

UNIVERZA V LJUBLJANI  
FAKULTETA ZA RAČUNALNIŠTVO IN INFORMATIKO

Bojan Pikel

**Uporaba digitalnih pisal in digitalnih  
zvezkov v podporo raziskavi in  
poučevanju na univerzi**

MAGISTRSKO DELO  
MAGISTRSKI PROGRAM DRUGE STOPNJE  
RAČUNALNIŠTVO IN INFORMATIKA

Ljubljana 2014



UNIVERSITY OF LJUBLJANA  
FACULTY OF COMPUTER AND INFORMATION SCIENCE

Bojan Pikel

**Using digital pens and digital  
notebooks for supporting research  
and teaching at university**

MASTERS THESIS  
SECOND CYCLE MASTERS PROGRAM  
COMPUTER AND INFORMATION SCIENCE

SUPERVISOR: prof. dr. Uroš Lotrič  
CO-SUPERVISOR: Daniel Spikol, Ph. D.

Ljubljana 2014



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## IZJAVA O AVTORSTVU MAGISTRSKEGA DELA

Spodaj podpisani Bojan Pikel, z vpisno številko **63050081**, sem avtor magistrskega dela z naslovom:

*Uporaba digitalnih pisal in digitalnih zvezkov v podporo raziskavi in poučevanju na univerzi*

S svojim podpisom zagotavljam, da:

- sem magistrsko delo izdelal samostojno pod mentorstvom prof. dr. Uroša Lotrič in somentorstvom Daniela Spikol, Ph. D.,
- so elektronska oblika magistrskega dela, naslov (slov., angl.), povzetek (slov., angl.) ter ključne besede (slov., angl.) identični s tiskano obliko magistrskega dela,
- soglašam z javno objavo elektronske oblike magistrskega dela v zbirki "Dela FRI".

V Ljubljani, dne 8. maj 2014

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# List of Acronyms

**PDF** Portable Document Format

**OCR** Optical Character Recognition

**API** Application Programming Interface

**ACM** Association for Computing Machinery

**IEEE** Institute of Electrical and Electronics Engineers

**WPF** Windows Presentation Foundation

**UCD** User Centred Design

**WYSIWYG** What You See Is What You Get

**ACC** Advanced Audio Coding





# Abstract

Digital pens combine affordances of paper and digital world. Documents with similar content could be combined into a single document called digital notebook. Our idea was to include the functionality of integrating different types of documents into a text editor, which enables users to edit the main document in one place. The application was developed for Livescribe and L<sup>A</sup>T<sub>E</sub>X because both tools are currently implemented among university teachers.

Tagging helps to organize and search for documents in digital notebooks. This thesis suggests more efficient tagging by focusing on the tags and simple way of handling documents.

The method used was design and creation complemented with interaction design. The work was evaluated with usability testing of the developed application. The results of the evaluation show that both solutions, embedding digital pen's documents into L<sup>A</sup>T<sub>E</sub>X and different approach to tagging of documents are useful in the research area.

**Keywords:** Livescribe, Evernote, Latex, pencast, digital pen, digital notebook, tablet, audio recording



# Povzetek

Digitalna pisala združujejo prednosti papirja in digitalnega sveta. Datoteke s sorodno vsebino bi lahko združili v en sam dokument, digitalni zvezek. Z našo idejo smo funkcije za integracijo različnih tipov dokumentov vključili kar v urejevalnik besedil in na ta način omogočili naknadno urejanje glavnega dokumenta. Aplikacijo smo razvili za Livescribe in L<sup>A</sup>T<sub>E</sub>X, saj sta obe orodji že uporabljeni med univerzitetnimi učitelji.

Označevanje pomaga pri organizaciji in iskanju dokumentov v digitalnih zvezkih. V delu predlagamo učinkovitejše označevanje, s tem, da damo večji poudarek oznakam ter enostavnemu delu z označenimi dokumenti.

Delo je sledilo iterativni metodi načrtuj in izdelaj, podprti z metodo interaktivnega načrtovanja in bilo ovrednoteno s kvalitativnim testiranjem uporabnosti predlaganih rešitev. Z evalvacijo smo ugotovili, da so naše rešitve učinkovite tako v smislu integracije datotek digitalnega pisala v L<sup>A</sup>T<sub>E</sub>X dokument, kot v smislu poenostavitve organizacije datotek.

**Ključne besede:** Livescribe, Evernote, Latex, pencast, digitalo pero, digitalni zvezek, tablet, snemanje zvoka



# Razširjeni povzetek

To magistrsko delo zadeva digitalna pisala in digitalne zvezke, ter urejanje datotek. Digitalna pisala se uporabljajo kot običajna pisala, s tem da digitalizirajo svoje poteze. To pomeni, da pisalo shrani vse karkoli napišemo oziroma narišemo in to kasneje lahko prenesemo tudi na računalnik. Ob enem, seveda, še vedno lahko obdržimo fizično verzijo na papirju. S pojmom digitalni zvezek označujemo program, ki nam omogoča izdelavo zapisov in shranjevanje datotek. Datoteke in zapise v digitalnem zvezku želimo imeti urejene, za lažje kasnejše brskanje, ko iščemo določen zapis ali datoteko. Primeri digitalnih zvezkov so OneNote, Google Keep in Evernote. V podpoglavju 4.1 primerjamo digitalna pisala in v podpoglavju 4.2 digitalne zvezke.

Raziskovalci se srečujejo z velikim številom papirnih in digitalnih dokumentov. Med digitalnimi dokumenti imajo razna besedila, slike, strokovne članke in podobno. Nekateri dokumenti različnih tipov bi lahko bili združeni v en sam dokument. Več vsebine v enem dokumentu bi raziskovalcem poenostavilo deljenje z drugimi. Poleg deljenja bi olajšalo tudi urejanje. Zaradi velike količine pa je prisotna tudi potreba po urejanju dokumentov. Ena od rešitev, ki jih lahko uporabijo za organizacijo digitalnih dokumentov je označevanje (angl. tagging). Označba je ena beseda ali besedna zveza, ki opisuje vsebino dokumenta. Dokumente s skupnimi lastnostmi označimo z enako označbo, da jih kasneje lažje najdemo. Tovrstna rešitev je pogosto uporabljena tudi na socialnih omrežjih.

Raziskovalno delo je bilo grajeno v več iteracijah. Prvi korak je bil pregled obstoječe literature s področja digitalnih zvezkov in digitalnih pisal. Pregle-

dali smo tudi raziskave o uporabi tabličnih računalnikov v izobraževalnem okolju. Povzetek pregleda obstoječe strokovne literature se nahaja v poglavju 2. Zatem smo imeli intervjuje z raziskovalci, ki del svojega časa tudi poučujejo matematiko na univerzi in pri svojem delu uporabljajo digitalna pisala. S pomočjo intervjujev smo želeli pridobiti razumevanje trenutne uporabe in odkriti rešitve, ki bi raziskovalcem olajšale njihovo delo.

Po analiziranju rezultatov intervjujev smo izdelali skice, ki so prikazovale primer uporabe aplikacije in vzorec uporabniškega vmesnika. Skicam je sledil razvoj interaktivnega prototipa aplikacije. Aplikacija je napisana v jeziku C#. Grafični vmesnik je napisan v ogrodju WPF. Deluje na operacijskih sistemih Windows in vsebuje dva dela. Prvi del aplikacije omogoča, da datoteke narejene z digitalnimi svinčniki Livescribe integriramo v okolje urejevalnika besedil  $\text{\LaTeX}$ . Drugi del deluje v kombinaciji s sistemom Evernote in se uporablja za urejanje datotek. Za urejanje datotek je uporabljeno označevanje. Posebnost naše aplikacije je to, da je poudarek na označbah. To nam omogoča bolj konsistentno uporabo označb. S tem se ognemo eni od pomanjkljivosti označevanja, ki je uporaba sopomenk s čimer dobimo 'podvojene' označbe.

Digitalna pisala Livescribe uporabljajo papir, ki ima prednatisnjeno posebno matriko. Samo pisalo vsebuje kamero in glede na matriko razbere položaj pisala na papirju. Posebnost Livescribe pisal je, da omogoča tudi snemanje zvoka, katerega sinhronizirajo s pisanjem. Na računalnik lahko prenesemo datoteko, kjer se sproti prikazuje pisava in predvaja zvok. Vsa vsebina lista je osivena, tako da jo uporabnik vidi že vnaprej. Uporabnik lahko klikne na določen del pisave in predvajal se bo zvok, posnet v tistem trenutku. Imamo torej nekakšen interaktivni video. Te datoteke se imenujejo pencast.

Aplikacija deluje v povezavi z MyLivescribe spletno stranjo, kjer uporabniki objavijo svoje pencast datoteke. Uporabnik aplikacije mora najprej svoj video objaviti na tej strani, nato pa aplikaciji podati spletno povezavo do pencast datoteke. Iz te povezave aplikacija izlušči identifikacijsko številko

pencast datoteke in prenese vse potrebne datoteke za predvajanje. Izhod so torej prenešene in obdelane datoteke za predvajanje pencast datotek. Poleg samih datotek aplikacija sestavi tudi  $\text{\LaTeX}$  kodo za vstavitev in predvajanje datotek. Uporabnik mora v svojem  $\text{\LaTeX}$  dokumentu uporabiti standarden media9 paket in prilepiti kodo, ki jo sestavi aplikacija. Poleg osnovnega načina pa aplikacija omogoča tudi, tako imenovani, konzolni način. Pri tem načinu uporabnik poveza do željenega pencasta prilepi kar v svoj  $\text{\LaTeX}$  dokument. Aplikacijo lahko požene z uporabo uporabniških ukazov v  $\text{\LaTeX}$  urejevalniku. Pot do datoteke je podana na vhod aplikacije. Ta odpre dokument in poišče povezave do pencast datotek, nato pa ustrezno označene povezave obdeli. To pomeni da prenese potrebne datoteke in tudi vstavi  $\text{\LaTeX}$  kodo v sam dokument. Prednost tega načina je, da uporabnik rokuje praktično le z urejevalnikom  $\text{\LaTeX}$ . S tem smo funkcije za integracijo digitalnih dokumentov v skupni dokument prenesli iz specializiranih orodij na urejevalnik besedil in tako omogočili naknadno urejanje skupnega dokumenta.

Drugi del aplikacije deluje v povezavi s sistemom Evernote. Aplikacija se sinhronizira z uporabnikovim računom Evernote in prenese informacije o digitalnih zvezkih. Ko uporabnik izbere določen zvezek, aplikacija prenese naslov, predogledno sliko in pripadajoče označbe vsakega zapiska v zvezku. Uporabnik nato dodaja nove označbe na zaslon. Naslednji korak je urejanje zapiskov. Uporabnik zapis povleče in spusti nad željeno označbo. S tem je zapis označen. Če želi enemu zapisu dodeliti več označb, potem ga le znova povleče iz prve označbe in spusti še nad drugo. Ko zapis prenaša med označbami, se le ta kopira. V primeru, da zapis dodeli napačni označbi, ga povleče nad ikono koša in zapis bo odstranjen iz seznama. Po končanem urejanju mora uporabnik sinhronizirati stanje s storitvijo Evernote, da shrani spremembe. Rokovanje je podobno kot urejanje datotek z Raziskovalcem, ki je večini uporabnikom, dobro znan.

Oba dela aplikacije sta bila ovrednotena s kvalitativnim testiranjem uporabnosti. Z evalvacijo smo ugotovili, da so naše rešitve učinkovite tako v

## *POVZETEK*

smislu integracije datotek digitalnega pisala v LaTeX dokument, kot v smislu poenostavitve organizacije datotek. Pri prvem delu so uporabniki posebej izpostavili uporabnost takšne aplikacije pri njihovem delu, saj omogoča, da izdelajo dokument PDF, ki ima vgrajen interaktivni video. Pri drugem delu pa je bila najbolj izpostavljena preprostost uporabe, saj kljub temu, da aplikacija omogoča prosto izbiro značk, hkrati vzpodbuja uporabo že obstoječih.

Ker je aplikacija v stanju prototipa, bi bile za redno uporabo potrebne še dodatne iteracije, kjer bi aplikacija postala stabilnejša in uporabniku prijaznejša.



# Chapter 1

## Introduction

This master's thesis covers the area of digital notebooks and digital pens to support research and teaching activities. The stakeholders participating in this thesis were researchers that work in a university environment as teachers of mathematics. They use teaching as a part of their research activities. In scope of this thesis the phrase *digital notebook* is used to address a software application used to create notes, and organize and share documents. Examples of similar existing software are Google Keep<sup>1</sup>, Evernote<sup>2</sup>, Microsoft OneNote<sup>3</sup> and others. The phrase *digital pen* addresses a hardware device that acts as a pen and digitalizes writing by using either an external device attached to paper or a special pattern printed on the paper. There are already digital pens available like Livescribe, Capturx, Zpen and others so no new hardware was developed.

