user's strokes was captured by the digitizer. In search for the reason of the problem, I found out that the batteries in the digital pen were all discharged, which was the cause for this failure.

The total number of notes made by the all the users was around 250. It was noticed that the users were writing more neatly than usual during interaction with Quickies, comparing

with the sticky notes seen on their desk. Still, in three cases of making a sticky note, the system failed to correctly convert the handwriting to digital version. And in six cases of making a sticky note, the system was unable to categorize the type of the note. These notes were given the type 'tag' by the system. There were eight cases where the system miscategorized the type of the notes. Most of these failure cases were due to ambiguity between 'to-do list' and 'list of items', and 'to-do list' and 'meeting reminders'. In a particular case where a user put down "Meet my cousin at 5PM" among his to-do list, the system seemed unable to decide whether to add this line of note to digital to-do list or to the user's calendar.

6.3 Limitations and Improvements

The qualitative user evaluation helped me understand some of the current limitations of the Quickies system. User feedback and observations also suggested what improvements should be made; and what are functionalities should be added or deleted.

The list of current limitations of the Quickies system includes:

- No feedback to the user on how the system interpreted what the user wrote, whether the system was able to do character recognition on the handwritten note and whether the system got the user's intention right.
- No feedback to the user on which steps the system has taken for a note or whether the system failed in any of the cases in taking the steps.
- Miscategorization of the composite notes – notes that can be categorized into more than one type or the sub-content of the note can be categorized as some type other than the type of the note.
- Need of digitizers to be attached when the user is writing on the note.
- Need of the specific kind of digital pen
- Requirement of battery for the digital pen.
- Inability in capturing the modifications and annotations made on the note, after the note has been detached from the digitizer pad.

The understanding of the current limitations suggested improvements and provided direction for the next steps in the project. It seems that the most important improvement to be made to the Quickies system is 'feedback to the user'. This feedback should confirm to the user not only that it has been able to perform the handwriting recognition, but also in what type the system has categorized the note, what actions have been taken after that, and whether the system has failed in taking those actions. This feedback can be provided by the digitizer pad, the digital pen or the individual sticky note. The feedback can be visual or sound. For example, an LED array or a tiny LCD display panel embedded in the digitizer pad or the digital pen could display the type of the note or alert the user of any failure in interpreting or processing the note. Alternatively, the sticky note itself can be augmented by the digitizer through printing the type of the note in textual or symbolic form on the sticky note.

In conclusion, this evaluation process and the results have confirmed to me that the ground-up, formative design approach has helped making Quickies a successful system. The fascination and interest the users have shown in Quickies indicate encouraging acceptance and approval of Quickies. At the same time, any difficulty they had with using the system and the ideas of new features they suggested will inevitably be the basis for improvements to Quickies in the near future.

7. Conclusions and Future Work

In this thesis, I have presented 'Quickies: Intelligent Sticky Notes', an attempt to bridge the gap between our physical and digital information worlds by bringing one of the most useful inventions of the 20th century, Post-it® Notes, into the digital age. It is a project that, through combining Artificial Intelligence, Natural Language Processing, RFID, and Ink recognition technologies, leverages the existing patterns of behavior of the usages of paper sticky notes. 'Quickies' enriches the experience of using sticky notes by linking hand-written sticky-notes to the mobile phone, digital calendars, task-lists, e-mail and instant messaging clients and thus augments the traditional affordances of the familiar and ubiquitous sticky notes.

Quickies are intelligent sticky notes that can be searched, located, and can send reminders and messages. As a user writes on a physical sticky note, the information is simultaneously captured and stored as a digital note on a computer, and automatically categorized according to the content of the note. In the specific case where a note is written

