Supporting Seamless Integration of Handwritten Casual Notes in Digital Tools through Semantic Classification

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Declaration

I hereby declare and confirm that this thesis is entirely the result of my own original work. Where other sources of information have been used, they have been indicated as such and properly acknowledged. I further declare that this or similar work has not been submitted for credit elsewhere.

Hagenberg, September 30, 2013

Eva-Maria Beatrix Schwaiger

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Preface

At this point, I would like to take the opportunity and express my gratitude to everyone who supported me, especially during the last year of my master's degree. First I want to say a huge thank you to my supervisor Michael Haller for challenging and advising me all along the way. Another big thanks goes to the Media Interaction Lab members Kathrin and David for patiently answering all my questions and pushing me softly in the right directions. Furthermore, I want to thank my family for their unconditional love and support throughout my entire studies. My friends also deserve a thank you, right from the bottom of my heart, for encouraging but also distracting me, whenever I needed it. And my final gratitude goes to Chris, my best friend and partner, for the loving advice, the excellent help and all the encouraging hugs.

I feel truly blessed to have such amazing people in my life. May God bless you.

Kurzfassung

Jeden Tag werden in Büros zahlreiche Informationen beiläufig auf Papier niedergeschrieben. Viele dieser Notizen enthalten wichtige Inhalte wie zum Beispiel Kontaktdaten oder Aufgaben. Um eine lange Lebensdauer von bedeutungsvollen Informationen zu gewährleisten, werden diese meist mühevoll durch manuelle Eingabe der Daten in Informationssysteme übertragen und so digitalisiert. Diese Arbeit befasst sich mit der Optimierung dieses Prozesses und präsentiert Design und Implementierung von *PECAN*. *PECAN* verarbeitet handgeschriebene Notizen und ermöglicht deren selektive Digitalisierung, automatische Kontext-Klassifizierung und Integration in digitale Systeme. Die Resultate einer Benutzerstudie zeigten eine signifikante Arbeitserleichterung und Leistungssteigerung im Vergleich zu einem manuellen Eingabeprozess.

Abstract

Casual note taking is an everyday office chore. While these notes oftentimes contain important information like contact details or to-dos, they do not have a long lifespan, since people prefer to manage important information in their digital information tools. Therefore, notes have to be captured, which can be cumbersome for users. This work presents design and implementation of *PECAN*, a tool to support selective digitization and automatic context classification of handwritten notes, to simplify and speed up the process of note capturing. An evaluation showed a significant workload reduction and performance improvement for digitizing notes compared to manual note handling.

Chapter 1

Introduction

Digital technologies and conventional paper are both part of our daily office environment. Our computers are providing us with huge advantages through work efficiency, fast searching, cheap archiving, automatic organization, and easy distribution to mention the most common. However, people still like paper for many note-taking situations, e.g. casual note taking, because of its unique affordances. Paper is cheap and provides fast and flexible interaction. It does not run out of battery, it is always at hand and does not require any formalities. There are also approaches to design paper-like devices, e.g. by introducing E-Ink Paper [8], which is sharing affordances of paper and the digital world. All these devices can be used for casual note taking in an office workspace. Those notes are usually jotted down on paper while handling a phone call. Unfortunately, they have a rather short life span. Still, they may contain important information (e.g. contact details or appointments), which users might want to process selectively. Digitizing important notes can be very time-consuming and cumbersome. Usually, users have to copy notes by hand and enter the information in e.g. a Personal Information Management (PIM) Tool [3]. An alternative approach is to take a picture of the note with e.g. a smartphone (probably multiple times because of bad image quality), transfer the picture to the computer, select the important information and somehow integrate it in the PIM Tool. Both ways are far from optimal and are therefore increasing the gap between physical and digital world. Our motivation was to build a bridge and use the advantages of both worlds by automatically integrating notes in the personal digital environment as shown in a first mockup (see Figure 1.1).

1.1 Importance of Paper

The medium paper is all around and an integral part of today's office environment, even though in 1975, George E. Pake (Head of Xerox Parc) predicted the Office of the Future being paperless [36]. He assumed this, because of

Figure 1.1: The main motivation for this thesis was to use the advantages of ordinary paper and combine it with digital advantages. Analog content should be digital available at the same time. (1) Note taking situation in the office, (2) contact details are jotted down, (3) a notification appears (4) contact can be added immediately.

the increasing use of computers and the gradual replacement of paper work. Ever since, many attempts have been made to fully replace the functionality of paper with digital tools or improve it by changing e.g. font size, font color, text arrangement, or adding full text search features. Even though computer technology was supposed to replace paper completely, this revolution in office life never occurred, in fact the use of paper is still raising [11].

In 2002, Sellen and Harper examined the current influence of paper on office work. They argue that paper is still persistent, due to many advantages for certain cognitive tasks over computers. The flexibility of paper is offering unique affordances and enables specific kind of use [29]:

> *Paper is still an important medium in work because it is better suited than many current technologies for certain tasks.*

Paper is tangible: we can pick it up, flip through, make a book, read it, annotate and scribble on it while we read. They say that the introduction of new digital technologies, does not get rid of paper, it just alters the way in which it is used [29]. A group of researchers stated that the usefulness of paper lies in creative things, e.g. for brainstorming activities, making annotations and face-to-face communication [9, 11]. Paper is a poor medium for archiving information, because it takes up much space and is hard to search. After the expression of ideas as a scribble, the note usually becomes worthless. As a solution to this paper problem Sellen and Harper suggested not to use less paper, but to keep less paper. This approach leads towards a combined use of paper and the personal computer [29]:

> *Rather than pursuing the ideal of the paperless office, they should work toward a future in which paper and electronic document tools work in concert and in which organizational processes make the best of both worlds.*

Given these affordances of paper, we were motivated to use them together with the possibilities of fast digital processing, to create a tool, which enhances the user experience and supports people with their office work.

1.2 Semantic Web

The World Wide Web provides loads of data in form of images and text. Most of this data is freely available for the public. According to Tim Berners-Lee most of the Web's content is designed human-readable and not machine-readable [41]. The semantic web is a concept to turn the web into a universal library [40]:

> *The Web is huge but not very smart. Computer scientists are beginning to build a 'Semantic Web' that understands the meanings that underlie the tangle of information [...]. The idea is to weave a Web that not only links documents to each other but also recognizes the meaning of the information in those documents - a task that people can ordinarily do quite well but is a tall order for computers, which can't tell if 'head' means the leader of an organization or the thing on top of a body.*

The key to the use of semantic web is, to present information in a familiar and intuitive way for users, structured humanly-readable and not in the underlying model data [26]. Therefore the semantic analysis process is used to create machine-readable content, which should be transformed to be readable for humans again later on. The web offers an endless pot of information, which can be used for further data processing, e.g. to spell check names, mail addresses, websites or addresses. Semantic analysis is just the starting point of exploring the opportunities of the automated and supporting World Wide Web.

These advantages of the endless knowledge of the World Wide Web were encouraging us to create a seamless user experience. Notes are semantically analyzed to assist users by automatically making content machine-readable and to display it in familiar ways.

1.3 Contributions

The main contribution of this work is the development of *PECAN* (Personal Extraction of Context from Analog Notes), a tool to support users when taking casual notes. *PECAN* captures notes selectively with a digital pen during their creation. Then the contents are processed using handwriting recognition and semantic analysis. According to the results of the semantic analysis, multiple opportunities for further managing the noted information within PIM Tools are suggested. Our empirical evaluation showed significant performance improvements when digitizing casual notes compared to the traditional workflow of manual copying notes.

1.4 Outline

The structure of this thesis is given in the following. Chapter 2 summarizes all background information that was gathered to get a better understanding of the topic. Related work, regarding pen and paper interfaces and smart interpretation of notes, published by other researchers is presented.

For digging deeper into the topic and getting an idea about the use of paper in an office environment, several office clerks were interviewed. These results are presented in Chapter 3, along with design goals and first concepts for the project. Based on the background knowledge, *PECAN* is presented in Chapter 4, giving a good insight into the necessary steps to convert analog notes into smart digital information. Further details on hardware and the technical implementation process are covered in Chapter 5. Especially the core functionality, the interpretation process of notes is explained in detail.

To evaluate the performance of *PECAN*, a within subject design study was conducted with sixteen participants. The experimental design is presented in Chapter 6. The results demonstrated accurate performance with an error rate less than five percent. The comparison of *PECAN* with a traditional digitizing process showed encouraging statistical significant results for the overall workload and for trial completion times of the adding process. Qualitative and Quantitative results are all presented in Chapter 7. Finally, Chapter 8 gives a conclusion about this thesis and presents future work.

Chapter 2

Related Work

For this thesis we investigated in previous research in the area of pen and paper interfaces and semantic interpretation of short notes. The collected background knowledge is presented in this chapter.

2.1 Pen and Paper Interfaces

Numerous pen and paper applications try to bridge the gap between paper and the digital world. Several digital pens are available from both commercial and academic products. One well-known solution are ultrasonic pens [19]. The advantage of this solution is that any kind of paper can be used. A disadvantages is the problem of manually calibrating the paper and indicating page change. Graphic tablets are capturing pen input, using induction. The most common technology is provided by *Wacom*[1] and does not necessarily need paper. This approach offers very high resolution, but has the same disadvantages as the ultrasonic pen on how to distinguish multiple paper sheets. Another technology provided by *Anoto*[2] tracks the pen with a camera on paper impregnated with a special dot pattern to identify the current position of the pen. This solution faces the problem of multiple paper handling, and was therefore chosen for further usage in this project. Most of the commercial applications for these products lack of an easy workflow. They do not provide automatic synchronization with tools for processing or they are fixed to a predefined page layout as e.g. the Anoto Livescribe Pen[3] or a tagging system as with Logitech's ioTag[4]. The provided software clients are typically standalone and do not offer an easy integration into required applications.

However, these technologies are used a lot in pen and paper interface

[1] http://www.wacom.com/
[2] http://www.anoto.com
[3] http://www.livescribe.com/
[4] http://www.logitech.com/en-us/support/963?crid=401

research. For example Mistry et al. [24] presented Quickies. Quickies is a project about intelligent sticky notes that can be searched, located, and can send reminders and messages. Mistry refers to sticky notes as an everyday office tool for reminders, to-do lists and contact information. The handwritten notes should link and combine physical and digital information. The information stored on the sticky notes are analyzed using artificial intelligence techniques and can be integrated in Personal Information Management (PIM) Tools afterwards. The Quickies project is great in terms of how information is digitalized and processed afterwards. For our project, we seek for a similar fluid transition between the paper based note and further processing steps, while considering more the actual user interaction steps and integration into PIM Tools. Another approach using Sticky Notes are the 'Move-it Sticky notes [25]', which are providing physical feedback through an enhanced paper clip. Move-it uses a predefined form to analyze content, in contrast to our project, which is aiming for informal content analysis.

ButterflyNet [39] was using *Anoto*'s technology to capture notes and integrate them into digital photographs. The notes are capturing facts and reminders as well as observation studies. The notes are later displayed in a digital browser. This work was inspirational, because of the linked contents and the note organization techniques used. However, this approach does not support context-based recognition.

Outpost [18] is a tool to physically annotate website information on a white board, using sticky notes. Their approach is to offer freeform sticky notes, which are analyzed using computer vision techniques. The extracted meta data is used to link the note information to the website on the whiteboard. Freeform is also aimed for our project. However, our project does not annotate existing documents, but is used for writing down context free short notes.

Besides these brief information pieces on sticky notes, others like PaperPoint [30] or Papiercraft [21], focus on annotating on paper. They are interacting with paper by tagging already existing documents on paper. A gesture based command system is used to create formal annotation, to interact with the document and describe its content. Papiercraft offers several pen gestures for tagging document passages with predefined or freely chosen keywords and for creating hyperlinks [33]. In contrary to this, our project does not focus on tagging and managing printed document, but its providing a form free environment that is not restricting users to a certain document. In contrary to Papiercraft, NiCEBook [5] offers a notebook for natural note taking that especially supports long term note taking (e.g. for meetings). The created content can be categorized, before or after writing down notes, by selecting an area and ticking on a paper checkbox to define the category it belongs to. NiCEBook itself depends on the categorization of the users to further process the notes, our approach is to automatically interpret the content and offer users several possibilities to interact with the already processed content. The content selection for *PECAN* was also inspired by the NiCeBook approach.

2.2 Semantic Tools

To provide the note analyzer with a context-sensitive recognition, we used syntax and semantic analysis. A related project is Sticky Notes for Semantic Web [16]. It is a tool that supports users to link their documents, e-mail messages, appointments, tasks and other information through annotation. It creates a natural language understanding system to analyze the contents and to provide machine-readable information, building upon semantic web standards. It is using the RDF (Resource Description Framework) Data Model to represent the modeled annotation ontology. Relevant documents can be located and recalled through analysis. Our project will not deal with creating ontologies, but rather use available semantic tools in combination with analog notes and furthermore preprocessing the contents for the user.

Jourknow [37] is another tool to structure notes and add them automatically to a PIM Tool. To identify the content, Jourknow provides three different methods to analyze text patterns. First a simple syntactical form, like regular expressions, then a recursive descent parsing[5] and at last a Notation3 logic[6]. This project also has similar aspects in project requirements by analyzing content to further process it in PIM Tools, but the semantic analysis is done by an available API, accessing endless information available on the World Wide Web.

[5] http://www.cs.engr.uky.edu/~lewis/essays/compilers/rec-des.html
[6] http://www.w3.org/DesignIssues/N3Logic

Chapter 3

Method

The design process of the project can be dissected to five steps of design thinking developed by ideo[1] (Empathy, Define, Ideate, Prototype, Test) following the basic process of Define—Design—Refine. At first we tried to frame the main problem of handling analog notes in a digital environment, by interviewing several office clerks about their casual note taking behavior, which is discussed later on in this chapter and by digging into related research areas as in chapter 2. As next step we started the definition of the project outlines, the design goals and specified features, followed by the ideation phase, which are both discussed in this chapter. We further developed a paper prototype to test the intended workflow of the application and improve it.

3.1 Empathy

The whole idea of this project was born during a discussion about the use of paper in our digital office environment and furthermore the integration of digital devices such as a digital pen. We wondered why it is not better integrated in our everyday life. Some researchers knew from experience that the usage of a digital pen lasted approximately a couple of days until they stopped. One of the main problems of the digitized notes was that it did require a lot of effort from the user, because it just offered a plain facsimile of the analog note and no further processing. Often it was easier, just to retype the information, than to copy the digital information to the required program. Thereupon, we did informal interviews with three administrative employees of our university to get a better understanding of how they use their office space and how we can support them in their note taking behavior. All interviews were given in German and translated for this thesis in English.

Even though they all use the computer as the main medium for their work, paper is still all around in their office space. They use notebooks, post its, plain sheets, and pads, which are all made of paper, as tools to support

[1]http://www.ideo.com/about/

them while doing their job. They reported the regular notation of casual notes on paper, in particular contact details, appointment information and to-do lists, while they are answering a phone call or a face-to-face conversation.

The interviewees all stated that they usually tend to keep analog notes for archiving or to have them visible on their desktop for reminding. Participants stated the following:

> *I still have my desk calendar because if I am not on my desk I do not have the information right in front of me. Sometimes I have 25 things open, and then the reminders are getting lost on my desktop. So I still prefer paper for this. – Interviewee 3*

> *I keep the paper notes, because I always have in mind that if I do not have my computer with me, nor internet available, I will still have access to the paper note. – Interviewee 2*

However, they also store casual notes in digital Personal Information Management (PIM) Tools, according to their importance and if they will need the information later on.

> *Usually I write down appointments on my desk calendar and add them to my digital calendar as well. – Interviewee 3*

> *I only digitize my notes selectively, depending on how important they are and if I will need them later on. - Interviewee 1*

Furthermore we asked the interviewees for samples of their casual notes, which are presented in Figure 3.1. The samples are clearly showing very short notes with only relevant information on contacts, appointments or to-dos, which were not explicitly labeled. The office clerks used arrows and lines to create a connection between the notes or to separate them.

3.2 Definition

As part of the process we started to define the project outlines together with the main goals and the specified features as presented in the following subsections.

3.2.1 Outlines

The main concern of the project was to support users in their natural behavior by enhancing their note taking workflow in an office environment. Since paper is still available in the office as a main medium for work, and it

Figure 3.1: Note samples of the three office clerks. Personal details were blurred.

has a great range of affordances, we wanted to combine it with the personal computer and to bridge this gap between the two media.

We wanted to provide a fast and easy way to digitize analog notes directly from paper to digital devices. Since there are multiple opportunities how to do so, we wanted to have as less effort as possible for the users, by directly using their input on paper and analyzing it. Furthermore by recognizing the content of the note and the context as well. The initial idea was that users write down notes about e.g. contacts or messages and this content is immediately interpreted and sent to their PIM Tools like e.g. Microsoft Outlook or Apple Mail (see Figure 4.1). This gives users the possibility to interact directly with their analog notes on a digital device without having the effort to transfer the notes themselves.

One of our inspirations was the Apple Mail application (Version 6.5)[2]. They did a great job in terms of smoothly integrating appointment or contact details into the Contacts and the Calendar application. By only hovering contact or appointment details in an e-mail, a pop-up menu appears, suggesting to add this information to PIM Tools. Inspired by this we created some design goals, described in the following section.

3.2.2 Design Goals

Before starting with a specific interaction concept and screen design, we defined the main design goals. For this process 4 design goals were determined providing rough outlines for further developing an overall application design:

1. fast and fluid interaction,
2. formless,

[2]http://www.apple.com/de/support/mac-apps/mail/

3. automatic context recognition,
4. integration in standard desktop applications.

