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Using Augmented Reality in Visualized Data Exploration

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Preface

This master thesis is the result of a year of hard work to complete my 'Master of Science in Engineering: Computer Science', specialization 'Human-Computer Interaction' at the KU Leuven.

I'm grateful to professor dr. ir. Erik Duval for making this subject available and giving me the opportunity to write this master thesis. Furthermore I would like to thank Sven Charleer for providing feedback and inspiring ideas throughout the academic year and ir. José Luis Santos for his guidance in the early development of my thesis. I thank Victor Alvarez for making it possible that the mobile application of this thesis could be used and evaluated at the Tenth European Summer School on Technology Enhanced Learning in Malta.

I thank all the users who participated in the user tests for their valuable feedback and invested time.

Finally, I especially would like to thank my family and my girlfriend for their continuous support.

De Moor Thomas

Contents

Abstract

Science2.0 is the result of applying Web2.0 tools and approaches to regular research processes in order to increase participation and collaboration among researchers. Reference managers are a main category of the Science2.0 movement, allowing users to discover, organize and collect research and fellow researchers. There is however little overlap between these tools and the traditional way of discovering and promoting research at conferences, workshop weeks and summer schools.

This thesis tries to narrow the gap that exists between the traditional way of discovering papers and authors and the Science2.0 tools. The narrowing process is supported by the development of a mobile application, called ConferExplore. This application uses augmented reality at the conference itself. The conference hall contains a network visualization of papers and authors. The network is augmented by ConferExplore and user specific information is shown on the mobile screen. This thesis will investigate whether augmented reality can serve as a proper coupling mechanism for the identified gap and is an appropriate technique to explore and interpret visual Science2.0 data.

This thesis describes the context, design and implementation of ConferExplore. The results of four evaluations regarding the usability and effectiveness of the mobile application are presented using the rapid prototyping technique. The design and evaluation of a final version of ConferExplore, operational at the Tenth Joint European Summer School on Technology Enhanced Learning, are also discussed.

The final evaluation clearly shows that there is a need for an application that eases the conference experience and helps to discover relevant research at the same time. Augmented reality can serve as a proper coupling mechanism between the traditional way of discovering research at conferences on the one hand and the Science2.0 tools on the other hand. It is shown that ConferExplore can contribute to the Science2.0 research community using augmented reality to explore and interpret visual Science2.0 data.

Samenvatting

Science2.0 bestaat uit het toepassen van *Web2.0* applicaties en benaderingen op klassieke onderzoeksmethoden om het engagement en de samenwerking tussen onderzoekers te vergroten. *Reference managers* zijn een belangrijke categorie in de *Science2.0* beweging en laten gebruikers toe om onderzoek en mede-onderzoekers te ontdekken, rangschikken en verzamelen. Nochtans is er weinig overlap met de traditionele manier om onderzoek te ontdekken en promoten op conferenties, workshops en summer schools.

Deze masterproef probeert de kloof tussen de traditionele manier om papers en auteurs te ontdekken en de *Science2.0* applicaties te verkleinen. Dit proces wordt ondersteund door de ontwikkeling van een mobiele applicatie, genaamd ConferExplore, die *augmented reality* gebruikt ter plaatse op de conferentie. In de publieke hal van een conferentie bevindt zich een visualisatie van een netwerk van papers en auteurs. Het netwerk wordt aangevuld door de mobiele applicatie en gebruikersspecifieke informatie is zichtbaar op het mobiele scherm. Deze masterproef zal onderzoeken of *augmented reality* geschikt is als koppelmechanisme voor de geïdentificeerde kloof en of het een bruikbare techniek is om visuele *Science2.0* data te onderzoeken en interpreteren.

Deze masterproef beschrijft de context, het ontwerp en de implementatie van ConferExplore. De resultaten van vier evaluaties, over de gebruiksvriendelijkheid en effectiviteit van de mobiele applicatie, worden voorgesteld aan de hand van de *rapid prototyping* techniek. Het ontwerp en de evaluatie van een finale versie van ConferExplore, gebruikt op de *Tenth Joint European Summer School on Technology Enhanced Learning*, worden eveneens besproken.

De finale evaluatie toont aan dat er een behoefte bestaat aan een applicatie die de conferentie ervaring verbetert en tegelijk helpt om relevant onderzoek te ontdekken. *Augmented reality* is geschikt als koppelmechanisme tussen de traditionele manier om onderzoek te ontdekken enerzijds en de *Science2.0* applicaties anderzijds. Deze masterproef toont aan dat ConferExplore kan bijdragen aan de *Science2.0* community, om met behulp van *augmented reality* visuele *Science2.0* data te onderzoeken en te interpreteren.

List of Abbreviations

API	Application Programming Interface
AR	Augmented Reality
CSV	Comma Separated Value
GPS	Global Positioning System
HMD	Head Mounted Display
HMPD	Head Mounted Projective Display
ID	Identification
JSON	JavaScript Object Notation
JTEL	Joint European Summer School on Technology Enhanced Learning
JUNG	Java Universal Network/Graph
OST	Optical See Through
PC	Portable Computer
PDA	Personal Digital Assistant
SDK	Software Development Kit
SUS	System Usability Scale
URI	Uniform Resource Identifier
VR	Virtual Reality
VST	Video See Through
XML	Extensible Markup Language

Chapter 1

Introduction

"Web 2.0 is the business revolution in the computer industry caused by the move to the internet as platform, and an attempt to understand the rules for success on that new platform. Chief among those rules is this: Build applications that harness network effects to get better the more people use them." - Tim O'Reilly

This Web2.0 definition of O'Reilly formulates a new usage of the Internet. It indicates that the World Wide Web will be used as a transport mechanism with interaction, collaboration and contribution of every user [41]. The static and passive use of the internet will disappear and activity, participation and dynamism will be promoted. The last decade, the Web2.0 movement has grown enormously with e.g. social networks, blogs, and wikis.

One of the early goals of the internet was to promote the sharing of information between researchers. With the upcoming Web2.0, this goal has been reemphasized. Science2.0 is the result of applying Web2.0 tools and approaches to regular research processes in order to stimulate and facilitate participation and collaboration between researchers [68, 76]. This influences how researchers experiment, get feedback on their work and interact with their research community [67]. The goal of Science2.0 is to accelerate, improve and share research and information on the scientific process itself.

Numerous applications exist that contribute to the Science2.0 movement. These can be categorized by the following types: scientific blogs, Journals2.0, reference managers, social taggers, open data tools, social scientific networks and audio- and video science tools [36]. Reference managers are one of the main categories; they stimulate the personal discovery, organization and collection of papers and authors by providing e.g. a library, a paper search functionality and contact management functionalities.

The more traditional way of discovering and promoting research and authors takes place at events such as conferences, workshop weeks and summer schools. Their main advantage is the real-time and face-to-face interaction and explanation of research. Different applications exist that enhance the event experience e.g. by providing a local map or personalizing the schedule. There is however little overlap between the traditional way of discovering research and the reference managers of the Science2.0 movement, and this despite the fact that these events remain important today to promote research, to discover papers and to meet authors and despite the fact that reference managers are powerful tools to organize and collect these discovered papers and authors.

This thesis is one step to narrow the gap between the traditional way of discovering research at events and the reference managers of the Science2.0 movement. A mobile application, called ConferExplore, is developed to support the narrowing process. The application can be used in-place at conferences, workshop weeks, summer schools or similar events. The setup consists of two parts: a visualization of the authors and papers of the conference in the common space and the mobile application in the user's personal space. The visualization in the common space is a network graph that can be consulted by the mobile application via the augmented reality technique.

Augmented reality merges computer-generated virtual reality with the real environment. Real world objects are detected and interpreted by the augmented reality device, after which the corresponding digital information is shown to the user. This digital information can be made interactive and manipulable, which creates a new set of human-computer interaction [62].

Recently, great progress has been made regarding augmented reality, both in research and commercial applications. The technique has several application domains, ranging from archeology and navigation to education and gaming [30]. Furthermore, the technique is applicable to all sorts of digital devices such as head mounted displays, projective displays and handheld displays. Due to the enormous amount of smartphones in use, the potential number of users of augmented reality is immense.

By allowing conference attendees to discover, organize and collect authors and papers in real-time and in-place, the coupling between the traditional way of discovering research at events and the reference managers of the Science2.0 movement is reinforced. The goal of this thesis is to study whether augmented reality is a proper coupling mechanism and can serve as a visual Science2.0 data exploring technique.

After further analyzing the current state of the art of the Science2.0 movement and the augmented reality technique in Chapter 2, the context of ConferExplore is sketched in Chapter 3. Chapter 4 elaborates on the iterative development of the application. The functionalities and evaluation of each prototype are discussed, and a final version of ConferExplore is presented. Chapter 5 describes the implementation of the mobile application. Finally, Chapter 6 concludes with an interpretation of the evaluation results and a reflection on future work.

Chapter 2

Literature Study

This chapter starts with a discussion on Science2.0 (Section 2.1). One aspect in particular is elaborated on: discovering, organizing and collecting new papers and authors with the help of Web2.0 tools. Secondly, applications that enhance the conference experience are discussed (Section 2.2). Then follows a study of augmented reality and some of its main research areas: tracking, display and interaction techniques (Section 2.3). Finally, the conclusion shows how augmented reality can fill the gap that is created between the discovery tools of the Science2.0 movement and the applications that enhance one of the traditional ways of discovering papers and authors at a conference (Section 2.4).

2.1 Science2.0

Science2.0 is the result of applying Web2.0 tools and approaches to common research processes in order to increase participation and collaboration among researchers [67, 76]. One of the key objectives of Science2.0 is to support the connection between researchers to stimulate cooperation. Discovering papers and authors is a key activity of a researcher. Several Web2.0 tools exist to find, organize, and collect papers and authors. Two main categories can be distinguished, as seen in Table 2.1.

A first category focuses on the social aspect of the research community. They try to create a social network of professionals (LinkedIn [19]) or researchers (ResearchGate [25], SSRN [26], Vivo [28]). Authors can complete a profile on their own work, promote themselves and follow other users.

The second category, reference managers, provides a personal library to organize and collect papers of interest, a functionality that is not present in the social tools. The reference managers of the right most column in Table 2.1 (Docear [10], JabRef [17], Qiqqa [23], Zotero [29]) require to add the papers manually or to import them from another database. In contrast to other reference managers, a search functionality is not provided by the software itself.

Most of the managers, where both a personal library and a search functionality are available, focus on one of the two. Search engines (CiteSeerX [4], Google Scholar [14], IEEEXplore [15]) integrate a small personal library with few functionalities.

The reference managers that focus on a fully functional personal library (Citavi 4 [3], CiteULike [5], Colwiz [6]), provide a link with online or database search engines to look for research topics, papers and authors.

Mendeley [20] is a reference manager that focuses on both functionalities. A built-in search engine browses a Mendeley database for literature results. Papers can be added and grouped in the personal library. Just as Zotero, Mendeley enables the possibility to add contacts and to share papers amongst those contacts. However, none of the applications above provide an integration functionality relevant for conferences, workshops or summer schools.

<table>
<tr><th colspan="5">Papers and Authors</th></tr>
<tr><th>Social tool</th><th colspan="4">Reference manager</th></tr>
<tr><td rowspan="3">LinkedIn
ResearchGate
SSRN
Vivo</td><th colspan="3">Library & Search</th><th>Library</th></tr>
<tr><th>Focus on both</th><th>Search focus</th><th>Library focus</th><td rowspan="2">Docear
JabRef
Qiqqa
Zotero</td></tr>
<tr><td>Mendeley</td><td>CiteSeerX
Google Scholar
IEEXplore</td><td>Citavi 4
CiteULike
Colwiz</td></tr>
</table>

Table 2.1: Overview of Web2.0 tools to discover, organize and collect new papers and authors. Two main categories can be distinguished: social tools and reference managers. The reference managers are categorized according to their focus on two functionalities: a personal library and a search functionality.

2.2 Conference Experience

Conferences are typical for the social dimension of scientific research. They are the opportunity to discover new research topics and meet interesting fellow researchers. Applications exist that try to enhance the experience of these events. By facilitating the gathering of researchers, connections and cooperation will be stimulated. Conference4Me [8] is a mobile application allowing users to consult a local plan, explore the program of the conference and compose their personal schedule. Conference Navigator [77] and ConPass [7] complement these functionalities with the adding of papers to favorites. Conference Navigator even integrates a social aspect into the application. Users can recommend papers to other conference attendees.

Furthermore, several frameworks exist to create similar conference applications. QuickMobile [24], EventMobile [11] and Mobile Event Guide [22] are examples of frameworks that allow to quickly develop a customized application for an event. But just as in the case of the applications in Section 2.1, there is no cross-functionality to discover, collect and organize papers and authors with Web2.0 tools .

2.3 Augmented Reality

The use of augmented reality is on the rise, both in research [78] and commercial applications [13, 16]. Augmented reality (AR) attempts to embed virtual elements into the real environment by using computer-generated sensory input [33]. Unlike virtual reality (VR), the real environment is not completely suppressed. A commonly accepted definition is that AR is a technique that (i) combines real and virtual imagery, (ii) is interactive in real time, and (iii) registers the virtual imagery with the real world [31, 78]. Thus, AR aims at enhancing the user experience by merging the real and the virtual worlds and providing a new way of context-sensitive interaction with the data [78]. To facilitate this interaction process, research has looked at the following aspects: (i) what real-life objects and images can be tracked and augmented (Section 2.3.1), (ii) the displays on which the augmented reality can be shown (Section 2.3.2) and (iii) which interaction techniques are possible (Section 2.3.3) [30, 31, 33, 78]. These research topics are the most mature and have shown the greatest development regarding AR [78]. The top of Table 2.2 shows the main research areas of AR. Each area is discussed below with a focus on their subcategories in the lower part of Table 2.2.

<table>
<tr><th colspan="8">Augmented Reality</th></tr>
<tr><th colspan="2">Tracking</th><th colspan="4">Display</th><th colspan="2">Interaction</th></tr>
<tr><td rowspan="2">In - Out</td><td rowspan="2">Out - In</td><td colspan="2">HMDs</td><td rowspan="2">Project-ion</td><td rowspan="2">Hand-held</td><td rowspan="2">Tangible</td><td rowspan="2">Collabo-ration</td></tr>
<tr><td>OST</td><td>VST</td></tr>
</table>

Table 2.2: Overview of augmented reality. Three main categories can be distinguished: tracking, display and interaction techniques, each with their subcategories.

2.3.1 Tracking Techniques

An accurate and consistent synchronism between the augmentation and the real world is essential to AR. The system needs to be continuously aware of the user's position in order to correctly augment reality [44]. If not, the user will not be able to associate the augmented information with the corresponding data in the real world. The tracking and registration problem is therefore one of the most fundamental challenges of AR research.

In general, a differentiation can be made between outside-in and inside-out tracking [71]. The first type, outside-in, represents a system where the sensors, such as a camera, heat sensor or motion sensor, are fixed. They track the movement of an object in the environment. Inside-out tracking refers to sensors that are attached to moving objects and use fixed emitters in the environment to calculate their position [33].

Vision-based tracking, or optical tracking, is a popular tracking mechanism that uses cameras and visual markers [69]. If the cameras are placed on the moving objects and the markers are fixed in the environment, it becomes an inside-out technique. The markers are often predefined and recognized by the augmented reality device [58, 70]. These markers clutter the view in the real world, certainly when they need to be shown next to other information that is already visualized. A solution could be to make the information visualization itself serve as a marker, called markerless tracking [38]. Recent mobile applications allow the user to choose any object as a tracker to visualize an augmented two or three dimensional object on [21, 37].

Thus, augmented reality needs to interpret the environment and at the same time provide additional information on it. This real-time experience causes delay to be one of the most important problems to overcome [49]. Even a small latency of milliseconds can make a statistically significant difference when performing tasks [45].

Another problem that arises is the depth perception of the augmented information. The position of the user's eye directly influences the perception [53]. Different angles and locations of the user result in different position and angle accuracy of the augmented reality [30]. When dealing with a handheld device to represent the augmented reality, an extra viewing angle offset is created, as seen in Figure 2.1. The viewing angle of the handheld device and of the eyes differs, which results in an indirect 'biased' view of the real world. Users may not be able to associate what they see through the mobile device and what they see directly in the real world [55].

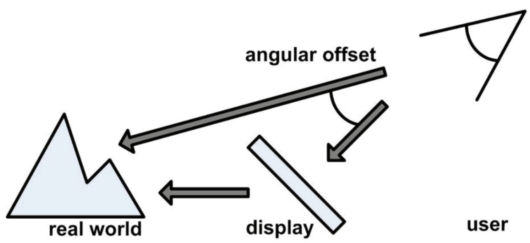


Figure 2.1: Angular offset between the user's eyes and the handheld device, which can result in an indirect view of the real world.