about an appointment, the Quickies system updates the user's digital calendar and also reminds him of the scheduled appointment via an SMS on his mobile phone. In case of a note with contact information, the system will add the new contact entry in user's address book. A to-do list gets synced with the digital task list and the message on the note gets sent using an SMS or an Email. As a memory keeper, the Quickies application not only allows the user to browse his notes, but also lets the user search for specific information through keywords. The Quickies system can understand the content and intended purpose of the note, in order to provide the user with just-in-time information. Additionally, each Quickies note carries a unique RFID tag, so that it can be easily located in the house or office sprinkled with inexpensive RFID readers. Therefore, the user can be sure never to lose a document or any other object marked with a Quickies note. Upon synchronizing with and connecting to the popular digital devices for information management, such as personal computers and mobile phones, the simple paper sticky notes are no longer alienated by tech gurus into an obsolete asylum and can once again demonstrate their indispensable practical usages in people's everyday life. At the same time, the intelligent paper sticky notes can prove to be a much more prevalent and intuitive user interface for people around the world, the majority of whom have found it frustrating struggling to enter a strange digital world dominated by mouse and keyboard.

Indeed, the future work on this project will focus on augmenting the traditional affordances of other forms of paper, after one of its variants, sticky notes, have proved to be a successful case. Empirical user studies have indicated that besides sticky notes, people also like using pocket-size notebooks and simple, plain foldable paper for tasks listed previously on sticky notes. With the increasing maturity of hand-writing recognition and other necessary technologies, one compelling possibility resides in enabling people to write information or reminders on any type of paper they usually carry around with them and receiving that information back whenever and wherever they wish. For instance, one will not have to visit a drop-box to drop or visit a post-office to mail a payment check. Instead, while the user is noting down the amount to pay and signing his checkbook, the information will be automatically captured and the user's bank account will perform the transaction using the electronic

verification. Parents and grandparents who like writing mails on beautiful letter paper with fountain pens can well be practicing their calligraphy skills, while the content of the mail is automatically sent to their kids who make exclusive use of e-mail and online messaging.

The design and implementation of systems that combine both the utilities of the digital world as well as intrinsic affordances of traditional artifacts still remain challenging. In the Quickies project, I have followed a ground-up approach, closely observing people's natural usages of sticky notes and studying the affordances of sticky notes, then identifying and narrowing down the list of needs and potential opportunities for improvement through empirical user studies, and lastly bridging the gap at where it is needed with appropriate modern technologies. With this design approach, I believe, not only can the people be more at ease with using technology tools, but also can the affordances of everyday objects be dramatically augmented.

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Appendix

- A. Survey questionnaire
- B. Pegasus NoteTaker
- C. Sample note entry in XML database
- D. Tagsense microUHF RFID Reader
- E. Brother MW-260 Portable Mobile Printer
- F. Publications and Media Coverage

A. Survey questionnaire

Tell me a little bit about you.

1. What describes you best?

- Student
 - Business person
 - Professional
 - Other, Please specify.
-

2. What is your age?

- 0 to 15
 - 15 to 25
 - 25 to 45
 - 45 to 60
 - above 60
-

3. You are

- Male
 - Female
-

4. You mainly work at

- Office/School
 - Home
-

Do you use sticky(aka. Post-It) notes?

5. Do you use or have you ever used sticky notes (Post-it notes)?

- Yes
 - No
-

6. How often do you use sticky notes?

- Every day
 - Several times a week
 - Several times a month
 - Rarely
-

7. Where do you usually use sticky notes?

- Home
 - Office/School
 - Other Locations, please specify
-

8. For what purposes do you usually use sticky notes?

- To-do list
- List of items(such as grocery list)
- Contact information (such as phone number or email)
- Meeting /appointment reminder
- Tag or label
- Message for someone
- Scribbling or doodling
- Brainstorming
- Others, please specify

9. To which surfaces do you attach your sticky notes?

- Walls
 - Doors
 - Computers
 - Documents
 - Books
 - Personal diary
 - White boards
 - Refrigerator
 - Food items
 - Others, please specify
-

10. What are some other non-digital media you have used for purposes that sticky notes are mainly used for?

11. Have you ever used digital/software sticky notes which are shown in a computer screen/monitor?

- Yes
 - No
 - I am not sure
-

12. Please describe the use of sticky notes in your daily life. Please also elaborate any other uses of sticky notes which are not mentioned above.