First of all the requirement for fast and fluid interaction is claimed to create a smooth workflow, which is fully supporting the users needs. Another important goal was creating a formless pen and paper interface. This is an essential part for user interaction, because people are not used being bound to predetermined areas, where certain input is expected. Instead people are doodling notes on paper in every possibly way as shown in Figure 3.1 For this approach, we also need an automatic context recognition to give the users a proper suggestion of what can be done with the note, instead of requiring users to tag notes according to their content as it is done for example by the NiCEBook [5]. Furthermore, the smooth integration of the context sensitive notes in standard desktop applications should be provided. It should offer direct access to PIM Tools and not being a standalone application, which requires users again to copy paste the note from one program to another.

3.3 Ideation

During ideation phase, *PECAN* was formed, and related by scribbling sketches and designing user interaction. Some sketches of the ideation process are reproduced in Figure 3.2. The sketches are showing a gradual evolution of the project. The first scribbles are showing a rough idea and necessary components, especially selection techniques and the actual technical workflow. The next step of scribbles are already showing desktop integration and a basic look of the application, as well as the relevant actions for each note type. In case of the contact, appointment, and to-do note type we decided to forward and save them to the users PIM Tool. The message note types should send a message on demand to the recipient. However, the scribble note type offers the possibility to either save the scribble or to forward it via e-mail. Our target was to offer users multiple supportive interaction possibilities with the note. For our design it is important that the content can be processed selectively. In the case of casual notes, they should only be digitized if they are important, since a lot of the quick notes are dumped later on. For this we thought about different selection techniques and decided to use the snapshot technique, were we only tag the bounds of the note as inspired by the NiCEBook [5]. On the one hand this selection technique is fast and easy to apply for the user, on the other hand, the bounds are rough and the risk of selecting other note contents is high. This selection technique allows users to process notes asynchronously after creation, which we think is important especially for casual notes, since they might be performing a different task (e.g. handling a phone call) while taking the note.

Figure 3.2: All basic workflow sketches were doodled beforehand, as well as the graphic design for the application. The sketches on top are showing the first ideas, connections and functionalities of *PECAN*. The ones on the bottom are displaying the first look and feel ideas on the actual application on the desktop PC.

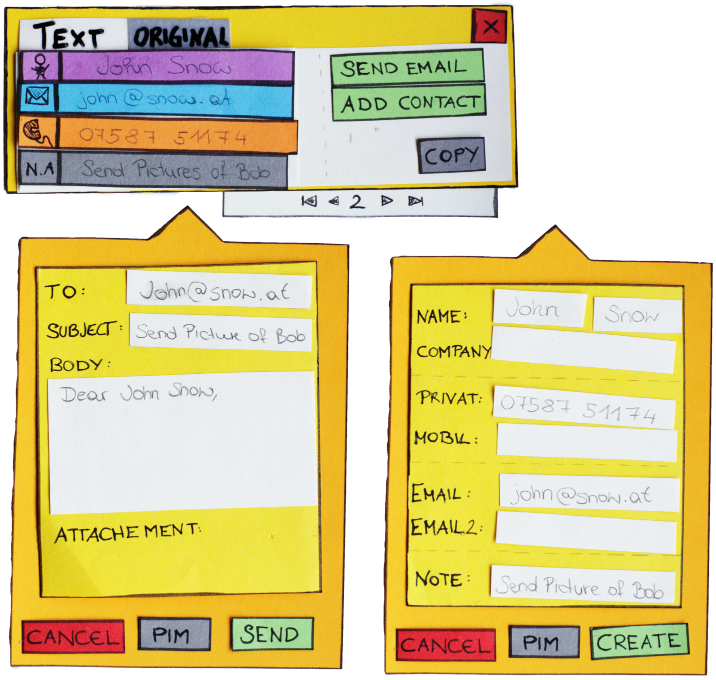


Figure 3.3: A first paper prototype was developed representing a notification and the various interaction steps.

3.4 Prototype and Evaluation

Furthermore we created a paper prototype to gain a general idea of the interaction techniques. The prototype in Figure 3.3 shows an early stage of *PECAN*. Later on we decided to have small notifications for less disturbance in the users work. We decided to only show a facsimile of the real note, so that users can distinguish between multiple notes, if he had selected more than one, and also to remind him later on, what note it is. The note is displayed at the same location as on the paper, to give users a direct reference to the note. By clicking at the notification further interaction details should be displayed in one window, giving easy possibilities to switch from one note type to another.

Chapter 4

Application Design

This chapter includes the design and functionalities of *PECAN*. *PECAN* is a tool to support users in their natural note taking behavior by enhancing the current workflow of digitizing notes. It is capable of selectively analyzing casual notes and smart classification within Personal Information Management (PIM) tools as depicted in Figure 4.1. To demonstrate the flexibility and versatility of *PECAN*, we have designed and implemented the processing of five different note categories (contact details, appointments, messages, to-dos, scribbles).

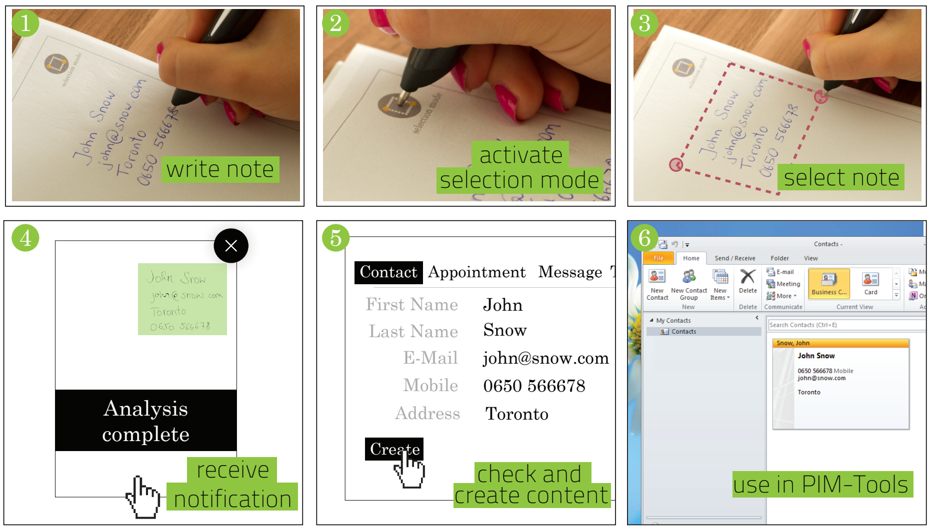


Figure 4.1: User interaction workflow in *PECAN*. After writing a note (1), users activate selection mode (2). Next, a note is selected (3), which triggers handwriting recognition and semantic analysis (4). Once the result is accepted (5), it is added to the PIM tool (6).

4.1 The *PECAN* Workflow

PECAN offers a simple and supportive way to add casual notes to digital PIM tools. For this we elaborated a workflow starting at capturing the notes on paper, interpreting the strokes, analyzing semantic contents and preprocess them for the user. *PECAN* is an approach to combine advantages of the physical and the digital world. Detailed description is given in following sections.

4.1.1 Note Capturing

Writing casual notes is as convenient and familiar as with traditional pen and paper. The use of a digital Anoto Pen has enabled this in combination with paper that is covered by a unique dot pattern to track the position of the pen on paper. Even though pen and paper look and feel normal, they contain enhanced technology, providing abilities to convert ink to digital data. This data is transferred via Bluetooth to the *PECAN* desktop application. The digital capturing of the notes is processed in the background. Up to this point, there was no difference to ordinary note taking for the user. A bounding rectangle is created, by tipping with the pen into the selection mode area, and by further marking two corners on paper. All content within this rectangle is sent to the desktop application for further processing. *PECAN* emphasizes selective analysis. Not every note doodled on a piece of paper is worth to be further processed, especially in the case of casual notes.

4.1.2 Content Processing

The processing of the content is the core component of *PECAN*. Usually, when notes are digitized, users choose a suitable application and retype the contents along the application's form requirements. This manual digitizing part is fully covered by *PECAN*. The first challenge is to classify the note type correctly in order to suggest the appropriate application. Secondly, to assign the information scraps correctly to the predefined forms of the PIM tools. To accomplish this, we reversed the natural workflow as presented in Figure 4.2 (a) and developed the note analyzing workflow as presented in Figure 4.2 (b). At first, the text is converted from the digitally transferred strokes using Microsoft's Handwriting SDK[1]. The text is then processed and ranked applying intelligent context-based rules. These rules are defined within the semantic online engine, Open Calais[2]. We further enhanced the analysis, with simple syntax rules to provide better context recognition. According to these results we defined the most suitable note type and displayed the information in a preview of the PIM tools.

[1]http://www.microsoft.com/en-us/download/details.aspx?id=22557
[2]http://www.opencalais.com

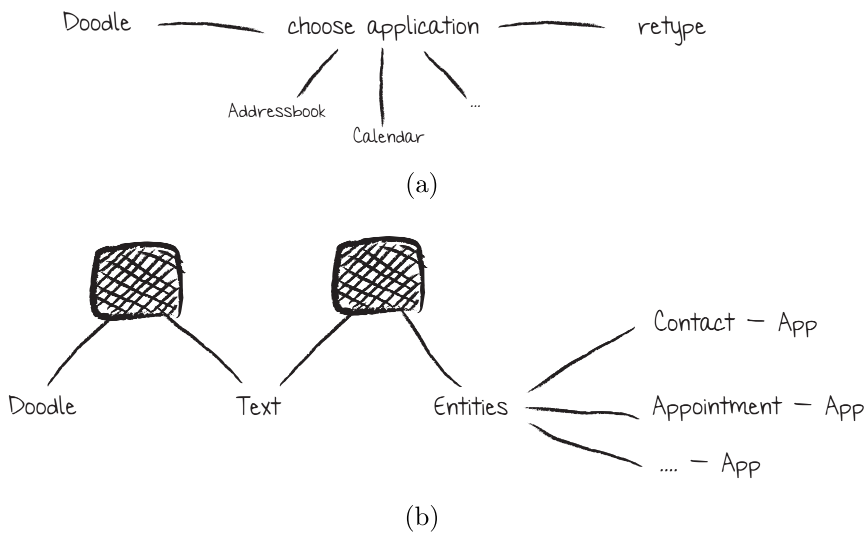


Figure 4.2: (a) A visualization of how notes are currently digitized. First they are doodled on a piece of paper, then an application to transfer is chosen, furthermore the content is retyped and saved. (b) *PECAN* digitized notes similar. First the note is interpreted as text, and the semantic matter is analyzed, resulting in assign entities for each note scrap. The note is further processed and pre filled in the form. Users only have to confirm the action after analyzing.

4.1.3 Notification

After the content was written and selectively analyzed, a notification appears in the top right edge of the primary screen, showing a small version of the actual note. By clicking on the notification the analyzed content is revealed, showing the notes classification suggestion. Switching to another note type can easily change the classification. The note can be added to PIM tools, directly opened by the suggested PIM tool or copied to the clipboard. After a confirmation, the note is synchronized with the integrated PIM tool Microsoft Outlook. Further implementation details are discussed in Chapter 5.

4.2 Supported Note Types

PECAN currently supports five different note types. They were chosen to cover the basic casual note taking scenarios in an office environment [6, 17]. The focus was mainly on textual input, but we also included the scribble note type to cover not identifiable note types. A note is consisting of multiple components (name, location, date, time, etc.). The components are classifying the note type. Further details about the classification process are discussed

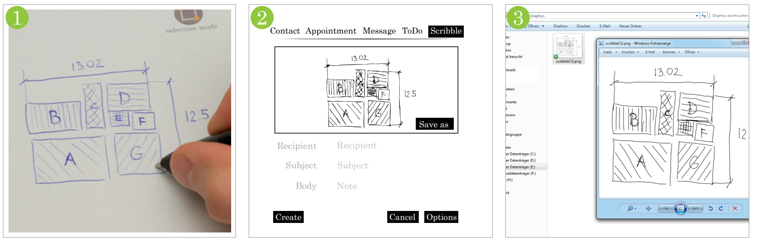


Figure 4.3: Scribbles can be either saved as an image or forwarded via e-mail.

Figure 4.4: To-Dos can immediately be saved to the To-Do List.

in section 5.3.5. These five note types are discussed in the following:

- **Scribbles** are usually rough sketches used to illustrate ideas or relations. This note type preview application offers the options to save the image to the hard drive or distribute it via e-mail (see Figure 4.3 for exemplary scribble processing).
- The **To-Do** note type is intended to cover all textual input in the form of tasks or reminder. Notes can directly be added to a task list, provided by Microsoft Outlook (see Figure 4.4 for exemplary to-do processing).
- **Messages** usually have an e-mail address or a telephone number or an already existing contact name and an actual message. Currently a message can only be send via e-mail (see Figure 4.5 for exemplary processed message).
- **Contact** notes cover basically all personal details about a person or a company. Contacts are saved to the address book (see Figure 4.6 for exemplary contact processing).
- **Appointments** are depended on date or time. Upcoming events are usually scheduled for future events and added to the Calendar (see Figure 4.7 for exemplary appointment processing).

Figure 4.5: Written Messages, can be send via *PECAN*, using e-mail.

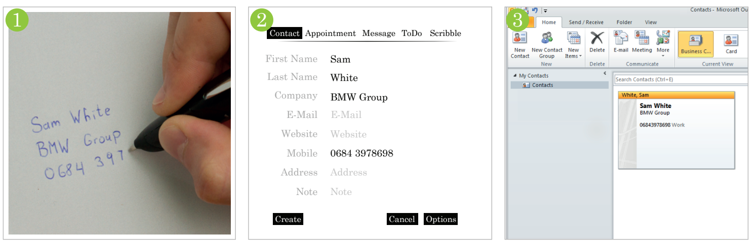


Figure 4.6: Contacts are added to the address book.

Figure 4.7: Appointments are directly added to Microsoft Outlook, enabling reminding and schedule planning.

4.3 Affordances of *PECAN*

Improving workflows and finding ways to save time and money are always an important issue in a modern office workspace. *PECAN* is giving a good insight of what is possible in the research area of pen and paper interfaces. This approach combines the affordance of the physical world of paper with numerous digital ones. Additionally, *PECAN* provides a number of unique affordances:

- familiar and easy process to capture notes through handwriting with conventional pen and paper,
- freedom of writing notes without using formalities,

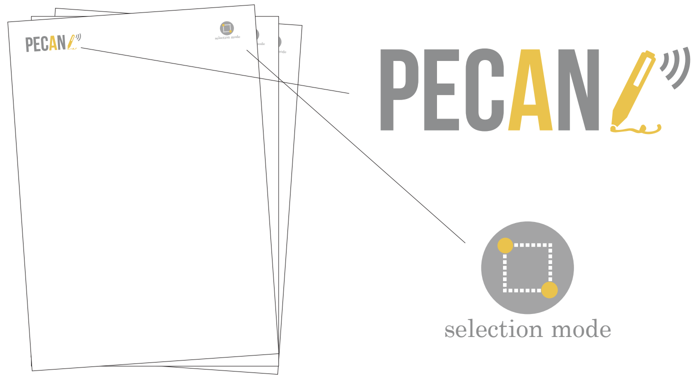


Figure 4.8: *PECAN* Paper.

- selective choice of notes,
- automatic context classification,
- automatic completion of forms,
- easy integration into PIM tools.

Furthermore, the flexibility of the system offers a lot more options than currently available. *PECAN* is about intelligent analysis and interpreted content focusing on casual notes in an office workspace. However, this can be easily expanded for mobile usage, creating and even more powerful personal assistant. *PECAN* can be utilized with any paper tool e.g. by supporting synchronization of an analog standing calendar with PIM tools, sharing creative ideas with friends using e-mails or social networks, creating a protocol of notes in a personal paper book, etc. To go even further, it can be used to interpret personal gestures and carry out tasks like making a reservation in a restaurant, ordering food from a grocery store according to a list, forwarding information or files to partners, etc. In conclusion, *PECAN* is a promising tool, which is supporting people in their natural environment and removes workload through automatically integrating their casual notes in their digital tools.

4.4 *PECAN* Graphic Design Elements

For *PECAN* a logo was developed illustrating the transfer of analog data to a digital receiver. This logo was part of the *PECAN* paper design used for the User study (see Chapter 6). The paper has a size of DIN A4 and has the proprietary Anoto pattern, the logo and a visualization of the selection mode button imprinted (see Figure 4.8).

Chapter 5

Implementation

This chapter provides an overview over the technical workflow implementation of *PECAN*. It gives a detailed description of the deployed hardware as well as implemented software and additional third party software components. The code samples presented in this chapter are all part of our project work on *PECAN*. The project is fully functional, but the code displayed may not be fully executable.

5.1 Overview

In Figure 5.1 the basic technical workflow of *PECAN* is displayed. At first user input is created using a digital pen. These notes are transferred and analyzed using Handwriting Recognition and a Semantic Web API. The notes are classified according to the results of the entity extraction by applying simple rules. The final content is displayed in a preview application for editing and further processing purpose. The project was developed using C# and Microsoft Visual Studio 2010.

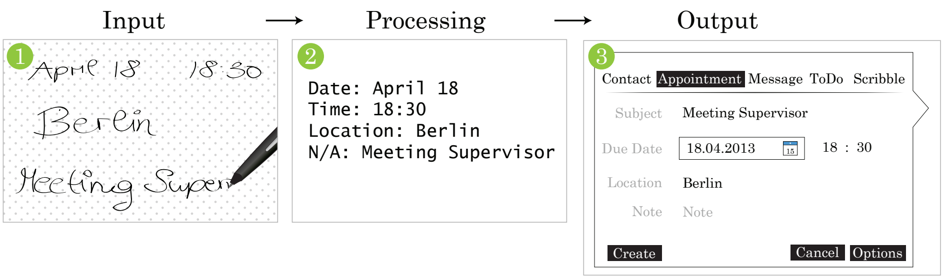


Figure 5.1: Simplified workflow procedure of *PECAN*. (1) Content is written on a piece of paper using a digital pen. (2) The note is then processed using handwriting recognition and semantic analysis. (3) The note is seamlessly added to PIM tools.