2.3.2 Display Techniques

A second building block of AR is the display technology. The augmented information and the demanded interaction often determine the type of display. When large amounts of information are augmented, the display may quickly become cluttered and unreadable when the display used is too small [30]. As mentioned in Section 2.3.1, the distribution of the information also depends on the user's viewpoint of the real world. Some augmented reality techniques use a filtering mechanism to reduce the amount of information while still keeping the relevant parts [52]. The cluttering can also be reduced by personalizing the information and just displaying user specific content. In general, three types of displays can be distinguished.

A first type is the see-through head-mounted displays (HMDs). This type can be again divided into two categories: optical see-through (OST) and video see-through (VST). OST displays are those that allow the user to see the world with his/her natural eyes and overlay information on it [78]. Google glass is the most recent example of this technology [13]. The main advantage of OST displays is that they still offer an instantaneous view of the real world. VST displays work by combining a closed view HMD and a camera [31]. The user has a video view of the real world superimposed with additional reality. This way a higher consistency between the real world and the augmented graphics can be achieved. For both categories it remains hard to manipulate or change the augmented reality with the HMDs itself. Voice control [13] or an extra tangible device can be used in combination with the HMD for pointing to or selecting the augmented information [72].

Projection-based displays are a second type of display technology. The virtual reality is directly projected on the objects or surfaces in the real world that need to be augmented [30]. It does not require several users to wear anything and is thus minimally intrusive [78]. However it is not possible to include user specific augmented reality since all users experience the same augmentation. Head-mounted projective displays (HMPDs) are a projection-based solution to this problem. This combination of HMDs and projectors uses mini-projectors mounted on the head projecting images onto retro-reflective objects that reflect the light back into the user's eyes. Beside the creation of a personal space, HMPDs offer a wider field of view. A disadvantage on the other hand is again the wearability and the intrusiveness of this technique.

Handheld displays form a third category of display technologies. They provide a good alternative to HMDs and projective displays because they are minimally intrusive and thus highly wearable. A handheld device can serve both as a visualization and as a good manipulation tool, although it has to be kept in mind that a user needs at least one hand to hold the mobile device [63]. The first handheld devices were based on tablet PCs, notebooks and PC hardware and were therefore heavy and large [46, 50]. With the recent developments of mobile and wireless technologies, handheld devices have shifted to lighter and more mobile PDAs and smartphones [47, 66, 75]. Furthermore, GPS sensors, accelerometers, physical sensors and infrared sensors of smartphones can help to improve the tracking and registration and contribute to a hybrid tracking solution.

2.3.3 Interaction Techniques

Beside work on the basic technologies of AR, research has focused the last years on how users interact and control AR. Two major trends appear in this research area: tangible augmented reality and alternatives and collaborative versus personal augmented reality. Both fields influence the way users experience augmented reality.

In AR the user sees the real world with virtual reality superimposed upon. As the real world remains visible in AR, in contrary to VR, real objects can be used as AR interface elements. These objects become an appropriate manipulation tool since they possess familiar properties and are easy to use [78]. Each user action can be mapped onto an effect [54, 72]. A rotating movement with the manipulation object for example can cause the augmented reality to rotate too. Instead of providing an extra object, the user's hand or fingers can also serve as an interface element [35, 43, 60, 73]. Recent technologies use a hybrid approach with additional voice commands to control the augmented reality [13, 51].

The introduction of an extra device to augment reality on, such as HMDs or handheld devices, divides the working space into two areas: a common space and a personal space [63]. The information visualization in the real world or the real world itself plays a roll as a common space where different forms of collaboration are possible. This is the second major research area regarding interaction forms. In a meeting for example, persons can use a tabletop as a digital working surface where augmented meeting content can be shown upon [54] or use handheld devices to create a remote face to face meeting with common virtual reality [53]. Manipulating data [61] and engineering processes can also be coordinated among multiple users in this kind of setting [42].

The augmented reality technique provides a personal and easily accessible space that gives each user a unique view and experience. Game environments often make use of this feature by visualizing the common information in the real world and showing the user specific data through the augmented reality device [56, 65, 74]. In general, this environment allows user to personally manipulate three dimensional virtual objects according to personalized information such as user's profile and preferences [63]. When each user has its own personal working space, each of them is theoretically able to manipulate and explore the data of the real world. These interactions need to be coordinated among all users so that the information visualized in the real world remains consistent [30].

2.4 Conclusion

This literature study has shown the existence of various applications to stimulate and intensify Science2.0, especially applications that allow to discover, organize and collect papers and authors (Section 2.1). On the other hand applications enhance the conference experience by personalizing the schedule, providing a local plan or creating a personal meeting system (Section 2.2). However, there is no application that combines the two functionalities, despite the fact that conferences are at the center of the research community. Authors gather at conferences and knowledge is promoted and discovered there.

In Section 2.3, the current state of the art regarding augmented reality is elaborated upon. Tracking, display and interaction techniques are exemplified. It is shown that augmented reality is a powerful technique with several challenges and advantages providing solutions to various problems. One of these advantages is the split up between a common and a personal space. Generic information can be presented in the common space, while user specific or private information is located in the personal space.

This master thesis tries to investigate if augmented reality can fill the gap between the discovery applications in the Science2.0 movement and the applications that enhance the conference experience. Consequently, it will be tested if augmented reality can serve as a visual Science2.0 data exploring technique. This development of a mobile application, called ConferExplore, is addressed. The goal of ConferExplore is to integrate the discovery of papers and authors at conferences, into the collection and organizational workflow of the researcher. More specifically, ConferExplore will provide an integration, with Mendeley [20], as a general collection and organization library, and the discovery phase, supported by augmented reality in real-time at the conference itself. ConferExplore will improve the Science2.0 experience using promising augmented reality technology.

Chapter 3

Context

The general approach being outlined, the research context is now further clarified by a user story and a corresponding storyboard.

The research in this thesis couples the traditional way of discovering papers and authors at conferences to the Science2.0 movement with the help of ConferExplore, a mobile application. Conferences, workshop weeks, summer schools and similar events are organized to promote research, gather with fellow researchers and exchange ideas. It is the essence of performing research. The schedule of these events is usually distributed as a plain list on the website, through mail or in a folder at the event itself. Yet there is often a more complicated underlying structure of the schedule. Some researchers contribute to the content of multiple lectures or workshops in such a way that the schedule becomes a network of lectures/workshops and authors. This deeper structure, which is not clearly visible in a list view, will be exploited by ConferExplore.

Besides the title, speakers, and a short description of the content of a specific session on the schedule, there are few automatic possibilities to consult research in more detail or to discover related research. Details are currently found by manually searching for the topic in search engines or reference managers. There is no automatic coupling between the content of lectures or workshops at the event itself and the reference managers of the Science2.0 movement. This gap will also be addressed by ConferExplore.

A real-time and in-place integration with reference managers and conferences entails that the personal information is present in these Science2.0 tools. This information can be introduced by splitting up the space into a common space and a personal space. The common space contains general information such as the conference schedule. The personal space on the other hand contains user specific information such as a user's digital library or contacts. ConferExplore will use augmented reality to split up the space into two and to provide an integration with the personal information of reference managers.

Concluding, the setup has three purposes: (i) giving attendees an overview of the underlying network structure of the conference schedule, (ii) making it possible to quickly consult research in more detail or to discover related work and (iii) allowing participants to additionally interact with personal information of reference managers, thus making the conference experience more user specific. The user story below and the corresponding storyboard (Figure 4.19) clarify how ConferExplore could enhance the conference experience.

Peter M. Robertson is a doctoral researcher at the Human-Computer Interaction research group of the department of Computer Science at the KU Leuven. Last year he obtained his Master in Computer Engineering 'cum laude'. His study results gave him the opportunity to start a PhD. Although Peter is very smart, his social skills can be improved upon. He is a bit shy and finds it difficult to start a conversation with unknown fellow researchers.

Next week, a conference on Human-Computer Interaction is taking place in Paris. This is certainly an event that Peter has to attend. After subscribing, Peter already feels a bit nervous. He wonders what lectures or workshops he should attend and which persons to talk to, as this a totally new experience to him.

The day of the conference has arrived. Peter is not prepared and does not know which lecture he should attend first. Taking a quick look at the titles on the conference schedule, none of the topics does ring a bell. Peter picks a lecture randomly.

After the lecture, during the break, Peter is disappointed. The talk was really boring and completely out of his field of interest. He gets a drink to cheer up and wonders if now is the time to meet fellow researchers. But Peter has just started in this research field and he doesn't know anyone. He decides to start talking to the person who looks the smartest.

Peter meets professor Bell. He is an expert in the domain of augmented reality and has just finished his lecture. Peter is unfamiliar with this research domain, but in the course of their conversation, he gets fascinated by the possibilities and future challenges of augmented reality. Peter regrets he did not chose the talk of professor Bell, but he assures professor Bell that he will look into the topic in more detail. As professor Bell is out of business cards, Peter remembers the professor contact details and writes down his main publications on his conference map.

The break is over and Peter did not get the time yet to explore the next lecture block. Again, he picks a lecture randomly. Arriving at the lecture room, Peter notices the same speaker as earlier that day. He will definitely not attend this talk and decides to quickly search for another one.

Five minutes later, Peter slips into another auditorium. The lecture handles gesture controlled displays and is really interesting. Peter writes down the title and the speaker of the talk, so he's able to explore the research topic in more detail later on. Suddenly he remembers that he has read a paper on a similar topic. It used a gesture recognition device to help elderly people. It's a shame that he does not remember the title or authors. He will look into this later on.

The conference is over. Peter is satisfied with his first conference experience. Despite the boring first lecture, it was a great success. Peter met professor Bell and he got to know more about his augmented reality research. The second lecture was *equally fascinating, as it discussed a whole new way of human computer interaction. With his handwritten notes, Peter goes home and he is already looking forward to look into the discovered research and researchers.*

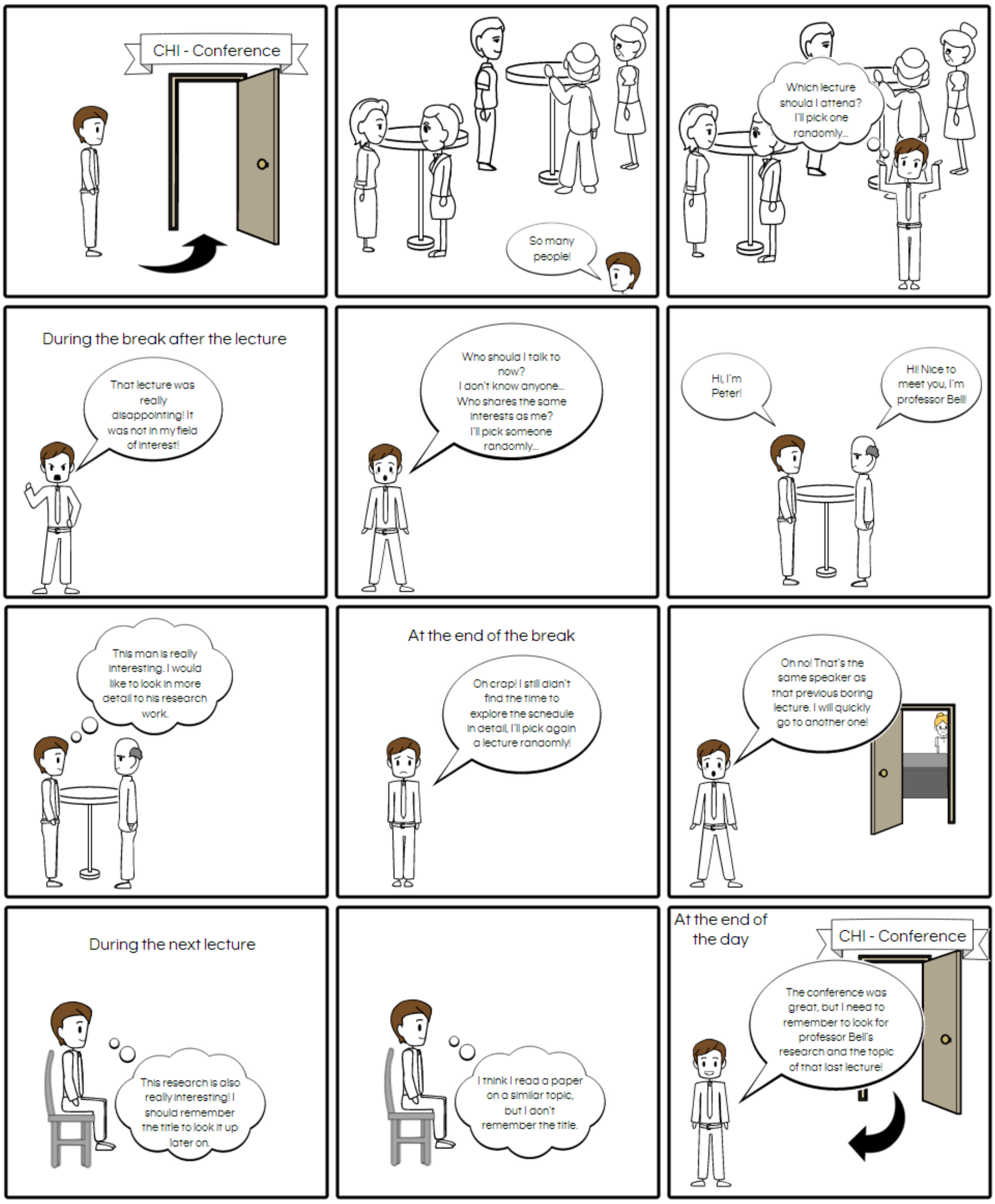


Figure 3.1: Storyboard of a conference experience.

Chapter 4

Iterative Development

ConferExplore was developed with the fast, yet powerful rapid prototyping technique [40]. Each prototype of the application is evaluated with real users. Their feedback and evaluation results of each iteration are used to construct and develop a new prototype. In total, two paper prototypes and two digital ones were developed with these user feedback cycles.

To evaluate Prototype I, III and IV, the think aloud protocol was applied [57]. In the evaluation of Prototype I, III and IV, the users answered a questionnaire with open questions, yes-no questions and statements that were rated on a Likert scale [59]. Furthermore, Prototype I and IV were evaluated with a SUS-questionnaire [34] (Appendix A.1) to obtain an objective measure to compare the different prototypes. Prototype III evaluated two types of network visualizations and not the application itself, thus a SUS-questionnaire was not applied. Prototype II was not evaluated with end-users since it served as initial ideas and limited amount of interactivity is possible with a paper prototype.

With the results of all prototypes, a final version of ConferExplore was developed and used at the Tenth Joint European Summer School on Technology Enhanced Learning in Malta [27]. The Summer School attendees filled out the same questionnaire as Prototype IV, also complemented with the objective SUS-questionnaire. This allowed to evaluate the final version of ConferExplore and to compare it with the prototypes.

4.1 Prototype I

A paper prototype of ConferExplore was developed using the Balsamiq Mockups tool [2] as a means to get initial user feedback and ideas. Figure 4.1a shows the home screen of the prototype. Its main functionality is the camera view with augmented search results. Additionally, it is possible to consult favorite papers and authors, start the camera view without search results and create and adjust a profile. First the functionalities are discussed in detail in Section 4.1.1 and summarized by a screen transition diagram (Figure 4.2). Secondly the evaluation process of Prototype I is elaborated on in Section 4.1.2.

4.1.1 Functionalities

Camera View with Search Results
When searching for a paper, author or any other search query, the application switches to the camera view (Figure 4.1b). The search results are augmented on a network of papers and authors. Each result is indicated by a red circle and a yellow star. By clicking the star, it colors green and the paper or author is added to or removed from the user's favorites list.