Digital tools

13. For what information management purposes do you usually use a computer?

- To-do list
 - List of items(such as grocery list)
 - Contacts
 - Meeting /appointment reminder
 - Messaging (Email, IM)
 - Others, please specify
-

14. For what information management purposes do you usually use a mobile phone?

- To-do list
 - List of items(such as grocery list)
 - Contacts
 - Meeting /appointment reminder
 - Messaging (SMS)
 - Others, please specify
-

15. Please select the information management tools you use mostly.

- Computer

- Mobile Phone
- Sticky Notes
- Personal Diary
- Others, please specify

16. Please describe the use of digital tools (such as computer, mobile phone) for managing information in your daily life.

Last page.

17. Please select the medium you use for the following tasks. Consider sticky notes, paper, personal diary, etc. as 'Physical' and computer, mobile phone, etc. as 'Digital'.

- None ▾ To-Do List
- None ▾ Contacts
- None ▾ Meeting /Appointment Reminder
- None ▾ Messaging
- None ▾ Brainstorming
- None ▾ Note Taking

18. Imagine that you have an assistant or secretary who helps you with your daily information management tasks. What would you like the assistant to do for you in the cases below? For example, in the case where you had written down an appointment on a piece of paper, you might want to receive a reminder of that appointment 15 minutes before the meeting from the assistant. This is just an example. I would like to know your preferences.

You write a To-do list. (e.g. Pay electricity bill, Email someone about your project, ...)

You write down contact information (phone and email of someone) while talking on phone.

You make a list of grocery items you need to buy.

You put a note on your desk for an upcoming meeting/appointment.

Someone left a message for you on a piece of paper or a sticky note when you were away.

You use your whiteboard and sticky notes for brainstorming about a project.

You use sticky note to tag or label some interesting portion of a book.

B. Pegasus NoteTaker

The Pegasus NoteTaker is a unique tracking device that captures user-handwritten notes and sketches. These notes can be taken on any paper size up to A4 or Letter and can be later edited on-screen. They can then be stored for future reference, transferred by email or local network and inserted into other documents. You can also set reminders so that they pop-up on any designated day or time. The Pegasus NoteTaker comes in either USB or standard Serial Port versions that are both easy to install and have identical functionality. With simple-to-use software and compact hardware, the Pegasus NoteTaker is an ideal solution for those who prefer to jot down notes by hand or send rough sketches without the need to use a keyboard.



Features and benefits

- Capture of handwriting from any plain paper or other writing surface
- Input of continuous writing up to A4 page size
- Insert sketches, signatures, equations, and notes into Word® documents
- E-mail sketches or handwritten notes in any language using MS OUTLOOK
- Convert handwriting to digital text using MS word recognition engine
- Annotate, add comments, edit and draw in your own handwriting onto MS office documents
- Create instant messaging using ICQ

Specifications

Coverage area: up to A4

Resolution: 100DPI

Communication: USB

Power (pen): 3X SR41 batteries

Certifications: meets CE and FCC radiation standards

Dimensions and weights:

Pen: L-136 mm, D-13.7 mm, 16 gr.

Base: 100X 47 X 27 mm, 60 gr.

C. Sample note entry in XML database

```
<?xml version="1.0" encoding="UTF-8" ?>
<notes>
<note>
...
</note>

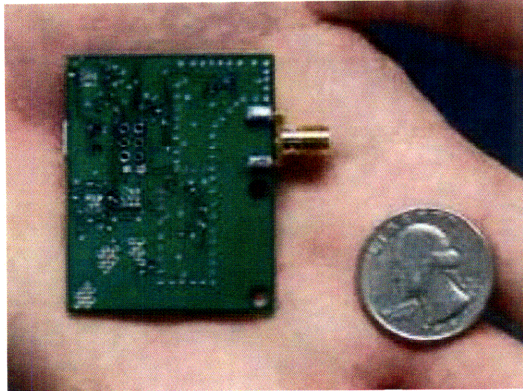
...

<note>
  <id>2136</id>
  <rfid>1003</rfid>
  <image>Projects\quickies\bin\Debug\2136.bmp</image>
  <author>Pranav</author>
  <saved_time>12:57:35 PM Monday, May 05, 2008</saved_time>
  <usertext>    Buy milk
                \n Meet Prof. Lee
                \n Call Mr. Johnson
                \n Pay MIT housing bill (*)
  </usertext>
  <type>TODO</type>
  <location>Office desk</location>
  <field_A>4</field_A>
  <field_B>Important - Pay MIT Housing bill</field_B>
  <field_C>Synced</field_C>
</note>

...

<note>
...
</note>
</notes>
```

D. Tagsense microUHF RFID Reader



The Micro-UHF reader is a small profile, low power, low-cost RFID reader with a USB interface suited for embedded applications, such as handheld readers, printers, laptops, or smart shelves. An external antenna can be connected via an SMA connector. A small yet powerful ASCII command set makes this reader useful for many applications.