A large part of research usually concerns gathering data. It is worth noting that researchers try to find interesting and relevant data [1]. They search for information in different places and consequently data is stored in different formats. This means that researchers have a lot of data stored on their computers. Additionally, researchers need to organize a lot of documents in a way that suits them. Examples of the documents include: research mate-

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<sup>1</sup>[docs.google.com/keep/](https://docs.google.com/keep/)

<sup>2</sup><http://evernote.com/>

<sup>3</sup>[office.microsoft.com/en-001/onenote/](https://office.microsoft.com/en-001/onenote/)

rials, learning materials or homework. An additional way for researchers to organize their digital documents was investigated. Tags are used to support organizing document. Tag is a word or a short phrase added to a document to describe its content. Despite being widely used, tagging is still not optimized, as shown by Gupta et al. [2]. In this thesis we investigated a reverse approach to tagging that is similar to card sorting technique, where notes would be cards and tags would be categories. The prototype is based on the existing Evernote service.

Documents that researchers collect come from different sources. Literature searches are performed on the internet, using search engines like Google Scholar, or journal specific libraries like ACM, IEEE, Digital Creativity etc. [1]. After researchers find an article that they want to use in their research they can save it as a PDF (Portable Document Format) file. Sometimes researchers save a copy of a web article or they use a link to an on-line video file. Researchers who work as teachers in real classrooms also need to create lecture material. Because of the wide variety of the types of documents sometimes they have problems combining and organizing them.

Affordances of combining digital documents of different types were also investigated. Specifically the embedding of interactive files produced by Livescribe<sup>4</sup> digital pens, called pencasts, into L<sup>A</sup>T<sub>E</sub>X documents has been investigated in cooperation with the stakeholders. These two technologies provide convenient options to create documents containing mathematical symbols in digital format and are often used by mathematicians. L<sup>A</sup>T<sub>E</sub>X is a document preparation system<sup>5</sup>. It became popular for its features to produce technical and scientific documents which often contain equations. Different way of using pencasts is shown by embedding them into a PDF. The hardware part of the pen was not improved in this thesis. Pencasts include writing and optionally audio recorded at the time of writing. It can be played back like a video. An advantage of pencasts is that writing of a pen is interactive

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<sup>4</sup><http://www.livescribe.com/>

<sup>5</sup><http://www.latex-project.org/>

and by clicking on the writing the audio recorded at that time starts playing. This means users can move backward and forward throughout their notes.

Digital pens are a part of this thesis because paper still plays an important role in the office and especially out of the office [3]. However, since the digital world provides better search functions and sharing options [4] researchers try to digitalize handwritten notes on a paper. These notes can be digitalized using a scanner, a digital pen or retyping. With digitalizing paper documents one often uses OCR (Optical Character Recognition) for purposes of searching and further editing.

An example scenario of embedding pencasts into  $\text{\LaTeX}$  documents could be researchers creating lecture material. One part would be writing theory in  $\text{\LaTeX}$ . Another part would be explaining the proof using digital pen and thinking out loud. By including the pencast into  $\text{\LaTeX}$  researchers can produce one single interactive document that is an off-line PDF file. They can share it with students. If students have problems with understanding certain parts they can read and listen to the explanation.

Another example could be students using a digital pen that can also record audio. Students can record their thoughts while working on an assignment. They can do this by thinking out loud and explaining what they are doing and why [5]. The purpose of this is to enhance the teachers' understanding of the students' thinking.

This work is based on the existing solutions. In collaboration with the stakeholders missing features were identified. Afterwards, a prototype application was developed and evaluated. The evaluation addressed some of the missing features in currently existing tools.

## 1.1 Motivation

Research on digital notebooks already exists [3, 6, 7, 8, 9]. We provide guidelines for a digital notebook that could support mathematics researchers. Mathematicians face a problem of writing math symbols on a computer with

a standard keyboard. This is one of the reasons that  $\text{\LaTeX}$  is a widely used tool for producing scientific documents among scientists and university math teachers.  $\text{\LaTeX}$  provides powerful options to insert symbols and formulas into documents. Our guidelines also include suggestions how digital pens can be used to support research and teaching. This is important in the field of mathematics because handwriting feels more natural [10].

Multimedia files are widespread nowadays. Consequently, documents often include images or even, for instance, a Youtube <sup>6</sup> video with an explanation. Math researchers sometimes want to combine the  $\text{\LaTeX}$  files with pencast files. A pencast is an interactive animation with sound produced using digital pen. Users record their voice and writing with the pen. Afterwards, one can see the writing and also listen to the audio that was recorded at the time of writing. Students like pencasts because they provide a good overview of written content, so that students can quickly move to the part that they are interested in. Currently, the stakeholders are not familiar with a way to integrate pencasts into their  $\text{\LaTeX}$  documents. The motivation to develop a prototype tool which would embed the pencast into  $\text{\LaTeX}$  document is to provide researchers and teachers a way of enhancing their documents.

Another reason for this research is to explore a new way of organizing digital documents. According to Handerson [11] there are different approaches to organizing documents. Two of Handerson's sample personas can optionally use tags. On the other hand Gao [12] shows users still have problems with tagging. He also argues that better tools could be developed to take more burden off of the users. As users tend to use consistent tags, we provided a different approach in this aspect.

## 1.2 Research questions

In this thesis we conducted the research to answer the following main research question:

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<sup>6</sup><https://www.youtube.com>

*What are the software requirements for further developing digital notebooks and digital pens for use in research and university teaching?*

In order to investigate this main research question the following sub-questions are needed:

- *What are the main user features and system requirements for digital notebooks that can be designed and developed to support research and math education?*
- *What key features are needed to support the integration and organization of digital notebooks and related media from digital pens?*

## 1.3 Goals

The main goal of this thesis was to investigate possible improvements in digital notebooks for supporting research. One goal was to explore the combining of different types of files that teachers and researchers have saved among their documents. Specifically, combinations of pencasts and L<sup>A</sup>T<sub>E</sub>X documents were researched. Pencasts are files produced by digital pens. They include audio and writing that was recorded by digital pens.

The second goal was to investigate a new way of organizing digital documents. The goal was to explore a different approach to the tagging of documents. Designed approach is similar to card sorting technique.

The proposed requirements for digital notebooks were evaluated. To be able to evaluate a prototype application was designed and developed. During the design phase the collected requirements were considered. Evaluation was conducted in collaboration with teachers of mathematics and mathematics researchers.

## 1.4 Limitations of this thesis

Our main stakeholders were maths researchers that are also teachers in the university environment and use digital pens in their research. The criteria for the participants was that they are either math teachers and use digital pens or researchers with long time experiences of using digital pens. The number of stakeholders in this research was very limited by only having four participants. The developed prototype is viewed as an interactive sketch that is used to test the approaches.

## 1.5 Contributions

This thesis explored the affordances of combining different types of digital documents for researchers. Our main stakeholders were maths researchers. Maths researchers often use  $\text{\LaTeX}$  environment to produce documents because it provides support for math symbols and equations. Digital pens offer a simple way to record audio along with handwriting and it produces pencasts. Here, specifically, the combination of pencast files and  $\text{\LaTeX}$  documents was explored.

Furthermore the thesis contributed to exploring a different way of organizing digital documents. As Gao [12] showed, tools for tagging could take some burden off of the user. Our approach is similar to piles of paper and card sorting technique. Both parts the embedding and tagging were evaluated by some of our stakeholders. For the evaluation purposes, an interactive prototype application has been developed.

# Chapter 2

## Literature review

The purpose of this literature review is to collect the knowledge of previous research in the area of digital pens and digital notebooks used in teaching and researching. It was conducted in connection with Oates's guidelines [1]: searching, obtaining, assessing, reading, critically evaluating, recording and writing a critical review. These steps were repeated multiple times as research progressed. The first step was to search for articles, journals and conference papers using Google Scholar and Science Direct search engines. Keywords that were used are connected with the goals such as 'digital notebook', 'anoto paper', 'digital pen', 'organizing digital documents', 'research organization' and 'tablet'.

The literature review first places our work into cooperative information systems. Sections 2.2 and 2.3 present affordances and limitations of current digital pens and existing digital notebooks. Section 2.4 shows importance of digital tools in teaching and 2.5 presents some caveats of tagging. In the last section we reflect the connection of our work and the reviewed literature and show identified gap in the current research.

## 2.1 Digital notebook as cooperative information system

An example of digital notebook, a computer based application, is Bio-Image Semantic Query User Environment (Bisque). Bisque is a web-based resource for management and analysis of biological images [7]. Users can annotate and upload images equipped with text and graphical meta-data. Bisque also provides an option for users to write custom analysis modules. Various programming languages are supported. Authors built it using modular approach, as a result of which it is very scalable. Bisque services are implemented using HTTP protocol and most of them also support the REST protocol to exchange data. Bisque is also a good example of a cooperative information system. Authors of the research provide three case studies of evaluating the application. Experts have used the application to produce point centroids in 3D. Authors even compared automatic annotations to ground-truth to show that they are comparable in quality. In a study conducted at Feinstein and Wilson labs [7], UCSB authors showed that their semi-automatic tracking module generates even better results as manual technique when image quality is sufficient. The data gathered using Bisque is also more reliable than by manually processing the images.

## 2.2 Digital pen

Liwicki and Schumacher [13] tried to connect digital papers and printed papers. The idea was to have all documents digitalized. When users wanted to use physical paper they printed it using custom software which prints it in a digital pen friendly way. Thus when users have the printed paper they can use the digital pen to annotate the document. Afterwards they use custom software, which reads annotations from a digital pen and synchronizes it with digital version of documents, again [13]. This way the user can maintain their digital documents up to date. The advantage is that the quality of the



document is not affected because only annotations get added to the original document. If users would simply scan the new, annotated document they would lose some quality and they would also lose all the digital information such as meta data [14]. According to the authors, the main limitation of this system is that it does not work with a wide variety of different documents. iPaper framework only supports OpenOffice documents [13]. Their main future goal is to provide support for Microsoft Office suite of applications and PDF documents which is de facto standard for printable documents on the web.

Stifelman et al. [15] proposed an Audio Notebook. The device synchronized audio recording with writing. The purpose was to facilitate the reviewing of audio recording during meetings, lectures or interviews. Audio Notebook connects audio recorded to users' hand writing. By combining these activities it provides users with the ability to search through the recorded audio based on the writings in the notebook. Similar work has been done using a computer or tablet pc. But in this case the authors use a classical notebook and ink pen. The authors built two prototypes. The second prototype had mostly front-end improvements over the previous one. They conducted a longitudinal study with four students and two researchers over a period of five months. The goal of the observation was to see how participants were using the device. They either used it to get a more efficient way to re-listen to the parts of recorded lectures that were unclear to them or take fewer notes as everything was recorded. In conclusion, the authors state that the connection of recorded audio with note-taking provides greater prospects for the note-takers when later reviewing their notes. Since the paper was written in 2001, it is a fact that technology has advanced in the meantime. Today, note-taking with digital pens and audio recording is even more efficient and user-friendly.

## 2.3 Existing digital notebooks

TutorMates is a product of a research and development by Addlink Research group [6]. It provides a math educating environment for students from 12 to 18 years old. Teachers can design exercise objects. The application then checks whether the exercise is appropriate for the student target group. It also uses the math engine Maxima <sup>1</sup>, which checks indirect calculations. This prevents students that do not know real numbers to see real numbers while solving the exercise. If the exercise is appropriate, TutorMates combines math and text. In the case that teachers also used graphs, it includes appropriate graphs in the final version. One part of TutorMates is also a digital notebook. Teachers can prepare lessons for students in the digital notebook. Teachers have the option to organize the chapters so that each chapter includes only the necessary parts for the subject explained. Students can annotate in the digital notebook, manipulate data, interactively solve exercises and send their work to the teacher for review. The TutorMates is written in Java, JavaScript and CommonLips programming languages, so it works on a different operating systems. Because authors thought it is important that it is available to everyone they kept it open source.

During an observation or an interview researchers often use video recording. Analysis of this video data is very time consuming. In their research Weibel et. al. used [8] digital pen to facilitate analysis of video recorded observation. Their idea was to connect handwriting with video recording. During the observation researchers made gestures or special marks on paper. By combining data from the digital pen with video data, they provided easy access to video segments at the time when the mark was drawn in the notebook. Thanks to this, researchers need to spend less time searching for video parts that are relevant to their research. Their future idea is to provide interactive buttons on paper, so researchers could search for a segment or control the speed of video playback, using only the digital pen. In the paper, authors

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<sup>1</sup><http://maxima.sourceforge.net/>

did not describe any evaluation techniques. They did state formal evaluation as a future work to better understand the existing and planned capabilities.