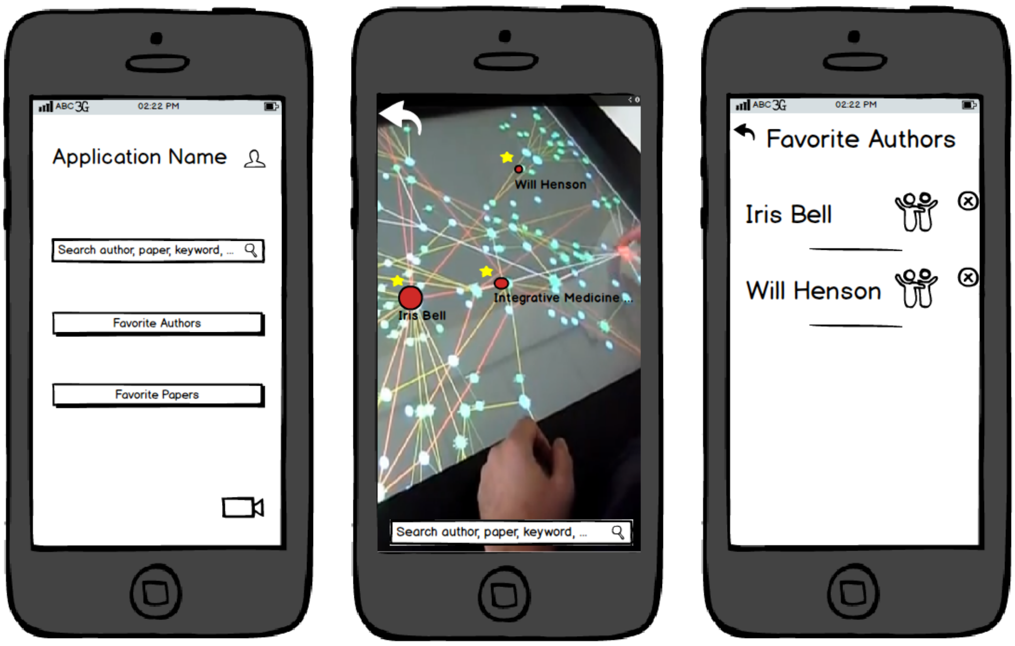
Favorite Authors and Papers
Favorite authors are listed with a symbol of two persons meeting each other (Figure 5.4c). Clicking on it informs the author via a notification on the author's mobile phone that the user would like to meet him/her. Favorite papers are listed in the same way (Figure 4.1d). Detailed information, including the abstract of the paper, is obtained by clicking on a paper (Figure 4.1e).

Camera View and Profile
The camera symbol on the home screen starts the camera view without search results (Figure 4.1a), while clicking on the profile picture it allows the user to adjust his/her profile information, such as username, password and email address. (Figure 4.1f).

4.1.2 Evaluation

The prototype was tested with the think-aloud protocol [57] in order to identify information about the interface design and the usability of the application. Four users (3 female and 1 male), between the age of 19 and 51, were asked to perform research paper discovery related tasks, manage their favorites and adjust their profile (List 4.1) on a paper version of a smartphone (Figure 4.3). Two of the users use a smartphone in their daily life. This semi-structured interview was complemented with seven questions (Table 4.1) and an objective SUS-questionnaire [34] (Appendix A.1) at the end. As the participants reported similar issues, no extra persons were evaluated [64].

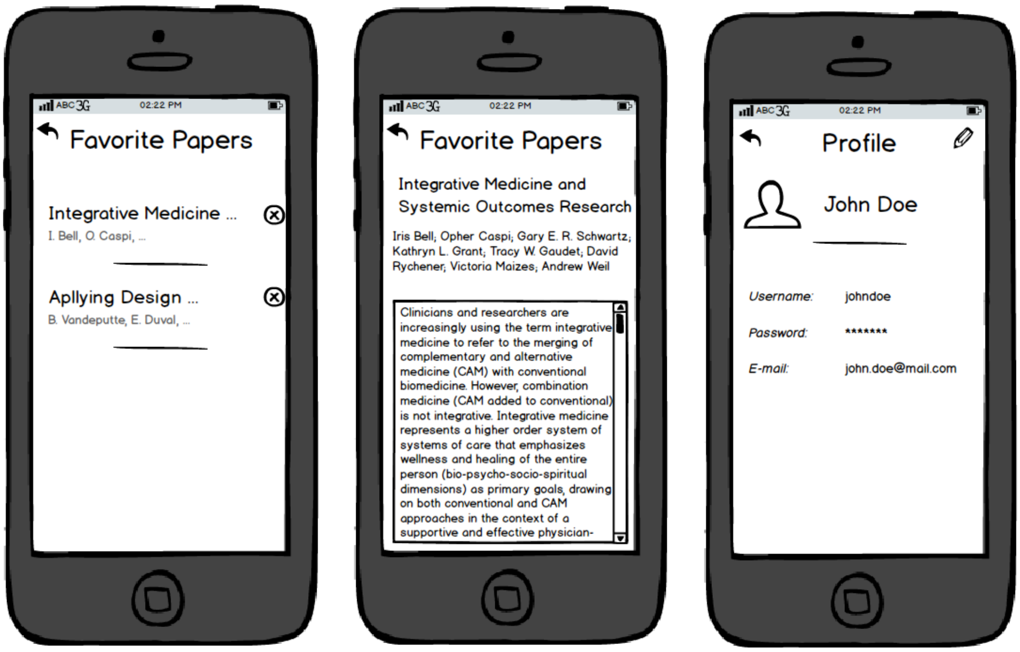
When asked to search for an author and add an augmented result to their favorites list, all four users did not notice the yellow star and clicked on the red circle instead.



(a) Home screen.

(b) Camera view with augmented search results.

(c) Favorite authors.



(d) Favorite papers.

(e) Detail of a paper.

(f) Profile information.

Figure 4.1: Screens of Prototype I.

Figure 4.2: Screen transition diagram of Prototype I. Top: adding author or paper via the camera view. Middle: notifying author to meet him/her via favorite authors list. Bottom: reading abstract of paper and delete paper via favorite papers list.

1. Search on Iris Bell and add this author to your favorites.
2. Add an augmented paper to your favorites.
3. Inform Will Henson, one of your favorite authors, that you want to meet him.
4. Delete Iris Bell from your favorite authors.
5. Read the abstract of the first paper on the list of your favorite papers.
6. Delete a paper.
7. Go to your profile and change your username.

List 4.1: The tasks presented to the participants in the evaluation of Prototype I.

Question	**Yes**	**No**
If you were at a conference, and all the technology was available, would you use ConferExplore?	2	2
Is it clear how to add a favorite trough the augmented reality interface?	0	4
Is the change to a green star, after adding a favorite, clear?	1	3
Would you like to have other options to add a favorite, beside via the camera view?	3	1
Is the symbol to inform someone else that you want to meet him/her clear?	3	1
Would you like to get a notification if someone wants to meet you?	4	0
Do you think ConferExplore will help you to establish connections on a conference?	4	0

Table 4.1: The questions presented to the participants in the evaluation of Prototype I and their answers.

As a consequence, three users pointed out that they would like an additional way to add authors and papers. Two users suggested to keep the yellow star as a symbol, but to enlarge it, making it more prominent.

One user expected the button to meet an author on the camera view too. The same user pointed out that the symbol representing this functionality in the favorite authors list was not clear. To adjust profile information like the username, three users did not notice the pencil. These results might indicate that these two symbols do not match their functionalities.

Table 4.1 summarizes the answers of the post evaluation interview. All four users

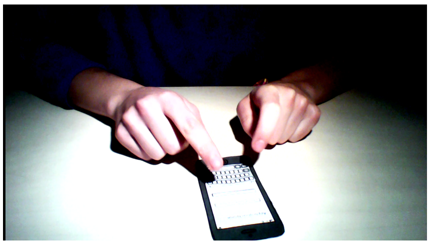


Figure 4.3: Test setup of Prototype I.

were convinced that this kind of application would help them to establish connections and discover new papers on conferences. However, only two users confirmed that they would use ConferExplore at a conference and the first question of the System Usability Scale [34] (Figure 4.4), 'I think that I would like to use ConferExplore frequently', received an average score of 3/5. The fact that three users never attended a conference has probably influenced this result. The user who attended conferences, answered with a score of 4/5.

Figure 4.4 shows the distribution of the scores on the individual questions of the SUS-questionnaire. These results sum up to SUS-scores of 71,25; 77,5; 87,5 and 87,5 [32]. This gives the prototype an an average SUS-score of 80,93, which positions the prototype in the top 10 percent of SUS-scores [32].

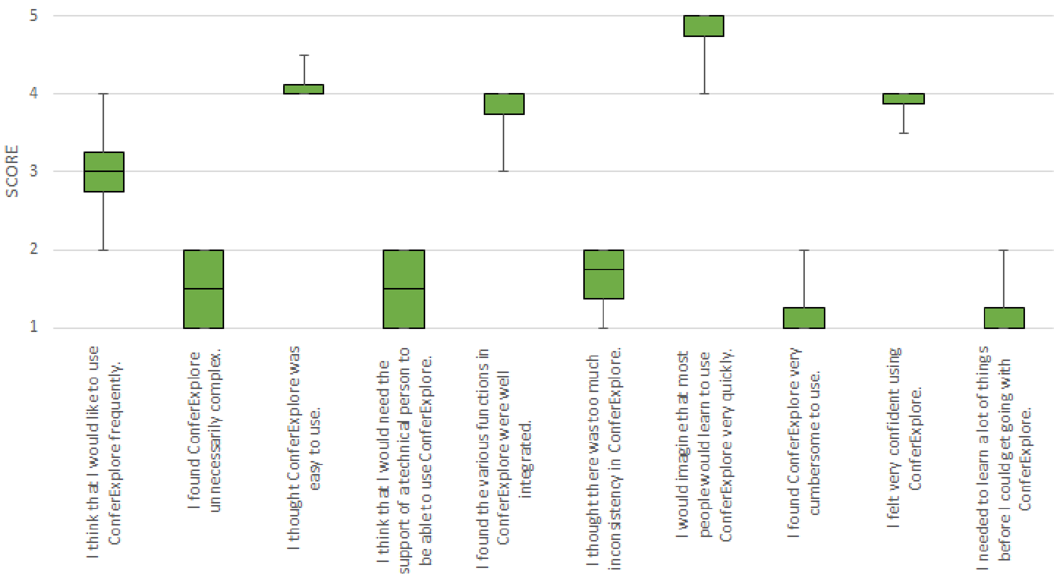


Figure 4.4: Distribution of the scores on the individual questions of the SUS-questionnaire for Prototype I. A score of 1 stands for 'strongly disagree', a score of 5 represents 'strongly agree'.

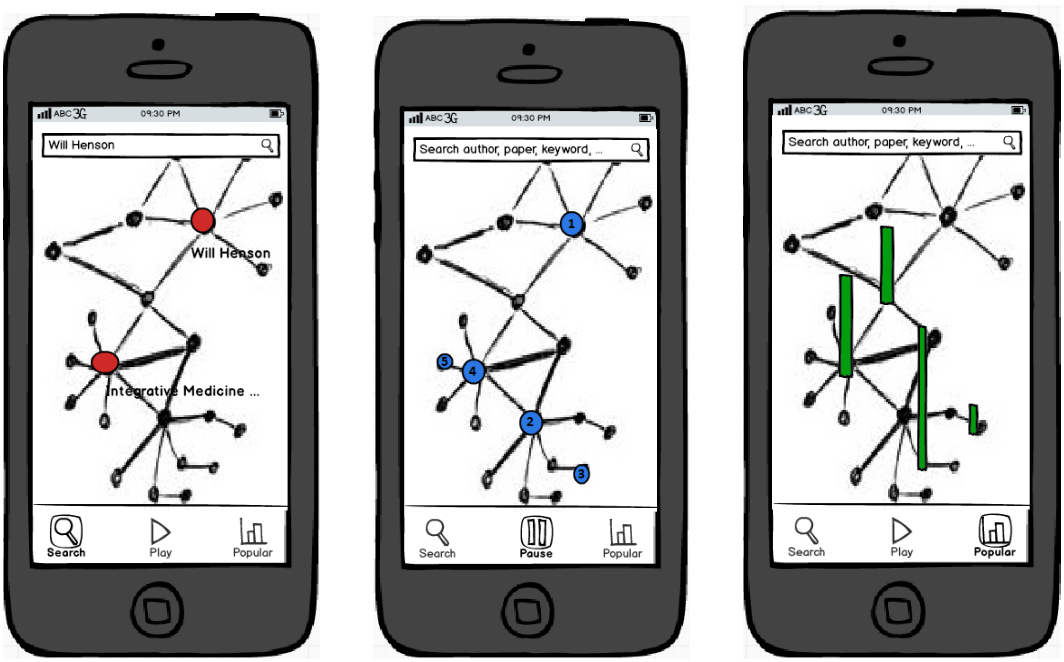
4.2 Prototype II

Prototype I (Section 4.1) focuses mainly on application functionalities. Prototype II, a paper prototype, complements this with a focus on information visualization. Three possible information visualizations were developed with the Balsamiq Mockups tool [2]. Since the visualizations served as initial ideas and a limited amount of interactivity is possible with a paper prototype, Prototype II was not evaluated with end users.

The first visualization is identical to Prototype I (Section 4.1). The results of a search query are augmented when viewing the network visualization through the camera (Figure 4.5a).

Figure 4.5b shows the second visualization. The numbers represent the order in which the papers are augmented. The sequence is determined by the publication date of the papers. Older papers are augmented before more recent ones. The interactive augmentation can be paused by the button at the bottom of the screen.

A third and final visualization represents the popularity of the papers by augmented bars (Figure 4.5c). The higher a bar, the more times a paper is cited in other papers.



(a) Camera view with augmented search results.

(b) Camera view with augmented papers in the same order as their publication date.

(c) Camera view with augmentation of bars on the papers proportional to number of times cited.

Figure 4.5: Information visualizations of Prototype II.

4.3 Prototype III

The main functionality of ConferExplore is viewing the network visualization through the camera view. The goal of this digital prototype is to compare two versions of the network visualization concerning usability and to establish which version users prefer. In order to make the prototype more accessible to a broader range of test users, authors were replaced by movie actors and papers by movies. In Prototype III a large television screen was used to display the network of actors and movies (Figure 4.6). Section 4.3.1 will explain each version in detail, then the evaluation process and results of Prototype III are being discussed in Section 4.3.2.

Figure 4.6: Test setup of Prototype III.

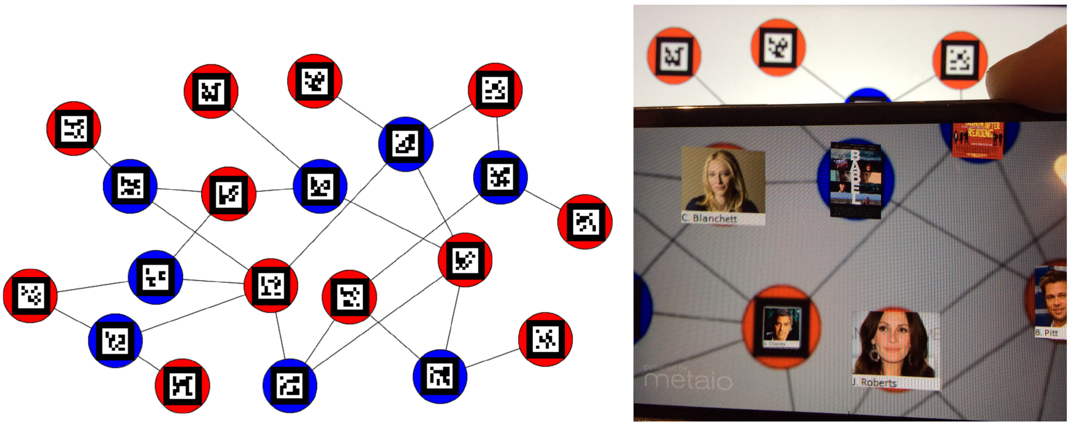
4.3.1 Two Network Visualizations

Tracker Version

The tracker version displays a network of tracker images (Figure 4.7a). Each red circle represents an actor, while a blue circle represents a movie . If an actor plays in a movie, the two nodes are connected. Each entity has a tracker image coupled to it, that can be detected by the application. This allows the application to augment an image of the accompanying actor or movie on the mobile screen (Figure 4.7b).