Unique Features:

- Very easy to use command set
- Multi-protocol: EPC Class 1 Gen 1, EPC Class 1 Gen 2 (Read/Write)
- Software-controlled power level
- Programmable number of time slots to allow for small and large tag populations
- Operates at both the European UHF frequencies (865-868 MHz) and North American UHF frequencies (902-928 MHz)
- Reader can automatically identify the protocol of the tag being read
- Programmable Reader ID code for networking many readers together
- Onboard EEPROM memory allows custom user configuration to be saved in memory so reader will automatically boot-up in a user-defined mode.

Specifications

Electrical Specifications

- Operating Voltage:
 - 5 VDC nominal (supplied by USB port)
 - 4.3 Volts Min

- 6 Volts Max.
- Current consumption:
 - 100mA for 50 msec when transmitting
 - <2 mA when idle
- Antenna:
 - 50 Ohms
 - SMA female jack
 - Can be customized
- RF Power Output:
 - 50 milliwatts (+17dBm) at connector

Performance Specifications

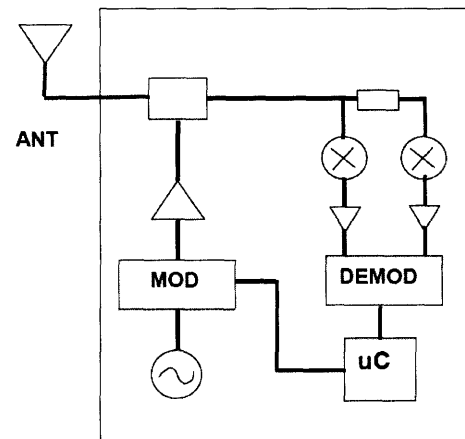
- Supported Protocols:
 - EPC Class 1 Gen1
 - EPC Class 1 Gen 2
 - Read and Write
- Reading range (avg):
 - 80 cm (30 inches) using standard 6dbi antenna
 - 40 cm (15 inches) using small patch antenna (ANT-LP1)

Physical Specifications

- Board Size:
 - Width = 38mm (1.5 inch)
 - Length = 46mm (1.8 inch)
 - Height = 7mm (0.27 inch)
- Environment:
 - 0C – 85C (32F – 185F)

Interface Specifications

- Host Interface:
 - 3-pin header (V+, GND, Data)
 - RS-232 TTL-level
- Sensor Input:
 - 3-pin header (V+, GND, Vin)
 - 8-bit A/D



The Micro-UHF is a single-antenna reader module. The backscatter signal is demodulated to baseband through a standard I/Q mixer stage and is filtered and amplified. The baseband signal is then sampled and processed by a microcontroller. The transmit RF power of the Micro-UHF is 50mW, which is sufficient for low-power short range applications. The Micro-UHF hardware supports software control for output power level.

E. Brother MW-260 Portable Mobile Printer

The MW-260 printer is the newest addition to Brother's successful MPrint mobile printer product line. At less than 1.2 lbs, the slim, lightweight design of the MW-260 printer is ideal for mobile professionals in field sales and service, retail and route delivery, law enforcement, mobile healthcare, and just about any industry that can benefit from on-the-spot, mobile printing. With 300 dpi printing on A6 size notepaper and carbon copy paper, the MW-260 printer provides professional-looking output for sales receipts, customer invoices, price quotes, maintenance and repair reports, tickets and fines, medical test results, patient instructions, and more.

At only 0.70 inch thick, the Brother MPrint mobile printer is feature packed with the latest technology.