Other researchers are more focused on collaboration, for example in office environments. One such system is NiCE Discussion Room [16]. NiCE Discussion Room links digital and paper based tools. It consists of a large white board where multiple participants can collaborate. Participants can also work with paper. They can work privately on a piece of paper and share with others later via displaying on the large white board. The system also provides a possibility to connect a laptop and use tangible palettes. The authors performed exploratory field study. The study included six meetings in a large company. After implementation they conducted a user study in which thirty-nine people participated. The sessions were also videotaped. Later they examined everything including log files in computers. In the results, the authors stated that they found that NiCE Discussion Room provided users with advantages over classical meeting rooms as it incorporates digital interfaces and paper documents. The participants used all of the offered tools: laptops, paper and the big interactive white board. Authors did identify some difficulties with using the overall system, so further studies will be continued.

CoScribe is another example of such a system [4]. It is a prototype of a concept for a combined work with printed and digital documents. The authors stated that CoScribe implements minimal invasion into traditional work of annotating and collaborating. A positive aspect is that it increases the efficiency of structuring and retrieving of documents. CoScribe's idea is to be able to print slides and other documents and annotate them. Authors went one step further with designing CoScribe. They implemented a tagging solution. The system gives users an option thank to which users can print a toolbar on paper. It provides users with an easy option for classification. While using CoScribe the user can also employ special gestures to link documents. This gesture is recognized by the system which creates hyperlinks and gives users the possibility to also draw links on paper so user can follow

the link without using a computer. The visible link will be ignored by the system. Authors conclude the paper by stating that their evaluation shows that combining digital documents and paper brings higher work efficiency and higher user satisfaction.

Researchers sometimes need to conduct part of the research outside the office. Most often, such action requires gathering data. Gienza et al. [17] and Yeh et al. [3] aim at using mobile devices in these situations. Researchers are conducting research in the usability of mobile digital devices in the field. The field presents a harsh environment for digital equipment such as: no external power, direct sunlight, wind, rain etc. The positive aspect about using digital devices is having GPS coordinates, automatic time stamps, digital photographs etc. With SCY-Lab [17] students or researchers can design input forms on the computer and transfer them to mobile devices. After having collected data they use a preset form to capture data in digital form instead of its paper counterpart. ButterflyNet [3] uses digital pen and paper to capture data on the field. Afterwards data from a digital pen is combined with digital data from other devices.

## **2.4 Digital notebook and digital pen in teaching**

He and Tymms [18] and Siozos et al. [19] discussed the use of tablet pcs with assessments. In these papers the authors presented design and development of systems for computer based assessment. Siozos et al. [19] also conducted a survey of students' satisfaction with taking assessments on a computer. Most students find such systems interesting. They did state that students using tablet pcs were more confident than students using a system on classical computers. The authors of these papers concluded that such systems are useful to analyze the students' activity during testing. Students participated in evaluation in both researches. He and Tymms [18] had 994 students from five different schools participate in their analysis. They all found that

students have problems concerning a lack of knowledge in working with computers. This problem is outside of our research area. Clariana and Wallace [20] conclude that students sometimes achieve better results when they take assessment test via computer. Their study involved 105 students and showed that students using computer based assessment achieved almost 7% better results on average, compared to students using traditional pen and paper based assessment.

Reba and Weaver [21] state the importance of active learning of math in the classroom. They support students' participation in the classroom during the lectures. Students should use tablet pc computers or digital pens. It should be noted that the authors use the term *digital pen* to describe the active stylus connected to tablet pc computer. The digital technology helps to overcome the gap between students and teachers. In 2006 they observed two classes. In one of the two classes students used tablet pcs. Students felt more engaged during the lectures. They evaluated the project in four categories: initial student comparability, performance measures, student behaviours and satisfaction and instructors' investment of time. Results of the study show slightly higher results in final grades 83.11 compared to 80.58. The authors also state that students using tablet pc used one week to get to know the software and hardware they were using. They conclude with a recommendation to develop more software specifically targeting tablet pcs and digital pens.

## 2.5 Tagging

A tag is one word or a short phrase representing a keyword describing the content of a file to which it is added. The main advantage of tags is that one file can have multiple tags and one tag can be added to multiple files. For this reason tags are used in digital notebooks to facilitate the organization of documents. Tagging on on-line social portals has become very popular

[2]. It started with sites like Flickr<sup>2</sup> and Delicious<sup>3</sup>. Flickr allows people to tag photos they upload. On Delicious users add tags to websites. Tags are also used on Facebook<sup>4</sup>, LinkedIn<sup>5</sup>, Youtube<sup>6</sup> and other popular social websites and blogs. On social web sites tagging is done by multiple users. Such tagging is called folksonomy.

Although tagging is widely used, it has certain problems [2]. One of the problems are outdated tags. For example 'best laptop' does not tell us when was the tagged laptop the best. These kind of tags sooner or later lose their validity. Another problem is ambiguity. Ambiguity in social tagging arises because different users can use different words to describe the same thing. Another reason for ambiguity are synonyms. Some of the tags are plural versions of the word. Jeong [22] argues that some tags are also erroneous. Joeng concludes that tagging significantly overlaps the existing meta-data. Meta-data in their study was title of movies on Youtube. It arises a question of effectiveness of tagging for later retrieval and searching.

In theory, tagging should reduce users' effort to organize and retrieve their documents. Gao shows that in practice it is not so [12]. In practice the use of tagging puts more workload on users. It also shows that users make more errors while trying to retrieve their documents. Users tend to be consistent with using a set of tags. This is often difficult because tags provide a high degree of freedom. He suggests that the designers of tools should perhaps slightly constrain the tags. Gao concludes that tagging should not be seen as a replacement but rather as an addition to categorization.

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<sup>2</sup><http://www.flickr.com/>

<sup>3</sup><https://delicious.com/>

<sup>4</sup><https://www.facebook.com/>

<sup>5</sup><http://www.linkedin.com/>

<sup>6</sup><http://www.youtube.com/>

## 2.6 Summary of literature review

Digital technology in the educational environments can also help to engage students in learning since they sometimes achieve better results [19]. Digital tools support learning and teaching. It also eases teachers' communication of mathematics to students outside the class. The digital world provides better organizational options compared to the ones we have with a physical objects [23]. Furthermore, with the widespread use of the internet, sharing of documents is much easier in the digital world. Nevertheless, paper still remains an important medium [24]. It presents a cost-effective and robust solution. A digital pen offers a popular solution that combines affordances of paper and advantages of tablet computers [14].

There are already ongoing research on digital notebooks [3, 6, 7, 8, 9]. Most notebooks target researchers of a specific field. The ButterflyNet [3] was developed to support biologists outside in the field gathering data. Bisque is supporting bioinformatics [7] and TutorMates [6] helps students learn math. A drawback of digital notebooks, compared to handwriting, was identified in regards with maths. Using handwriting as an input method when learning mathematics is more natural to people compared to typing on a computer keyboard [10]. Furthermore, current digital notebooks do not provide an easy way to combine different types of files. Researchers can produce more engaging documents by embedding the multimedia files like YouTube<sup>7</sup> videos and pencasts. For this reasons we explored affordances and possibilities of embedding pecast files into PDF documents using L<sup>A</sup>T<sub>E</sub>X.

Another gap in currently existing tools lies in the organizational part. Tags are one way to organize digital documents. As shown by Gao [12], tools supporting tagging could be more user-friendly and take some burden off of the user. Reversed approach to tagging was explored in this thesis. With reversed approach users focus on their tags and then drag and drop notes on the tags. This way tags used are more consistent. This chapter showed that

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<sup>7</sup><http://www.youtube.com/>

the reviewed literature supports the gaps identified in the first chapter. The next chapter will discuss the methodology used to undertake the research.



# Chapter 3

## Methodology

The research method used for this thesis was a design and creation complemented with interaction design. Both methods use the iterative process of research [1, 25]. Interaction design was used to have a user centered approach [25]. In the first stage the semi-structured interviews were used to collect the requirements from users. The collected requirements answer the first research sub-question. The second step was the development of an interactive prototype to answer the second research sub-question. In the final step the prototype was evaluated using usability evaluation. The time horizon of our research was cross sectional as it was performed in one time slot. Research was not repeated over time to observe changes. The research outcomes are the results received from data collection, analysis and feedback acquired from evaluating our prototype implementation. The following sections explain each of our methods more in detail. Section 3.3 presents other methods that were also considered.

### 3.1 Design and creation

Our main research method was design and creation complemented with interaction design. The IT artifact in our method was an instantiation, which means a computer based working system. First, the design for the applica-

tion was developed. As with design and creation, the design was analyzed and later developed. Not all development can be viewed as research. The literature review was performed to gain knowledge of current research on the topic. Our decisions were supported by arguments in the design and development parts of the research. Development was driven by the requirements collected from the initial interviews.

The design and creation was done in five steps [1]. The first step was recognition and articulation of a problem called awareness. It is connected with the literature review, where we look into other studies. The second step was making a distinction between pure curiosity in a certain field and between an actual suggestion, in which we provided potential solutions to the problem. When there is an idea, the development can be started and the idea implemented as suggested. After developing a prototype application it needs to be evaluated in order to examine the developed solution. The last, fifth, step concludes our research; this is where we presented the results of our research and propose possible future work.

## **3.2 Interaction design**

The design and creation method has been complemented with an interaction design. The interaction design method offers a user centered approach, so stakeholders were included early in the design process [26]. Therefore, requirements for the prototype were defined based on the interviews conducted with researchers at the beginning. Afterwards, the prototype application developed was evaluated.

Interaction design has three main activities that are also presented in other design processes. These activities fulfill the requirements, satisfying these requirements and evaluating produced designs. These main activities also cover the five steps in design and creation. It is important that the users and other stakeholders are involved in the design. Therefore, the initial design must not only be understandable to the designers but also to users

and others [25].

Sharp et al. [25] argue that it is important to include users early in the process. The two arguments they present are expectation management and ownership. The first is important so that users know what to expect and they do not feel cheated or let down. Users' involvement into creating product gives them the feeling of ownership so they are more receptive when they get the product. The most effective way to gather feedback is to develop a prototype of the product. In some cases where time is limited they advise the use of paper prototypes. Also in this thesis, first a paper prototype has been designed. Besides focusing on users, principles of iterative design were used.

Figure 3.1 shows iterative process of interaction design. Iteration is necessary when cooperating with users. Sometimes users do not have a clear vision of their idea. Sometimes designers do not understand users' ideas properly. Therefore, we need to go back and revise the design of a product. The next step is to repeat the evaluation of the new revised design. Now users can yet again propose additional changes, which makes another iteration.

Our research also made use of the iterative approach. The first iteration consists of developing a paper prototype. The next step was development of an interactive prototype. The second prototype was evaluated by the stakeholders.

### **3.3 Methodological considerations**

Other appropriate methods that were not chosen include action research, experiment and case study. Action research is used to investigate and improve working practices [1]. Because the aim of action research is to solve a problem and change the situation [1], it was not chosen for our research. Our goal was not to change the situation, but to explore what is needed to change it. Our plan was not to provide an improved working solution, but to provide requirements to improve solution. A prototype was designed and developed

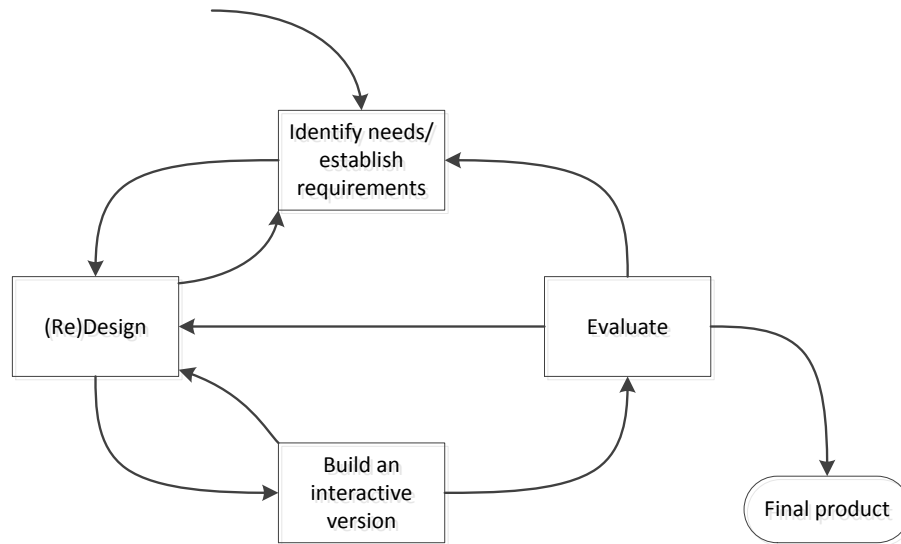


Figure 3.1: Iterative process of interaction design adapted from Sharp et al. [25].

to evaluate our requirements. Our prototype is not an application to be used in the working environment, although a future aim will be to develop more robust prototypes.

When researchers want to prove or disprove a link between an observed outcome and the hypothesis they use the experiment method [1]. Experiment could be our method to test design in the initial step. Experiment was not our choice because of the lack of time to conduct an experiment. Another reason was not sufficient knowledge to conduct an experiment.