Image Version

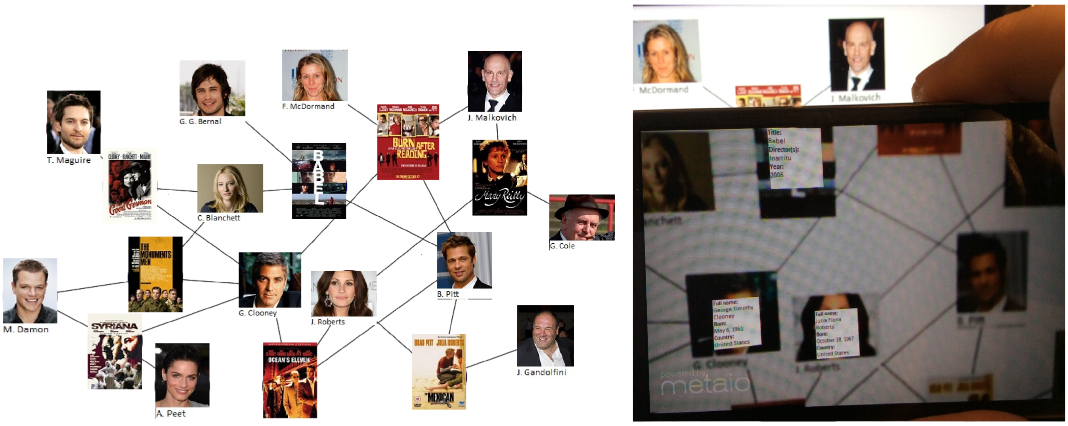
Without the augmentation through the application, the red and blue circles in the tracker version provide no information to the user. The image version tries to overcome this issue, by replacing the trackers with the images of the actors and the movies (Figure 4.8a). When detecting the images, additional information about the image is augmented (Figure 4.8b). In the case of an actor, this information is their full name, birth date and country of origin. In the case of a movie, the information is its title, release date and director. Users can retrieve additional information if they want, but the network visualization still provides useful information on its own.



(a) Network visualization.

(b) Augmented images on the mobile screen.

Figure 4.7: Tracker version of Prototype III.



(a) Network visualization.

(b) Augmented images on the mobile screen.

Figure 4.8: Image version of Prototype III.

4.3.2 Evaluation

Five people (3 female and 2 male) participated in the evaluation of Prototype III, all between the age of 16 and 51. Two of them already participated in the evaluation of Prototype I (Section 4.1.2). The participants were asked to answer questions using the application and the two network visualizations (List 4.2 & 4.3). Three users were presented with the image version first, followed by the tracker version. The remaining two participants started with the tracker version. The results of these questions are summarized in Table 4.3 and discussed below.

1. What do the red and the blue circles represent?
2. Which actors on the screen do you know?
3. With the help of the application, can you name three actors that played in the movie ‘Burn After Reading’?
4. Did ‘Julia Roberts’ and ‘John Malkovich’ ever play together in a movie?
5. What movies does ‘Cate Blanchett’ play in?

List 4.2: The questions presented to the participants in the evaluation of the tracker version of Prototype III.

1. Which actors on the screen do you know?
2. With the help of the application, can you name three actors that played in the movie ‘Ocean’s Eleven’?
3. Did ‘Cate Blanchett’ and ‘Brad Pitt’ ever play together in a movie?
4. What movies does ‘Matt Damon’ play in?
5. Who directed ‘The Mexican’?
6. How old is ‘Tobey Maguire’?
7. When was ‘Babel’ released?

List 4.3: The questions presented to the participants in the evaluation of the image version of Prototype III.

Category	**Tracker Version**	**Image Version**
Naming more actors	0/5	3/5
Reading problems	3/5	1/5
Preferring version	0/5	5/5

Table 4.2: Summary of the results of the evaluation of Prototype III.

The participants were requested to name as many actors on the screen as possible who are familiar to them. Three participants recognized more actors on the image version, while the other two participants discovered the same number in both versions. In the tracker version, each person found out what the red and blue circles represent

(List 4.2, Question 1). To search for actors, they had to explore each red tracker with the application. In the image version, the users could just skim the network visualization, then augment nodes of interests, resulting in a quicker workflow and naming more actors.

Three users found it hard to read the title of a movie from the augmented image in the tracker version. One user pointed out that the augmented detailed information in the image version, like the director of a movie or the birth date of an actor, was too small to read. The four other users had no problems reading detailed information.

All participants preferred the image version to the tracker version. While the tracker version was not efficient, one user found its entertainment level higher, as searching for a right answer was more challenging. Thus in the next prototypes, the image version or a variant will be used.

4.4 Prototype IV

The setup of ConferExplore divides the space into two: a common space where the network visualization is shown and a personal space with the augmented reality on the mobile screen. To enhance the personal space and enable the integration with a reference manager, Prototype IV links the visual information with the user's Mendeley account [20]. Mendeley is a desktop and web application with a library where users can discover, collect and organize papers of interest and manage Mendeley contacts. There are functionalities to explore details of a paper and to consult its related documents. ConferExplore connects the personal information of the user's Mendeley account in the personal space to the network visualized in the common space.

Based on the results of Prototype III (Section 4.3), the speakers at a conference are represented on the network visualization by their profile picture of Mendeley (Figure 4.9). Papers, which have no distinguishable image, are displayed as a tracker image and the network visualization is projected on a wall .

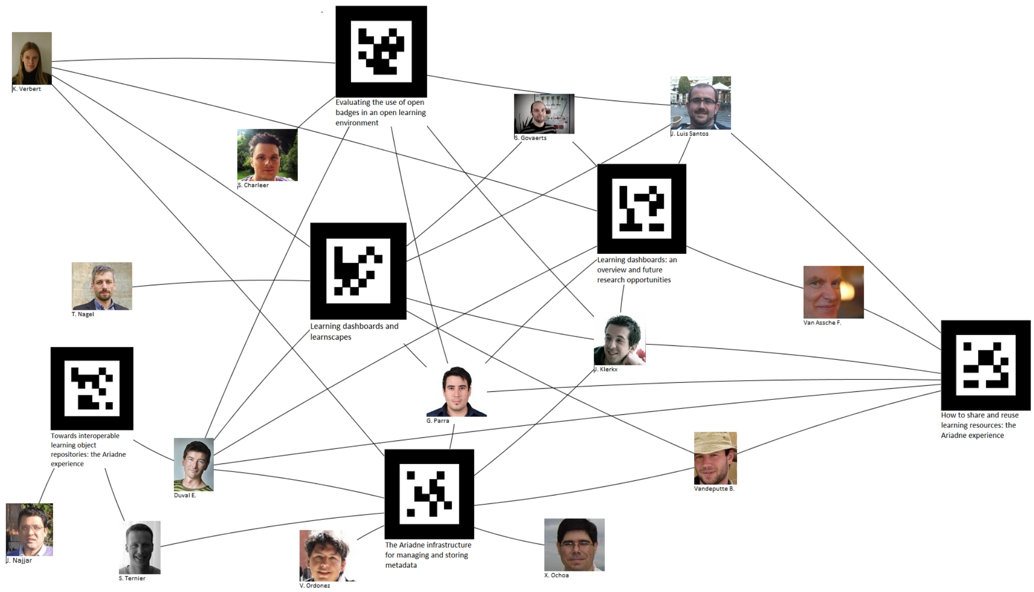


Figure 4.9: Network visualization in Prototype IV.

Depending on what the users view through the mobile device, different types of images are augmented on the mobile screen (Figure 4.10). Each type will be discussed below in Section 4.4.1, followed by the evaluation of Prototype IV in Section 4.4.2.

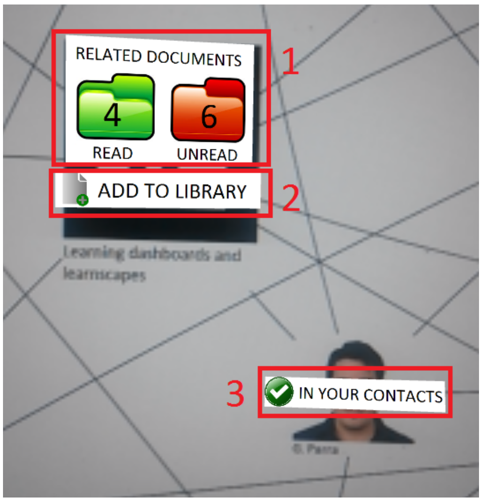


Figure 4.10: Mobile screen with augmented images when viewing the network visualization of Prototype IV. 1: 'Related documents' image. 2: 'User's library' image. 3: 'User's contacts' image.

4.4.1 Functionalities

User's Library

When detecting a tracker that represents a paper, the data is augmented with specific information on whether the paper is part of the user's Mendeley library or not (Figure 4.10.2). Tapping the button adds the paper to or removes it from the user's Mendeley library (Figure 4.11).

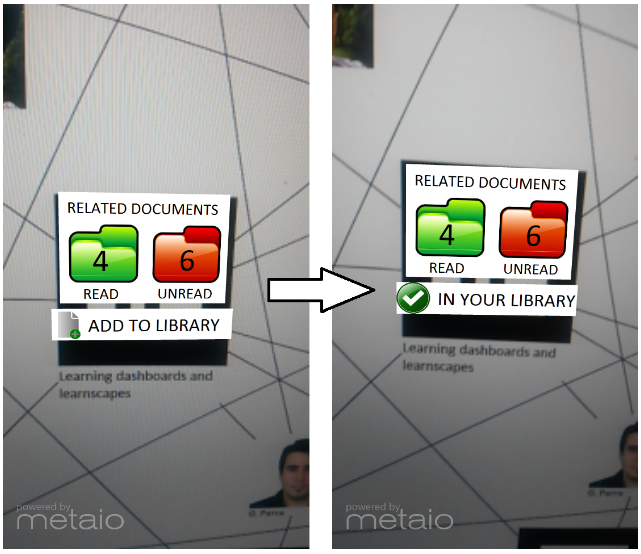


Figure 4.11: Adding a paper to your Mendeley library.

Related Documents

The 'related documents' functionality in the Mendeley application gives the ten most related papers to the selected paper. This top ten is determined by a mixed analysis based on the content of the selected paper and what other users with similar interests are reading [20].

When detecting a paper, it is augmented with the related documents (Figure 4.10.1). Based on the user's Mendeley library, the augmentation visualizes how many of these papers the user already has read. On Figure 4.10, the user read four related documents of the augmented paper node.

The user can also click on the 'related documents' image to get a more detailed list view of the related documents, as seen in the left of Figure 4.12. A related document can be added (Figure 4.12, Middle) and further explored (Figure 4.12, Right).

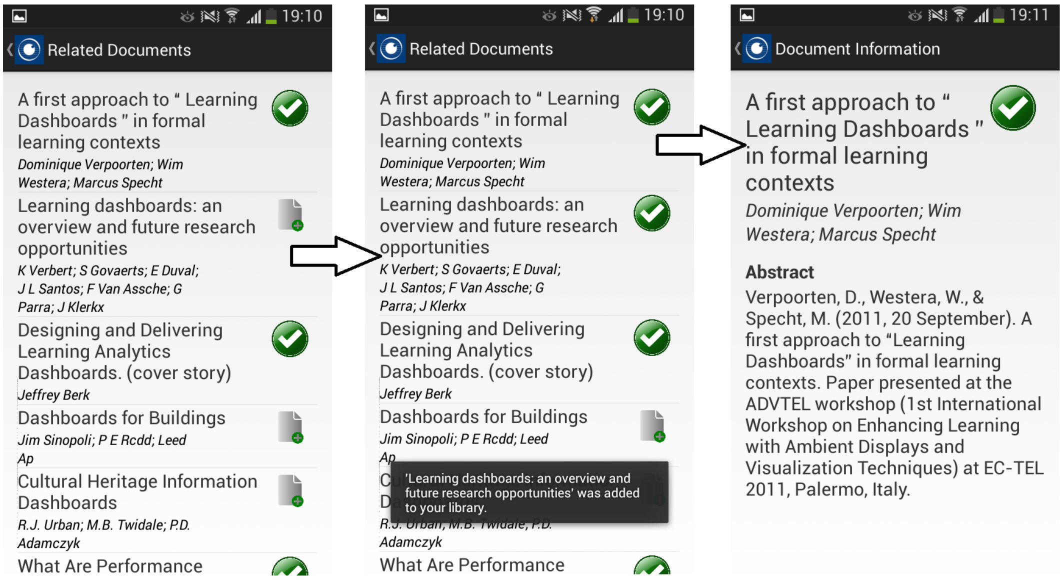


Figure 4.12: Left: 'Related documents' view. Middle: Adding a related document to your Mendeley library. Right: Details of a related document.

User's Contacts

Profile pictures are augmented giving an indication of whether an author is part of the user's Mendeley contact list (Figure 4.10.3). As with a paper, the author can be added or removed from the contact list through the application (Figure 4.13).

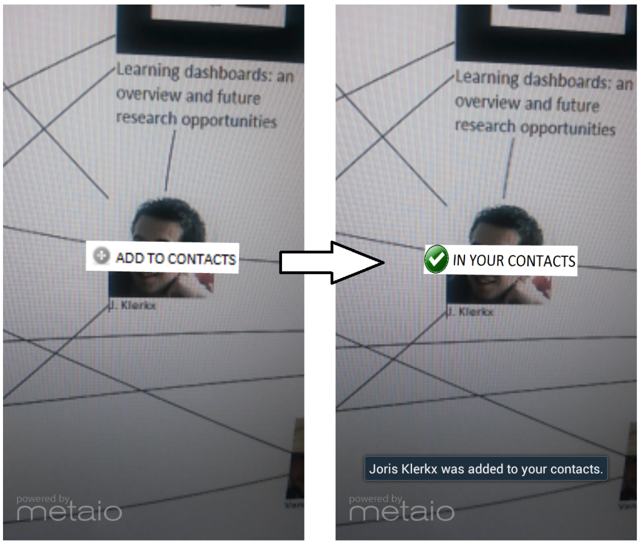


Figure 4.13: Adding an author to your Mendeley contacts.

4.4.2 Evaluation

The goal of this iteration is to combine the results of Prototype I (Section 4.1.2) and Prototype III (Section 4.3.2) and to discover new usability and functionality problems. Prototype IV was evaluated during two studies. The first study was conducted in a class of students, while the second one focused on possible conference participants and researchers in the human-computer interaction domain.

Study 1: Students

The sixteen participants (4 female, 12 male) of the first study are all computer or web engineering students between the age of 22 and 28. All of them use smartphones in their daily lives and had no previous experience with reference managers. With a projection of the network visualization of Figure 4.9 on a wall, they were asked to start the application, log in with a Mendeley account and point to the network. They were given access to a dummy account, set up for this study. Figure 4.10 shows the augmented images when viewing the network through the mobile phone. The users were asked to explore the application on their own. Afterwards they were presented with a small questionnaire, from which the results are shown in Table 4.3.

Three participants were not able to remove a person from their Mendeley contacts and eight participants could not remove a paper from their Mendeley library. This could indicate that the button representing the removal of a paper is not clear enough. This button only shows the text ‘In your library’, as seen on the right of Figure 4.11, and does not indicate that it can be used for removal.

Three other users did not realise that adding a contact meant they were adding Mendeley or phone contacts. A solution could be to replace the button ‘Add to contacts’ of Figure 4.13 by ‘Add to Mendeley contacts’.

Question	Yes	No
Did you understand the network that is projected on the wall?	16	0
Did you manage to add someone to your Mendeley contacts?	15	1
Did you manage to remove someone from your Mendeley contacts?	13	3
Did you understand what ‘related documents’ means?	13	3
Did you manage to add a paper to your Mendeley library?	11	5
Did you manage to remove a paper from your Mendeley library?	8	8
Did you manage to read the abstract from a paper?	13	3

Table 4.3: The questions presented to the participants in the evaluation of the first study of Prototype IV and their answers.

Beside the questions, the users rated two statements with a Likert scale between 1 and 5 [59]. Data that is difficult to measure can be quantified by a Likert scale. The statement ‘I would use the application to add authors to my Mendeley contacts’ received an average score of 3,5/5. The same statement regarding the adding of papers scored 3,56/5. Both scores show that the application could certainly be useful at a real conference to discover new authors and papers.

Study 2: Researchers

To precisely verify the already discovered problems and to test functionalities that were not used in the first study, a second study amongst researchers was conducted. Six participants (6 male between the age of 21 and 35), who were all familiar with conferences, participated in the second study of Prototype IV. Five participants use a smartphone daily. In contrary to the first study of Prototype IV, the participants were presented specific tasks and questions (List 4.4).

Unlike the result of the first study, only one user was not able to remove a paper or an author. The other users discovered that a click on the buttons 'In your library' and 'In your contacts', as seen on the right of Figure 4.11 and Figure 4.13, removed the corresponding paper or author.

In answer to the question: ‘Which of the papers, that are not in your library, would you read first and why?’, two users chose the paper from which they already read the most related documents and one person chose a paper based on personal interest. Three of the users did not notice the title of the ‘related documents’ image (Figure 4.10.1) and picked a paper randomly.

Continuing on the same question, three users would have liked that the application provided a better guidance through the data. Possible solutions are to highlight the paper with the most related documents read count or to augment an arrow on the mobile screen that points to the most interesting place on the network visualization.

After explaining the 'related documents' functionality to the three users that did not notice the title, all users were able to consult the 'related documents' view and explore further details of the papers.

The functionality to search for all the papers of an author on the network visualization was lacking, according to two users. Furthermore, one participant requested the functionality to read the abstract of a paper on the network.