- **Input:** The *PECAN* Input Manager captures the information processed by a digital Anoto pen during annotation. The movement of the pen is registered across the paper, which has a unique dot pattern to locate the position of the pen. The input events are forwarded to the stroke analysis for further processing. Input handling is described in detail in Section 5.3.1. The selection of notes on paper is furthermore described in Section 5.3.2.
- **Stroke Analysis:** The strokes are analyzed using Handwriting Recognition, which translates the contents into machine-readable text. The text is further processed using semantic analysis. Stroke analysis is described in detail in Section 5.3.3.
- **Semantic Analysis:** The resulting text is sent to a semantic web API, which is extracting entities out of the note. The entities are attached to an entity list, which is then forwarded to the classification rules. Semantic analysis is described in detail in Section 5.3.4.
- **Classification:** Classification is processed according to defined rules. The classification process is described in detail in Section 5.3.5.
- **Output:** Once the content is fully processed, the OutputManager launches the digital representation of the paper note as notification. This notification offers the possibility to transfer the contents directly to Personal Information Management (PIM) Tools. Output managing is described in detail in Section 5.3.6.

5.2 Hardware

We decided to use Anoto[1] technology as input device for capturing annotations. Anoto is providing a digital pen and paper with an encoded dot pattern. The pen has a digital camera in its stylus tip, and a communication and advanced image processing unit integrated. Moreover it contains an ink cartridge to support writing on paper. The dot pattern on the paper consists of tiny dots where one of these is 0.1 mm in size. The dots are positioned relative to a square grid with a spacing of about 0.3 mm and their position is a slight displacement of the grid in 4 possible directions as shown in Figure 5.2. The pen can interpret an area of about 1.8 mm^2 with 6×6 dots within. Therefore it is possible to create a large area of unique pattern by displacing the dots as mentioned before. The total pattern defines an area of 60,000,000 square kilometers. Hence to the unique and non-repetitive pattern it is possible to identify exactly the location where the pen is writing on. The pen's movements are stored internally or transferred via Bluetooth as coordinates. Furthermore the pen also transfers pressure data and different Pen Actions like Pen Connected, Pen Up, Pen Down, and Pen Disconnected.

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

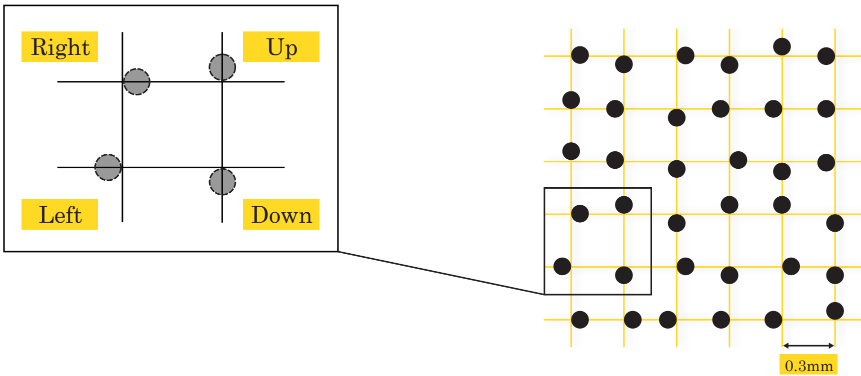


Figure 5.2: The Anoto pattern is a proprietary pattern to identify correctly the current location of the pen. It consists of small dots with a diameter of 0.1 mm. Through displacement of the dots along the square grid, a unique non-repetitive pattern is created.

5.3 Technical Process

The application is component based designed. We are using third-party software and for this we created an interface to provide easily exchangeable components. Figure 5.3 illustrates a detailed structure of the technical workflow and Program 5.1 shows the sequential interpretation process in code after content selection.

5.3.1 Input

The Anoto Pen is used as digital input device. The `InputFrameworkHandler` captures input events, indicating the current position and state of the digital pen. The `System.Windows.Input.StylusPoint` is added to a set of points, which is combined to a `System.Windows.Ink.Stroke`. All strokes are administered by the `DigitalPaper`-Class representing the physical paper sheet, which has DIN A4 paper size. For each physical paper sheet a new `DigitalPaper` is created, identified by the encoded page address.

5.3.2 Select Content

The selection of a specific note is captured with the pen. First users have to point with the pen in the selection area on the top right edge of the paper (see Figure 3.3). The `InputFrameworkHandler` registers the event by checking if the selection point is within the specified bounding box. The action starts the selection mode, which is confirmed for the users by a short sound. Sounds are played using `System.Windows.Media.MediaElement`. At selection mode

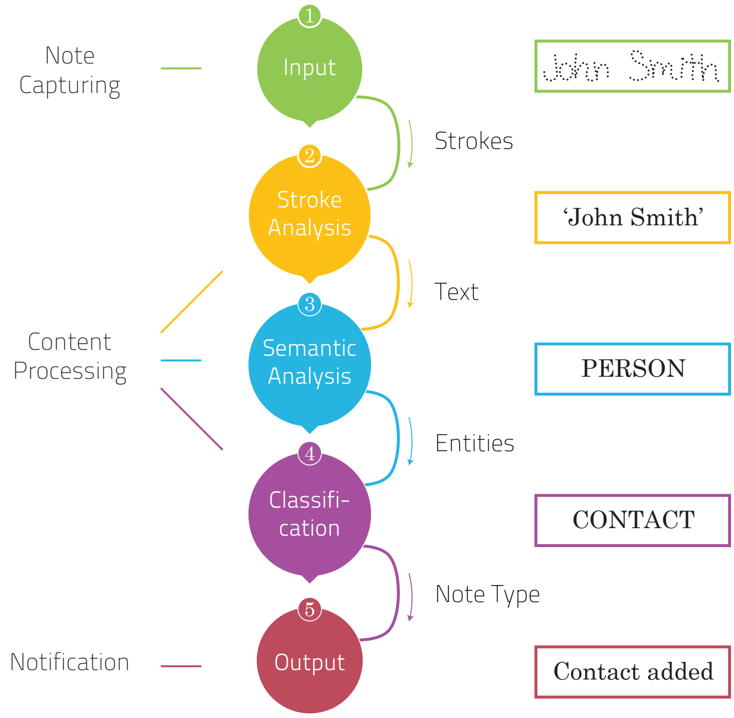


Figure 5.3: The technical structure of *PECAN* starts with the digital pen input (1), the handwriting analysis (2), a semantic processing (3), note classification (4), and ends with an output window displaying all analyzed contents (5).

start, the `InputFrameworkHandler` expects two selection points. Selection points are defined as the next two Pen Up Events. Every selection point triggers a short sound feedback for the user. During selection mode new strokes cannot be added to the `DigitalPaper`. The two selection points span a box as presented in Figure 5.4. All strokes intersecting with this box are extracted from the `DigitalPage`, combined as a new `DigitalNote`. The stroke contents are forwarded to the stroke analysis, which is explained in detail in the following section.

5.3.3 Stroke Analysis

The *PECAN* Handwriting Recognition uses `Microsoft.Ink.Recognizer`. The strokes of the `DigitalNote` contain `System.Windows.Ink.Stroke`, these are converted to `Microsoft.Ink.Ink` and analyzed by the `Microsoft.Ink.Recognizer`. The Recognizer returns multiple strings and confidence levels. The language code identifier used for the Handwriting Recognition was 1033 (English USA).

```
public void Analyze(DigitalNote note)
{
  //Creates UserControl to give users feedback displaying a loading bar
  NotificationControl control = CreateNotificationControl(note);
  if (0 != note.Strokes.Count) // empty selection
  {
    control.Update();
    control.RemoveAfterXSeconds(3);
    return;
  }
  //Handwriting interpretation
  note.HandwrittenString = HandwritingRecognizer.GetInstance().
    Interprete(note.Strokes);

  if(0 != note.HandwrittenString.Length)
  {
    //Semantic Analysis using Open Calais and syntax analysis
    note.SetEntityList(SemanticAnalyzer.GetInstance().Analyze(note.
    HandwrittenString));
  }

  //Computation of recommended note type
  note.ComputeClassification();

  //Update NotificationControl and display the analysis results.
  control.Update();
}
```

Program 5.1: The program code shows the analysis process of one note. After the content was selected, a NotificationControl is displayed giving the users feedback. A progress bar is displayed until the Handwriting Recognition, Semantic Analysis and Classification compute results.

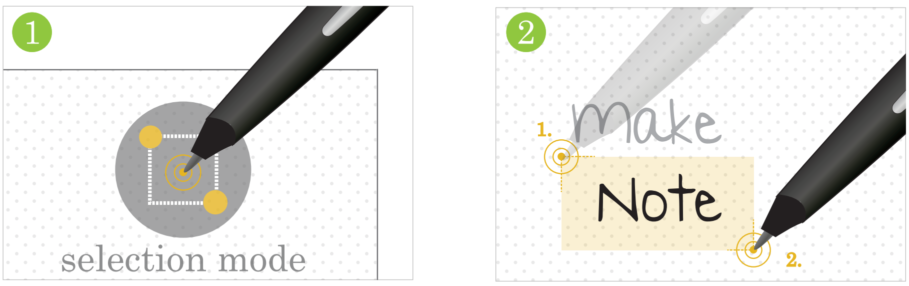


Figure 5.4: Notes are extracted selectively from a page. By triggering the selection Mode (left) and selecting two points, which are forming a rectangle, all intersecting strokes are extracted and are creating a new digital note.

5.3.4 Semantic Analysis

In 1994 Riloff and Lorenzen defined the term Information Extraction (IE), to obtain Information out of a context automatically [34]:

> *IE systems extract domain-specific information from natural language text. The domain and types of information to be extracted must be defined in advance. IE systems often focus on object identification, such as references to people, places, companies and physical objects.*

IE is used to gain structured information out of unstructured content, like text, images, videos or audio files. There are several areas within the IE, but the Named Entity Recognition (NER) is the most important for this project. The NER aims to find and extract special terms (e.g. the name of person or a company, a product, a date, time or measurements of any kind) within an unstructured text [14, 23].

There are several Semantic APIs available, which are usually commercial products but for a limited access also without costs. They all offer similar functionality as to enrich unstructured text with semantic metadata [2]. However, they all have different key aspects and offer a variety of meta data [10]. We evaluated several for this project relevant APIs. *OpenCalais*, *Zemanta*[2] and *AlchemieAPI*[3]. Another online tool called *Semantlink* [12] is also taken into consideration.

- **Semantlink** is a student work that is still in progress. It implements entity extraction and relevance evaluation to classify documents in german language. This is somewhat interesting because most of the other tools only provide support for the english language.
- **Zemanta** returns meta data for unstructured text. This data can be images, articles, links, keywords and categories as well. It is mainly used to support blogging tools. Zemanta is extracting keywords out of the text.
- **Alchemy API** offers similar information as OpenCalais and Zemanta but supports also language detection in about 97 languages. The concepts of NER and Keyword Extraction are related to this thesis as well.
- **Open Calais** is one of the most popular and developed Semantic APIs. It offers web services to automatically create semantically enriched meta data. It returns back: Categories, Social Tags, Named Entities, Facts and Events. The recognition of named entities is most interesting for this project to classify the notes.

[2] http://www.zemanta.com/

[3] http://www.alchemyapi.com

Figure 5.5: Annotation rules for the syntax analysis of dates (left) and times (right).

After performing spot tests on all available APIS, we were choosing *Open Calais* because of its advanced development and best matching with our purpose. Using an online API for the application offers great potential in terms of having an infinite knowledge base available. However it also limits the application because of its dependency on a stable Internet connection. To communicate with *Open Calais* Web API we integrated the Open Source Framework *Calais.NET*[4] in our project. We mainly used the NER to categorize our notes. The entities Person, Company, E-Mail, Location, Phone Number, URL were extracted via Open Calais. Furthermore we needed a date and time entity extraction to enable appointments recognition for *PECAN*. For this we did a simple syntax analysis using regular expressions for Date, Time and Number entities.

For the regular expression we used `System.Text.RegularExpressions.Regex` and checked if the string contains month names or numbers. For this project, we only implemented several special annotation rules. A date starts with the full month name, followed by the day and then the year. The time entity had to consist of 4 numbers with a colon after the second number (see Figure 5.5 for an exemplary note).

A regex example for time extraction in presented in the program code below:

```
private bool IsTimeComponent(String str)
{
  Regex regex = new Regex(@"^([0-1][0-9]|[2][0-3]|[0-9]):([0-5][0-9])");
  return regex.IsMatch(str);
}
```

The note components were tagged based on their entity extraction results. Not identified components were tagged as ‘Unknown Entity’.

5.3.5 Classification

The Classification process determines the correct destination for each note. *PECAN* currently provides the classification of 5 different note types. Scrib-

[4]http://calaisdotnet.codeplex.com

ble, Task, E-Mail, Contact and Appointment. For each note type we created a simple set of rules. The entity list received from the semantic analysis is parsed and the rules are applied to define the most suitable note type. Every note type is per default a Scribble (see Equitation 5.1). If the note type has entities with the tag 'Unknown Text Entity' they are considered as text and treated as To-Do (see Equitation 5.2). Furthermore, if a note has exclusively e-mail and a text tag and no telephone number, company, time or date it is identified as Message as displayed in Equitation 5.3. Notes consisting of a person, e-mail, location, telephone number, company or URL, are classified as Contact type (see Equitation 5.4). All notes containing either time or date are considered as Appointment note types as displayed in Equitation 5.5. The logical rules are applied in the following order to classify the note.

$$\begin{aligned}
Scribble &= \neg Text, && (5.1)\\
Task &= Text, && (5.2)\\
Message &= Text \wedge Mail \wedge \neg Phone \wedge \neg Company \wedge \neg Time \wedge \neg Date, && (5.3)\\
Contact &= Person \vee Mail \vee Location \vee Phone \vee Company \vee URL, && (5.4)\\
Appoint. &= Text \wedge (Time \vee Date). && (5.5)
\end{aligned}$$

The classification can be ambivalent, which means that more than one note type would be suitable for the specific note. The classification results from rules, where the order of the analyzed note type is also important. For this we decided to put the more likely ones later in the classification chain to get the best results possible for this purpose. For incorrect classification, users can easily switch between note types. This behavior is considered in the following Output section.

5.3.6 Output

The visual layout was primarily done with the WPF XAML designer using Visual Studio 2010 professional. The Graphical User Interface (GUI) consists of multiple windows popping up like build-in notifications on the right side of the primary screen.

If there are multiple notifications available at the same time, the notifications are stacked on the bottom of each other. If one notification is removed, the remaining windows rearrange themselves to get a stacked formation again. Every window that was removed by the user, can be retrieved from the notify context menu. There is a maximum history of 10 items.

The notifications are objects of the type *NotificationWindow*. The states of the notification window are presented in Figure 5.6. Each *NotificationWindow* has an *InteractionWindow*. Appearing, disappearing, and state changes of the windows are animated changes of opacity and position values. A more

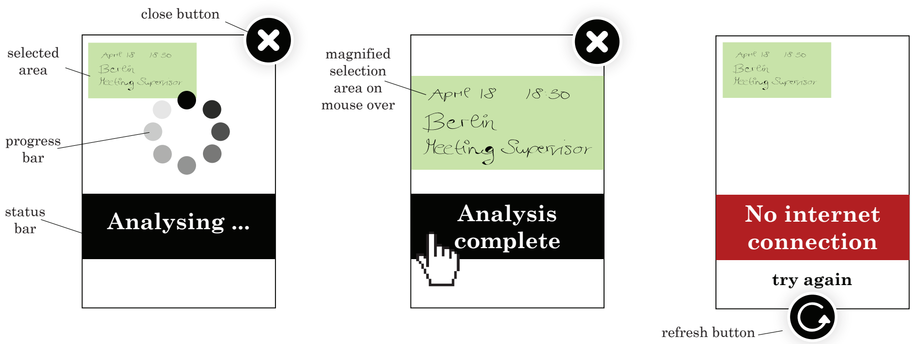


Figure 5.6: The Notification Window displayed in three different states. The loading state (left), the analysis complete screen (middle) and the Internet connection error screen (right).

detailed description of the *NotificationWindow* and the *InteractionWindow* is given in the following.

Notification Window

Each *NotificationWindow* resembles a piece of paper displaying the selected note. The position of the note is in alignment to the location on the physical paper. The selected area is rendered to the same canvas, represented by a colored rectangle. A new canvas appears by hovering over the notification. This is a facsimile of the first canvas, but the note is scaled up to the bounds of the *NotificationWindow* and the selected area.

The *NotificationWindow* is appearing right after the content was selected, to provide accurate feedback for the user. Since the time for the content analysis depends on the speed of the Internet connection a loading bar informs users about the current state. After the Analysis finishes, a banner appears within the *NotificationWindow* stating the completion of the analysis. If there is no Internet connection, the same banner appears stating the absence of an Internet connection. A reload button appears on the bottom of the *NotificationWindow*, starting the analysis all over again. If there are no strokes transferred, and therefore no analysis possible, a *NotificationWindow* appears stating that there was no content selected. This window disappears after 10 seconds. The *NotificationWindow* is an interactive button. This button toggles the *InteractionWindow*. The button has opacity of 0.01%, which makes the button invisible to the human eye, but it still triggers a button click event, which would not be possible with zero opacity. For closing the *NotificationWindow* an exit button is positioned on the top right edge of the notification.

Figure 5.7: The *InteractionWindow* appears on *NotificationWindow* click (top). The classified note type is always shown first. Using the menu bar, users can switch to other note types. Content can be added and edited. The other note type representations are variations of components as date fields or an image (bottom).