The last method considered, but not chosen was case study. Case study takes one instance of the problem and observes it in depth. The focus of case study is very narrow. Case study could be used to test our design. Again because of the lack of time, the decision was not to choose case study for our research method. Another reason is the lack of experience with case studies.

The design and creation complemented with interaction design was chosen

because of our background from technical studies. Design and creation allows to create a tangible artefact. As suggested by the method, the first step was recognition of the problem combining of different types of documents and tagging. Next, an application, which can be viewed as a sketch was developed and then evaluated. The last part is the conclusion with the results and proposed future work. Interaction design was added to allow us a user centered approach to the research.

## 3.4 Data generation methods

In order to perform the research we used the following research methods. First, interviews were conducted with chosen researchers. The next step was to collect user and system requirements by making an affinity diagram. After collection of the requirements the sketches were designed. The sketches allowed us to get an overview of how the product that follows the requirements would be used. Afterwards the prototype application was developed. The last method was usability evaluation of this prototype application.

### 3.4.1 Interviews

Semi-structured interviews were used with researchers to obtain their thoughts and opinions on what user requirements are needed for digital notebooks. Another option was a structured interview in which researchers prepare a set of questions that they want interviewees to answer [1]. During the interview researchers ask a set of questions that are prepared in advance. Because interviewers have to stick to the structure, there is no option to start new topics. In a semi-structured interview researchers do not exactly follow a pre-set of questions but allow the interviewee to open new topics and lead the interview in different directions. We decided to choose a semi-structured type of interview because of its more flexible structure. It also allows us to gain information about certain features that the interviewee might mention during the interview. Through the interview our goal was to gather

information about the features of digital notebook.

After interviews were conducted the data needed to be analyzed. The affinity diagram can be used to analyze the results. It is an old method used to analyze qualitative data [27]. The affinity diagram method is also useful to find themes in interview results. The researchers first start by finding relevant ideas in the interview recordings. All of the ideas they found have to be recorded separately on their own piece of paper. Afterwards, all the similar chunks have to be grouped together. Finally, all the groups need to get a label. Labels represent common data features of a group. By performing these steps, the affinity diagram is finished. It gives a good overview of relevant groups and the data in each group.

The participants in the interviews were researchers that use digital pens. All researchers work in the area of maths. The first participant has used digital pen for 6 years in a number of projects. The participant used it in interviews for commercial projects and with middle school and high school students. Our second partaker has been conducting research in the field of math for 5 years. The main research area are integrals and the use of software in teaching. Our partaker researched what difficulties teachers have using software to support teaching and also difficulties that students face when learning. The digital pen has been introduced only recently to them. The next participant is also a mathematician. His main research area is education and is currently teaching in a combined program for teachers and engineers. This participant has been using digital pen for a long time. The last participant is also a mathematician. He has been teaching and researching in this field for four years. The main area of the research is mathematical memory which is different from the rest. One important requirement for him is to be able to reproduce the exact same writing. His last research included observing students solving math problems.

### 3.4.2 Sketching

First, the requirements were collected from the interviews. The next step was designing a paper prototype. As shown by Greenberg and Buxton [26], usability evaluation can be harmful sometimes. In today's practice it is necessary to use usability evaluation. This is due to the fact that it often produces important results that are very useful. However, there are situations where usability evaluation can suppress good ideas or misdirect developers. Like in art, early design should be considered a sketch. A sketch has a significantly different role than a prototype. It is 'a roughed out design' [26] that suggests, questions, explores and proposes one or more idea. A prototype on the other hand describes, answers, refines and tests the idea. The differences between a prototype and a sketch are seen in figure 3.1. By using this approach Greenberg and Buxton aim for 'Getting the Right Design' and after that 'Getting the Design Right'.

<b>Sketch</b>		<b>Prototype</b>
Evocative	$\Rightarrow$	Didactic
Suggest	$\Rightarrow$	Describe
Explore	$\Rightarrow$	Refine
Question	$\Rightarrow$	Answer
Propose	$\Rightarrow$	Test
Provoke	$\Rightarrow$	Resolve
Tentative	$\Rightarrow$	Specific
Noncommittal	$\Rightarrow$	Depiction

Table 3.1: Differences between sketch and prototype, adapted from [28].

In this regard a paper prototype has been designed first. The design of the paper prototype met the requirements, extracted from the interviews. For the paper prototypes a sketching technique was used.

### 3.4.3 Evaluation

Results were obtained during evaluation and analysis of our research. The evaluation approach used was usability testing. In usability testing users usually carry out a set of tasks in a controlled, laboratory like environment [25]. It is most often used with a prototype or product. Field study could be used where users are observed in their natural environment. It is usually used in early design stages, to define requirements for the prototype. Researchers gain qualitative data possibly equipped with sketches or described scenarios. The field study evaluation was not chosen because of the lack of time.

In usability testing a semi-structured interview was the method used. Participants were asked to complete a set of given tasks. They were observed and asked a set of questions to explain their thinking. Findings of the evaluation of our developed prototype are reported in the results of this thesis.

Our evaluation was guided by DECIDE framework proposed by Sharp et al. [25]. The framework consists of the following six steps:

1. Determine the *goals*.
2. Explore the *questions*.
3. Choose the *evaluation approach* and *methods*.
4. Identify the *practical issues*.
5. Decide how to deal with the *ethical issues*.
6. Evaluate, analyze, interpret, and present the *data*.

The first step is to determine goals. In our case, the goal of the evaluation was to assess whether researchers find combining of different types of files useful. The second goal of this evaluation was to test the reversed approach to tagging with researchers. The evaluation was supposed to answer the following questions:



Is the embedding of pencasts into L<sup>A</sup>T<sub>E</sub>X documents effective with our prototype application?

Does the reversed approach to tagging eases organizing documents for a researcher?

In this evaluation the usability evaluation approach was used. In order to collect data we used semi-structured interviews, like before. Observation was considered as a method but the interview has been chosen because it takes less time and experience than observing users. The evaluation sessions were kept short and effective in respect to participants time. The data was analyzed using an affinity diagram in a similar fashion to data from the first interviews. Results are presented in the results chapter of the thesis.

To collect the data screen-recording software was used on the computer that also recorded audio. Another audio recording device was used to record the users' voice for backup purposes. We also took notes during the evaluation.

## 3.5 Ethical considerations

Ethics were considered multiple times during the research like when preparing for the interviews and evaluation. Participants in the interviews were first informed about the research and also explained what the purpose of the interview was and why their participation was essential. All the data collected from the participants was treated with confidentiality. We did not reveal any of the data to any third parties. Personal information like names, was not disclosed neither in this report nor during the presentation of the thesis.



# Chapter 4

## Technology for sketching a prototype

After the methods described in the previous chapter were selected, the research continued. The next step was to conduct a series of interviews to collect the requirements. Results of the interviews and further details about the requirements are presented in the next chapter. This chapter describes the process of developing the prototype based on the following requirements extracted from the interviews with the stakeholders:

Embedding of pencasts into  $\text{\LaTeX}$  documents

- User requirements:
  - Combining of different types of files (pencasts,  $\text{\LaTeX}$ ),
  - Overview and interactivity of the content from the pen,
  - Export to PDF.
- System requirements:
  - Cloud based solution,
  - Digital pen supports audio recording,
  - Synchronization of writing and audio,

- Off-line availability.

Reversed approach to tagging

- User requirements:
  - Drag and drop,
  - Easy to share notes,
  - Support different types of files.
- System requirements:
  - Cloud based solution,
  - Synchronized, local clients,
  - Off-line availability.

After the interviews, affinity diagrams were used to categorize data and extract the requirements for the prototype application. Requirements listed are either important to them or not successfully implemented in currently used tools. Because of the limitations stated in section 1.4 the requirement for cloud based solution was not met with the developed prototype in scope of this thesis. These requirements were also considered while choosing the technologies used to develop a prototype.

To get a brief idea of the requirements two storyboards were designed and can be seen in appendices B and C. The first three parts of this chapter explain the decisions for technologies. The last two sections presents the interactive prototype developed.

## **4.1 Digital pens**

A digital pen is a pen that can digitize handwriting on paper [29]. A digital pen is used in the same way as ordinary pen, by holding it in hand and writing on a paper. The advantage is that the digital pen monitors its position, as a

result of which all writing, sketching and drawing is digitalized. Afterwards the pen can be synchronized with a computer so users can review the content.

Most digital pens use either Anoto<sup>1</sup> technology or have an accompanying sensor device. In the case that the pen has an additional sensor, the pen can be used on any paper. As the pen is moved by hand it transmits its position to the receiver device that must be positioned on paper. As shown in figure 4.1 the movements are captured by the device and stored as a handwriting in the device. After synchronization with a computer the handwriting is presented on a screen.

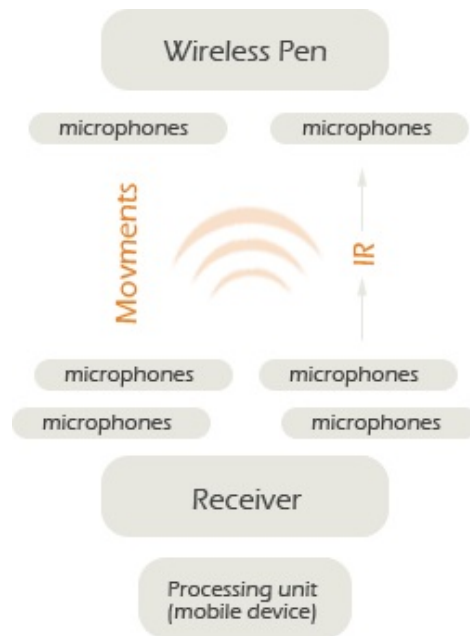


Figure 4.1: Technology of LogiPen digital pen [30].

If the pen uses Anoto technology, the user needs a special dot pattern to be printed on the paper. The dot pattern consists of small dots like shown in figure 4.2, which are arranged on an imaginary square grid. The dot pattern is unique for each 0.3 mm square. It is also practically invisible to the human eye so it does not distract the user. The digital pen uses infrared LED and a camera to take a snapshot of the dot pattern 75 times in a second. It uses a

<sup>1</sup>[www.anoto.com](http://www.anoto.com)

processor to read the dot pattern from the snapshot. This way the pen knows its position on a paper at all times. The computer inside the pen records the position of the pen. After the pen is synchronized with a computer users can see the handwriting or drawings on the computer screen.

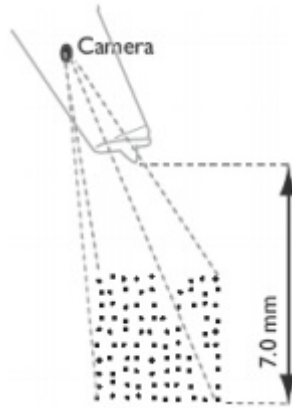


Figure 4.2: Livescribe technology by Anoto [31]

Feature	Livescribe Echo	Capturx	MDS *	Zpen	Logipen
Desktop SW	x		x	x	x
Use as mouse	x	x	x	x	x
Record audio	x				
Sync audio	x				
Mobile use	x	x	x	x	x
Bluetooth		x			
Technology	Anoto	Anoto	sensor	sensor	sensor
OS support	Mac, Win	Win	Win XP	Mac, Win	Win

Table 4.1: Comparison of different digital pens [32]. (\*Mobile Digital Scribe)

The table 4.1 shows five digital pens that were considered in this research. Both technologies, with an external sensor and a special pattern on paper, were considered. All considered pens are mobile devices and can be used to capture writing on their own. The Livescribe pen is the only one which

supports audio recording and that is the main reason that it was used in this research. It is also supported on all major operating systems.

For this research, a Livescribe digital pen has been used. It uses Anoto technology. According to Livescribe, one third of their digital pens are used by college students and teachers [31]. Researchers that collaborated with us also used Livescribe digital pens. What sets Livescribe pen further apart from other digital pens is an inbuilt audio recorder, which allows user to record audio while taking notes. The pen not only records audio but it synchronizes it with handwriting. After synchronization of the pen with a computer the user can export the notes with audio as a PDF pencast file or upload it on-line. The Livescribe software allows for exporting to different popular applications and sharing with other people.

## 4.2 Digital notebooks

Digital notebook used in our research is a freeware Evernote<sup>2</sup> service. Microsoft OneNote<sup>3</sup> was also considered. The main disadvantage is that it is not a freeware application. Also Google introduced a new service known as Google Keep<sup>4</sup>, which allows users to add notes including pictures. Users can choose the notes' color and add a list, but nothing more. Google has not released an API interface at the time of this research. In the table 4.2 you can see comparison of features of the three digital notebooks.

Evernote is a very popular web-based note-taking software. It has a large user base of over 11 million users [33]. It performs OCR on all the files so it supports searching on the content of the PDF and image attachments. Evernote provides applications for a wide range of mobile phone platforms, tablets and desktop computers. All the platform specific applications support synchronizing with the web and some also off-line editing and storage.