- Fast thermal printing (up to 3 pages per minute) so there's no frustrating wait for printouts.
- Print on
 - Therma Plus M paper - feels like plain paper, Easy to write on, works with standard highlighters.
 - Carbon Copy - 2 ply sheets allow duplication when authorization or proof of receipt is required.
- Stationary print head provides virtually silent printing.
- Internal paper cassettes allow quick and easy exchanging of paper.
- Replaceable rechargeable lithium ion battery.

Specifications

Printing speed	20 seconds/page (ThermaPlus® M paper by Brother®: A6 size paper, 7% print density)
Printing resolution	300dpi x 300dpi
Paper size	Brother® A6 paper (4.1" x 5.8")
Printable area	3.9" x 5.4" (For Carbon copy type: 3.7" x 5.2")
External dimensions	8.3" (L) x 5.1" (W) x 0.7" (H)
Weight	1.2 pounds (including the battery and paper cassette containing 50 sheets of ThermaPlus M paper)

Power supply	Replaceable, rechargeable lithium ion battery with compact switching AC adaptor for recharging purposes included.
Number of printable pages	Up to 50 during continuous printing with a fully charged battery (based on 7% coverage at an ambient temperature of 25 degrees Celsius)
Operating systems	Microsoft® Windows® 2000 / XP / Vista, Microsoft® Windows® Mobile 2003, Windows® Mobile 5.0 and 6.0; BlackBerry OS 4.2 and higher.
Interface	USB, Version 1.1; Bluetooth®, Version 1.1 Class 2, serial port profile supports as standard; IrDA, Version 1.2.

F. Publications and Media Coverage

Publications

P. Mistry, P. Maes. **Quickies: Intelligent Sticky Notes**. In the *Proceedings of 4th International Conference on Intelligent Environments (IE08)*. Seattle, USA. 2008.

P. Mistry, P. Maes. **Intelligent Sticky Notes that can be Searched, Located and can Send Reminders and Messages**. In the *Proceedings of the ACM International Conference on Intelligent User Interfaces (IUI2008)*. Canary Islands, Spain. 2008.

Media Coverage

Discovery Channel News

<http://dsc.discovery.com/news/2008/01/18/smart-sticky-notes.html?dcitc=w19-506-ak-0009>

Popular Science

<http://www.popsci.com/entertainment-gaming/article/2008-05/it%E2%80%99s-sticky-no-it%E2%80%99s-quickie>

The Tech Herald

<http://www.thetechherald.com/article.php/200819/897/Post-it-notes-make-21st-century-leap-courtesy-of-MIT>

Gizmodo

<http://gizmodo.com/383715/mit-develops-quickies-post-it-notes-for-the-21st-century>

Engadget

<http://www.engadget.com/2008/05/01/mit-reinvents-the-post-it-note-with-post-it-notes/>

Slashdot

http://tech.slashdot.org/article.pl?no_d2=1&sid=08/05/02/2217225

Gizmodo Japan (Japanese)

<http://www.gizmodo.jp/2008/05/quickies.html>

Golem.de (German)

<http://www.golem.de/0804/59279.html>

Presstext.de (German)

<http://www.presstext.de/pte.mc?pte=080426009>

Times of India - Mumbai Mirror

<http://www.mumbaimirror.com/net/mmpaper.aspx?page=article§id=7&contentid=200802102008021002270924836dc5988>

Yahoo India News

http://in.news.yahoo.com/ani/20080120/r_t_ani_sc/tsc-now-e-sticky-notes-to-remind-you-thr-f32bc39.html

Zee News

<http://www.zeenews.com/articles.asp?id=419303&sid=ENV&ssid=29>

Thaindian News

http://www.thaindian.com/newsportal/health/now-e-sticky-notes-to-remind-you-through-e-mails-or-sms_10013517.html

Khabar Express

http://www.khabarexpress.com/1/20/2008/Now-E-sticky-notes-to-remind-you-through-e-mails-or-sms-news_10224.html

WebIndia123 News

<http://news.webindia123.com/news/Articles/India/20080120/872872.html>

TopNews.in News

<http://www.topnews.in/now-e-sticky-notes-remind-you-through-e-mails-or-sms-215461>

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