Interaction Window

The *InteractionWindow* displays the interpreted content as illustrated in Figure 5.7. The analyzed content can be displayed in 5 different note categories. According to the classification of the note, the recommended note type is displayed first. However, users can easily swap between the different categories. Each category embeds text box, date picker and image controls individually. The *OptionControl* template is used for the buttons on the bottom, where the button actions can be individualized through the XAML file. A sample code of *AppointmentControl* is displayed in program 5.2.

```
<StackPanel>
<localui:LabelAndTextBox  LabelText="Subject"/>
<localui:LabelAndDateTimePicker  LabelText="Due Date"/>
<localui:LabelAndTextBox  LabelText="Location"/>
<localui:LabelAndTextBox  LabelText="Note" LineCount="3"/>

<localui:OptionsControl ActionButtonLeft="Create_Click"
            ActionButtonCenter="Cancel_Click"
            ActionButtonOpenWithOutlook="Outlook-Click"
            ActionButtonCopyToClipboard="Clipboard_Click"
            SuccessLabel="Appointment created"/>
</StackPanel>
```

Program 5.2: Each note type has its own XAML file representing its values. This is a sample XAML Code of AppointmentControl.

Microsof Outlook Interop

To integrate the analyzed note into *Microsoft Outlook* we were using `Microsoft.Office.Interop.Outlook`. The notes are directly synchronized to *Microsoft Outlook* using `Outlook.ContactItem` for adding contacts, `Outlook.AppointmentItem` for Appointments, `Outlook.MailItem` for E-Mails, and `Outlook.TaskItem` for creating task.

Chapter 6

Evaluation

As mentioned in the preceding chapters, *PECAN* is a tool to support note taking especially in an office environment. *PECAN* includes some design features that should facilitate note taking and is therefore offering a supportive tool for users through directly digitizing, analyzing and processing the contents. However, the expected benefit needs to be validated through experimental analysis. We decided to test the performance of *PECAN* by measuring the accuracy of the handwriting recognition and the semantic analysis, since this is an important factor to get the user's acceptance. According to the literature, the threshold of error tolerance lies somewhere in-between an error rate of 6.9% and 13.8% [15]. Secondly we are giving a comparison of speed, accuracy and perceived workload between the *PECAN* Workflow and the Traditional Workflow, which is further discussed in the following subsections.

6.1 Independent Variables

For this study we defined two types of independent variables. The note types and the workflow types are explained in this section:

6.1.1 Note Types

For *PECAN* various categories of note types were implemented. For this study four note types were evaluated (see Figure 6.1). These note types are defined as follows:

- **Doodling a Sketch:** This type requires no semantic analysis. For the study, we chose simple shapes like circles, boxes and triangles to be easily redraw-able for all participants.
- **Adding a new To-Do:** This type consists of only a plain note without any other semantic content.

Figure 6.1: Exemplary transcription of notes according to their note types. (a) Scribble, (b) To-Do, (c) Contact, (d) Appointment.

- **Adding a new Appointment:** This type has optional date or time objects and some plain text.
- **Adding a new Contact:** This note type consists of various optional fields, which are full name, company name, mail address, postal address or phone number.

6.1.2 Workflow Types

For saving analog notes to a digital Personal Information Management (PIM) Tool, we compared *PECAN* with a common Traditional Workflow, saving the notes directly to Microsoft Outlook.

- **Traditional Workflow:** In this workflow participants used ordinary pen and paper. The notes are later manually transferred by opening a PIM Tool e.g. Microsoft Outlook, creating the required note type, entering the content and saving it again within the PIM Tool.
- ***PECAN* Workflow:** In this workflow participants had to use Anoto paper and a digital Anoto pen to transfer the data to the computer. First, the participants take notes using these tools, and then they make the selection of the required note on paper. The note now appears as notification. By clicking on the notification, the content view appears and participants can add or edit contents. Next, the note can be saved directly as Microsoft Outlook Item.

6.2 Hypotheses

We expect that *PECAN* would demonstrate a high percentage of correct recognized notes and offers a more performant and supportive way to digitize casual notes in comparison to the Traditional Workflow. In particular, we were interested in the following key hypotheses:

- *Hypothesis 1: PECAN* classifies casual notes correctly in more than 95% of the use cases.
- *Hypothesis 2:* Using *PECAN* is less time consuming than using the Traditional Workflow.
- *Hypothesis 3:* According to the final digital note contents *PECAN* is more accurate than the Traditional Workflow.
- *Hypothesis 4:* Using *PECAN* is judged less exhausting in terms of workload than using the Traditional Workflow.

6.3 Experimental Design

For the first experiment each of the 4 note types was tested 5 times resulting in 20 total trials for each participant.

For the second experiment, participants had 5 minutes to write and transfer data using the two different workflows. The amount of trials was dependent on the speed and accuracy of the participants. After the completion of a workflow, participants had to answer a questionnaire based on the NASA Task Load Index (TLX) [13].

6.3.1 Experiments

For all experiments, we chose a repeated measure design, where we evaluated speed, accuracy, and learning.

Experiment 1: *PECAN* Performance Tests

Each of the 4 categories was completed 5 times. Consequently performance tests consisted of 20 trials per participant for the *PECAN* Workflow. The categories were alternated and counterbalanced using a 4×4 Latin Square (see Appendix A).

On average one workflow consisted of 4 words (26 characters) characters, where contacts consisted of 4.8 words (34.4 characters), appointments of 4 words (25 characters), and to-dos of 3.2 words (18.8 characters).

Experiment 2: Comparing the Workflows

As already explained in the preceding subsections, we used the Traditional Workflow to compare performance and work load against the *PECAN* Workflow. Each workflow block is consisting of four steps. Step one, was the writing phase. Participants had three minutes for writing down as many appointments as possible. These appointments had different levels of detail and were counterbalanced using a 4×4 Latin Square (see Appendix A). Step two was a two minutes distractive phase to make sure that the appointment details are not stored in short-term memory. For step three, the adding phase, as many of these appointments had to be transferred to Microsoft Outlook using either the Traditional or the *PECAN* Workflow. Step four, completed the experiment, a NASA TLX questionnaire was provided to indicate the workload level for each workflow.

6.3.2 Experiment Contents

For average sample notes we selected data from online lists to create equal opportunities. Exemplary note types are displayed in Figure 6.1. Each note has its own component and therefore a different constellation of contents was necessary.

- **Scribbles** are consisting of primitive shapes. For this we chose rectangles, circles and triangle. One scribble task had usually two or three shapes to draw.

- For **To-Dos** we selected everyday chores. They consisted of 15-21 characters.
- For **Contacts** we used pre names, surnames, companies, e-mail provider, telephone numbers and locations as note components. Pre names were picked from the top names of the last century (1913-2012) [46]. A name was usually three to six characters long and was an even distribution of gender. Surnames were picked from the top 50 last names of century [43] and five to seven characters long. Companies were chosen out of a list of 25 well-known ones [44]. E-Mail providers were selected by a top list of free e-mail services [42] three to five characters long. Telephone numbers were randomly generated with an area code of four to five digits and a personal number of six to seven digits. Locations were picked from a list of European capitals.
- **Appointment** had date, time and location. Months were chosen equally over the year, as well as time, which was a four-digit number on a twenty four hour clock. Locations were picked from a list of European capitals.

We aimed for equal word complexity and similar cost of writing.

6.4 Participants

16 unpaid right-handed participants (4 male, 12 female) aged between 24 and 50 years ($M = 32.43$, $SD = 7.56$) were recruited for the user study. 9 of them were employees doing mainly administrative work, 3 scientific researcher and 4 students all from the local university. Due to the restrictions of the system to the English language all content was provided in English, even though the native language of all participants was German. All participants confirmed that they are familiar with the English language. Participants stated using their computer on average for 8.7 hours a day ($SD = 1.8$). All participants were mainly Windows users and each one uses a PIM Tool like Microsoft Outlook ($68,8\%$) or some kind of webmail like Gmail (50%) on a regular basis. Participants were also questioned about their experience with digital pens and the usage of handwriting recognition. 50% of the participants reported that they never had any experience with a digital pen, 25% only used it for playful testing one or two times, 12.5% uses them sometimes and the other 12.5% use digital pens on a regular basis.

Experience with handwriting recognition was reported by 43.75% of the participants, but most of them do not use it frequently, Most of the time they used it for playful interaction and sometimes for scanning documents. 56.25% reported that they never used that technology before.

Furthermore we asked participants about their general note taking behavior in a preliminary questionnaire. 43.75% reported the frequent note taking of contact details, 75.00% of appointments, 87.50% of to-dos, and 31.25% of

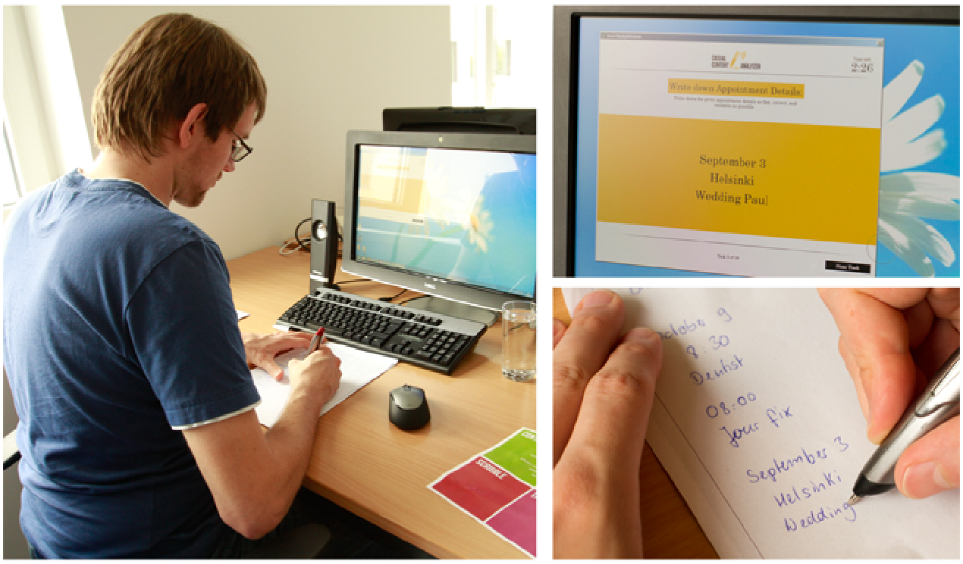


Figure 6.2: The apparatus of the *PECAN* evaluation (left) with the task instruction window (top right) and exemplary paper notes (bottom right).

scribbles. All participants reported the use of paper as personal note taking tool on a daily basis, furthermore 93.7% are using their computer and 50% are using their mobile devices in addition. Overall, for specific note taking situations, people preferred paper during phone calls (98.47%), for spontaneous ideas (68.42%), scribbles (73.68%), meeting one persons (89.47%), meeting with more people (73.68%) and for talks (52.63%). To digitize handwritten notes 93.75% retype them, 25.00% also use smartphones or SLR cameras, and 25.00% use the scanner. To digitize scribbles, 50.00% use the scanner, 12.5% stated to redraw it with a graphic tablet, 25.00% are using smartphone or SLR cameras, 37.50% redraw it using the mouse and 6.25% use the touchpad to redraw. 31.25% stated that they do not digitize their scribbles.

6.5 Apparatus

The study was conducted on a GeForce GTX260 machine with 2×3.18 GHz and 4 GB RAM running 64 bit Windows 8. All experiments were performed using a 21.5"TFT DELL SX2210T monitor with a screen solution of 1920×1080. Additionally, the hardware setup contained a Bluetooth 4.1. adapter connecting two digital Anoto pens (ADP301). Each participant got a pile of *PECAN* paper covered with Anoto pattern (see Figure 4.8), which was placed first on the left side of the participants. Users were invited to create a comfortable setup for themselves (see Figure 6.2).

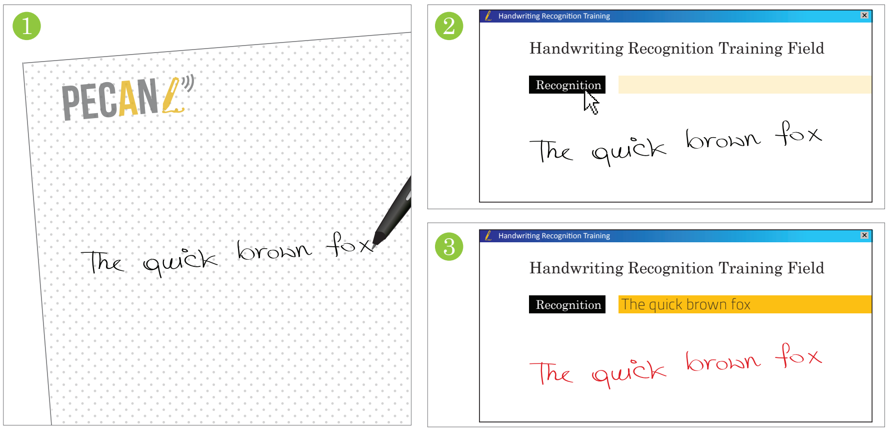


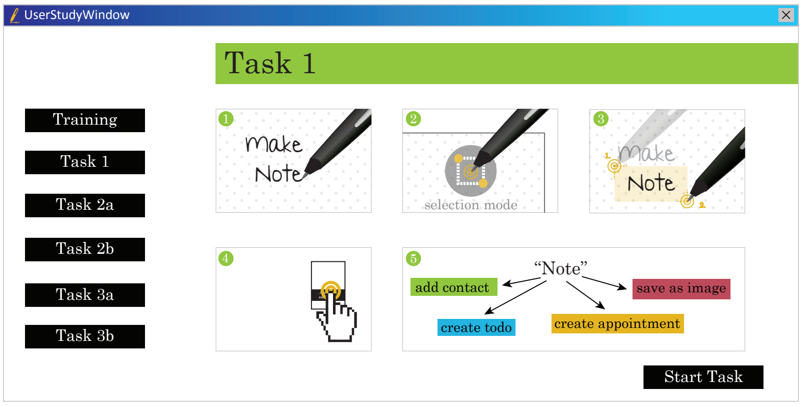
Figure 6.3: The *Handwriting Recognition Training* Application. (1) Paper Interface. (2) Application after Digital Pen Input. (3) Application after interpreting content.

Furthermore two Windows desktop application were implemented for the study. The first one, the *Handwriting Recognition Training* application (see Figure 6.3), was developed for the participants to get familiar with digital pens and handwriting recognition. Libraries and interaction possibilities were the same as used with *PECAN*. The application resembled an analog A4 paper displaying strokes and offering the possibility to analyze this notes using handwriting recognition. The analyzed content was displayed right on top of the application window.

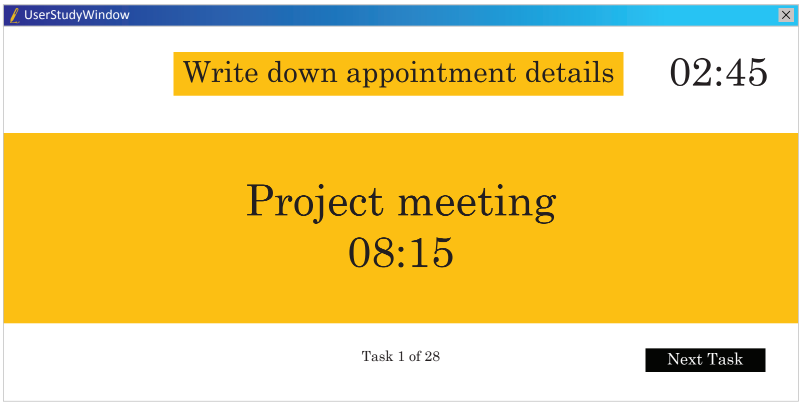
The *UserstudyControlCenter* application implemented logging mechanisms and displayed the instructions on the left side of the screen (see Figure 6.4). We implemented a button to navigate through the notes, and also the possibility of using the right arrow key. The study was conducted in a calm office environment with all external distractions like mobile phones, e-mail clients, etc. deactivated.

6.6 Procedure

The study consisted of five main blocks: introduction, training, *PECAN* performance tests, comparative tests, and conclusion. An overview about the five blocks is given in Appendix A. The study was completed in one session lasting approximately sixty minutes. Participants were guided through the study the full time by the study conductor, who was available at all time for any questions arising.



(a)



(b)

Figure 6.4: Interface User Study Control Centre. (a) *PECAN* performance tests: Start screen. (b) Comparative Tests: Content screen.

6.6.1 Introductory Block

At first participants were welcomed and introduced to their workspace. Participants were given a digital pen, which had to be used for the whole study. They were asked to position keyboard, mouse, chair, pen and the pile of paper, like they would use it in their office environment. Afterwards they had to sign a consent form and to fill out a short questionnaire about their analog and digital note taking habits.

After finishing the questionnaire, the study conductor gave them some short information about Anoto's technology. To get more familiar with the pen and its possibilities as well as with handwriting recognition, we introduced them to the *Handwriting Recognition Training* (see Figure 6.3). Participants were told to write down notes like their names, Arabic numerals and special characters to learn about how the handwriting recognition works best for them. They were also informed that the system was optimized for the English language. By writing down content on Anoto paper, the strokes were displayed within the application as shown in Figure 6.3. The content was analyzed by clicking either the button on the paper with the pen or by clicking the analyze button within the application. This first block lasted for approximately fifteen minutes.

6.6.2 Training Block

The second block consisted of a specific introduction and training of *PECAN*. First they were shown an info graphic (see Figure 6.4) explaining the basic workflow. As the participants clicked the selection mode buttons, they were told to listen to the sounds to make sure that their selection worked properly. By performing the workflow with the to-do type, the participants learned that they had to write down the text as it is displayed. If there was a type recognition error or a spelling error in the recognized text, the participants had to correct them. The appointment type was used to explain that the system currently has format requirements for dates and times. While the participants were writing down the given contact details, they were told to have a spacing of approximately $10mm$ in between the notes to avoid selection errors. This block lasted for approximately ten minutes.

6.6.3 *PECAN* Performance Tests Block

The *PECAN* Performance test block was quite similar to the Training block. The participants were now told that they had to finish each note type five times in total and that they had to finish each workflow cycle as fast and as accurate as possible. The experiment instructions were displayed in the *UserStudyControlCentre* window. For this, participants were prevented to continue to the next subtask, by disabling the next button, until they finished the current workflow cycle. Once they were done with this, they could either use the next subtask button or the right arrow key to move on. This block took approximately fifteen minutes to complete.