1. Name an author that is not in your Mendeley contacts, and add the author.
2. Remove an author from your Mendeley contacts.
3. Add a paper to your Mendeley library.
4. Remove the same paper from your Mendeley library.
5. Which of the papers, that are not in your Mendeley library, would you read first and why?
6. Explore the related documents of a paper that is in your Mendeley library.
7. Read the abstract of a related document and add it afterwards to your library.
8. Remove the same related document via the related documents view.

List 4.4: The tasks and questions presented to the participants in the evaluation of the second study of Prototype IV.

Comparison SUS-scores

Both studies finished with filling out a SUS-questionnaire by the participants [34] (Appendix A.1). Figure 4.14 compares the scores of the two studies for each question. The odd questions are positively formulated, while the even questions have a negative connotation. On average the scores of the second study are higher for the odd numbered questions and lower for the even numbered questions, which results in a higher SUS-score for the second study (Figure 4.15).

Figure 4.16 summarizes and compares the results of the first question of the SUS-questionnaire 'I think I would use ConferExplore frequently' with the result of Prototype I. An improvement is observed between the results of Prototype I and those of Prototype IV. This could be explained by the much more realistic and functional Prototype IV.

However the average SUS-score gives a lower result, namely 70,31 for the first study of Prototype IV with students in a class room, while the other two averages are 80,94 for Prototype I and 80,83 for Prototype IV with the researchers. Figure 4.15 shows the distribution of the SUS-scores. The newly integrated features of Prototype IV in comparison to Prototype I may be a cause of the decrease in overall usability, especially with users having no previous experience using reference managers, like students. This effect is corrected with the participants of the second study of Prototype IV, who are familiar with reference managers and have experience in the human computer interaction research domain. Their confidence level with the application is higher, as confirmed by the ninth question of the SUS-questionnaire 'I felt very confident using ConferExplore' (Figure 4.14). This may be a reason why their overall SUS-score is also higher.

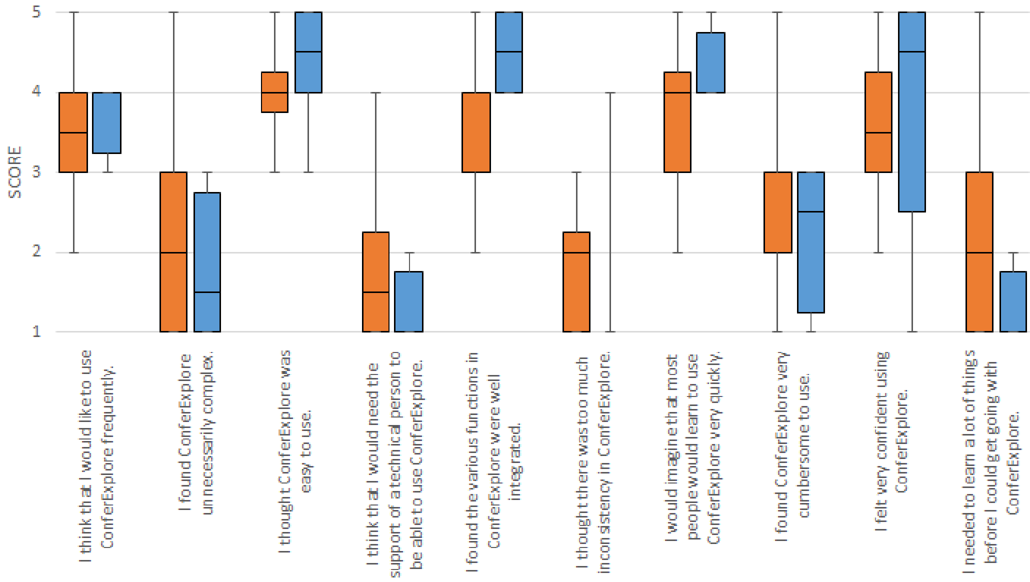


Figure 4.14: Distribution of the scores on the individual questions of the SUS-questionnaire for the first (orange) and second (blue) study of Prototype IV. A score of 1 stands for 'strongly disagree', a score of 5 represents 'strongly agree'.

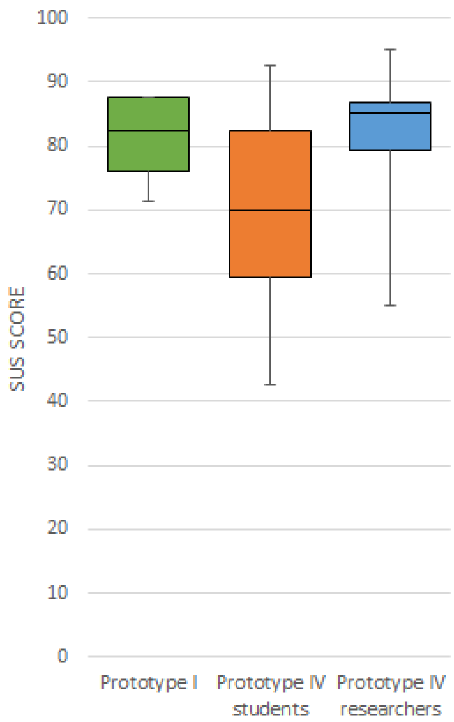


Figure 4.15: Distribution of the SUS-scores of Prototype I (green), the first (orange) and the second (blue) study of Prototype IV.

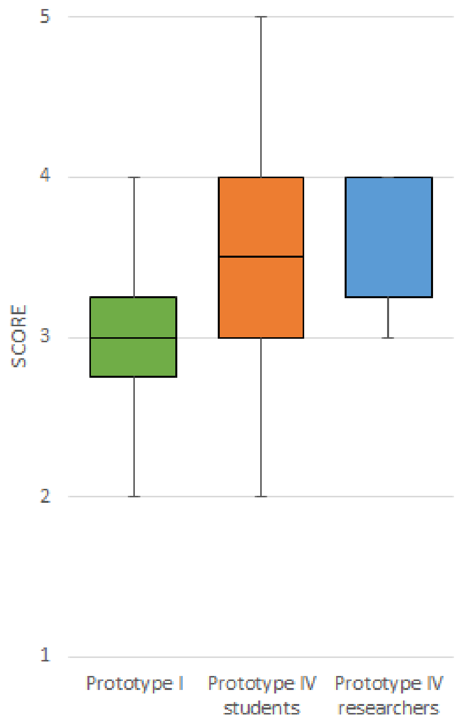


Figure 4.16: Distribution of the scores on the first question of the SUS-questionnaire: 'I think I would use ConferExplore frequently' of Prototype I (green), the first (orange) and the second (blue) study of Prototype IV.

4.5 ConferExplore at the JTEL Summer School

From April 28th to May 2nd 2014, ConferExplore became the official application of the Tenth Joint European Summer School on Technology Enhanced Learning (JTEL Summer School) in Malta. The summer school aims to encourage participants to adopt a critical stance in thinking about the role of technologies in providing opportunities for learners and the potential of these opportunities in terms of learning [27]. The conference program consisted of six lectures, six methodologies and twenty-two workshops.

ConferExplore was spread amongst the summer school attendees through mail and publicity on the official Facebook-page. Android users could download the source file of ConferExplore on a website [9]. This site also contained the download and evaluation instructions. Furthermore, ConferExplore was presented in the workshop 'Educational Augmented Reality: Methodology and Application' on the fourth day of the summer school. Workshop participants took part in a search game constructed around the application and were encouraged to fill out the evaluation form afterwards. Non Android users got the chance to discover ConferExplore by Android tablets and phones that were provided.

As the summer school handled lectures, methodologies and workshops instead of papers contained in the Mendeley database, ConferExplore was adjusted. Beside the necessary changes to make ConferExplore suitable to the summer school, the results of the evaluation of Prototype IV (Section 4.4.2) were also taken into account. The different adjustments made to the application are each discussed below in Section 4.5.1, followed by the evaluation of ConferExplore at the JTEL Summer School in Section 4.5.3.

4.5.1 Changed Functionalities

Network Visualization

The network visualization was adjusted to contain the lectures, methodologies and workshops of the summer school. Each day corresponded to a network visualization. Figure 4.17 shows the network for the fifth day of the summer school. It consisted of one lecture, one methodology, two workshops and nine presenters. Consistent with the evaluation results of Prototype III (Section 4.3.2), Mendeley profile pictures when applicable were used to visualize the presenters. Presenters without a profile picture on Mendeley or with no Mendeley account were visualized as a tracker image with a default profile picture. The main goal was to distinguish them from the tracker images that represent a lecture, methodology or workshop. Due to practical issues, the network visualization was not projected, but printed in gray on A3 paper and sticked to the wall. Each summer school participant also received a printed version of the network visualization upon registration.

Changed Buttons

Taking into account the results of the evaluation of Prototype IV (Section 4.4.2), the augmented buttons on a profile picture or tracker image of a presenter were adjusted.

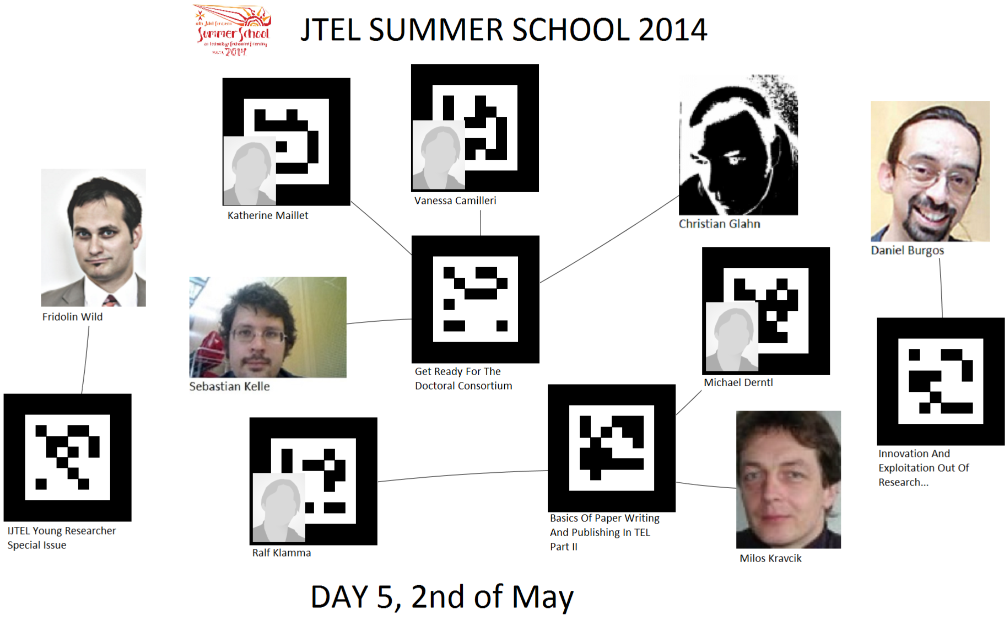
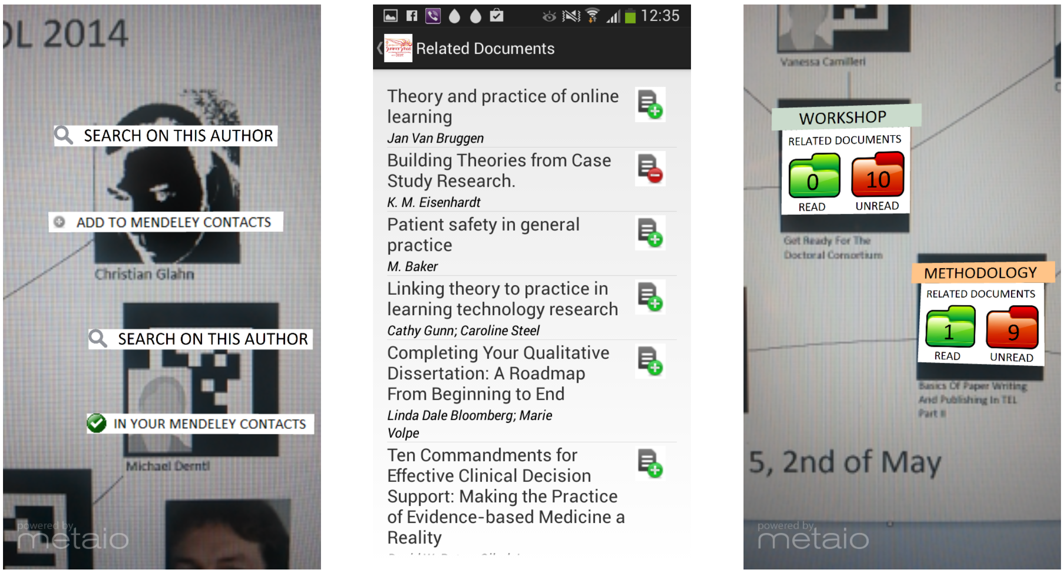


Figure 4.17: Network for ConferExplore at the JTEL Summer School.

Due to the confusion between phone contacts and Mendeley contacts, the buttons 'Add to contacts' and 'In your contacts' changed to 'Add to Mendeley contacts' and 'In your Mendeley contacts' (Figure 4.18a). Two users reported during the evaluation of Prototype IV that the functionality to search for papers of an author was lacking. An extra button was added to comply with this requirement (Figure 4.18a). Clicking on the button 'Search on this author' resulted in the opening of a similar screen as the 'related documents' view with the top ten papers of the author listed. As seen in Table 4.3, users had difficulties in adding or removing a paper from their Mendeley library. This obstacle might have been caused by unclear adding and removing buttons in Prototype IV. The buttons were replaced by identical buttons as used on the Mendeley web and desktop application, thus being more familiar to Mendeley users (Figure 4.18b).

Guidance Through Data

In the evaluation of Prototype IV, three users would have liked the application to provide a better guidance through the data. As the network visualization at the Summer School contained three types of events (lectures, methodologies, workshops), the demand for better guidance was expected to be even higher. Each event received a new augmented header, indicating its type and in the same color as in the program folder of the JTEL Summer School [27] (Figure 4.18c).



(a) New 'Search on this author' button. Changed button text to 'Add to Mendeley contacts' and 'In your Mendeley library'.

(b) Changed buttons to add a paper to or remove a paper form the user's Mendeley library.

(c) New headers to annotate the type of event on the network.

Figure 4.18: Adjustments of ConferExplore for the JTEL Summer School.

4.5.2 Context

To further clarify the use of ConferExplore at the JTEL Summer School, a user story and corresponding storyboard are shown below. They are a variation on the user story and storyboard of Chapter 3 with ConferExplore at the JTEL Summer School integrated in the story.

Peter M. Robertson is a doctoral researcher at the Human-Computer Interaction research group of the department of Computer Science at the KU Leuven. Last year he obtained his Master in Computer Engineering 'cum laude'. His study results gave him the opportunity to start a PhD. Although Peter is very smart, his social skills can be improved upon. He is a bit shy and finds it difficult to start a conversation with unknown fellow researchers.

Next week, a summer school on Technology Enhanced Learning is taking place in Malta. This is certainly an event that Peter has to attend. After subscribing, Peter already feels a bit nervous. He wonders what lectures or workshops he should attend and which persons to talk to, as this a totally new experience to him.

The day of the conference has arrived. The day before yesterday, Peter received an email from the organizers with the final program and additional information. The mail also informed Peter that he could install a mobile application, called ConferExplore, *to enhance his conference experience and to discover new papers and authors. Curious about this application, Peter installed it on his phone, but he did not have the time to explore it yet.*

Peter arrives at the conference and attends the first introduction talk. During the break, Peter goes to the public room to drink some coffee. While wondering if now is the time to meet and address people, he notices a group of people gathering before a wall and approaches to take a closer look.

Peter hears a conversation between two other attendees and finds out that a projection on the wall visualizes the publications and authors of the conference. It is a graph network, nodes stand for authors or papers and connections represent authorship relations. Suddenly a person takes out his smartphone and starts filming the network. It is now that Peter notices that other people are filming the network with their smartphone too. Peter does not have a clue. Why are all these people filming the network and at the same time performing interactions on the phone itself?

Suddenly Peter notices the same logo on the projection as the one from ConferExplore. He takes out his smartphone, starts the app and logs in with his Mendeley account. He starts filming notices an extra overlay on top of the visualization on his phone. Pointing to a paper, an augmented image informs Peter how many related documents of the paper are saved in his Mendeley library. He discovers a paper and notices that he has already read 8 related documents. Another augmented paper is the topic of the lecture later that day. But Peter does not really know what the lecture is about, so he clicks on the augmented image of the paper and scrolls over the related documents. Many of the related documents are really interesting, so Peter decides to attend the corresponding lecture. Furthermore, he adds some of the related documents to his Mendeley library via ConferExplore.