A lot of Evernote users come from the educational field. One can find

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<sup>2</sup><http://evernote.com/>

<sup>3</sup>[office.microsoft.com/en-001/onenote/](http://office.microsoft.com/en-001/onenote/)

<sup>4</sup>[docs.google.com/keep/](http://docs.google.com/keep/)

	Evernote	Keep	OneNote
Text input	x	x	x
Handwriting	x	x	x
Record audio	x	only on Android	x
Attachments	x	only image	x
Tagging	x		x
Sharing	x		x
OCR	x		x
Freeware	x	x	
API	x		x
OS support	Mac, Win, Moblie	Android, Chrome	Mac, Win, Moblie

Table 4.2: Comparisson between Evernote, Google Keep and Microsoft OneNote.

blogs, Pinterest <sup>5</sup> and other social network groups dedicated to the use of Evernote in education. Evernote has also an active community of developers. It provides API (Application Programming Interface) for all major programming languages like Phyton, Java, C#, Ruby, etc. The API is well documented and developers can search for help on the Evernote forums.

Evernote service satisfies a lot of the requirements as it is. It is a cloud based solution. Evernote applications are available for most of the popular desktop, tablet and mobile operating systems. A user can import notes by dragging and dropping documents, by emailing it or by creating new notes from within Evernote. It accepts all kinds of attachments. Additionally, it offers quality support for developers to extend the functionality. It can be used to develop off-line or on-line applications with a wide range of programming languages. The main reason for the usage of Evernote was the fact that it was free.

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<sup>5</sup><http://pinterest.com/>



## 4.3 Software considerations

Our prototype application is developed in C# programming language. For the user interface we used WPF (Windows Presentation Foundation) graphical subsystem. The downside is that it is only supported by Windows-based desktop and laptop computers. The prototype is also an off-line based application. On the other hand, there are several positive points. Combination of C# and WPF provides good support for rapid prototyping. Griffiths states (among others) the following advantages in using C# with Visual Studio [34]:

- WYSIWYG GUI development tools,
- Debugging tools and testing tools,
- A lot of included libraries,
- Automated memory management,
- Exceptions handling.

The use of HTML and JavaScript were considered to develop a web-based solution. Reviewing all the available libraries and choosing the best one would take too much time and it would be beyond the scope of this thesis. The aim of this prototype is to be able to evaluate the proposed technique of combining multiple heterogeneous documents and different propose to tagging.

According to Buxton [28], developers should first develop the right design. Only after different design ideas have been tested, should developers start to optimize the chosen design. For this reason we developed our prototype application in the technology that is the least time consuming for us. Our prototype does not include optimized user interface or user experience. Our developed prototype should be viewed as a sketch. The design is not finished and there are still open ways how to continue developing it. We want to test the technology of approach. For this reason it is also sufficient for us to develop a desktop based solution. This prototype is evolution of the paper based sketches that were designed first.

## 4.4 Prototype application

The prototype application has two main parts. One part is the support for embedding Livescribe pencasts into  $\text{\LaTeX}$ . The other part is tagging notes stored on Evernote. Before using the application, users must adjust the settings in accompanied XML file. The settings file contains the info needed to connect to the Evernote account.

The embedding of the pencast is supported by MyLivescribe web site. This means users must first upload the pencast on-line to the Livescribe website. The next step is to find it and copy a link for web embedding of pencast. Users can also use publicly available pencasts created by others. Once they have copied a web-embed link they can switch to our application and click the button *LS embed*.

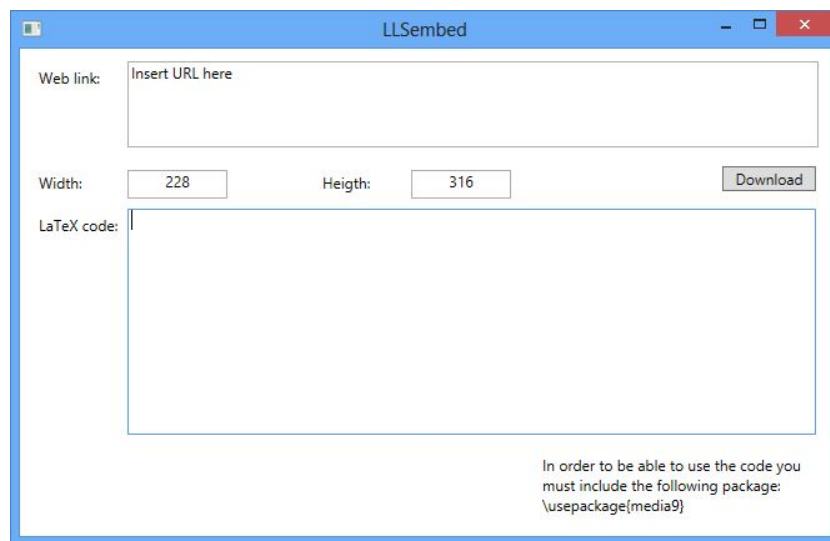


Figure 4.3: The part of prototype application to embed the pencast to  $\text{\LaTeX}$ .

A new window opens with two text boxes and a *Download* button as seen in figure 4.3 . Users paste the previously copied link to the *web link* text box and press *Download* button. The application downloads the necessary files to its directory. When the download is finished the  $\text{\LaTeX}$  code is shown in the second text box. An example of the output is shown in figure 4.4.

Afterwards users can copy the code and paste it into their  $\text{\LaTeX}$  documents to get a PDF file with embedded pencast.

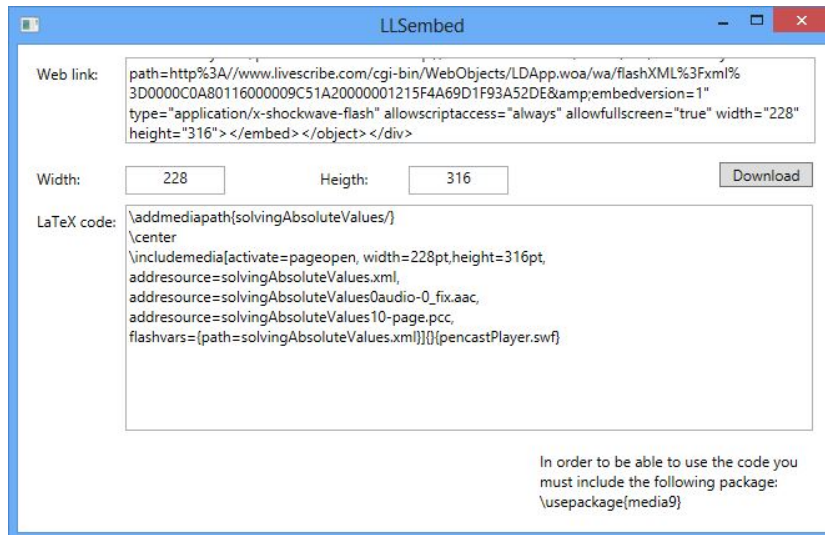


Figure 4.4: When needed files are downloaded prototype application displays  $\text{\LaTeX}$  code.

The other part of the prototype application is tagging of Evernote's notes. To start, users must open the prototype application and click *Connect Evernote* button. The application connects to Evernote using the Evernote API for C# and collects' the users tags and notebooks. Notebooks are in the top drop down list and notes from the first notebook are shown in the list of notes as seen in 4.5. Users can later change the notebook using the drop down list. When they choose a different notebook, the application connects to Evernote again and displays all the notes from the selected notebook. For each note title, thumbnail and associated tags are displayed. By double clicking on a note, the note is displayed in Evernote desktop application. For this to work users must have Evernote application installed.

Next, users can add tags using the *Add new tag* button. The tag component consists of a text box with tag names and list box that shows the notes associated with the tag. Users then drag and drop notes on those tags. When the note is dragged out of the main list it is erased from it like shown



In case users want to remove the note from the tag, they drag and drop it onto the basket icon in the corner of the application. The note is erased from the tag. After they have finished the tagging, users can save the tagged notes back to the Evernote by clicking the *Save* button. The application again uses the Evernote API to update the tagged notes and shows the message box after finishes. Now users can view the tagged notes on-line and in local clients.

## 4.5 Coding of the prototype

The interactive prototype application was developed as a Windows desktop application using C# programming language. It consists of a part that embeds pencasts into L<sup>A</sup>T<sub>E</sub>X documents and a part that tags notes from Evernote. In the first iteration both parts were part of one application, while in the second iteration we developed two separate applications, one for each part.

### 4.5.1 Embedding pencasts into L<sup>A</sup>T<sub>E</sub>X documents

First attempt was to embed the pncast as a PDF page into L<sup>A</sup>T<sub>E</sub>X. To achieve that we used a PDF package *pdfpages*. It did not work because the L<sup>A</sup>T<sub>E</sub>X package did not preserve the interactivity of pencasts in the produced PDF files. The output files only had a PDF page displayed with no interactivity or audio. The second attempt was to embed the pncast PDF page into PDF document created, using L<sup>A</sup>T<sub>E</sub>X. That was achieved using a free PDF library iTextSharp. We tried multiple functions like PdfStamper and PdfWriter, but again none of these preserved the interactivity.

Pencasts available on Livescribe website are played using flash player. The idea evolved to download the pncast in flash format and embed it into L<sup>A</sup>T<sub>E</sub>X and produce a rich media enabled PDF since PDF documents offer support for flash based content. First we tested a *movie15* package. Because it is a deprecated package we later used *media9* package after doing an on-

line search. *Media9* is a standard L<sup>A</sup>T<sub>E</sub>X package providing support to embed Adobe flash, 3D, sound and video files and streams [35]. The package also has support to choose custom flash player.

The next step was to reverse engineer the Livescribe website source code and find the files needed to play pencasts. Then we examined the source code of MyLivescribe website. Particularly, the *Echo Pencasts* subsite was examined where pencasts are published. The tag `video_src` looked like it points to the pencast video. Part of the HTML source is shown in figure 4.7.

```

55 <link rel="image_src" href="
    http://www.livescribe.com/cgi-bin/WebObjects/LDApp.woa/wa/
    pencastPreview?sid=Bsd6R5PW9Jdb" />
56 <link rel="video_src" href="
    http://www.livescribe.com/media/swf/fbPlayer.swf?path=http
    ://www.livescribe.com/cgi-bin/WebObjects/LDApp.woa/wa/flas
    hXML?xml=0000C0A80116000009C51A20000001215F4A69D1F93A52DE
    " />
57 <meta name="medium" content="video" />

```

Figure 4.7: Part of HTML source code of Livescribe web page with pencast's link.

When the link was copied and pasted into the web browser a page with only pencast was shown. That was the proof that this tag links to pencasts. A long string at the end of the link looked like an ID. Checking the source of different pencasts confirmed that because each had a different string. The link consists of two parts. First part is a link to a *fbPlayer.swf* file, which is a flash player for pencasts and the second is a path to the pencast's XML file with the unique ID at the end. The location of the XML is passed to the pencasts player as a parameter. Both files were downloaded. During the further processing of the XML file, two interesting tags were discovered: *audio* and *coordinates*. The audio tags link to ACC (Advanced Audio Coding) files that have audio stored in. The coordinates tags link to PCC files. We downloaded all the files linked from the XML to the local storage. The links in the XML file were manually corrected as appropriate. Afterwards we

created an HTML file to test the playing of a pencast from a local storage. This test proved that all needed files were obtained and accessible.

The next step was to import those files into the  $\text{\LaTeX}$  document and embed them into the PDF using the *media9* package. The previously downloaded *fbPlayer.swf* file was used as a pencast player. The *media9* package supports adding parameters to the player, therefore the XML file was passed as a parameter. The files linked from XML had to be included in the document as well so the player can access them when playing a pencast. The result was a PDF with pencast embedded and its interactivity preserved.

The next step was to automate the downloading and embedding of files. The prototype application takes the web embed link as an input argument. It loads the link as an `XmlDocument` object and passes it to extract the pencast's title and ID. It uses the pencast's title to name the folder in which the files are saved, and an ID to access the files, needed to play the pencast, on the server. To download the files the application uses the `WebClient` class, that provides common methods to send and receive data over the network.

The prototype application first downloads a flash player file and then the main XML of the pencast. Then it loads the main XML as an `XmlDocument` object and processes it to find links to the files needed to play the pencast. Figure 4.8 shows a sample of a main XML file.

The application downloads all the files that are linked with a `src` property into the same folder as the main XML and renames them appropriately. It also corrects the links in the main XML which is saved when all the files are downloaded.

While processing the main XML file, it generates the  $\text{\LaTeX}$  code. The  $\text{\LaTeX}$  code consists of a pencast's size, all the audio and coordinate files, the location where they are stored and a *fbPlayer.swf*. Figure 4.9 shows a sample  $\text{\LaTeX}$  code to embed the pencast.