6.6.4 Comparative Tests Block

Each of the two workflows was performed once. This block lasted approximately seven minutes for each workflow and fourteen minutes in total. Both were executed in the following order as shown in Figure 6.5.

Writing Phase

For this part, participants got the instruction to write down as many appointments as possible within three minutes. They were also reminded that

Figure 6.5: The comparative tests were split up in four phases. (1) The Writing phase. (2) The Distraction phase. (3) The Adding phase. (4) The emotional state measurement phase.

Figure 6.6: This info graphic was shown to the participants to get distracted from the written appointments. It shows simple instructions of how to bath a parrot. First choose a warm and sunny day (1), then spray water on to the parrot (2), if he is fluttering, he likes it (3), let him air dry and clean himself (4) [31].

later on these notes had to be transferred to Microsoft Outlook either by using *PECAN* or by entering the appointment content manually. The notes had to be written down in order and they had to be readable afterwards. By hitting the 'start task button' the timer started and was displayed in the right top edge of the application window. Three minutes later the bell resounded to indicate the end of the subtask.

Distraction Phase

To make sure that the appointment details are not stored in short-term memory, participants had to go through a distractive exercise. They had about thirty seconds to look at info graphics. They were told to memorize the content and explain it to the study conductor afterwards.

The first info graphic was about how to poach an egg. The second one showed how to bath a parrot. Both graphics were taken out of the book 'Show me How- 500 things you should know' [31]. An exemplary info graphic is displayed in Figure 6.6.

Adding Phase

Next, they had to transfer the content to Microsoft Outlook either manually or by using *PECAN*. While performing the Traditional Workflow, participants had to click a button within the *UserStudyControlCentre* window to open the Microsoft Outlook appointment window.

Then they had to type in the content and click the save button in the end. For the *PECAN* Workflow, participants got the instructions to select a note first, then they had to quick check and correct the content delivered and lastly they had to save the appointment. After finishing one note, they started all over again. After two minutes the bell resounded again and participants had to finish adding the appointment they were currently working on.

Emotional State Measurement Phase

To asses the perceived workload experience for each workflow, participants were shown the NASA TLX questionnaire. The NASA TLX was used with a multidimensional rating scale. This includes six 20-point scales (mental demand, physical demand, temporal demand, performance, effort, frustration) and the weighting of the scales to compensate differences in the workload definition. The combination of the information on magnitude and the sources of each of the six factors offers the possibility to derive a sensitive and reliable estimate of workload [13].

6.6.5 Finishing Block

In the last block, participants were asked to fill out another questionnaire about their demographics, their digital pen and handwriting recognition experience and how they liked working with *PECAN*. They were also asked if they have any additional ideas, or feature requests for the application.

6.7 Measurements

This section gives an overview for each experiment about the collected data.

6.7.1 Trial Completion Times

The time for all experiments was recorded in milliseconds. For the *PECAN* Workflow the timer started on clicking the 'start task' or 'next task' button and ended when the workflow was fully performed by clicking 'create' or 'save as'. Concerning the comparative tests, Writing and Adding Phase were recorded differently. Time was restricted to three minutes for Writing Phase and two minutes for Adding Phase.

For both, the *PECAN* and the Traditional Workflow, the Writing Phase timer started for each trial by clicking the 'start task' or 'next task' button and ended when the participant hit the 'next task' or 'finish task' button. Adding Phase was recorded separately for the Traditional and the *PECAN* Workflow. The Traditional Workflow timer started by clicking the 'create appointment' button and ended on saving the note. For testing *PECAN* the timer started by hitting the select button and was completed on clicking 'create'.

Program 6.1: Minimum String Distance Implementation

```
public double GetMinimumStringDistance(string a, string b)
{
  for (int i = 0; i <= a.Length; i++)
  {
    valueMatrix.setValue(i, 0, i);
  }
  for (int j = 0; j <= b.Length; j++)
  {
    valueMatrix.setValue(0, j, j);
  }
  for (int i = 1; i <= a.Length; i++)
  {
    for (int j = 1; j <= b.Length; j++)
    {
      int value = Math.Min(valueMatrix.getValue(i - 1, j) + 1,
                  Math.Min(valueMatrix.getValue(i, j - 1) + 1,
                  valueMatrix.getValue(i - 1, j - 1) +
                  r(a.ElementAt(i - 1), b.ElementAt(j - 1))));
      valueMatrix.setValue(i, j, value);
    }
  }
  return valueMatrix.getValue(a.Length, b.Length);
}
```

6.7.2 Error Rates

The error rates were measured using the Levenshtein [20] Minimum String Distance (MSD) algorithm. This algorithm calculates the number of primitive operations, like substitutions, insertions or deletions, needed to transform the transcribed text to the presented text. William Soukoreff and Scott MacKenzie [28] propose a definition of the text entry error rate as depicted in Equitation 6.1. This algorithm divides the MSD value by the maximum denominator, and multiplies it by 100 percent to return the error rate as percentage value. We implemented the algorithm as presented in Program 6.1.

$$ErrorRate = \frac{MSD(A,B)}{\max(|A|,|B|)} \times 100\%. \tag{6.1}$$

This algorithm creates a matrix defined by two text entry strings. The computation starts in the top-left cell and fills the matrix sequentially. The final MSD value is in the right bottom cell. An exemplary calculation matrix of the MSD is visualized in Figure 6.7.

Presented Text

Transcribed Text	a	S	T	O	C	K	H	O	L	M	
b	0	1	2	3	4	5	6	7	8	9	
S	1	0	1	2	3	4	5	6	7	8	
H	2	1	1	2	3	4	4	5	6	7	
O	3	2	2	1	2	3	4	4	5	6	
D	4	3	3	2	2	3	4	5	5	6	
H	5	4	4	3	3	3	3	4	5	6	
O	6	5	5	4	4	4	4	3	4	5	
L	7	6	6	5	5	5	5	4	3	4	
M	8	7	7	6	6	6	6	5	4	3	← MSD

$$ErrorRate = \frac{2}{10} \times 100 = 20\%.$$

Figure 6.7: Minimal String Distance Calculation Example (top). Text entry error rate calculation (bottom) [32].

6.7.3 Perceived Workload

To measure the perceived workload, the participants were required to complete an online NASA TLX questionnaire [13]. For this, we used an already existing HTML and Javascript based online form [45], where we adapted the content to fit our needs. The data was sent to a local server using an Ajax call. A PHP script receives the data and saves it as a CSV (Comma-Separated Values) file. The formula for the calculation of the total workload takes the numeric rating for each category (0–100) and multiplies it by the number of times it was chosen on the task demand questionnaire. This product is calculated for each of the six categories, summed up and totally divided by fifteen (total number of weights). The final workload figure is a number between 0 and 100.

Chapter 7

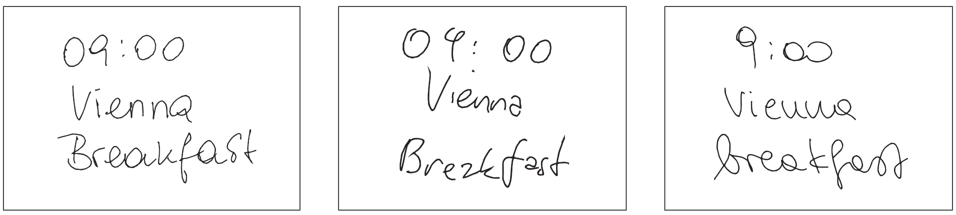
Results and Discussion

The first part of this chapter presents the quantitative results of the user study, which was evaluating *PECAN*. The methodology is described in Chapter 6 and the workflow design is covered in Chapter 4. The qualitative feedback of the participants is given in the second part of this chapter. The third part discusses the results.

7.1 Study Results

This section presents error rates, trial completion times, characters written per second, and the results of the work load rating. A significance level of $\alpha = 0.05$ was used for all statistical data. Trial completion time was recorded in milliseconds for precision, but is presented in seconds for better understanding. Three different types of errors were measured:

1. **Handwriting Recognition Errors** are presented as percentage of incorrectly identified letters. These errors are only considering the results of text input errors as with contact, appointment and to-do note types.



(a) (b) (c)

Figure 7.1: Handwriting examples (a) Participant 15: 0.0% errors, overall error rate for all notes M=1.33%, (b) Participant 4: 5.00% error rate ('9' was recognized as a '4'), overall error rate for all notes M=6.33%, (c) Participant 5: 15.00% error rate (no leading '0', and Vienna was recognized as 'Vieuua'), overall error rate for all notes M=8.87%.

6 different error categories were defined for better understanding of the handwriting recognition errors. Errors resulting out of non-recognizable handwriting were split up in text and number recognition errors. Handwriting samples along with the average handwriting recognition error rate are presented in Figure 7.1. Since the handwriting recognition used for *PECAN* is based on American language code to analyze the strokes and all of the participants were of Continental European origin, some of these errors can be lead back to differences in handwriting between America and Europe [38]. The other error categories are:

- **Capital Letters Errors:** The letter capitalization did not match the original string. These errors are measured separately because of its importance to the semantic analysis.
- **On Paper Correction Errors:** Spelling errors were corrected by scratching out note parts or by overwriting letters.
- **Note Selection Errors:** The selection bounding box was either to small to select all strokes, or too big and therefore intersecting with other notes.
- **Spelling Errors:** Simple spelling errors, where letters were left out or mixed up by the participant.

A visualization of these error categories is presented in Figure 7.2.

2. **Semantic Classification Errors** are presented as percentage of incorrectly identified note types.
3. **Final Result Errors** are the percentage of incorrect letters saved to the final Microsoft Outlook Item.

Errors were measured by comparing strings using the Minimal String Distance as described in Section 6.7.2. The work load was rated using the NASA Task Load Index (TLX).

7.1.1 Experiment 1: *PECAN* Performance Tests

This experiment measured the performance of *PECAN*, testing four different note types. *PECAN* is expected to perform accurate with an error rate less than 5% (*Hypothesis 1*).

Trial Completion Times

The average overall trial completion time for a full workflow was 33.8 seconds (SD = 13.7 s). This includes writing time (M = 18.2 s, SD = 8.2 s) with 1.15 characters written per second, selection time (M = 1.9 s, SD = 0.7 s), handwriting recognition analysis time (M = 0.3 s, SD = 0.2 s), semantic analysis time (M = 1.2 s, SD = 1.6 s), and content review time (M = 12.2 s, SD = 8.5 s) as depicted in Figure 7.3.

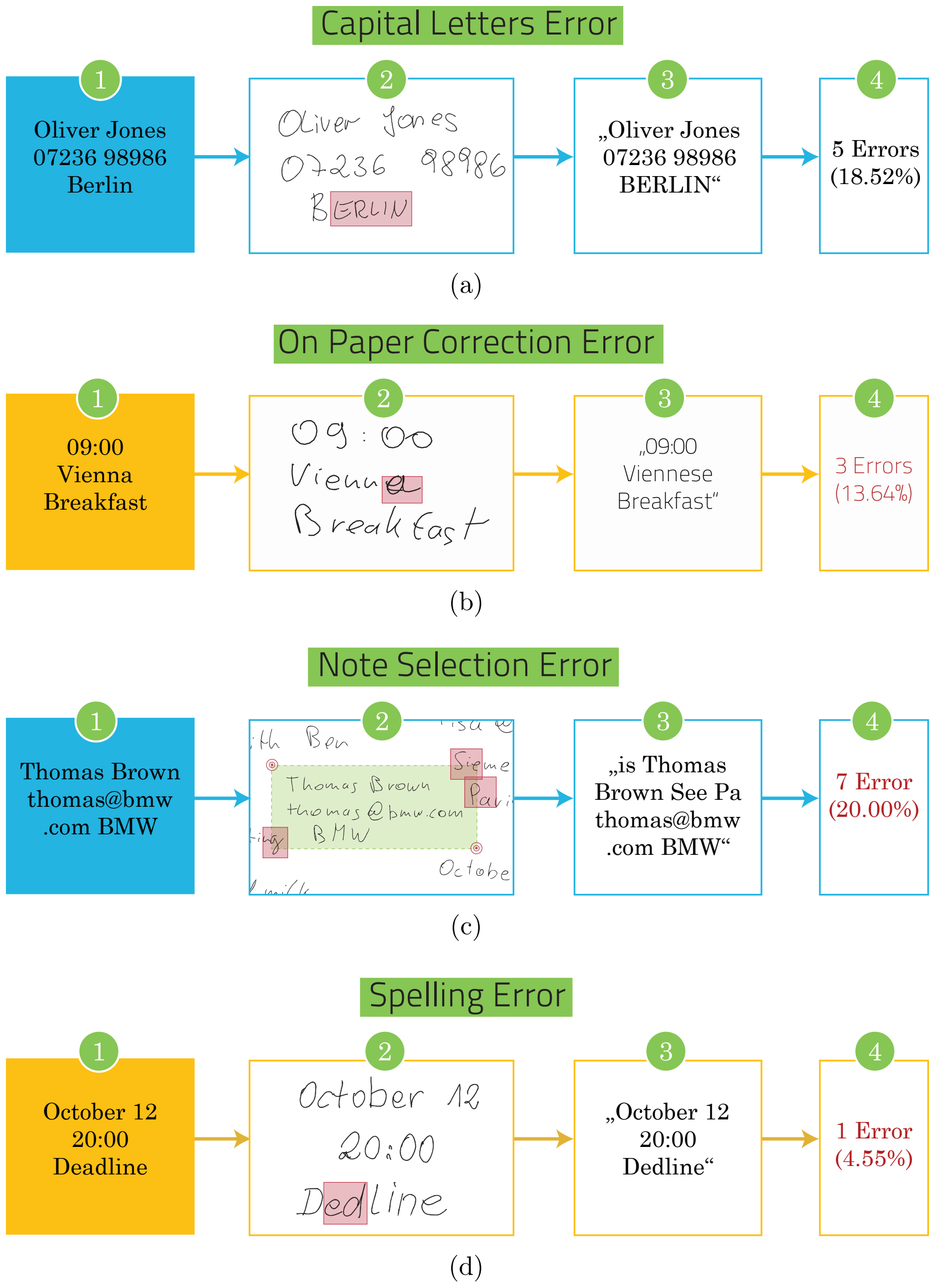


Figure 7.2: A visualization of the error categories: (1) shows the template text, (2) the actual written text by the participant, the error that has occurred is marked in red, (3) the text analysis result by the handwriting recognizer, (4) Minimum String Distance (MSD) error calculation (error percentage).

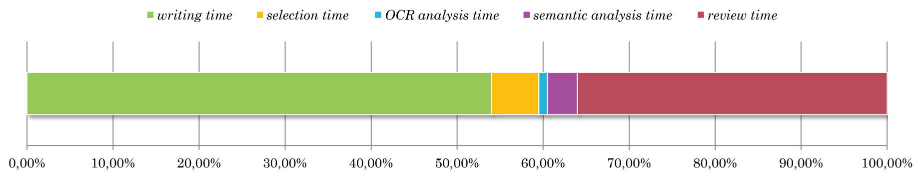


Figure 7.3: The average trial completion time for a full *PECAN* Workflow was 33.8 seconds. 53.98% were writing time, 5.54% selection time, 0.98% handwriting recognition time, 3.48% semantic analysis time and 36.04% content review time.

For the 4 different types, the overall trial completion times differed. On average the workflow for the Contact note type took 46.7 seconds ($SD = 12.9$ s), for the Appointment 35.9 seconds ($SD = 12.6$ s), To-Do 26.1 seconds ($SD = 8.4$ s) and Scribble 26.5 seconds ($SD = 8.9$ s).

The writing time was directly related to the amount of characters to write. On average it took participants 27.2 seconds ($SD = 6.9$ s) for the Contact note type, 19.7 seconds ($SD = 6.2$ s) for Appointments, 15.7 seconds ($SD = 4.9$ s) for To-Dos, and 10.4 seconds ($SD = 3.2$ s) for scribbles. The normalized data to characters per second showed almost no difference in writing speed between the types (Contact: $M = 1.17$ char/s, Appointment: $M = 1.19$ char/s, To-Do: $M = 1.11$ char/s).

Over 50% of the working time for one note is used for the handwriting part. We observed that participants were especially concerned about the handwriting recognition. This slowed down the note taking process. Selection time, handwriting recognition analysis time and semantic analysis time did not have a major impact on the overall time as expected. Since the content is processed on the fly, it needs about 3 seconds for every note. This can be improved by preprocessing the notes. The review process took about 36% of the time, because participants rechecked every letter and corrected them if they were mistaken. Error corrections cost a lot of time, and therefore offer great improvement possibilities.

Error Rates

The overall error rate of the handwriting recognition was 3.97% ($SD = 6.76\%$). The semantic classification error rate was 5.63% including the scribble note type. By only considering textual input note types the semantic classification error rate was 2.92%. The error rate for contact note types was 5.39% ($SD = 7.46\%$), for appointments 3.54% ($SD = 5.9\%$) and for to-dos 2.99% ($SD = 6.67\%$). These results are supporting *Hypothesis 1* ('*PECAN* classifies casual notes correctly in more than 95% of the use cases.').

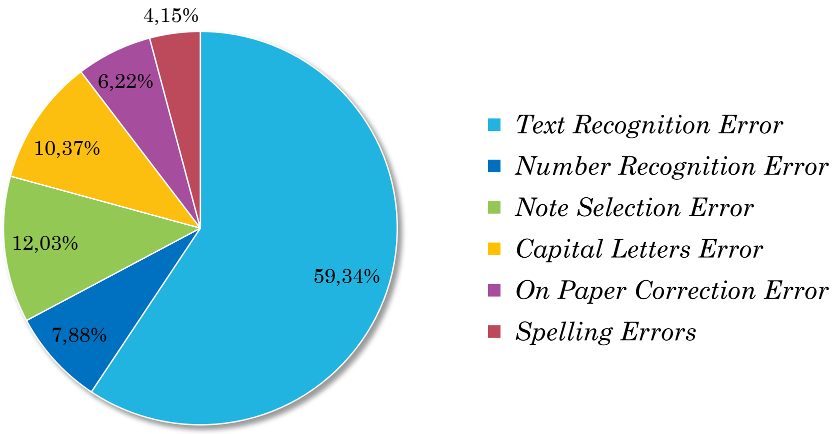


Figure 7.4: The handwriting recognition errors were split up in 6 categories to get a better understanding for the cause of the errors. Text recognition errors (59.345%). Number recognition errors (7.88%). Note selection errors (12.03%). Capital letters errors (10.37%). On paper correction errors (6.22%). Spelling errors (4.15%).