Peter further explores the network by viewing it through his mobile phone. Different papers and authors are augmented, when suddenly he spots a colleague on the network! He is not yet in Peter's Mendeley contacts, so Peter adds him through the augmented reality interface. Three months ago, they published a paper together. Peter wants to know if the paper will appear in the list if he searches on the author via the augmented reality button. Indeed, after pressing 'Search for this author', their co-publication appears as second in the list. Peter also adds some other papers of his colleague to his Mendeley library, so he can read them when he is back in Leuven.

At the end of the day, Peter is really tired. On his way home, Peter is glad he attended the lecture, he discovered through ConferExplore. He also received a notification of Mendeley that his colleague accepted his Mendeley contact request. He will never forget his first conference experience!

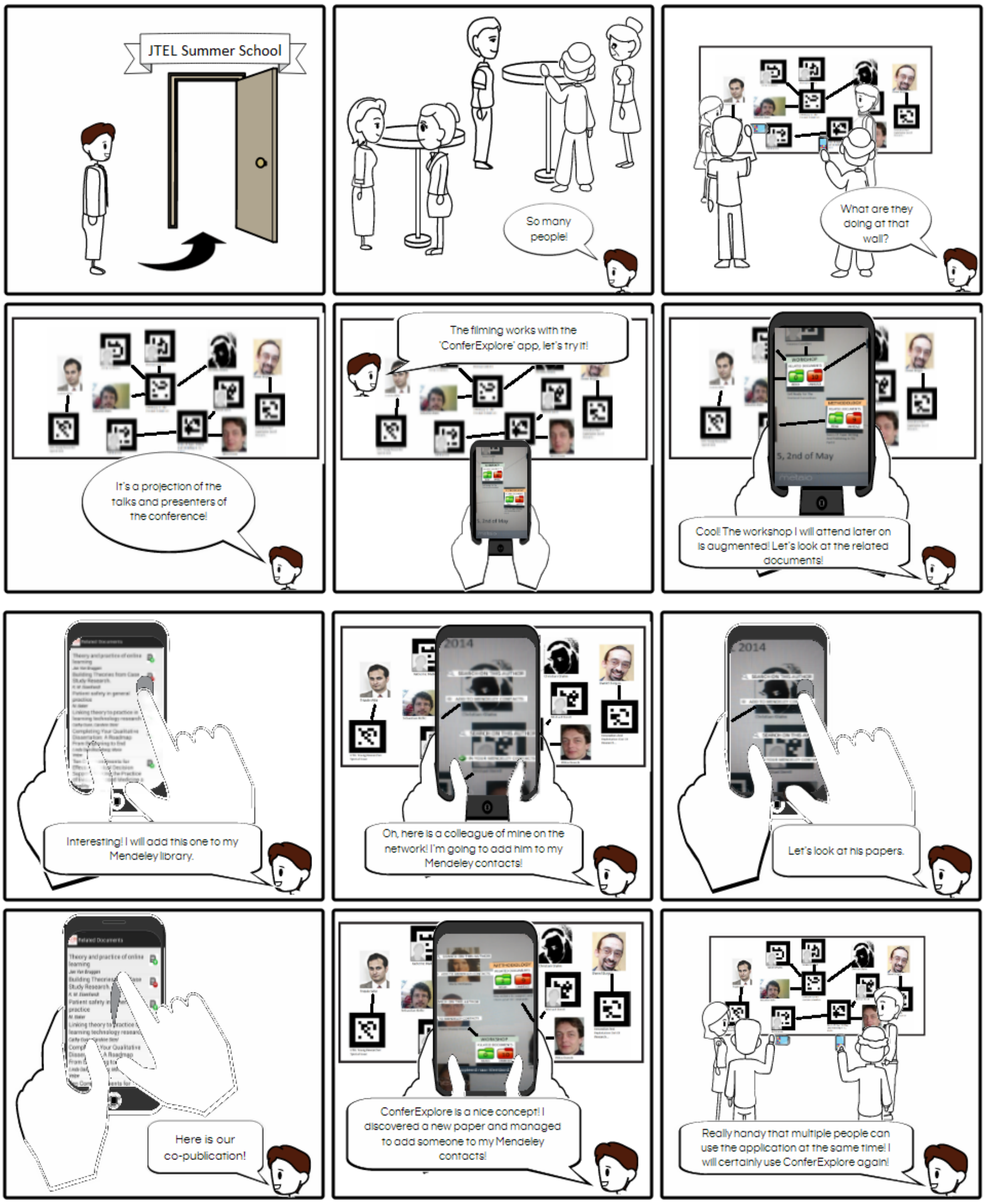


Figure 4.19: Storyboard of the use of ConferExplore at the JTEL Summer School in Malte.

4.5.3 Evaluation

The goal of this iteration is to compare the use of ConferExplore in an artificial test environment with the usage in a real life setting. Thus the evaluation form was comparable to the one of the first study of the evaluation of Prototype IV, containing most of the questions of Table 4.3 and a SUS-questionnaire. Eleven participants (6 male, 5 female), between the age of 27 and 41 filled out the online evaluation form. First the answers to the questions are discussed and compared with the answers to the evaluation of the first study of Prototype IV. Then the same comparison is done for the results of the SUS-questionnaire.

Comparing Questions
In comparison to the first study of Prototype IV (Table 4.3), two questions were removed and one was added, as seen in Table 4.4. The question 'Did you manage to remove someone from your Mendeley contacts?', was removed because this functionality reduces the user's Mendeley network. The second question 'Did you understand what 'related documents' means?' was removed because thirteen out of sixteen participants already understood the term in the first study of Prototype IV and the question did not concern any performable task. The new functionality to search for an author's top ten papers was tested by the added question 'Did you manage to find someone's papers through the augmented reality button?'. Seven participants managed to use this functionality correctly.

Question	**Yes**	**No**
Did you understand the network that is projected on the wall?	8	3
Did you manage to add someone to your Mendeley contacts?	4	7
Did you manage to add a paper to your Mendeley library?	4	7
Did you manage to remove a paper from your Mendeley library?	2	9
Did you manage to read the abstract from a paper?	6	5
Did you manage to find someone's papers through the augmented reality button?	7	4

Table 4.4: The questions presented to the participants in the evaluation of ConferExplore at the JTEL Summer School and their answers.

The results of the other questions are compared in Figure 4.20. The height of the green bars indicates the percentage of participants answering 'Yes', the red bars represent the 'No' answers. The left bar of each question visualizes the results of the first study of Prototype IV, the right bar the results of ConferExplore at the JTEL Summer School. In comparing the two evaluations, all questions show a decrease in positive answers. The questions 'Did you understand the network that is projected on the wall?' and 'Did you manage to read the abstract from a paper?' had a higher negative score but still showed an acceptable amount of positive answers. For the other three questions however, more negative answers were given. Contrary to the first study of Prototype IV, where fifteen out of sixteen users managed to add an author to their Mendeley contacts, only four out of eleven participants succeeded in this task with ConferExplore at the JTEL Summer School. The same number did not manage to add a paper to their Mendeley library and only two users succeeded in removing a paper from their Mendeley library. These results might indicate that the adjustment of the buttons (Section 4.5.1), representing the evaluated functionalities, were not successful.

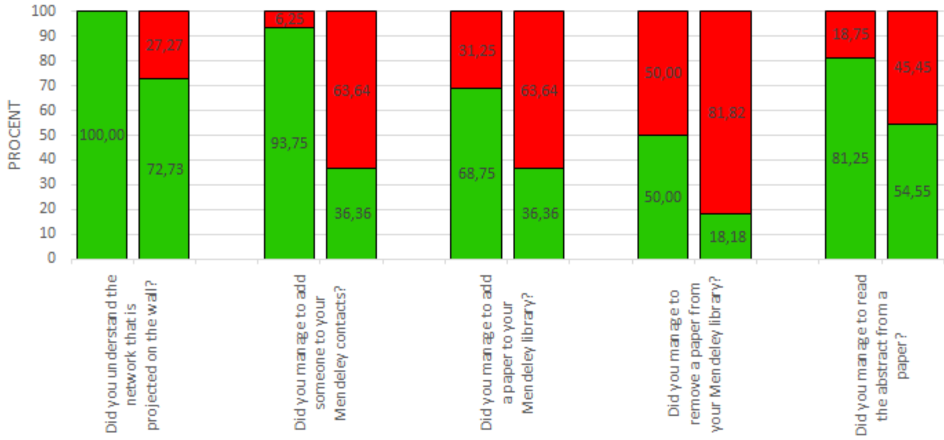
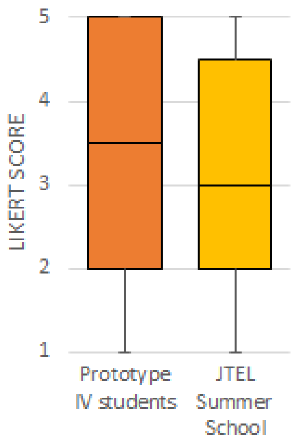


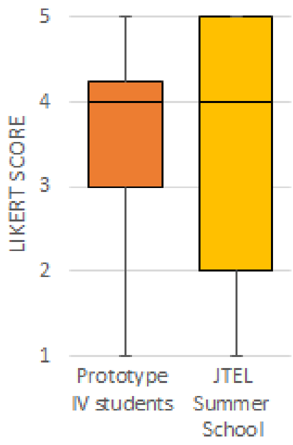
Figure 4.20: Comparison of the common questions of the evaluation of the first study of Prototype IV (left bar of each question) and the evaluation of ConferExplore at the JTEL Summer School (right bar of each question). The height of the green bars indicates the percentage of participants answering 'Yes', the red bars indicate 'No'.

Two statements with a Likert scale [59] were also included in the questionnaire. The statement 'I would use ConferExplore to add authors to my Mendeley contacts' got an average score of 3,19/5, which is a slight decrease in comparison to the first study of Prototype IV. The same evolution is observed with the statement 'I would use ConferExplore to add papers to my Mendeley library'. The average score went from 3,56/5 for the first study of Prototype IV to 3,28/5 for ConferExplore at the JTEL Summer School. The distributions of the results on both statements and for both evaluations can be seen in Figure 4.21a and Figure 4.21b. As this evaluation occurred in a real life setting, an extra statement was added to the evaluation. 'I would chose to attend a lecture/methodology/workshop based on its related documents' got an average score of 3,36/5. The distribution of the scores is seen in Figure 4.21c. These three results indicate that according to the participants, ConferExplore is certainly useful in a real life setting such as a summer school, workshop week or conference.

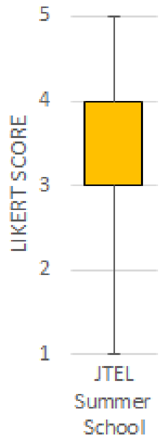
Despite the added augmented headers indicating the type of event, two users would like to have seen more screen guidance. One user suggested to include instructions when the camera view starts. One other user found a login button was lacking. At



(a) Distribution of the Likert scores on the statement 'I would use ConferExplore to add authors to my Mendeley contacts' for the first study of Prototype IV (left) and ConferExplore at the JTEL Summer School (right).



(b) Distribution of the Likert scores on the statement 'I would use ConferExplore to add papers to my Mendeley library' for the first study of Prototype IV (left) and ConferExplore at the JTEL Summer School (right).



(c) Distribution of the Likert score on the statement 'I would chose to attend a lecture/methodology/-workshop based on its related documents' for ConferExplore at the JTEL Summer School.

Figure 4.21: Distribution of the scores on the statements with a Likert scale.

the moment, the user only provides his/her Mendeley credentials and presses the 'Go' button of the mobile keyboard. Another user found the interface of ConferExplore attractive and two iPhone users even requested the development of ConferExplore for iOS so they could use the application at other conferences.

Comparison SUS-scores

Users were also requested to fill out a SUS-questionnaire. Figure 4.22 shows the distribution of the scores on the individual questions. The large score variability is striking. The distribution of the scores of almost every question ranges from 1 to 5. Yet the median of the distribution is around 4 for the odd questions and 1 for the even ones. The odd questions are positively formulated, while the even questions have a negative connotation. However, the eight question 'I found ConferExplore very cumbersome to use' has just a median of 3. This confirms the need for better screen guidance when using ConferExplore for the first time.

The same variability is noticed in the distribution of the total SUS-scores (Figure 4.23). The scores range from 15 till 100, giving an average SUS-score of 66, putting the application in the top 50 percent of all SUS-scores. This is a decrease in comparison to the previous prototypes and may be due to the fact that it was the first time that ConferExplore was used in a real life setting. Beside the need for better screen guidance, the network visualization was also printed in gray on

A3 paper and not projected on a wall, which may have complicated the detection process of the trackers on the network visualization.

Taking a closer look at the distribution of the scores on the question 'I think I would use ConferExplore frequently', the median is 4, which is higher than the previous prototypes. This result can probably be explained by the fact that ConferExplore was tested on summer school attendees, who are familiar with conferences and experience the need of an application easing the conference experience and helping them to discover new authors and papers.

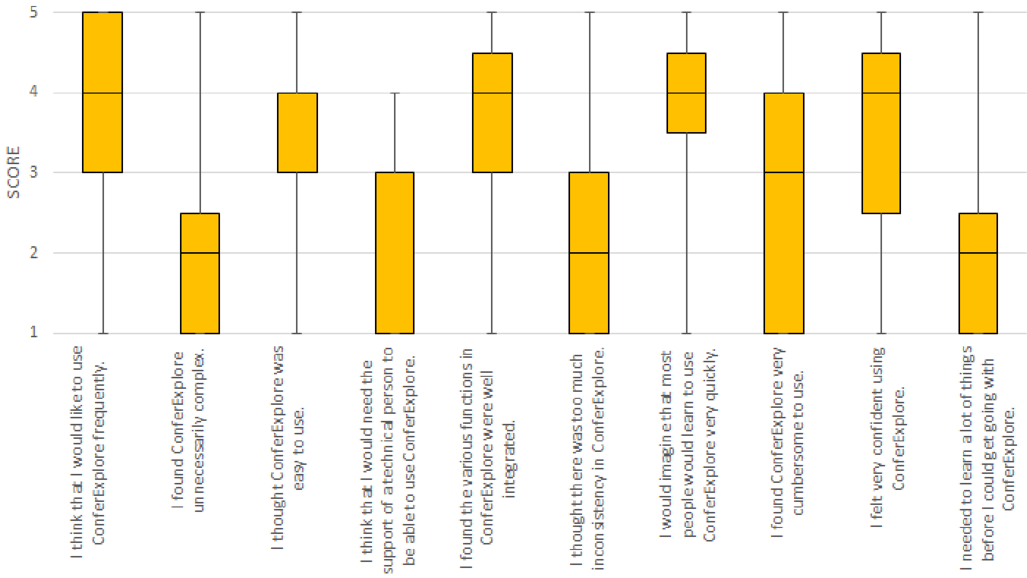


Figure 4.22: Distribution of the scores of ConferExplore at the JTEL Summer School on the individual questions of the SUS-questionnaire. A score of '1' stands for 'strongly disagree', a score of '5' represents 'strongly agree'.

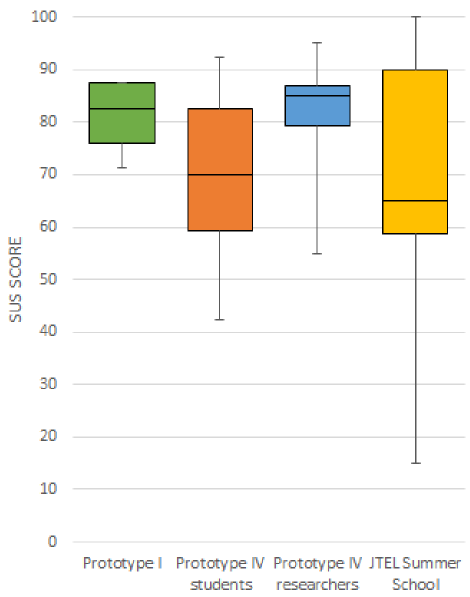


Figure 4.23: Distribution of the SUS-scores of Prototype I (green), the first study of Prototype IV (orange), the second study of Prototype IV (blue) and of ConferExplore at the JTEL Summer School (yellow).