In the second iteration we improved the GUI. The text fields for a size can now keep proportion, so users do not need to calculate both sides. If the width and height are not proportional, then the output PDF has a black

```

1  <?xml version="1.0"?>
2  <pencast version="1.4">
3    <title>Test Pencast</title>
4    <author>Livescribe</author>
5    <duration>124696</duration>
6    <audio src="/cgi-bin/WebObjects/LDApp.woa/wa/flashXML?
xml=0000C0A80116000009C51A20000001215F4A69D1F93A52DE&
audio=PRS-bd498447&file=audio-0_fix.aac" type="flv"
begintime="536" duration="124160" filesize="0" />
7    <page id="0" label="1" width="2065" height="3400"
8      background="#ffffff">
9      <coordinates src="/cgi-bin/WebObjects/LDApp.woa/wa/flashXML?
xml=0000C0A80116000009C51A20000001215F4A69D1F93A52DE&
page=0" format="PCC1.4" filesize="28000" />
10    </page>
11  </pencast>

```

Figure 4.8: Source code of main XML file.

```

25  \addmediapath{solvingAbsoluteValues/}
26  \begin{center}
27    \includemedia[activate=pageopen,width=249pt,height=346pt,
28      addresource=solvingAbsoluteValues.xml,
29      addresource=solvingAbsoluteValues0audio-0_fix.aac,
30      addresource=solvingAbsoluteValues10-page.pcc,
31      flashvars={path=solvingAbsoluteValues.xml}] {}
32    {pencastPlayer.swf}
33  \end{center}

```

Figure 4.9: Sample L<sup>A</sup>T<sub>E</sub>X output code produced.

border on the side. Users turn the proportion on or off by ticking or unticking the *checkbox*. Minor detail is that when users paste a new link, the output window is cleared. This way, it is obvious to the user that the new process has started. Also, there is a copy button in the application which puts the L<sup>A</sup>T<sub>E</sub>X code on the clipboard. In the previous version users had to select the whole text and copy it. Now they can just click the button to copy the whole text.

Another major addition is that the prototype application has a support for a command line, so it can be operated from a command line and it



can accept parameters. This mode was added so it can be used as a user command from within a  $\text{\LaTeX}$  editor like shown in the figure 4.11. When users start it from a command line, the TEX file's location must be passed as a parameter, so the application can access the TEX file. It parses the file and checks for all lines that start with a special sequence shown in figure 4.10. Once the application finds a link, it checks whether it has already processed

```

44 convallis nec bibendum sem viverra. Proin ut tortor
45 nisl, sit amet adipiscing urna.
46 %\PencastLink:http://link
47 Etiam urna arcu, pellentesque eget sagittis ac, iaculis
   ac nibh. Vivamus lacinia mattis nulla quis convallis.

```

Figure 4.10: Sequence to embed pencast, where `link` is the pencast's web embed link.

it or whether it is a newly added link. If it has already processed it, then it skips it, otherwise it calls the same function as from the GUI mode to download all the files and generates the  $\text{\LaTeX}$  code. The difference here is that the  $\text{\LaTeX}$  code is pasted automatically in the TEX file immediately after the comment with the original link.

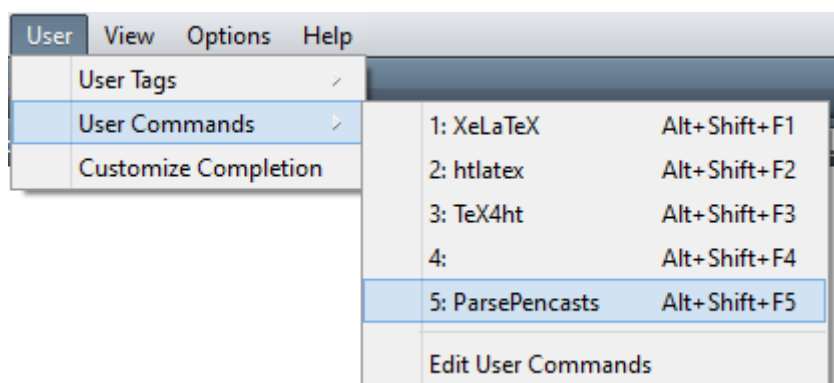


Figure 4.11: An example use as a custom user command in TexMaker  $\text{\LaTeX}$  editor.

### 4.5.2 Tagging notes from Evernote

The second part of the application provides a reverse approach to tagging. This part works in connection with Evernote. Evernote is a widely used digital notebook service with more than 10 million users [33]. The prototype application uses Evernote API to access the Evernote files. The API is available for a wide range of programming languages.

When users start the application, it looks for the *Settings.xml* file in its root directory and parses it. The settings file stores user data needed to connect to the Evernote account. Currently it only supports developer accounts. Afterwards the application tries to connect to Evernote and reads all the tags users have stored on the server. This information is used later on, when application saves the changes. All the settings and tags are stored in an `EvernoteInfo` class so they can be accessed at later times.

When the application connects to Evernote it fetches all notebooks stored on the server and shows their names in a drop down list. By default it selects the first available notebook and displays its notes. This process takes some time as it connects to the server and downloads the data. During this process the mouse cursor shows a waiting icon. The application requests notes' meta-data and also downloads the thumbnail image of each note. When the application receives the meta-data, it checks if the thumbnail for each note exists locally, otherwise it downloads it. For each note the application stores the following information: GUID (id of the note), title, image location and existing tags. When all the notes are processed the mouse cursor is put back to the default icon. The process of downloading the notes' meta-data and thumbnails is repeated each time users choose a different notebook. The application shows notes in the main listbox positioned under the dropdown list with notebooks.

When the notes are loaded users can start adding tags. The tag object for GUI is created in the code. As shown in the figure 4.12 the main component is a stack panel that has vertical orientation. First object inside is another stackpanel but it is horizontally oriented. Inside the second stackpanel is a

textbox that holds the tag's name or title. In the second iteration a label was added, that displays how many notes were dropped inside this tag. The label has a **MouseDoubleClick** event attached to it. When counter label is double clicked the tag object is resized. By default it shows only one note. When it is resized all the notes under a tag are visible. This is achieved by assigning the **Double.NaN** as a size, so object is resized automatically depending on the number of notes it contains.

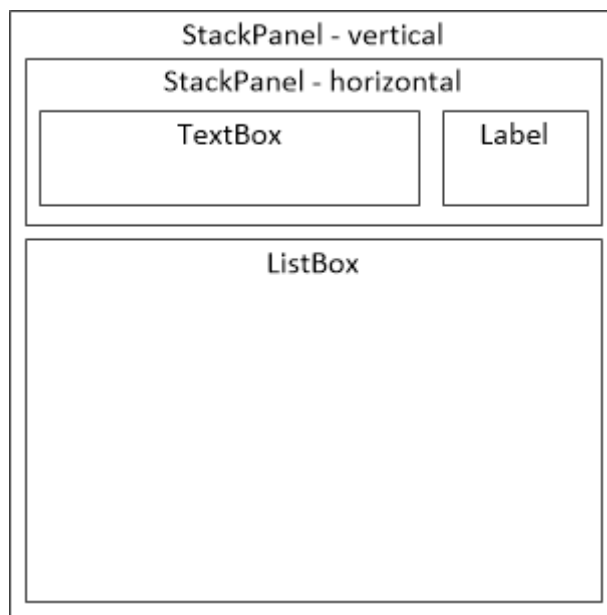


Figure 4.12: Structure of the tag object.

The second object in the main stack panel is a listbox. The listbox contains notes dropped onto the tag. It has events for drag and drop attached and also event for double click of an item. When note is double clicked, it opens in the Evernote desktop application using the Evernote protocol: **evernote://link**. At last the main stack panel, with all its elements, is added to the wrap panel which holds all the tags created. The options to view note in Evernote application and to resize the tag were added in the second iteration.

It is worth noting the importance of a calling **RegisterName** function.

From MSDN<sup>6</sup>: "Calling `RegisterName` is necessary in order to correctly hook up animation storyboards for applications when created in code." This function registers the object into visual tree so it can be found later. In case the `RegisterName` is not called, the object is not be found although it is appropriately named.

The listboxes have attached events to support drag and drop operation. Drag is started when mouse button is clicked and moved for at least minimal distance defined by the system variables as shown in figure 4.13.

```

1  if (e.LeftButton == MouseButtonState.Pressed &&
2      ((Math.Abs(diff.X) >
3          SystemParameters.MinimumHorizontalDragDistance)
4      || (Math.Abs(diff.Y) >
5          SystemParameters.MinimumVerticalDragDistance)))

```

Figure 4.13: If sentence that decides whether or not drag was initiated.

When the condition is true, drag is initiated and the function finds the item in the listbox and extracts the note in the item. Then it creates `DataObject` with note's data and passes it to the `DragAndDrop` event. When the note is dropped onto another listbox the function checks if the note is still in the main list box. If it is, the function removes it. It is only removed from the main listbox. The reason for this is to enable copying of notes between different tags. This means that the same note can be assigned to multiple tags. It is then added to the new list-box and the list-box is scrolled to the bottom so it displays the last item. The note counter is updated - increased by one.

Users can also drop notes onto the bin icon in the bottom left corner. In this case the application removes the note from the source's listbox and disposes it. It also decreases the source counter by one. This is implemented so that users can remove notes from a tag in case they mistakenly assign it to a tag.

When users finish tagging notes, they can click *Save* button to synchronise

---

<sup>6</sup><http://msdn.microsoft.com/en-us/library/system.windows.framework.element.registername.aspx>

changes back to the Evernote server. The application iterates through each tag. It checks the name of the tag and tries to create a new tag on the server. If the error, that the tag already exists, occurs, it finds it in the `EvernoteInfo` object where all user tags are stored and requests its GUID. If the tag does not exist on the server, the method creates a new tag and returns its GUID. Once it knows the tag's GUID it iterates over all the notes under the tag and updates their information about the tags assigned. If the note does not have any tags, it creates a new string array, otherwise it adds the tag to the existing array as shown in figure 4.14.

```
1  if (note.TagGuids != null)
2      note.TagGuids.Add(tagGuid);
3  else
4      note.TagGuids = new List<string>(new string[] {tagGuid});
5  noteStore.updateNote(authToken, note);
```

Figure 4.14: Code that assigns a tag to a note.

Livescribe web site provides a link to download the pencast as a PDF file. In essence, this application downloads the pencast's flash files from the Livescribe web site. In order to download pencast files, reverse engineering approach was used. In the scope of this thesis the Livescribe's end user agreement was not checked, so before further development either this should be done, or the users should be limited to only downloading their own pencasts.



# Chapter 5

## Results

The first step in this research was conducting a literature review. In connection with the methods described in chapter three, the next step was collecting the requirements. That has been done by analyzing interviews conducted with the stakeholders. The following section presents the interviews' results. Afterwards, the prototype application has been developed as described in the chapter 4. The second section of this chapter presents the results of the evaluation of the prototype application.

### 5.1 Interview results

Interviews were conducted with four participants. All participants have a background in research and teaching. Participants were first asked to introduce themselves, then describe how and why they use digital pens and digital notebooks. They were also asked to think about what functionalities are missing in the applications that they use and what they would develop. The last part concerned organizing documents and the use of cloud based solutions. A cloud based solution defines a centralized on-line service where data is also accessible via local clients. The questionnaire used during the interview can be found in the appendix A.

Some examples of research they have conducted include middle school

students who used digital pens to record themselves while solving a math problems [36]. To achieve more accurate results, students solved the problems at home. By being in a home environment, they did not feel the pressure of the teacher. Researchers later reviewed the results. Another example is observing students at solving math problems to study mathematical memory. First they introduced digital pens to students. After they became familiar with it, the observation started and they used digital pens at every step during the problem solving. Researchers were able to reproduce the exact steps in linear order afterwards.

All of the participants stated that they used audio recording with the digital pen. An important feature is also the synchronization of the writing with the audio. They stated different use cases. Some participants focused more on the speech and only wrote down main reference points. This is useful while conducting interviews or attending meetings. In other cases, it is essential to be able to reproduce the exact linear story with both audio and writing. This is especially useful when working with students.

Two participants used digital pens to create lectures for students. One participant appreciated the easiness of use compared to graphic tablets and screen casting software. As previously mentioned, math symbols and equations can be difficult to input in the computer using a keyboard. Because digital pen acts like an ordinary pen, handwritten math symbols are as easy to use as other letters and symbols. It provides a simple way to produce a so called mini-lecture and publish it on-line. One advantage over screencast (or digital camera recording) is that pencast provide an overview of the content presented. This allows the audience (students) to skip to the part that they are interested in. As the document can be in PDF format, it is easy to print it and to share it by email. Participants also like that their notes still exist on the paper not only in digital format. The participants use cloud solutions, but they prefer to have synchronized clients with local storage, so they are not dependent on the internet connection.

Problems the participants stated were difficulties combining the pencasts



produced by a digital pen and  $\text{\LaTeX}$  document processing software. They also wish to have different organizational options of digital options that were similar to physical piles of paper. The last comment was about simplified synchronization between digital pens and computers.