The handwriting recognition errors were analyzed and categorized as shown in Figure 7.4. 61.22% of the handwriting recognition errors were only due to number or text recognition failures, 38.78% of the handwriting recognition errors were based on inaccurate user input or faulty user interaction with the paper. Semantic errors were retraceable and were due to incorrect text recognition.

7.1.2 Experiment 2: Comparative Tests

The comparative tests were divided in the Writing, Adding and Emotional State Measurement phase. This experiment measured all phases separately. First we will present the overall times for the writing and adding phase and we will have a deeper look into all phases individually. For the writing and adding phase, *PECAN* was expected to be faster (*Hypothesis 2*) than the Traditional Workflow. Additionally, it was expected that the results of the adding phase are more accurate by using *PECAN* (*Hypothesis 3*). The work load is expected to be less exhausting while using *PECAN* (*Hypothesis 4*).

Overall Comparison

For comparing the overall trial completion times, we summed up the separately measured writing and adding times. On average it took 29.2 seconds

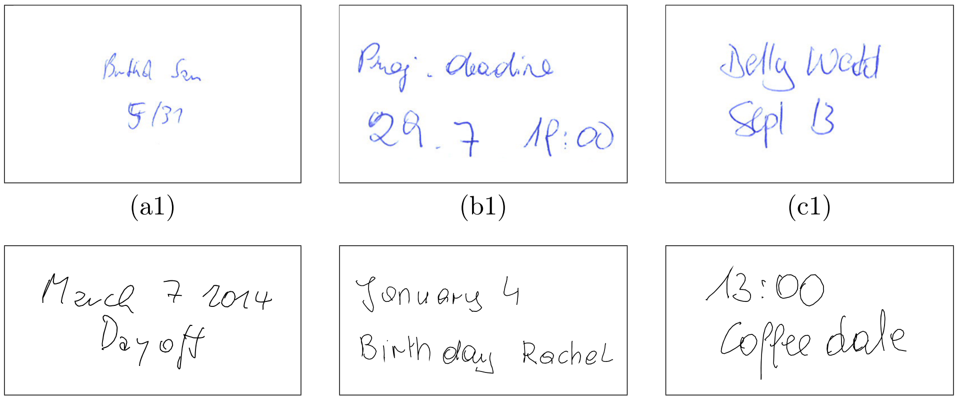
($SD = 4.1$ s) to write and add the appointments with the Traditional Workflow and 30.2 seconds ($SD = 2.9$) with *PECAN*. There was no significant difference in trial completion times between the two workflows detectable, $t_{15} = 1.24, p = 0.118$. However, these results are rejecting *Hypothesis 2* ('The *PECAN* Workflow is faster than the Traditional Workflow'). We suspect that this was due to longer writing times, because participants were concerned about correct interpretation of the handwriting recognition and they made more effort in writing machine readable. To investigate *Hypothesis 2* more, we took a closer look at all phases separately.

Writing Phase

The performance measurement results show that the writing time of the Traditional Workflow was on average 11.1 seconds ($SD = 1.6$ s) for one note, with 1.91 characters written per second ($SD = 0.33$). The average times of *PECAN* was 14.3 seconds ($SD = 2.6$ s), resulting in 1.45 characters per second ($SD = 0.26$). Furthermore, the total note completion was 17.13 notes ($SD = 2.6$) for the Traditional Workflow and 13.44 notes ($SD = 2.28$) for *PECAN* within 3 minutes. The analysis showed a main effect for, the trial completion time, $t_{15} = 6.42, p < .001$, the characters per second, $t_{15} = 7.31, p < .001$, and the amount of notes completed, $t_{15} = 6.95, p < .001$.

Looking at the actual notes on paper, we found that 9 participants used abbreviations (see Figure 7.5 for samples) during the Traditional Workflow. By comparing the characters written per second for participants without abbreviations, a significant difference was still found, $t_7 = 5.09, p < .01$ with $M = 1.78$ characters per second ($SD = 0.23$) for the Traditional Workflow and $M = 1.36$ characters per second ($SD = 0.34$) to the *PECAN* Workflow. Participants using abbreviations were also significantly faster, $t_9 = 5.48, p < .001$ with $M = 2.02$ characters per second ($SD = 0.37$) for the Traditional Workflow and $M = 1.48$ characters per second ($SD = 0.18$) for the *PECAN* Workflow. The time to write a note without abbreviations ($M = 11.95$ s, $SD = 3.03$ s) was longer than for shortened notes ($M = 10.76$ s, $SD = 1.48$ s). On average, participants completed 1.49 more notes by using abbreviations. The characters written per second, presented in Figure 7.6, show that participants, who were shortening their notes, were faster in terms of writing speed (0.24 char/s) for the Traditional Workflow, but surprisingly also slightly faster for *PECAN* ($M = 0.12$ char/s).

As a matter of fact, the Traditional Workflow was faster for the writing phase than *PECAN*. Therefore *H2* must be rejected for the Writing phase. However, we suspect that this is due to confidence issues in the handwriting recognizer. We observed that some participants wrote more narrow and smaller letters with the Traditional Workflow. For *PECAN* they tried to write with a nice handwriting to be machine-readable.



(a1) (b1) (c1)

(a2) (b2) (c2)

Figure 7.5: Handwriting samples for the comparative tests. Abbreviation examples for the Traditional Workflow (upper part): (a1) Participant 4: Birthday Sam May 31 (M = 2.43 char/s, SD = 0.51), (b1) Participant 9: Project deadline July 29 19:00 (M = 1.59 char/s, SD = 0.38), (c1) Participant 12: Betty Wedding September 13 (M = 1.85 char/s, SD = 0.37). Handwriting examples for the *PECAN* Workflow (lower part): (a2) Participant 4: March 7 2014 Day off (M = 1.64 char/s, SD = 0.19), (b2) Participant 9: January 4 Birthday Rachel (M = 1.50 char/s, SD = 0.16), (c2) Participant 12: 13:00 Coffee date (M = 1.39 char/s, SD = 0.17).

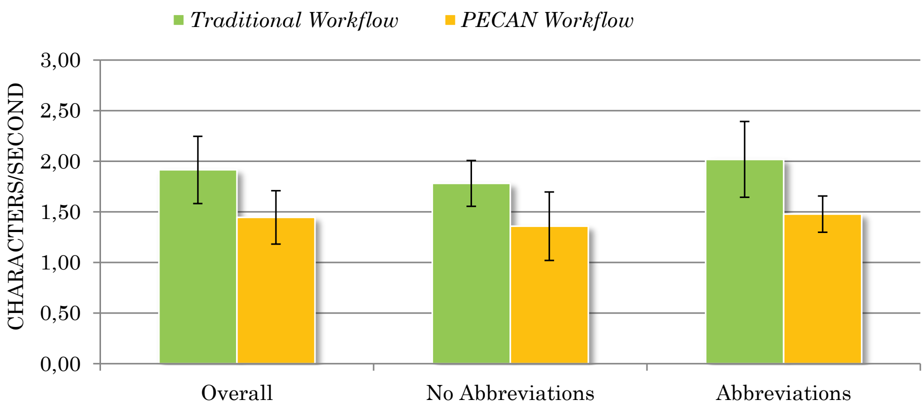


Figure 7.6: Characters written per second as part of the writing phase. The graph shows the values of the overall performance (left), the performance of the participants without abbreviations (middle) and the performance of participants using abbreviations (right). Errors bars show standard error.

Adding Phase

On average it took 18.1 seconds (SD = 3.9 s) to add an appointment to Microsoft Outlook typing in the content all manually (about 7 appointments).

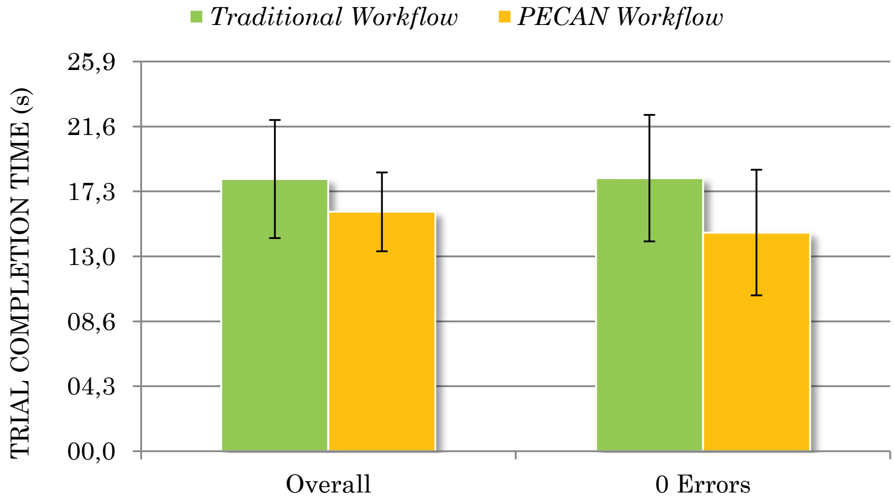


Figure 7.7: The graph shows the overall trial completion time for adding notes to Microsoft Outlook (left) and the average trial completion time for all notes added without an handwriting recognition error (right). Errors bars show standard error.

It was 15.9 seconds ($SD = 2.6$) by using *PECAN*, adding 8.5 appointments. A significant main effect for adding time, $t_{15} = 2.40, p < .05$ and total note completion, $t_{15} = 3.67, p < .01$, was found supporting *Hypothesis 2* ('*PECAN* Workflow is faster than the Traditional Workflow') in contradiction to the Writing phase. The average handwriting recognition error rate of *PECAN* was 6.99%. The analysis of the final data saved to Microsoft Outlook showed no main effect for the error rate, $t_{15} = 0.007, p = 0.497$. The error rate with the *PECAN* Workflow was slightly higher ($M = 1.86\%$, $SD = 0.06\%$) than with the Traditional Workflow ($M = 1.85\%$, $SD = 0.061\%$). Since there was no significant difference in the final results error rate, *Hypothesis 3* ('According to the final digital note contents *PECAN* is more accurate than the Traditional Workflow.') must be rejected.

Further analysis of the *PECAN* Workflow data, by only considering the results of a faultlessly working system, with 0 handwriting recognition errors, is once again proving the theory of *Hypothesis 2* and shows an even better adding time ($M = 14.5$, $SD = 4.2$) and a significant difference to the Traditional Workflow, $t_{13} = 2.30, p < 0.05$. Trial completion times are presented in Figure 7.7.

For further investigation and improvement of *PECAN* we split up the total working time as shown in Figure 7.8. The start time ($M = 3.5$ s, $SD = 3.9$) indicates the time participants needed to start selection. Selection time ($M = 1.9$, $SD = 1.4$), handwriting recognition analysis time ($M = 0.3$s,

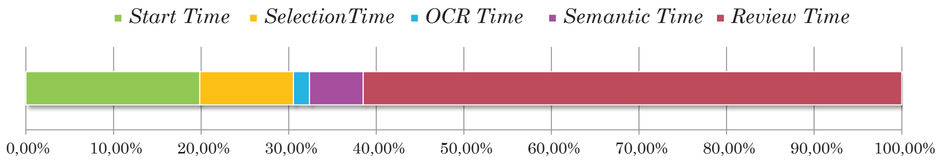


Figure 7.8: The average trial completion time for the adding phase of the *PECAN* Workflow was 17.8 seconds. 3.5 seconds (19.84%) were trial starting time until the content selection, 1.9 seconds (5.54%) selection time, 0.3 seconds (1.82%) handwriting recognition time, 1.1 seconds (6.13%) semantic analysis time and 10.9 seconds (61.51%) content review time.

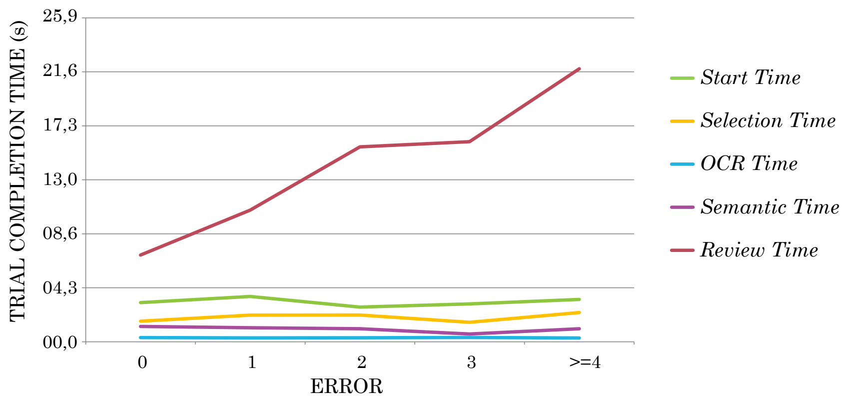


Figure 7.9: The *PECAN* adding phase split up to the different workflow steps, showing the average time by number of errors. Only the content review time is strongly affected by the number of errors as shown in this graph.

SD = 0.1s) and semantic analysis time (M = 1.1 s, SD = 1.3 s) are equal to the *PECAN* performance tests (see results of the performance tests in Subsection 7.1.1). The average time needed to review the content (10.9 s, SD = 6.8 s), was 2 seconds faster than for the performance tests. Review time also depended on the number of handwriting recognition errors in one trial. The time needed to check the content is increasing with the number of errors as shown in Figure 7.9, until it remains static. This is because participants tended to clear inaccurate strings at a certain level and type it all again. Start time, selection time, handwriting recognition time and semantic analysis time are not affected by the errors.

The general error type distribution is comparable with the *PECAN* performance tests errors. The main sources of errors were handwriting recognition errors, with 46.71% text recognition errors and 22.1% number recognition errors. 4.79% were content selection errors, 14.97% capital letter errors,

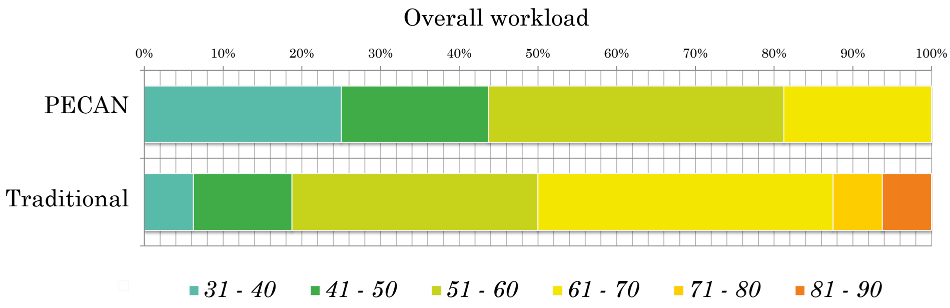


Figure 7.10: Overall Workload of the two workflows, obtained through the Nasa TLX questionnaire.

4.19% on paper correction errors and 7.19% spelling errors. The handwriting recognition error rate was 7.03% and the semantic type correctness showed an error rate of 6.62%.

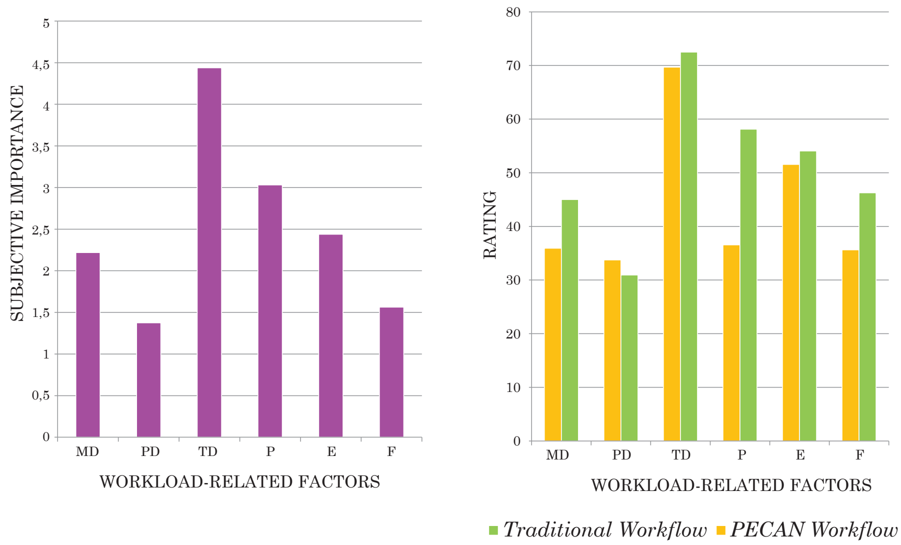
Emotional State Measurement Results

The NASA TLX questionnaires were used to assess participant's subjective workload. To determine if the workload differed significantly between the two workflows the overall workload for each participant was calculated (see Figure 7.10) using the rating of the subjective importance of the categories (see Figure 7.11 a) and the average subjective rating (see Figure 7.11 b).

This was showing a significantly lower workload for the use of the *PECAN* Workflow, $t_{15} = 2.29, p < 0.05$. To determine, which attributes caused this difference in workload, six paired sample t-tests were performed, one for each category. These showed that participants had recorded significantly lower mental demand ($t_{15} = 1.858, p < 0.05$) and a better task performance ($t_{15} = 3.326$, p<0.05) for the *PECAN* Workflow, which is very encouraging and showing that users had the feeling that they can work well with *PECAN*. The tests for physical demand ($t_{15} = 0.816$, $p = 0.214$), temporal demand ($t_{15} = 0.789$, $p = 0.221$), effort ($t_{15} = 0.502$, $p = 0.312$) and frustration ($t_{15} = 1.618$, $p = 0.063$) were not significant. A graphical summary of these results is shown in Figure 7.12.