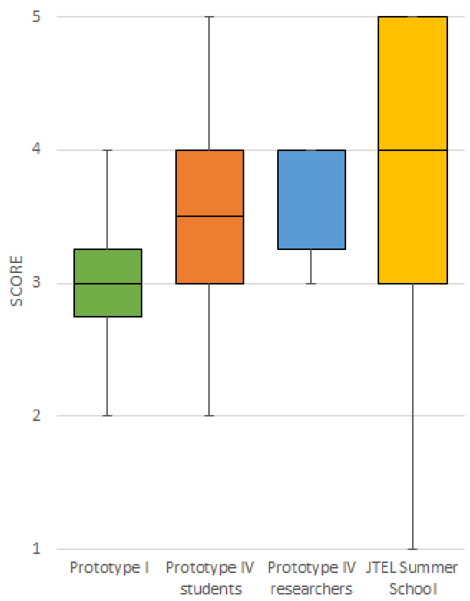


Figure 4.24: Distribution of the scores of Prototype I (green), the first study of Prototype IV (orange), the second study of Prototype IV (blue) and of ConferExplore at the JTEL Summer School (yellow) on the first question of the SUS-questionnaire: 'I think I would use ConferExplore frequently'.

Chapter 5

Implementation

The implementation of ConferExplore consists of two main parts. First, there is the network visualization that is projected on a wall. To handle various data and to speed up its development, this visualization process was automated. This automation is described in Section 5.1. The second main part is the mobile application itself. ConferExplore is an Android application, that uses two main techniques: augmented reality and interaction with the Mendeley API. These are discussed in Section 5.2.

5.1 Network Visualization

The evaluation of and the consideration between the tracker and the image version in Prototype III (Section 4.3) was performed with static images. The image and tracker network were 'hand-drawn' using graph drawing software, named Gephi [12]. To make the application more generic and flexible and to introduce interactivity in further prototypes, the network visualization process was automated.

The JUNG (Java Universal Network/Graph) framework [18] was used and modified to automate the drawing of the network. After parsing the data, e.g. as a CSV-file (Figure 5.1), the corresponding images and links are loaded into the framework.

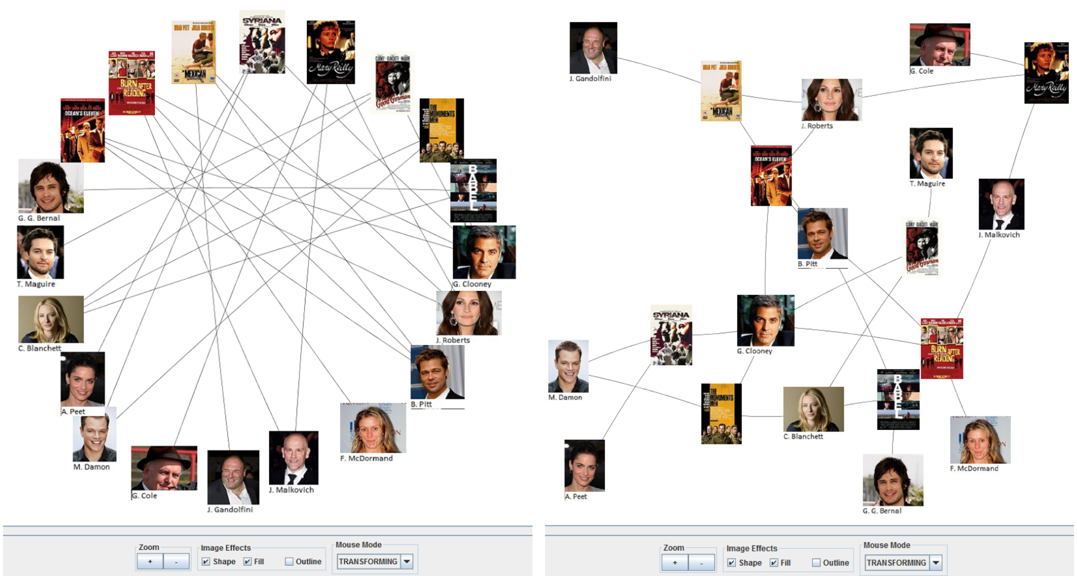
The JUNG framework provides different network layouts, even dynamic ones. Two examples can be seen in Figure 5.2.

Zooming, node picking and transforming were added in order to increase the flexibility of the network drawing.

With this automating, it became possible to load every kind of data and the corresponding images, choose the layout of the network and to speed up the whole process of the network visualization.

1	George Clooney	Actor				
2	Brad Pitt	Actor				
3	Julia Roberts	Actor				
4	Frances McDormand	Actor				
5	John Malkovich	Actor				
6	James Gandolfini	Actor				
7	George Cole	Actor				
8	Matt Damon	Actor				
9	Amanda Peet	Actor				
10	Cate Blanchett	Actor				
11	Tobey Maguire	Actor				
12	Gael Garcia Bernal	Actor				
13	Oceans Eleven	Movie	George Clooney	Brad Pitt	Julia Roberts	
14	Burn After Reading	Movie	George Clooney	Frances McDormand	Brad Pitt	John Malkovich
15	The Mexican	Movie	Brad Pitt	Julia Roberts	James Gandolfini	
16	Mary Reilly	Movie	Julia Roberts	John Malkovich	George Cole	
17	Syriana	Movie	George Clooney	Matt Damon	Amanda Peet	
18	The Monuments Men	Movie	George Clooney	Cate Blanchett	Matt Damon	
19	The Good German	Movie	George Clooney	Cate Blanchett	Tobey Maguire	
20	Babel	Movie	Brad Pitt	Cate Blanchett	Gael Garcia Bernal	

Figure 5.1: Data file for the network visualization: ID | Name | Type | Links



(a) Circle layout. (b) FR layout.

Figure 5.2: Two types of network visualizations layouts provided by the JUNG framework.

5.2 ConferExplore: an Android Application

ConferExplore is developed as an Android application. Android applications consist of loosely coupled activities. An activity is an application component that provides a screen users can interact with and is often bounded by a particular functionality [1]. ConferExplore consists of six activities, which can be seen together with their transitions in Figure 5.3.

The 'MainActivity' is launched first and starts the 'MendeleyLogin' activity. After logging in with the Mendeley credentials, the Mendeley data of the user is collected in the 'MendeleyData' activity. The 'CameraView' activity starts the back camera of the phone automatically and augments the images corresponding to the authors and papers on the network visualization. Adding or removing a paper or author by clicking on the 'Add to Mendeley contacts' or 'Add to library' button changes the augmented image, but does not start another activity. Clicking the related documents image however, starts the 'RelatedDocuments' activity, where documents are listed and marked with a read or unread symbol. By further exploring the details of a document, the 'DocumentInfo' activity starts. Each time a new activity starts, the one initiating it is pushed on the 'back stack'. The stack works by the 'last in, first out' principle so pushing the back button on an Android phone causes the top activity to start again. This occurs when going from the 'DocumentInfo' activity to the 'RelatedDocuments' activity and when going back from the 'RelatedDocuments' activity to the 'CameraView' activity.

Two types of functionalities can be distinguished in ConferExplore. A first type interacts with Mendeley or the user's Mendeley account via the OAuth2.0 protocol and the Mendeley API. The second type handles the interaction with the network visualization and provides the augmented reality to the user in the 'CameraView' activity. The process of augmentation and its interaction is described in Section 5.2.1. Section 5.2.2 discusses the Mendeley interaction.

5.2.1 Augmented Reality

The Metaio SDK [21] is used to detect the images of the authors and papers and to provide the corresponding augmentation. The use of this SDK can be divided into four phases. First there is a configuration phase to adjust the Metaio SDK to ConferExplore. Secondly, the images that will be augmented are initialized. The third phase is the actual augmentation of the images. In the fourth phase, the SDK is adapted to handle the interaction with and the touching of the augmented images. The implementation and adaptation of the SDK in each phase is discussed below.

Configuring Image Markers
The Metaio SDK provides three tracking configurations depending on the marker that is being tracked: ID marker, picture marker and image marker configuration (Figure 5.4). ID markers are predefined markers that do not need further configuration. In the picture marker configuration, any image can be used as a marker. The only constraints are that the reference image should have a dark border and is printed

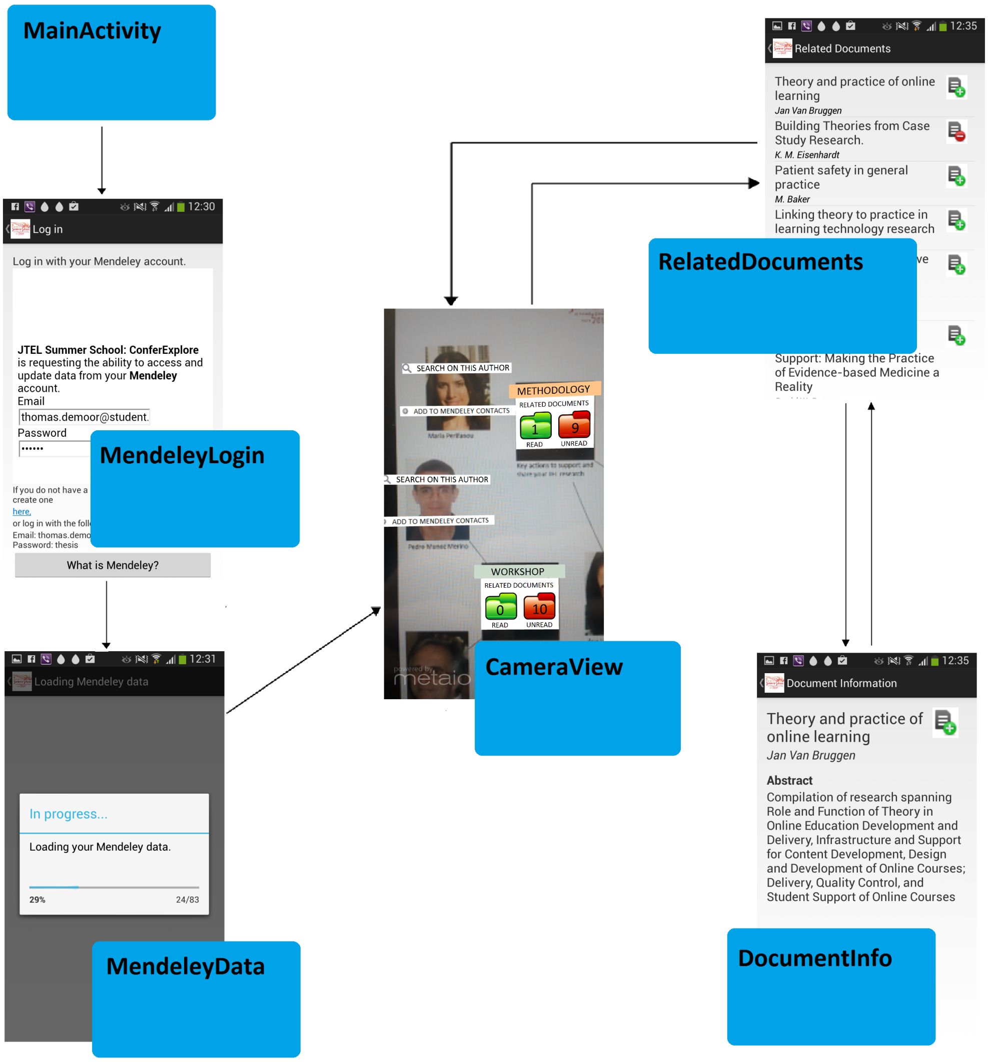


Figure 5.3: Corresponding screens to Android activities and their relationships.

in front of a bright background. The image marker configuration finally has no constraints, resulting in the most generic configuration. It is therefore used in ConferExplore. The network visualization completely consists of image markers (Figure 4.17). Note that an ID marker can also serve as an image marker since there are no specific constraints to this type of tracking configuration.

The configuration is done with an XML-file (Listing 5.1). First the parameters for the tracking in general are specified. The number of objects to detect per frame and the number of objects to detect in parallel is set to 10. This setting is a balance between detecting all markers and speed: the higher the number of markers, the slower tracking happens. A default similarity threshold is set to 0.9, which means

(a) ID marker. (b) Picture marker. (c) Image marker.

Figure 5.4: Three sort of markers that can be used in the tracking configuration of the Metaio SDK.

the view through the camera needs to have a 90 percent correspondence with the image marker in order to become detected. Thereafter the reference image source and the specific similarity threshold are set for each image marker independently.

Initializing IGeometry Objects

The application parses the same data file (Figure 5.1) as used in the network drawing (Section 5.1). Each parsed author or paper corresponds to an image marker of the network visualization, that is configured in the XML-file of Listing 5.1. Next, an IGeometry object is created for each type of image that will be augmented on an image marker. For example, Listing 5.2 shows the creation of an IGeometry object with the augmented image that represents whether or not the author is in the user's Mendeley contacts. First the tracking configuration is set with the XML-file of Listing 5.1. Subsequently, in the looping over the images markers, the type of each marker is checked. If the type equals *'Author'*, the source (or *imagePath*) of the IGeometry object is set to the *'In_Your_Contacts.png'* image when the author is in the user's Mendeley contacts, or to the *'Add_To_Contacts.png'* image if that is not the case. Eventually the IGeometry object is created with the help of the *'createGeometryFromImage()'* function of the Metaio SDK. The type of the geometry is saved and the geometry is linked to its corresponding tracker. This creation process is executed for each image that needs to be augmented on an image marker.

Augmented IGeometry Objects

When detecting an image marker, the IGeometry objects corresponding to that marker are each linked to a coordinate system. The parameters of such a coordinate system are set in the same XML-file as the one of Listing 5.1. An example is shown in Listing 5.3. Here, a coordinate system called *'MarkerlessCOS1'* is defined relatively to the image marker with ID *'Patch1'*. At the time of detecting that marker, the coordinate system of a corresponding IGeometry object is set to *'MarkerlessCOS1'* with the function *'setCoordinateSystemID()'*. The *'SmoothingFuser'* attribute predicts movement and handles noise. The *'KeepPoseForNumberOfFrames'* parameter sets the number of frames in which the coordinate system still applies when detection fails. In *‘COSOffset’* a translation and rotation offset can be set. In the example of Listing 5.3, the augmented image will be translated 50 units downwards relative to the center of the image marker with ID *‘Patch1’*.

Interacting With IGeometry Objects

Besides augmenting IGeometry objects on the image markers, it is also possible to interact with them. The effect of touching an IGeometry object depends on the type. Listing 5.4 shows the code when touching the IGeometry object representing if an author is in the user’s Mendeley contacts. Either the author is added or removed from the user’s Mendeley contacts by touching the object. First the type of the IGeometry is checked. If it equals *‘Contacts’*, it is checked whether the author is already in the user’s Mendeley contacts or not. If that is indeed the case, the author is removed as a contact, the *‘imagePath’* is set to *‘Add_To_Contacts.png’* and a pop-up is shown to the user that the author was removed. If the author was not in the user’s Mendeley contacts, the opposite commands are executed. The line *‘mSurfaceView.queueEvent(new changeGeometryRunnable(imagePath, geometryIndex))’* changes the source of the IGeometry object in a separate thread.

```xml
<?xml version="1.0"?>

<TrackingData>
 <Sensors>
  <Sensor Type="FeatureBasedSensorSource" Subtype="Fast">

   <SensorID>FeatureTracking1</SensorID>

   <Parameters>
    <FeatureDescriptorAlignment>regular</FeatureDescriptorAlignment>
    <MaxObjectsToDetectPerFrame>10</MaxObjectsToDetectPerFrame>
    <MaxObjectsToTrackInParallel>10</MaxObjectsToTrackInParallel>
    <SimilarityThreshold>0.9</SimilarityThreshold>
   </Parameters>

   <SensorCOS>
    <SensorCosID>Patch1</SensorCosID>
    <Parameters>
     <ReferenceImage>Ralf_Klamma.png</ReferenceImage>
     <SimilarityThreshold>0.9</SimilarityThreshold>
    </Parameters>
   </SensorCOS>

   <SensorCOS>
    <SensorCosID>Patch2</SensorCosID>
     <Parameters>
     <ReferenceImage>Pecha_Kucha.png</ReferenceImage>
     <SimilarityThreshold>0.9</SimilarityThreshold>
    </Parameters>
   </SensorCOS>

   ...

  </Sensor>
 </Sensors>
</TrackingData>
```