The following requirements were extracted from the interviews conducted to meet the needs of the stakeholders: User requirements (UR):

- UR1 - Drag and drop,
- UR2 - Easy to share notes (exists with Evernote),
- UR3 - Combining of different types of files (pencasts,  $\text{\LaTeX}$ ),
- UR4 - Overview and interactivity of content from the pen,
- UR5 - Export to PDF (exists with  $\text{\LaTeX}$ ).

System requirements (SR):

- SR1 - Cloud based solution (exists with Evernote),
- SR2 - Synchronized, local clients (exists with Evernote),
- SR3 - Off-line availability (exists with Evernote),
- SR4 - Digital pen supports audio recording (exists with Livescribe),
- SR5 - Synchronization of writing and audio (exists with Livescribe).

These are not all the requirements that should be met when developing a digital notebook. These are requirements that were specified by the participants. According to them, some requirements are not successfully implemented in the existing solutions.

## 5.2 Evaluation results

The goal of this evaluation was to assess the easiness of use, satisfaction and effectiveness of the prototype application. Participants first listened to the explanation of the process. Then they carried out the two tasks. The last part of the evaluation was a debrief session. This section presents the results of the evaluation with the participants.

During the preparation of the evaluation plan, we faced a problem with the tagging part of the prototype application. The application currently works only with the Evernote developer accounts so evaluators cannot use their notes to test the prototype. They may also not have wanted us to see the content of their notes. The first idea was to simulate received homework from students that the evaluators would sort with the prototype application. To tag notes, evaluators need to know a content, and that would take unnecessary time during the evaluation. The final decision was to create a notebook and put in it images of famous brands' logos. Each brand represented one note. This way evaluators could quickly recognize the meaning of a note and have an idea of how to sort it. The evaluation plan can be found in appendix D.

The prototype application uses Evernote API. Evernote is a cloud based solution (SR1). Researchers can access their notes either on-line or by using local clients (SR2). Evernote's desktop clients have local databases that allow researchers to work with their documents off-line (SR3). In the prototype application users move, copy and delete notes by using dragging and dropping (UR1). Part of the prototype application offers embedding pen-casts in  $\text{\LaTeX}$  documents (UR3). The output of  $\text{\LaTeX}$  documents is usually a PDF file (UR5). Having more content in a single document simplifies sharing (UR2). Evernote API also has functions to share users' notes with others (UR2). Through the use of a Livescribe digital pen researchers can record audio (SR5). The pen automatically synchronizes the audio with handwriting (SR5). When researchers transfer data from the pen to the computer they can export the pencast as a PDF files or publish it on-line. Either way,

the audience of the pencast have a good overview because all the content is displayed and the user can go back and forth by clicking on the handwriting.

The evaluation covered both parts of the application: the embedding of pencasts in  $\text{\LaTeX}$  and the reversed approach to tagging. The part that helps with embedding pencasts into  $\text{\LaTeX}$  documents was well accepted by the evaluators. The main advantage was that it keeps the interactivity of the pencasts once embedded in the PDF. In their opinion such a tool would be helpful to produce a lecture materials and enhance the reports they write. Another advantage they have stated is that merging of different types of files allows users to have one document with more content. In this case, it is a PDF file with embedded pencasts. Participants appreciated that because it simplifies sharing of the documents. By having the content off-line all files are embedded in the PDF which solves the problem of where to put external files. One disadvantage is that it is a Windows desktop application because researchers use different operating systems.

When trying the prototype themselves they had no major problems. Some were a bit confused of where to find web embed link on the Livescribe web site. That was consequence of not being familiar with the website's structure. One participant also tried to copy the link of the web page instead of the web embed link. This option was not chosen because when users access MyLivescribe in the Livescribe desktop application web link is not visible. Once they copied the link they understood the rest of the process. The operation flow of the prototype application was straightforward to them. They had some comments about possible advances and improvements. An advice was that there should be an option to keep the size proportions and the other was a copy button that would put the  $\text{\LaTeX}$  code on the clipboard.

The next part was tagging notes from Evernote. This part would need another iteration because the goal here is not so directed. The tool heavily depended on the Evernote desktop application. Nevertheless, it still showed how the gap discovered in this research can be filled. The main thing that the evaluators were fond of was the easiness of use and simplicity. Users can

quickly create a personal structure from the ground up. This way it is similar to their mental model so they can add files at a later stage. The prototype is simple to use so it adopts users needs. Drag and drop operation proved to be a natural operation because the participants understood the principles of use quickly. While using the application they followed their own rules so they did not have problems understanding the structure.

The main problem is that the tool does not provide a way to get an overview of the notes under one tag. At any time only one note is visible under a tag. Participants wanted to see what notes they put under a tag. Sometimes users could forget what kind of notes they assigned to a certain tag. There should be a way to get an overview of the notes under a tag. This is important while organizing files so users can refresh their idea. The prototype can be difficult to use when users do not know how tagging works. Participants found a similarity between organizing of notes in this way, and folders and files on a computer system. This connection enhanced their understanding furthermore.

### 5.3 Summary of results

This chapter presented the answers of the two research sub-questions that guided the research. The first section discusses *What are the main user features and system requirements for digital notebooks that can be designed and developed to support research and math education?* To answer this question, interviews were conducted with researchers, who also work as teachers. Data collected during the interviews was analyzed using affinity diagram. Requirements for digital notebooks to support a research were extracted and presented in section 5.1.

To answer the second research sub-question *What key features are needed to support the integration and organisation of digital notebooks and related media from digital pens?* prototype application was developed considering these requirements. Development of the prototype is discussed in chapter 4.

The developed application was evaluated, and results are presented in section 5.2 which also shows how requirements, implemented in the prototype were collected.

This section answers the main research question: *What are the software requirements for further developing digital notebooks and digital pens for use in research and university teaching?* The answer is drawn from both the interview and evaluation results. With the growing popularity of tablet computers, some researchers use more than one device. Furthermore, these devices use different operating systems. To overcome these two obstacles digital notebooks should be developed as a web-based solution (SR1). To be able to access the same data from different devices local clients should be developed (SR2). Some researchers have pointed out the importance of off-line availability (SR3) in case there is no internet connection available.

One requirement was that it should support a drag and drop operation (UR1). Evaluation proved that drag and drop provides a natural way to move documents. Also, researchers did not have problems understanding how to use the tagging part of the prototype application. Researchers that participated in this research were also teachers. They share their documents with students and other researchers. They want to be able to share their documents (UR2). The prototype relied on the desktop Evernote application for this matter. The prototype application provides an option to embed pencast into L<sup>A</sup>T<sub>E</sub>X documents (UR3). Because the pencast is embedded (and not just linked) all content is in one file. This also simplifies sharing. L<sup>A</sup>T<sub>E</sub>X documents can be exported to PDF format (UR5).

Digital pens used in research should support audio recording (SR4) and synchronize it with writing or drawing (SR5). By having audio saved with handwriting, researcher can focus on the speaker and later they can listen to the audio recorded at the time of writing. Another advantage of using a digital pen is that researchers still have a paper copy. Paper provides a good overview of the content. Pencasts in digital format also display all the content (UR4) so the audience can move to the part they are interested into

by clicking on the writing.

These requirements should be met developing digital notebook for supporting a research. Paper is an essential medium so it should not be overlooked. That is one of the reasons that the requirements include digital pen. Organizing options should be in connection with researchers' mental models, so they understand it. With multitude of devices, digital notebook should be cloud based. The next chapter provides the conclusion of the research report and discuss some possible future works.

# Chapter 6

## Conclusion and future work

The previous chapter discussed the results. The results come from conducted interviews and evaluation of the developed prototype application. Researchers can create interactive documents and share them with co-workers and students. In case they share teaching materials with students, students can review it, solve the exercises and send it back. Researchers then correct and analyze the data. They can access their documents from multiple devices that synchronize to the Evernote's cloud. It is convenient to have documents stored on one place, to organize them.

This thesis discusses benefits of digital notebooks to support a research. The whole process is described and explained in writing and can be reproduced by other researchers. The following section provides some ideas how can the topic be further researched.

### 6.1 Future work

As stated before, the prototype is a desktop application. For future work, it could be developed as an on-line application. This way researchers could access the application from multiple devices that they use. Another possible improvement would be using a wider range of stakeholders.

For the first part, minor improvements would be to erase the last output

when users start a new download. Currently, the tool presumes that the directory with pencasts files is in the same directory as  $\text{\LaTeX}$  document. It could ask users about the save location. To enhance users experience the prototype could accept web link to the pencast instead of web-embed code. Users could only copy a link instead of searching for web-embed code and copy that. Also link is shorter than web-embed code.

Some data could be confidential, in which case researchers would not like to publish it on-line. That problem could be overcome by providing a way of embedding the local files. Another future improvement could be the ability to embed only a certain part of pencast page. This way users could embed small chunks of a page into  $\text{\LaTeX}$ . More research could be done on providing embedding in other documents, e.g. Microsoft Word, LibreOffice. On the other hand, the tool could support embedding of additional types of multimedia documents in  $\text{\LaTeX}$  so one tool could be used for embedding of rich media files. It could be developed as a  $\text{\LaTeX}$  package.

The main requirement during the evaluation, for the second part of the prototype, was to provide an overview of notes under a tag. In second iteration this was added so users have a good overview of the notes under each tag so they can refresh their initial meaning of a tag at any time. Another improvement could be the visualization of tags, in sense of tag-cloud. This could also be useful to get an overview of the tags. As mentioned participants in the evaluation found this tagging approach similar to file system. Nested tags could provide an efficient way to organize notes. Because this is not a directed tool, a more detailed evaluation is necessary. The evaluation might provide better results if participants used their personal notes and used the tool for a longer period of time to reproduce more real world setting.



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# Appendix A

## Interview questions

[Introduce myself]

[Discuss the purpose of this interview]

[Ethics (interview recorded, data kept confidential)]

### 1. Introduction

- (a) Who are you?
- (b) What do you teach and research?
- (c) How long have you been teaching and researching?

### 2. Digital notebooks and pens

- (a) Do you use digital pen?
- (b) How do you use digital pen in your research?
- (c) Why do you use it?
- (d) What benefits do you gain using it?
- (e) Do you use Evernote?
- (f) What functionalities are missing in the tools you currently use?
- (g) What would you develop?

### 3. Organizing files

- (a) Do you digitalize your paper documents?
- (b) How do you organize your files?
- 4. Do you use Livescribe pen?
- 5. Would you prefer on-line or off-line solution?



# Appendix B

## Tagging story

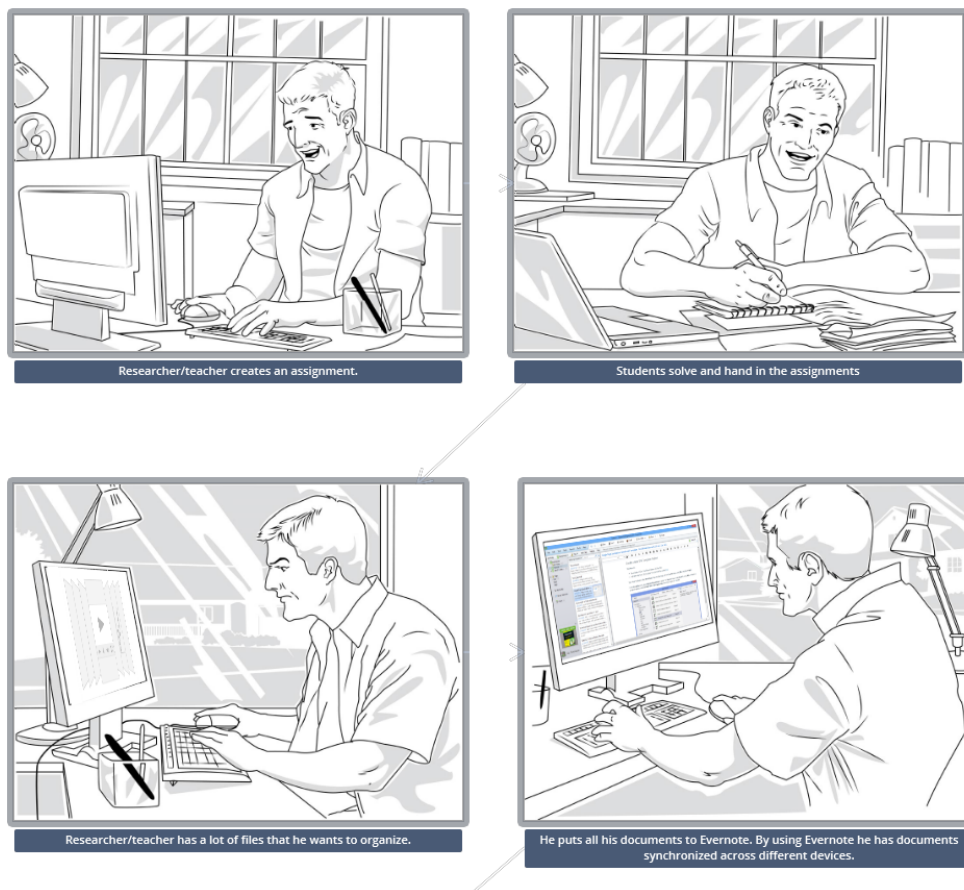


Figure B.1: Storyboard for organization (part 1)