7.1.3 Summary

The data for the *PECAN* performance tests showed that trial completion times were strongly depending on the number of characters to write for each note type. This was similar for all types with 1.15 characters/second. The most time consuming parts of the workflow were identified as the writing phase and especially the review phase. There was no learning curve de-



(a) (b)

Figure 7.11: Ratings of the perceived workload. (a) Rated importance of workload related factors. (b) Average subjective ratings.

tectable. The handwriting recognition error rate and semantic classification error rate are summarized in Table 7.1.

Error Rate	Contact	Appointment	To-Do	Scribble
Handwriting Recognition	5.39% (7.46)	3.54% (5.89)	2.99% (6.67)	
Semantic Analysis	2.50%	5.00%	1.25%	13.75%

Table 7.1: Handwriting recognition error rate and semantic classification error rate, showing mean (standard deviation).

The quantitative data collected for the comparative tests experiment is showing a statistically significant difference for all 3 phases. For the writing phase the Traditional Workflow was significantly faster (1.91 characters/second) than *PECAN* (1.45 characters/second). *PECAN* performed better for the Adding phase. Participants were faster and were able to create more notes (M = 8.50, SD = 1.51) than the Traditional Workflow (M = 7.00, SD = 1.75). Furthermore, *PECAN* Workflow was rated with the lowest workload. The final results error rate showed no statistical significance. Trial completion times and the overall workload are summarized in Table 7.2.

Figure 7.12: Ratings in the NASA TLX survey assessing six workload related factors (*mental demand, physical demand, temporal demand, performance, effort, frustration*) using the *PECAN* Workflow and the Traditional Workflow.

Phase	Traditional WF	*PECAN* WF	t_{15}	p
Writing	11.1 sec (1.6)	14.3 sec (2.6)	6.42	0.000
Adding	18.1 sec (3.9)	15.9 sec (2.6)	2.40	0.015
Workload	58.65 (11.50)	51.73 (11.57)	2.29	0.018

Table 7.2: Trial completion times and the overall workload (NASA TLX) for the comparative tests per phase, showing mean (standard deviation).

7.2 Subjective Feedback

After finishing both experiments, participants were asked to complete a questionnaire about their experiences with *PECAN*.

7.2.1 Participants Rating

First, participants had to rate the usability of *PECAN* based on a 5-point Likert scale. These results are presented in Figure 7.13. Generally speaking, we can conclude that the participants liked to interact with *PECAN*. 68% agreed that it was comfortable to use, and everybody found it easy to learn and easy to use as well. 75% of the participants stated that they had fun while using this tool. But only 19% stated that they found it more time consuming than the Traditional Workflow, which is interesting because the overall trial completion time for the writing part was 3.2 seconds less for the Traditional Workflow, and during the adding phase *PECAN* was only 2.2 seconds faster. Besides that, 75% of the participants felt supported and 63% would be using *PECAN* as note taking tool in their office environment.

7.2.2 Participants Feedback

Next, we were asking about the problems participants encountered while using *PECAN*. 43.75% stated that they had troubles with the error rate of the handwriting recognition and that they had to proofread and correct the contents afterwards. 31.25% of the participants found the thickness of the pen unpleasing. The frequent transition between pen and mouse was also considered by 12% to be disturbing. This was also observed during the study where may participants had issues by handling pen and mouse at the same time. All participants were using the same hand for handling the mouse and the pen. Therefore most participants ended up with both object in their hand as demonstrated in Figure 7.14.

Furthermore, one participant stated that the integration into *OneNote* would be suitable for him. Two participants said that they would like to use it

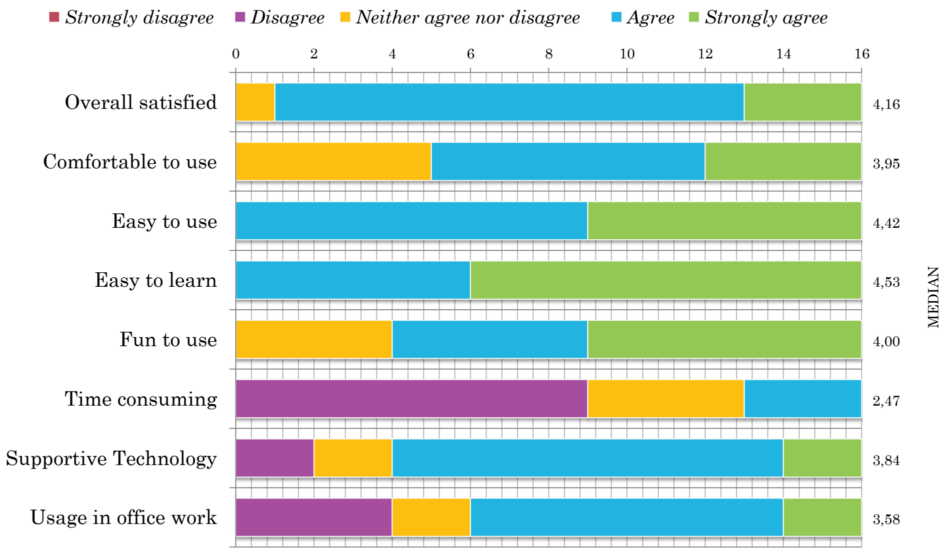


Figure 7.13: The post-study questionnaire ratings on the usability of *PECAN*.

for meetings to have a log afterwards. One person suggested the introduction of lists, and two others requested the use of only textual notes.

3 participants stated that they would like to have the contents pasted to their clipboard to have the note more generally available. Additional features requested by two participants were a solution for handling incorrect strokes and better selection techniques, to avoid selecting strokes that are close by, but not meant to be part of the note. One Participant also stated that he got confused when note type was not the one he had expected. Besides that, Two participants also stated that they liked they minimalist design of the application, but three of them also criticized small font size, which was not easily readable for them.

7.3 Discussion

Summarizing experiment one, we can say that *PECAN* was satisfying our expectations, concerning the correct identification of notes. It is very encouraging that even though we used a system, which was optimized for American handwriting in an European context, *Hypothesis 1* was confirmed. All note types except the scribble note type, which was a non-textual note type, had a correct classification rate of over 95%. The scribble type, which was only fleetingly covered for the *PECAN* project showed a quite high classification error rate ($M = 13.75\%$). Since the focus was on textual notes, this

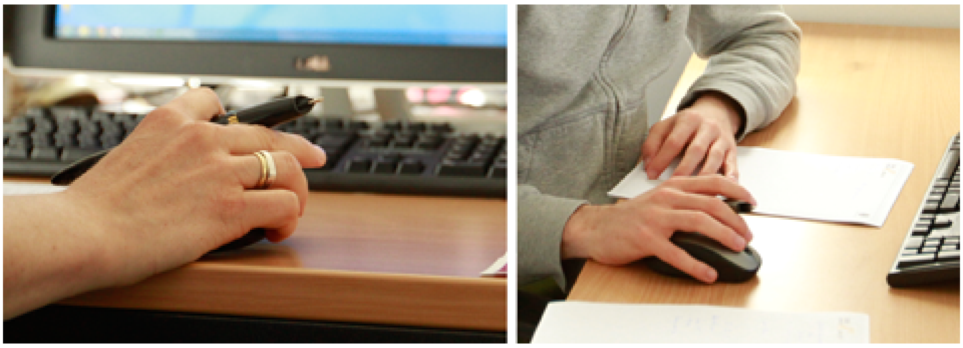


Figure 7.14: One major problem encountered by the participants while working with *PECAN*: The thickness of the pen and the combined usage of mouse and pen at the same time.

is not an important factor. However, there is great room for improvement by introduction algorithms for image and text differentiation, for instance the hierarchical framing process [4], Boundary Detection [27] the white-tiles approach [1].

The classification error rate is also highly depended on the handwriting recognition error rate, which was also one of the main problems of *PECAN* stated by the participants. This might be improved by using more state-of-the-art handwriting recognition techniques adapted to the handwriting characteristics of the target population. Another improvement factor is the reduction of user errors like stroke selection or on paper correction. This can be improved by introducing stroke clustering or by offering possibilities to edit strings.

Apart from that, our second hypothesis regarding the performance of *PECAN* in comparison with a Traditional Workflow had to be partly rejected. It was highly significant that for the writing phase, participants were faster under the Traditional Workflow condition. This may be because for the *PECAN* Workflow participants always had to consider that the content needs to be machine readable, so they wrote as accurate as possible, in contrast to the Traditional Workflow, where the contents only needed to be in humanly-readable style. While transferring the notes, participants also could work content aware, which means that it is not required to have a 100% readability to still transfer the contents correctly. However, sometimes participants also complained during the adding phase that their notes are hardly readable. This arises the question if it is still readable for them in a day or two, despite the fact that the lifespan of casual notes is quite short, their readability should be guaranteed. It was also observed that participants (about 56%) tended to use abbreviations especially for dates and common event types like 'Wedding' was shortened with 'Wed.' or 'Family' with 'Fam.'. There were also differences between the target groups, especially administrative people used abbreviations for their every day activities (e.g.: 'Jour fixe' was 'JF'). Abbreviations are not available with *PECAN* yet, but it would be possible to use an automatic detection of common abbreviations [35] and user defined abbreviations.

However, according to the analysis of the adding phase, participants were significantly faster here, even though there was still a certain error quote and they had to correct the analysis afterwards. The time needed to review a 100% correctly analyzed note shows an even better Trial completion time. These results are very promising and thus, we conclude that our expectations were confirmed. Therefore we can state that *PECAN* offers a fast approach to digitize and classify casual notes.

Given the facts we can see that overall the Traditional Workflow was still faster for the participants. Even though the adding phase was faster with the *PECAN* Workflow. By having a deeper look into the review times of *PECAN*, we found out that the content review time is consuming most of the time needed to add an appointment, because participants do not fully trust in handwriting recognition. The review time was increasing with the number of errors. To reduce the review time it would be necessary to, on the one hand, reduce the basic review time by improving the UI with an adaption of font size and more clear arrangements, and on the other hand reducing the cost of error correction by adding spell correction, or by validating the contents, e.g. e-mail addresses, zip codes, etc. According to the post-questionnaire, participants did not find that the *PECAN* Workflow was generally slower than the Traditional one. This might be, because they finished the adding phase more successfully, and this was the main interaction part with the digital device.

The third hypothesis, that the *PECAN* Workflow is more accurate than the Traditional Workflow, was rejected because there was no main effect and the average error rates were only slightly different.

The results for *Hypothesis 4* showed positive results for the overall workload in favor of *PECAN*. Specifically, the results indicated for five of the six scales that the Traditional Workflow had a higher workload, except the physical demand was rated higher for *PECAN*. As participants were asked for the importance of the work-related factors, physical demand was lowest, so it had no direct influence on the total workload.

The general feedback on *PECAN* was also very encouraging, because it states the general usability was working for the users, and they were also feeling supported by the technology.

Chapter 8

Conclusion and Future Work

This thesis introduces *PECAN*, a tool that combines the advantages of physical paper interfaces with digital processing benefits. *PECAN* captures analog notes selectively. These notes are processed using handwriting recognition and web API to extract semantic contents. A set of rules classifies the note and on user confirmation, the content is forwarded directly to Personal Information Management Tools (e.g. Microsoft Outlook). This work describes the method, concepts and implementation details of *PECAN*. An empirical laboratory study was conducted to investigate the performance of the technology. Furthermore, *PECAN* was compared with the Traditional Workflow of manual copying notes. The study was presented in detail, as well as results and a discussion. The results revealed that *PECAN* performs with an accuracy of 95%, with a high chance of improvement by implementing more advanced technologies. Moreover, we found that participants were writing faster without having a handwriting recognition system in mind, but *PECAN* showed major improvements in terms of speed when adding the note to Microsoft Outlook. Participants also rated *PECAN* with a lower overall workload. The final questionnaire showed a general satisfaction with the tool and 10 out of 16 participants would be using *PECAN* to support their everyday office work.

Given the results of the user study, we are even more motivated to adapt the current system with the insights we achieved and to investigate new ways to improve user experience. For example, there is huge space for improvement, concerning technology. The implemented handwriting recognition worked well for our purpose and proves the concept. However, for a satisfying high end product, the error rate was still too high and the handwriting recognition worked insecurely. The handwriting recognizer should especially be adaptable to the regional and personal handwriting style. For this we recommend the usage of state of the art handwriting recognition technology. The semantic analysis can be further improved by introducing multiple semantic web APIs specialized on Named Entity Recognition. The errors made by the handwriting recognizer are quite costly and annoying for the users to correct. Currently these errors are corrected by user interference. Correct recognition is defined as what the user intends, and this is very hard to achieve [22]. For this concern automatic error correction would be desirable to give users a choice of different possible interpretations. This might be realized by introducing a simple spell check, or going even further by rechecking mail address, telephone numbers, addresses, names, etc. by e.g. Google search appearance ranking. This information can be displayed by giving the user repetition and choice mediation techniques as proposed by Mankoff et al. [22] or by using Chang et al.'s [7] fluid negotiation. Furthermore, the application also requires a possibility to select multiple notes at once to speed up the digitizing process. One possible solution for this would be to cluster notes by proximity and by time. During the study we also experienced that participants liked to use abbreviations. Therefore a desirable feature could be to support adaptable abbreviations personalized for each user. Finally a field study could evaluate the actual applicability of *PECAN* in a real world scenario.

Appendix A

Study Material

A.1 Consent Form

Einverständniserklärung

Studie zur Untersuchung von „PECAN"

Bitte lesen sie sich dieses Dokument sorgfältig durch und wenden Sie sich bei möglichen Fragen direkt an die Untersuchungsleiterin Eva-Maria Schwaiger.

Alle von Ihnen erhobenen Daten werden vertraulich behandelt. Nur die Mitglieder des Projektteams haben Zugang zu den von Ihnen erhobenen Daten. Die Darstellung der Untersuchungsergebnisse erfolgt ausschließlich in anonymisierter Form. Personen-bezogene Informationen werden, falls erforderlich, so verändert, dass keine Rückschlüsse auf die Ursprungsperson möglich sind.

Ihre Teilnahme an der Untersuchung ist freiwillig. Sie können die Bereitschaft zur Teilnahme jederzeit widerrufen beziehungsweise die Teilnahme an der Untersuchung abbrechen.

Durch Ihre Unterschrift erklären Sie, dass Sie freiwillig an der Untersuchung teilnehmen und dass Sie den Inhalt der Einverständniserklärung gelesen und verstanden haben.

Bei Fragen zur Untersuchung und zu Ihren Rechten als Untersuchungsteilnehmer stehen Ihnen die Untersuchungsleiterin Eva-Maria Schwaiger (eva-maria.schwaiger@fh-hagenberg.at), sowie Dr. Michael Haller (michael.haller@fh-hagenberg.at) gerne zur Verfügung.

□ Ich erkläre mich einverstanden, dass Fotos der Studie in wissenschaftlichen Publikationen verwendet werden.

Name, Datum, Unterschrift

A.2 Questionnaires

Nummer Datum

Fragebogen über das Notizverhalten am Arbeitsplatz

1. Wie häufig machen Sie sich folgende Notizen?
   (1 = sehr selten, 5 = sehr häufig)

	-- (1)	- (2)	o (3)	+ (4)	++ (5)
Kontaktdaten(Namen, Telefonnummern, Adressen)	☐	☐	☐	☐	☐
Termine	☐	☐	☐	☐	☐
To Do's	☐	☐	☐	☐	☐
Skizzen	☐	☐	☐	☐	☐
Ideen	☐	☐	☐	☐	☐
Entscheidungen	☐	☐	☐	☐	☐
Zusammenfassungen	☐	☐	☐	☐	☐

Anmerkungen:

___

2. Welche Tools verwenden sie derzeit um sich am Arbeitsplatz Notizen zu machen?

☐ Papier und Stift ☐ PC ☐ Smartphone ☐ Tablet (iPad,...)
☐ sonstiges: ___

3. Wie oft verwenden sie das Medium Papier als Notizhilfe in ihrem Büroalltag bei folgenden Aktivitäten:
   (1 = sehr selten, 5 = sehr häufig)

	-- (1)	- (2)	o (3)	+ (4)	++ (5)	nie
Telefonat	☐	☐	☐	☐	☐	☐
Spontane Gedanken notieren	☐	☐	☐	☐	☐	☐
Skizzen zeichnen	☐	☐	☐	☐	☐	☐
Geschäftliches Gespräch 1:1 (2 Beteiligte)	☐	☐	☐	☐	☐	☐
Meeting (mehrere Beteiligte)	☐	☐	☐	☐	☐	☐
Vortrag (Zuhörer)	☐	☐	☐	☐	☐	☐

Anmerkungen:

___

___

4. Wie oft verwenden sie das Medium Computer als Notizhilfe in ihrem Büroalltag bei folgenden Aktivitäten:
(1 = sehr selten, 5 = sehr häufig)

	-- (1)	- (2)	o (3)	+ (4)	++ (5)	nie
Telefonat	☐	☐	☐	☐	☐	☐
Spontane Gedanken notieren	☐	☐	☐	☐	☐	☐
Skizzen zeichnen	☐	☐	☐	☐	☐	☐
Geschäftliches Gespräch 1:1 (2 Beteiligte)	☐	☐	☐	☐	☐	☐
Meeting (mehrere Beteiligte)	☐	☐	☐	☐	☐	☐
Vortrag (Zuhörer)	☐	☐	☐	☐	☐	☐

Anmerkungen:

____

____

5. Wie oft verwenden sie Mobile Geräte (Tablet PC, Smartphone,..) als Notizhilfe in ihrem Büroalltag bei folgenden Aktivitäten:
(1 = sehr selten, 5 = sehr häufig)

	-- (1)	- (2)	o (3)	+ (4)	++ (5)	nie
Telefonat	☐	☐	☐	☐	☐	☐
Spontane Gedanken notieren	☐	☐	☐	☐	☐	☐
Skizzen zeichnen	☐	☐	☐	☐	☐	☐
Geschäftliches Gespräch 1:1 (2 Beteiligte)	☐	☐	☐	☐	☐	☐
Meeting (mehrere Beteiligte)	☐	☐	☐	☐	☐	☐
Vortrag (Zuhörer)	☐	☐	☐	☐	☐	☐

Anmerkungen:

____

____

6. Welches Medium um Notizen zu machen bevorzugen sie üblicherweise für folgende Aktivitäten? *(nur eine Auswahl pro Zeile möglich)*

	Papier	PC	Portables Gerät (Smartphone, Tablet)	Keines
Telefonat	☐	☐	☐	☐
Spontane Gedanken notieren	☐	☐	☐	☐
Skizzen zeichnen	☐	☐	☐	☐
Geschäftliches Gespräch 1:1 (2 Beteiligte)	☐	☐	☐	☐
Meeting (mehrere Beteiligte)	☐	☐	☐	☐
Vortrag (1 Vortragender – mehrere Zuhörer)	☐	☐	☐	☐

Anmerkungen:

___

___

7. Wie digitalisieren sie üblicherweise handschriftliche Notizen, die sie wiederverwenden möchten? *(Mehrfachauswahl möglich)*

☐ Abtippen
☐ Abfotografieren mit Smartphone Kamera
☐ Abfotografieren mit Compact/SLR Kamera
☐ Digitaler Stift
☐ Scanner
☐ Ich digitalisiere keine Notizen.