Listing 5.1: Image marker configuration used in ConferExplore.

```
protected void loadContents()
{

  String trackingConfigFile = AssetsManager.getAssetPath("
      TrackingData_MarkerlessFast.xml");
  boolean result = metaioSDK.setTrackingConfiguration(
      trackingConfigFile);

  for(int i = 0; i< NBOFMARKERS; i++) {

    String imagePath = null;
    String type = markerTypes.get(i);

    if (type.equals("Author")) {

      String authorName = markerNames.get(i);

      if (CONTACTS.contains(authorName)) {
        imagePath = AssetsManager.getAssetPath("In_Your_Contacts.png")
            ;
      }
      else {
        imagePath = AssetsManager.getAssetPath("Add_To_Contacts.png");
      }

      if (imagePath != null) {
        IGeometry geometry = metaioSDK.createGeometryFromImage(
            imagePath);
        geometries.add(geometry);
        geometryTypes.add("Contacts");
        geometryAndTrackerIndex.put(geometry, i);
      }
      else {
        MetaioDebug.log(Log.ERROR, "Error loading geometry: "+
            imagePath);
      }

    }

    ...

  }
}
```

Listing 5.2: The creation of an IGeometry object representing if an author is in the user's Mendeley contacts.

```xml
<COS>

 <Name>MarkerlessCOS1</Name>

 <Fuser Type="SmoothingFuser">
  <Parameters>
   <KeepPoseForNumberOfFrames>2</KeepPoseForNumberOfFrames>
  </Parameters>
 </Fuser>

 <SensorSource>
  <SensorID>FeatureTracking1</SensorID>
  <SensorCosID>Patch1</SensorCosID>
  <COSOffset>
   <TranslationOffset>
    <X>0</X>
    <Y>-50</Y>
    <Z>0</Z>
   </TranslationOffset>
   <RotationOffset>
    <X>0</X>
    <Y>0</Y>
    <Z>0</Z>
    <W>1</W>
   </RotationOffset>
  </COSOffset>
 </SensorSource>

</COS>
```

Listing 5.3: Defining of a coordinate system *'MarkerlessCOS1'* relatively to the image marker with the ID *'Patch1'*.

```java
protected void onGeometryTouched(IGeometry geometry)
{

  String imagePath = null;
  Integer geometryTrackerIndex = geometryAndTrackerIndex.get(geometry
     );
  Integer geometryIndex = geometries.indexOf(geometry);
  String geometryType = geometryTypes.get(geometryIndex);

  if (geometryType.equals("Contacts")) {

    String authorName = trackerNames.get(geometryTrackerIndex);

    if(CONTACTS.contains(authorName)) {
      CONTACTS.remove(authorName);
      imagePath = AssetsManager.getAssetPath("Add_To_Contacts.png");
      Toast.makeText(getApplicationContext(),"'"+authorName + "' was
          removed from your contacts." , Toast.LENGTH_LONG).show();
    }
    else {
      CONTACTS.add(authorName);
      imagePath = AssetsManager.getAssetPath("In_Your_Contacts.png");
      Toast.makeText(getApplicationContext(),"'"+authorName + "' was
          added to your contacts." , Toast.LENGTH_LONG).show();
    }

    if (imagePath != null) {
      mSurfaceView.queueEvent(new changeGeometryRunnable(imagePath,
          geometryIndex));
    }
    else {
      MetaioDebug.log(Log.ERROR, "Error loading geometry: "+imagePath)
          ;
    }

  }

  ...

}
```

Listing 5.4: Interaction with an IGeometry object to remove an author from or add an author to the user's Mendeley contacts.

5.2.2 Mendeley Interaction

The second type of functionality present in ConferExplore is the interaction with the Mendeley API. This interaction can be divided into three categories. The first category is the user authorization when logging in to ConferExplore. The permission of accessing the user's Mendeley data happens with the OAuth2.0 protocol [48]. A second category is the Mendeley interaction in the 'CameraView' activity while images are augmented as discussed in Section 5.2.1. The final interaction category takes place in the 'RelatedDocuments' and 'DocumentInfo' activities when related documents are explored and more details are requested. Each category is explained in more detail below.

Logging In And Retrieving Data

The 'MendeleyLogin' activity connects ConferExplore with Mendeley by authorizing the user. The authorization process is shown in the first part of the sequence diagram of Figure 5.5. The OAuth2.0 protocol is used [48]. It is an open authentication protocol that enables ConferExplore to access the user's Mendeley data. By accessing the application, a Mendeley login form is presented to the user. Users logging in with their Mendeley username and password, allow ConferExplore to access their Mendeley data. The Mendeley authorization server provides an authentication code to ConferExplore via the redirect URI. This URI was registered beforehand at the Mendeley website together with the ConferExplore ID and ConferExplore secret. The authorization code, the ID and the secret are sent back together to the Mendeley authorization server. At that moment the server provides an access token. With this unique token, ConferExplore is able to access the resources of Mendeley, related to the user who logged in.

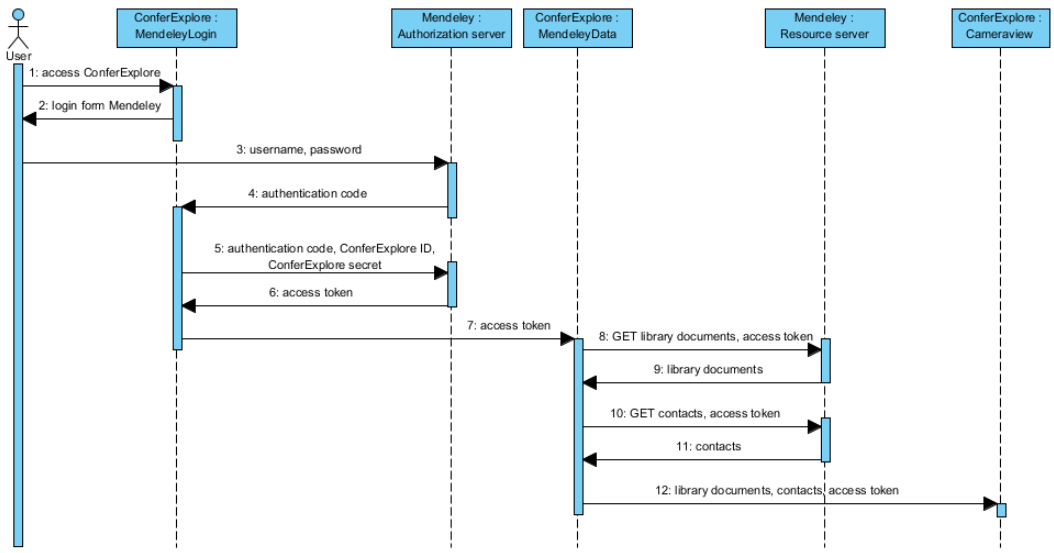


Figure 5.5: Sequence diagram of logging in to ConferExplore with a Mendeley account. The OAuth2.0 protocol is used.

After obtaining the access token in the 'MendeleyLogin' activity, the user is directed to the 'MendeleyData' activity, as seen in the second part of the sequence diagram of Figure 5.5. To obtain the user's Mendeley library, an Http GET request is sent to the Mendeley API. More specifically to:
https://api-oauth2.mendeley.com/oapi/library?access_token="+ACCESS_TOKEN with ACCESS_TOKEN having the received access token value. The response is JSON encoded and contains all the IDs of the user's library documents. The same process is executed to obtain the user's Mendeley contacts, after which the application proceeds to the 'CameraView' activity.

Augmenting Images

A limited amount of Mendeley interaction happens when detecting a paper, as seen in the sequence diagram of Figure 5.6. First it is checked whether the paper is in the user's Mendeley library that was obtained in the 'MendeleyData' activity and the right image is augmented as explained in Section 5.2.1. To retrieve the related documents of the detected paper, a Http GET request is sent to the Mendeley API together with the access token. All related documents are searched in the user's library and the right 'related documents' image is augmented (Figure 4.10.1). When detecting an author, no Mendeley API request is necessary. The augmentation of the image on an author is described in detail in Section 5.2.1.

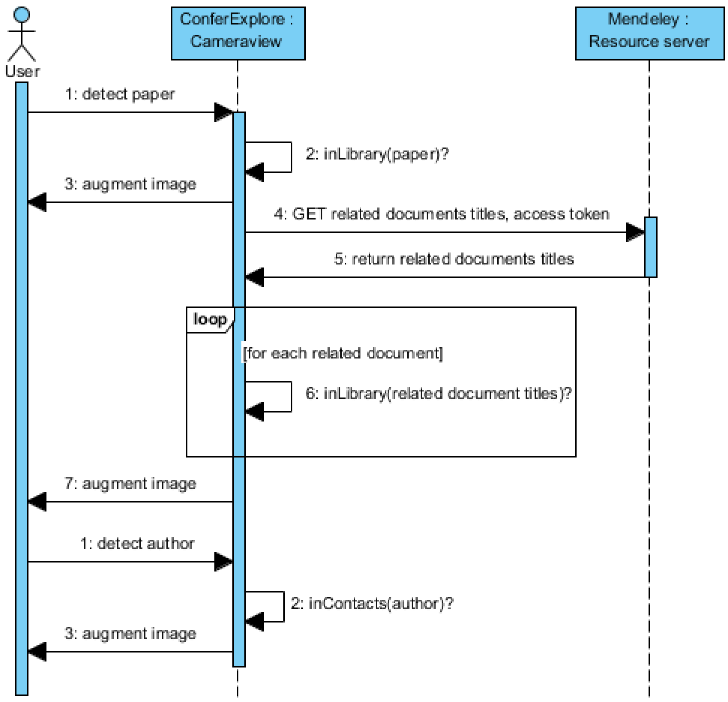


Figure 5.6: Sequence diagram of detecting a paper or an author and augmenting the corresponding image.

Related Documents And Details
Clicking on a 'related documents' image, causes the 'RelatedDocuments' activity to start, as seen in the beginning of the sequence diagram of Figure 5.7. The activity receives the titles of the 'CameraView' activity that were obtained when the paper was augmented. To get more details such as the authors and the abstracts of the related documents, an Http GET request is sent together with the access token to the Mendeley resource server. The titles and the authors of the related documents are presented as a list to the user. More details can be requested by clicking on a related document in the list. The 'DocumentInfo' activity starts, but no interaction with the Mendeley API happens, because all details, including the abstract, were already obtained in the 'RelatedDocuments' activity.

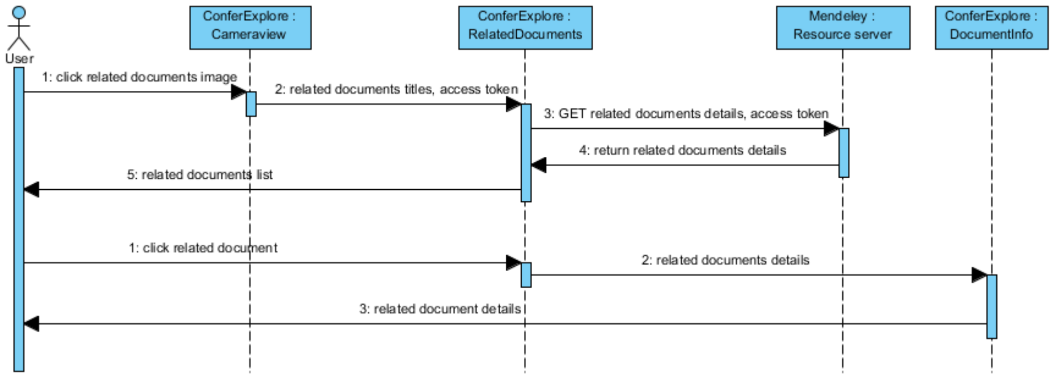


Figure 5.7: Sequence diagram of consulting the related documents list and details of one related document.

Chapter 6

Conclusion & Future Work

This thesis identified one ingredient of the gap between the traditional way of discovering papers and authors at conferences and the discovery tools of the Science2.0 movement. With the help of ConferExplore, a mobile application, it was investigated if augmented reality could serve as a coupling mechanism to bridge this gap. At the same time an integration of augmented reality within the domain of visual Science2.0 data exploration and interpretation was established.

ConferExplore improves the discovery of new papers and authors at conferences by augmenting the network visualization of authors and papers with user specific information. Four prototypes of ConferExplore have been tested thoroughly with the rapid prototyping technique [40]. Two paper and two digital prototypes were subjected to four iterations of user tests. The think aloud protocol [57] was applied and complemented with SUS-questionnaires [34] and other questions on a Likert scale [59]. The evaluation results were used to construct each subsequent prototype.

In Prototype I and Prototype IV, mainly problems about unclear buttons or symbols, meant to add or remove (favorite) papers and authors, arose. Prototype IV pointed out that a better guidance through the data has to be provided, as well as a new functionality to search for information on the papers and authors on the network visualization itself. A first study of Prototype IV amongst students showed a decrease in the average SUS-score in comparison to Prototype I. This decrease in usability may be explained by the introduction of integrated features Users with no previous experience in using reference managers, like students encountered more difficulties when tested. This effect is corrected by the researchers in the second study of Prototype IV, who are familiar with reference managers and have experience in the human-computer interaction domain. Prototype III compared two versions of the network visualization; it became clear that the version using real images was preferred by all users.

A final version of ConferExplore was developed, used and evaluated at the Tenth European Summer School On Technology Enhanced Learning in Malta [27]. The adjustment of the adding and removing buttons, in comparison to Prototype IV, caused a decrease in successfully completed tasks, proving this adjustment was not appropriate. Summer school attendees however answered positively to the questions 'I would use ConferExplore to add authors/papers to my Mendeley account' and 'I would chose to attend a lecture based on its related documents', which could indicate that ConferExplore is useful in a real life setting. The average SUS-score of ConferExplore at the JTEL Summer School shows a slightly decrease in comparison to the prototypes. This might be explained by the fact that it was the first use of ConferExplore in a real environment.

Looking closer at the results of the individual questions of the SUS-questionnaire, it is noticed that the attendees answered with a higher average score than all the previous testpersons on the statement 'I think I would use ConferExplore frequently'. This can probably be explained by the familiarity of the attendees with conferences and the need for an application that eases the conference experience.

Next steps in improving the application involve solving the issues that came up in the evaluation of ConferExplore at the JTEL Summer School. On top of that, testing the following adjustments will be useful: the replacement of an ordinary projector by a high definition projector, the use of a mobile tablet instead of a mobile phone, the introduction of a horizontal tabletop with touch technology. The latter will make the network visualization interactive. Thus turning the static network into a dynamic and adjustable one. Users are able to zoom in or out, select and filter content and automatically search for relevant authors or papers in the network.

Further research into the social aspect of the application is recommendable. Whether ConferExplore enhances the social interactions at the place where the network visualization is shown and whether or not researchers start collaborating using ConferExplore is still unknown. The network visualization can be mapped to real authors and conference attendees. Ideally, each conference participant wears a badge with a profile picture or a marker image, that can be detected by ConferExplore. Attendees thus easily discover each other's research by scanning the badge via the augmented reality technique.

Gamification is the inclusion of gaming elements in a non-gaming context to stimulate the accomplishing of user's actions [39]. Introducing gamification into ConferExplore would be another asset. A user who adds five papers to his her Mendeley library or a user with a top score in using ConferExplore can be rewarded with badges or other gaming elements. In a search game context ConferExplore would require users to add specific papers or authors as fast as possible, following a track of network visualizations at different spots in the conference location.

The realization of an integration with existing conference applications, like Conference Navigator [77], is obvious. Conference participants would be able to combine the organization of their conference schedule with the discovery of new papers and authors through ConferExplore. Adding corresponding lectures or workshops to one's personal conference schedule via the augmented reality interface becomes similar to adding papers to one's Mendeley library.

ConferExplore is a general tool, applicable to other application domains than a research setting. As seen in the example of Prototype II, the mobile application is suitable in an entertainment setting as well; papers become movies and authors change into movie actors. A similar application can be developed for exhibitions, with artists instead of authors and paintings or sculptures replacing papers.

Based on the research and results of this thesis, it can be concluded that ConferExplore contributes to the research community of Science2.0, assisting researchers in their discovery phase and enhancing the collaboration and communication between them. Furthermore, this thesis shows that augmented reality serves as a proper coupling mechanism between the traditional way of promoting and discovering research and fellow researchers at conferences on the one hand and the new way of discovering papers and authors with Science2.0 tools on the other hand. The coupling was successfully performed by using augmented reality to explore and interpret visual Science2.0 data.

Appendices

Appendix A

SUS-questionnaire

System Usability Scale

	Strongly disagree				Strongly agree
1. I think that I would like to use this system frequently	1	2	3	4	5
2. I found the system unnecessarily complex	1	2	3	4	5
3. I thought the system was easy to use	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
5. I found the various functions in this system were well integrated	1	2	3	4	5
6. I thought there was too much inconsistency in this system	1	2	3	4	5
7. I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
8. I found the system very cumbersome to use	1	2	3	4	5
9. I felt very confident using the system	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

Figure A.1: The System Usability Scale used in the evaluation of Prototype I, Prototype IV and ConferExplore at the JTEL Summer School.