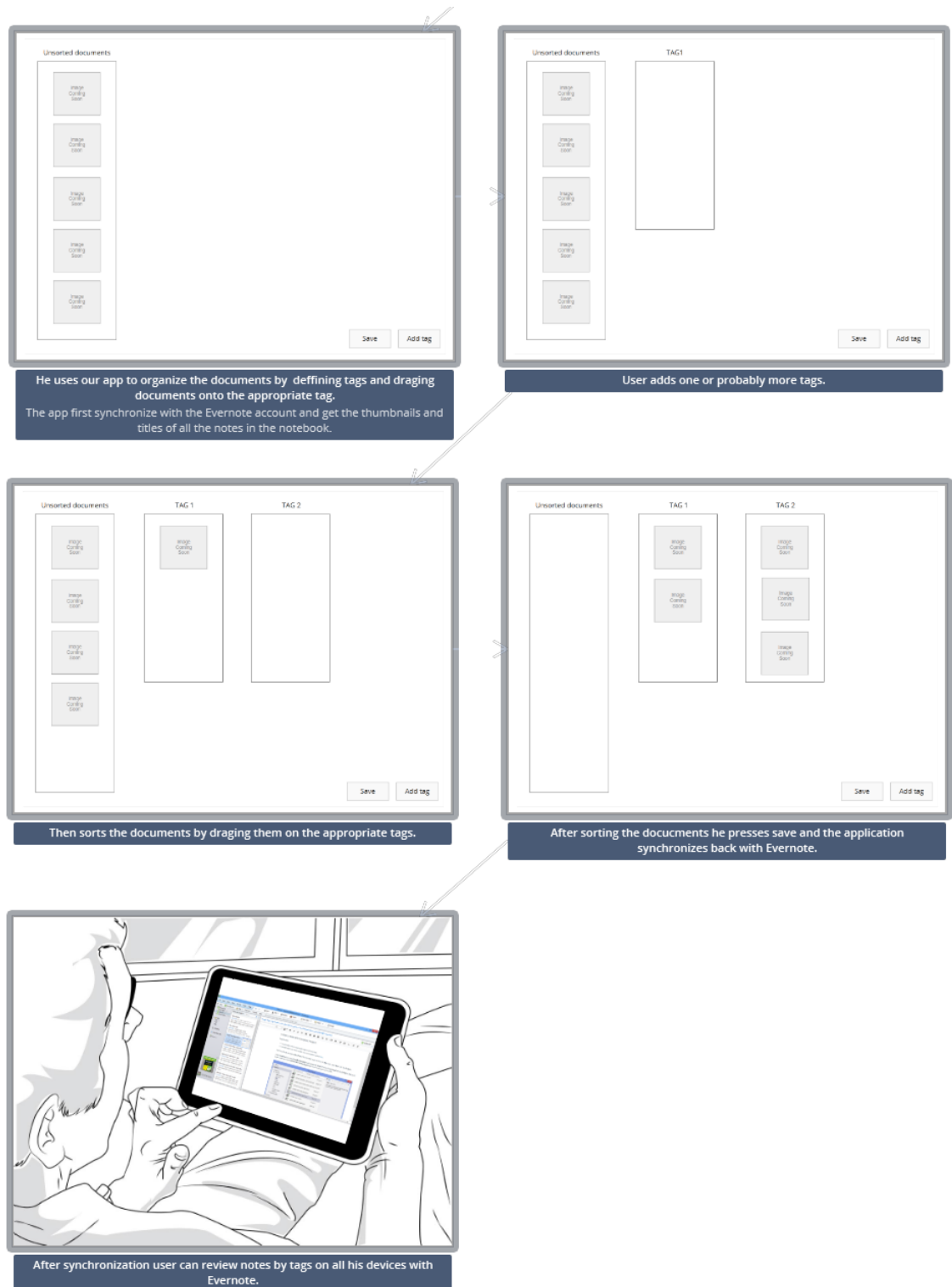


Figure B.2: Storyboard for organization (part 2)

## Appendix C

# Embedding story

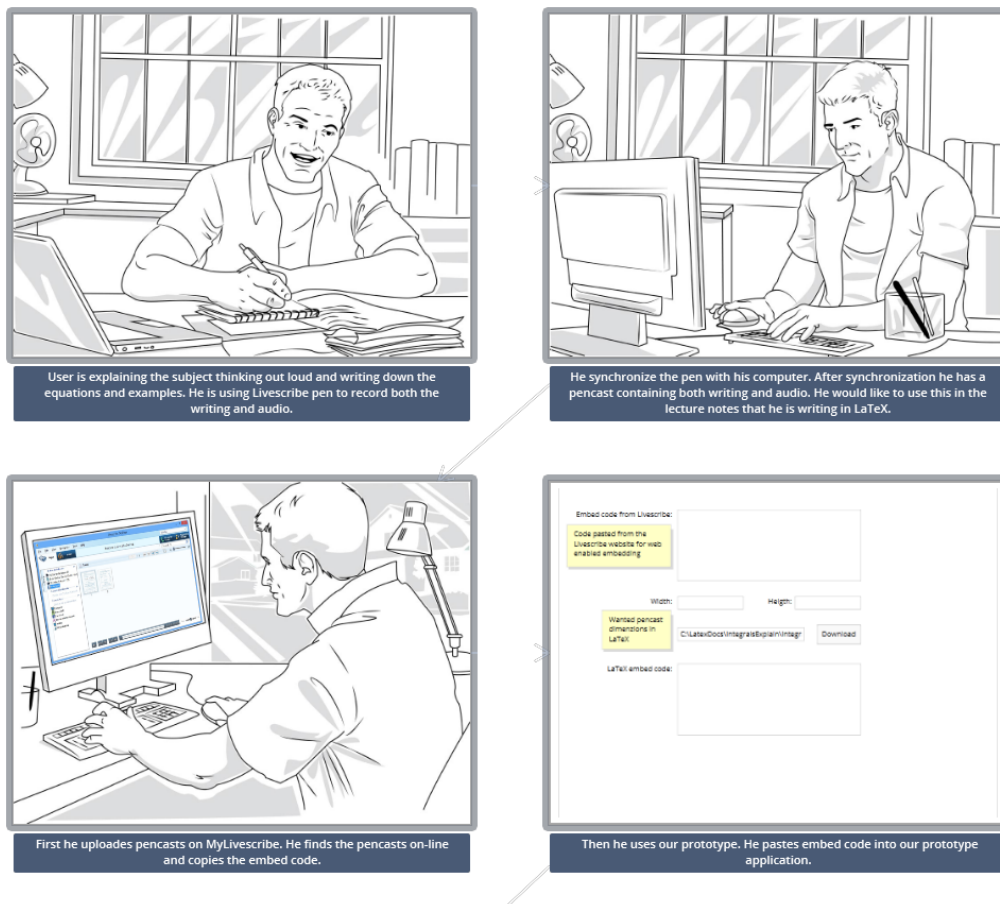


Figure C.1: Storyboard for combining (part 1)

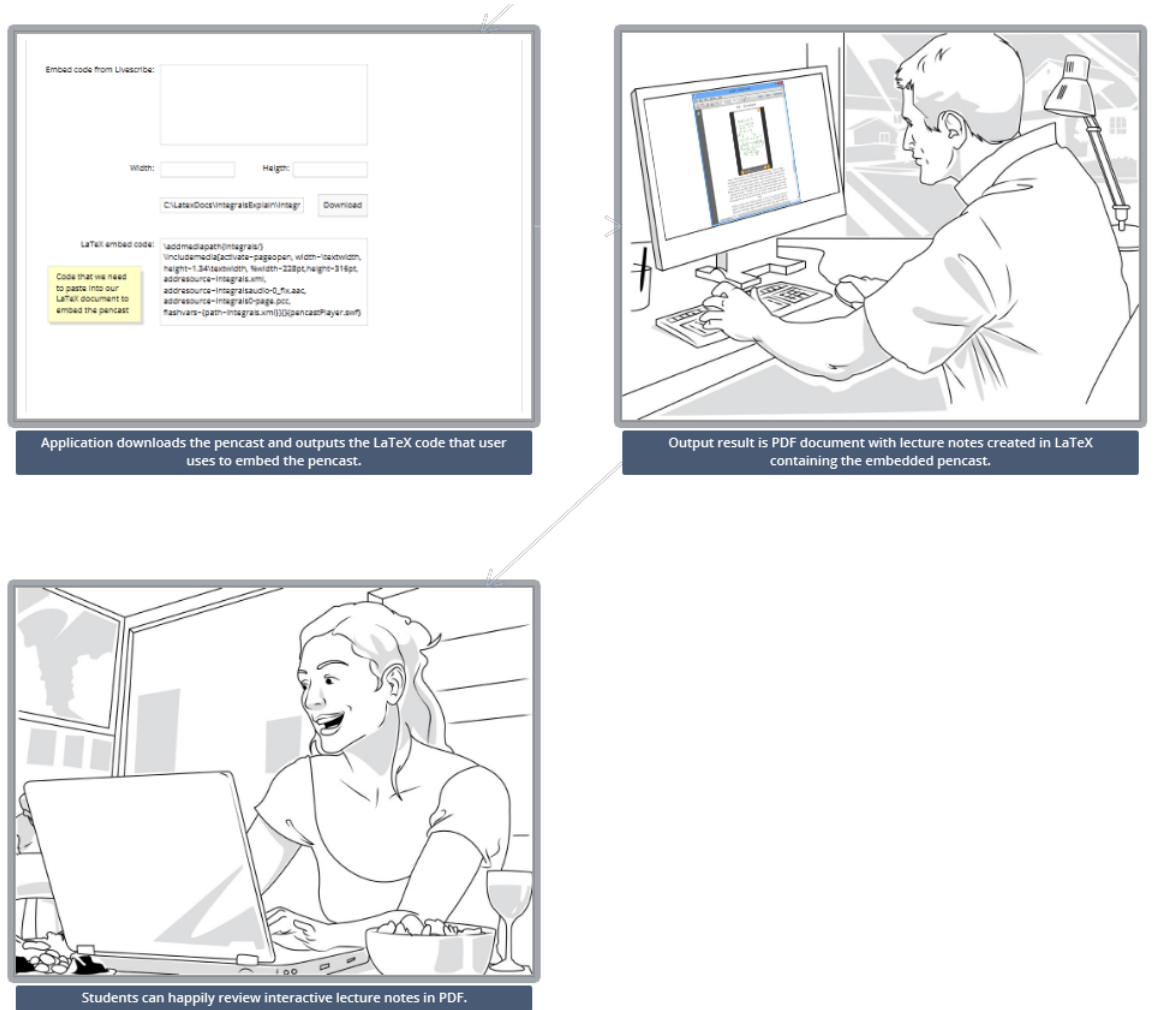


Figure C.2: Storyboard for combining (part 2)

# Appendix D

## Evaluation plan

### Introduction

In this usability evaluation effectiveness, ease of use and satisfaction will be tested (adapted by Sharp et al. [25]).

### Goals

Is the embedding of pencasts into L<sup>A</sup>T<sub>E</sub>X documents effective with our app?

Is the reverse approach to tagging effective for organizing documents

Are both parts easy to use and are researchers satisfied?

### Tasks

Embed the pencast into L<sup>A</sup>T<sub>E</sub>X using the prototype application.

Tag notes (Logos notebook) using the prototype application.

### Test scripts

- *Greet:* Thanks for participating in this evaluation. The goal is to evaluate the usability of embedding the pencasts into L<sup>A</sup>T<sub>E</sub>X with the prototype application. The second goal is to evaluate the usability and effectiveness of reversed approach to tagging. You will be asked to use the tool. While you are using it please think aloud. Your voice will be recorded. Your identity will be kept confidential. Please let me know if you have any questions?
- *Explain:* [How to use the prototype application]

The subject of the evaluation is the prototype application not you, so do not worry about your performance. Do you have any questions now?

- *Introduce:* Now you will try to use the tool.  
[Ask participant to embed a pencast]  
[Ask the participant to tag notes from logos notebook]
- *Direct:* [If participant is stuck:] What are you thinking? Are you stuck?
- *Debrief:*
  1. How did you feel about your performance?
  2. [Optional] Tell me what happened when you got stuck?
  3. What would you say was the best and the worst thing?
  4. Could you imagine using this tool during your research process?
  5. Do you have any future ideas?
  6. Was is satisfying for you to use this tool?
  7. Was the tool easy to use?
  8. Do you think the tool is effective?

### **Conclusion**

Thank you for your participation and your time.