☐ sonstiges: ___

8. Wie digitalisieren sie üblicherweise Skizzen? (*Mehrfachauswahl möglich)*

☐ Digitaler Stift
☐ Scanner
☐ Neu zeichnen Grafiktablet
☐ Abfotografieren mit Smartphone Kamera
☐ Abfotografieren mit Compact/SLR Kamera
☐ Ich digitalisiere keine Skizzen.
☐ Neu zeichnen mit Maus
☐ Neu zeichnen mit Touchpad
☐ Neu zeichnen mit Tablet(iPad,...) via Touch
☐ Neu zeichnen mit Tablet(iPad,...) via Stylus

☐ sonstiges: ___

9. Allgemeine Anmerkungen:

___

Vielen Dank

Nummer Datum

Fragebogen zur Verwendung von *PECAN*

1. Allgemeines

Alter: ___________

Geschlecht: ☐ Männlich ☐ Weiblich

Beruf ___________________________

Muttersprache: ☐ Deutsch ☐ English ☐ Andere ___________________________

Schreibhand ☐ Links ☐ Rechts

2. Computer Nutzung

Welches Betriebssystem verwenden sie hauptsächlich:

☐ Microsoft Windows ____ ☐ Mac OSX ☐ Andere ___________________________

Wieviele Stunden pro Tag verbringen sie durchschnittlich an Werktagen am Computer (Arbeitsplatz & Zuhause)?

____

Welche analogen „Persönlichen Information Management Tools“ verwenden Sie regelmäßig?

☐ Kalender ☐ Adressbuch ☐ Schreibblock
☐ Notizbuch ☐ Post its ☐ Andere ___________________________

Welche digitalen „Persönlichen Information Management Tools“ verwenden Sie regelmäßig?

☐ Microsoft Outlook ☐ Thunderbird ☐ Apple Mail/ iCal / ....
☐ Webmail(Gmail,..) ☐ Andere ___________________________

Wie oft haben sie mit folgenden Technologien bis jetzt gearbeitet?

	Noch nie	1-2x	Selten	Ab und zu	Sehr häufig
Digitaler Stift	☐	☐	☐	☐	☐
Handschrifterkennung	☐	☐	☐	☐	☐

Anmerkungen (z.B.: wo sie diese Technologien eingesetzt haben):

____

3. Feedback PECAN

Wie haben Sie das Arbeiten mit PECAN empfunden? Bitte geben sie dazu an, inwieweit sie folgenden Aussagen zustimmen:

	-- (1)	- (2)	o (3)	+ (4)	++ (5)
Ich bin zufrieden damit was PECAN mir anbietet.	☐	☐	☐	☐	☐
Der PECAN war angenehm zu verwenden.	☐	☐	☐	☐	☐
PECAN war einfach zu verwenden.	☐	☐	☐	☐	☐
Die Anwendung von PECAN war einfach zu erlernen.	☐	☐	☐	☐	☐
Das Verwenden von PECAN hat Spaß gemacht.	☐	☐	☐	☐	☐
Die Verwendung von PECAN war ein zeitlicher Zusatzaufwand	☐	☐	☐	☐	☐
Ich habe mich von PECAN in meinen Aufgaben unterstützt gefühlt	☐	☐	☐	☐	☐
Ich wäre gerne bereit PECAN in meinem Arbeitsalltag einzusetzen.	☐	☐	☐	☐	☐

Gab es Probleme auf die Sie beim Arbeiten mit dem PECAN gestoßen sind?

☐ Ja ☐ Nein

Wenn ja welche? ______________________________

Gibt es noch weitere Notiz-Kategorien (abgesehen von Addressbuch, Termine, Aufgaben und Zeichnungen) die Sie sich für ein Tool wie PECAN wünschen würden?

☐ Ja ☐ Nein

Wenn ja welche? ______________________________

Gibt es noch weitere Funktionen, die sie sich für PECAN wünschen würden (z.B.: in Zwischenablage speichern)?

☐ Ja ☐ Nein

Wenn ja welche? ______________________________

____

4. Anmerkungen ______________________________

____

Vielen Dank!

A.3 Miscellaneous

Group 1	appointment	to-do	contact	scribble
Group 2	to-do	contact	scribble	appointment
Group 3	contact	scribble	appointment	to-do
Group 4	scribble	appointment	to-do	contact

Table A.1: Counterbalancing of the note types.

Group 1	time	date, location	date	date, time
Group 2	date, location	date	date, time	time
Group 3	date	date, time	time	date, location
Group 4	date, time	time	date, location	date

Table A.2: Counterbalancing of the alternating appointment details.

	Block name	duration (minutes)
1	Introduction	15
2	Training	10
3	*PECAN* performance tests	15
4	Comparative tests	15
5	Conclusion	5

Table A.3: User Study Schedule Overview.

Appendix B

CD Contents

B.1 Thesis

Path: /

Thesis_Eva-Maria_Schwaiger_2013.pdf Masterthesis.

B.2 Figures

Path: /images

Introduction	Pictures and Graphics from Chapter 1: Introduction.
Method	Pictures and Graphics from Chapter 3: Method.
ApplicationDesign	Pictures and Graphics from Chapter 4: Application Design.
Implementation	Pictures and Graphics from Chapter 5: Implementation.
User Evaluation	Pictures and Graphics from Chapter 6: User Evaluation.
Results	Pictures and Graphics from Chapter 7: Results and Discussion.

B.3 Study

Path: /Study

material	Material used for the study
results	Analysis of logged data during the study in excel.

B.4 Online Sources

Path: /Sources

- StudyMaterial . . . . . . All sources provided content for sample notes as part of the user study.
- A_Smarter_Web.pdf . An article about semantic web mentioned in the introduction chapter.
- Scientific_American _The Semantic_Web.html An article about semantic web mentioned in the introduction chapter.

References

Literature

[1] Apostolos Antonacopoulos and R. Tim Ritchings. "Segmentation and classification of document images". In: *Proceedings of the IEE Colloquium of Document Image Processing and Multimedia Environments.* 1995, pp. 16/1–16/7.

[2] Andrea Bauer. "Analyse von Semantic Web-APIs und deren Methoden". Master Thesis. Hagenberg, Austria: University of Applied Sciences Upper Austria, Interactive Media, 2011. URL: http://theses.fh-hagenberg.at/thesis/Bauer11.

[3] Michael Bernstein et al. "Information scraps: How and why information eludes our personal information management tools". In: *ACM Transactions on Information Systems* 26.4 (Oct. 2008), p. 24.

[4] Nikolaos G. Bourbakis. "A methodology of separating images from text using an OCR approach". In: *Proceedings of the 1996 IEEE International Joint Symposia on Intelligence and Systems.* 1996, pp. 311–317.

[5] Peter Brandl, Christoph Richter, and Michael Haller. "NiCEBook: supporting natural note taking". In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.* (Atlanta, Georgia, USA). CHI '10. New York, NY, USA: ACM, 2010, pp. 599–608.

[6] Christopher Campbell and Paul Maglio. "Supporting notable information in office work". In: *CHI '03 Extended Abstracts on Human Factors in Computing Systems.* (Ft. Lauderdale, Florida, USA). CHI EA '03. New York, NY, USA: ACM, 2003, pp. 902–903.

[7] Bay-Wei Chang et al. "A negotiation architecture for fluid documents". In: *Proceedings of the 11th annual ACM symposium on User interface software and technology.* (San Francisco, California, USA). UIST '98. New York, NY, USA: ACM, 1998, pp. 123–132.

[8] Nicholas Chen, Francois Guimbretiere, and Abigail Sellen. "Designing a multi-slate reading environment to support active reading activities". In: *ACM Transactions on Computer-Human Interaction* 19.3 (Oct. 2012), p. 18.

[9] Damon J. Cook and Brian P. Bailey. “Designers’ use of paper and the implications for informal tools”. In: *Proceedings of the 17th Australia conference on Computer-Human Interaction: Citizens Online: Considerations for Today and the Future.* (Canberra, Australia). OZCHI ’05. Narrabundah, Australia, Australia: Computer-Human Interaction Special Interest Group (CHISIG) of Australia, 2005, pp. 1–10.

[10] Fefie Dotsika. “Semantic APIs: Scaling up towards the Semantic Web”. In: *International Journal of Information Management* 30.4 (Aug. 2010), pp. 335–342.

[11] Malcolm Gladwell. “The social life of paper”. In: *The New Yorker* (2002), pp. 92–96.

[12] Stephan Hamberger. “Entitätenextraktion und Relevanzbewertung mit Hilfe von semantischen Datenquellen und APIs”. Master Thesis. Hagenberg, Austria: University of Applied Sciences Upper Austria, Interactive Media, 2012. URL: http://theses.fh-hagenberg.at/thesis/Hamberger12.

[13] Sandra G. Hart and Lowell E. Stavenland. “Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research”. In: *Human Mental Workload.* Elsevier, 1988.

[14] Marti A. Hearst. “Clustering versus faceted categories for information exploration”. In: *Communications of the ACM* 49.4 (2006), pp. 59–61.

[15] Satu Jumisko-Pyykkö, Vinod K. Malamal Vadakital, and Miska M. Hannuksela. “Acceptance Threshold: A Bidimensional Research Method for User-Oriented Quality Evaluation Studies”. In: 2008 (2008).

[16] David R. Karger et al. “Sticky notes for the semantic web”. In: *Proceedings of the 8th international conference on Intelligent user interfaces.* (Miami, Florida, USA). IUI ’03. New York, NY, USA: ACM, 2003, pp. 254–256.

[17] Fawzia Khan. *A Survey of Note-taking Practices.* Tech. rep. Bristol, UK: Hewlett-Packard Laboratories, Dec. 1993. URL: http://www.hpl.hp.com/techreports/93/HPL-93-107.html.

[18] Scott R. Klemmer et al. “The designers’ outpost: a tangible interface for collaborative web site”. In: *Proceedings of the 14th annual ACM symposium on User interface software and technology.* (Orlando, Florida). UIST ’01. New York, NY, USA: ACM, 2001, pp. 1–10.

[19] Jaejun Lee, Sang H. Hong, and Yunmo Chung. “Robust Tracking of Ultrasonic Pen for Handwriting Digitizer Applications”. In: *IEEE Transactions on Consumer Electronics* 53.3 (Aug. 2007), pp. 1098–1102.

[20] Vladimir Levenshtein. “Binary Codes Capable of Correcting Deletions, Insertions and Reversals”. In: *Soviet Physics Doklady* 10 (1966), p. 707.

[21] Chunyuan Liao, François Guimbretière, and Ken Hinckley. "Papier-Craft: a command system for interactive paper". In: *Proceedings of the 18th annual ACM symposium on User interface software and technology.* (Seattle, WA, USA). UIST '05. New York, NY, USA: ACM, 2005, pp. 241–244.

[22] Jennifer Mankoff, Scott E. Hudson, and Gregory D. Abowd. "Interaction techniques for ambiguity resolution in recognition-based interfaces". In: *Proceedings of the 13th annual ACM symposium on User interface software and technology.* (San Diego, California, USA). UIST '00. New York, NY, USA: ACM, 2000, pp. 11–20.

[23] Andrew McCallum. "Information Extraction: Distilling Structured Data from Unstructured Text". In: *Queue* 3.9 (Nov. 2005), pp. 48–57.

[24] Pranav Mistry. "QUICKIES: the future of sticky notes". In: *CHI '09 Extended Abstracts on Human Factors in Computing Systems.* (Boston, MA, USA). CHI EA '09. New York, NY, USA: ACM, 2009, pp. 3529–3530.

[25] Kathrin Probst et al. "Move-it: interactive sticky notes actuated by shape memory alloys". In: *CHI '11 Extended Abstracts on Human Factors in Computing Systems.* (Vancouver, BC, Canada). CHI EA '11. New York, NY, USA: ACM, 2011, pp. 1393–1398.

[26] Dennis Quan, David Huynh, and David R. Karger. "Haystack: A Platform for Authoring End User Semantic Web Applications." In: *In Proceedings of the International Semantic Web Conference.* (Sanibel Island, Florida, USA), pp. 738–753.

[27] Priti P. Rege and Chanchal A. Chandrakar. "Text-Image Separation in Document Images Using Boundary/Perimeter Detection". In: *ACEEE International Journal on Signal Image Processing* 3.1 (Jan. 2012). Ed. by Dr Vinu V Das, p. 5.

[28] David Sankoff and Joseph B. Kruskal. *Time warps, string edits, and macromolecules: the theory and practice of sequence comparison.* Addison-Wesley Pub. Co., Advanced Book Program.

[29] Abigail J. Sellen and Richard H.R. Harper. *The Myth of the Paperless Office.* Cambridge, MA, USA: MIT Press, 2003.

[30] Beat Signer and Moira C. Norrie. "PaperPoint: a paper-based presentation and interactive paper prototyping tool". In: *Proceedings of the 1st international conference on Tangible and embedded interaction.* (Baton Rouge, Louisiana). TEI '07. New York, NY, USA: ACM, 2007, pp. 57–64.

[31] Lauren Smith and Derek Fagerstrom. *So geht das! Das ultimative Anleitungsbuch. 500 Dinge und wie man sie macht.* MOEWIG, 2009.

[32] R. William Soukoreff and I. Scott MacKenzie. "Measuring errors in text entry tasks: an application of the Levenshtein string distance statistic". In: *CHI '01 Extended Abstracts on Human Factors in Computing Systems.* (Seattle, Washington). CHI EA '01. New York, NY, USA: ACM, 2001, pp. 319–320.

[33] Jürgen Steimle, Max Mühlhäuser, and James D. Hollan. *Pen-and-Paper User Interfaces: Integrating Printed and Digital Documents.* Human–Computer Interaction Series. Heidelberg: Springer, 2012.

[34] Tomek Strzalkowski. *Natural Language Information Retrieval.* Text, Speech and Language Technology. Heidelberg: Springer, 1999.

[35] Kazem Taghva and Jeff Gilbreth. "Recognizing Acronyms and their Definitions". In: *International Journal on Document Analysis and Recognition* 1.4 (1999), pp. 191–198.

[36] "The Office of the Future – An in-depth analysis of how word processing will reshape the corporate office". In: *Business Week* 4 (May 1975), p. 48. URL: http://www.businessweek.com/stories/1975-06-30/the-office-of-the-futurebusinessweek-business-news-stock-market-and-financial-advice (visited on 07/23/2013).

[37] Max Van Kleek et al. "Gui — phooey!: the case for text input". In: *Proceedings of the 20th annual ACM symposium on User interface software and technology.* (Newport, Rhode Island, USA). UIST '07. New York, NY, USA: ACM, 2007, pp. 193–202.

[38] Jean R. Ward and Theodore Kuklinski. "A model for variability effects in handprinting with implications for the design of handwriting character recognition systems". In: *IEEE Transactions on Systems, Man, and Cybernetics* 18.3 (1988), pp. 438–451.

[39] Ron Yeh et al. "ButterflyNet: a mobile capture and access system for field biology research". In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.* (Montreal, Quebec, Canada). CHI '06. New York, NY, USA: ACM, 2006, pp. 571–580.

Online sources

[40] Mark Fraunfelder. *A smarter web.* 2001. URL: http://www.ece.uc.edu/~mazlack/ECE.716.Sp2010/A_Smarter_Web.pdf (visited on 07/16/2013).

[41] *The Semantic Web.* May 2001. URL: http://www.cs.umd.edu/~golbeck/LBSC690/SemanticWeb.html (visited on 07/23/2013).

[42] *"http://michifus.hubpages.com/hub/How-to-set-up-an-email-address".* URL: http://michifus.hubpages.com/hub/How-to-set-up-an-email-address (visited on 05/10/2013).

[43] *"http://names.mongabay.com/mostcommonsurnames.html"*. URL: http://names.mongabay.com/most_common_surnames.html (visited on 05/10/2013).

[44] *"http://www.hongkiat.com/blog/logo-evolution/"*. URL: http://www.hongkiat.com/blog/logo-evolution/ (visited on 05/10/2013).

[45] *"http://www.keithv.com/software/nasatlx/"*. URL: http://www.keithv.com/software/nasatlx/ (visited on 05/02/2013).

[46] *"http://www.ssa.gov/oact/babynames/decades/century.html"*. URL: http://www.ssa.gov/oact/babynames/decades/century.html (visited on 05/10/2013).

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