

# PimVis: Exploring and Re-finding Documents in Cross-Media Information Spaces

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## ABSTRACT

Over the last decade, we have witnessed an emergence of Personal Information Management (PIM) solutions. Despite the fact that paper documents still form a significant part of our daily working activities, existing PIM systems usually support the organisation and re-finding of digital documents only. While physical document tracking solutions such as RFID- or computer vision-based systems are recently gaining some attention, they usually focus on the paper document tracking and offer limited support for re-finding activities. We present PimVis, a solution for exploring and re-finding digital and paper documents in so-called cross-media information spaces. The PimVis user interface enables a unified organisation of digital and paper documents through the creation of bidirectional links between the digital and physical information space. The presented personal cross-media information management solution further supports the extension with alternative document tracking techniques as well as augmented reality solutions. A formative PimVis evaluation revealed the high potential of fully integrated cross-media PIM solutions.

## CCS Concepts

•**Human-centered computing** → **User interface management systems**; *Visualization toolkits*; Ubiquitous and mobile computing systems and tools;

## Keywords

Personal information management, document tracking, paper-digital interface, cross-media information spaces

## 1. INTRODUCTION

In order to complete certain tasks, most people interact with digital and physical documents on a daily basis. The activities of keeping/creating, organising and re-finding information are the main topics investigated in Personal Information Management (PIM) research. It is a well-known

fact that people face various issues when performing some of these PIM activities. For example, the organisation of paper documents in filing cabinets is a time-consuming task and we are often not willing to invest much time for the filing process [3]. In addition, studies have shown that in order to keep the general context of filed documents, people create complex and inconsistent labels for digital files and folders as well as for physical file folders [11]. As a result of these complex and inconsistent labels, the re-finding of documents gets more difficult. On the other hand, the use of piles leads to a more contextual organisation and requires less organising effort. Nevertheless, due to the fact that piles are not labelled, they generally do not scale well for archiving purposes [25]. PIM activities are complex by nature and each individual is different in their behaviour [25, 21], making it challenging to develop tools to support users in their personal information management. Over the last decade, we are facing new PIM challenges due to information fragmentation over different applications and devices. Last but not least, people are not exclusively working in digital or physical space but rather across the boundary between the digital and physical space. A PIM solution should therefore support these so-called cross-media environments [21].

In order to overcome some of these PIM issues, we have seen various research on tools to support users in managing their personal digital information. These PIM tools range from improved search techniques based on augmented file systems indicating where a digital document has been stored [6] to exploratory user interfaces such as iMapping [7]. Nevertheless, as a matter of fact, we still use a significant amount of paper documents in our daily work [19]. In order to integrate paper documents as well as other physical artefacts with digital information and services, the concept of augmented desks has been introduced in the 1990s. The DigitalDesk [24] and its successors (e.g. DocuDesk [5]) enable an integrated interaction with digital and physical content. Another approach is to digitally augment physical storage artefacts such as filing cabinets or bookcases. By tracking individual documents, systems such as SOPHYA [9] provide hints where a specific physical document has been stored and thereby improve the re-finding of paper documents. For example, an LED attached to a file folder in a filing cabinet might light up when the folder contains the searched document. However, these cross-media applications often focus on the tracking of a paper document's location only. When users work with multiple cross-media applications, they have to use the application which is used for tracking a specific document in order to re-find the doc-

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ument and tracking information is normally not available across different applications.

We present PimVis, an application for exploring and re-finding personal digital *and* physical documents in cross-media settings. We contribute to existing solutions by enabling users to have a unified organisation of their digital and physical documents. Furthermore, PimVis serves as a unifying platform for existing PIM applications for digital documents and cross-media applications. PimVis consists of a graphical user interface and a web server for document management and the interaction with third-party applications. We first elaborate on related work in the domains of PIM as well as digital-physical interaction and introduce our personal cross-media information management solution called PimVis. We then discuss the results of a formative PimVis evaluation and provide some concluding remarks.

## 2. BACKGROUND

Over the last few decades, various PIM solutions for managing digital information have been developed. In order to improve the re-finding of personal digital documents, applications can, for instance, augment the hierarchical folder view of a file system with some extra functionality. TagFS [1] enables a user to simply tag documents in order to form groups. These groups can later be explored during re-finding activities. Another example is the augmentation of the file system explorer application with recommender functionality as done by Fitchett et al. [6]. When a user starts to type the name of a document label, the application highlights the folders which most likely contain the requested document. Similarly, the desktop interface can be used to provide better support for the organisation and re-finding of documents. Presto [4] redesigned the desktop interface and allows users to create groups of documents which can be seen as digital piles. Besides augmenting existing file system explorers and desktops, some PIM solutions investigate alternatives to the hierarchical file system structure. iMapping [7] provides a treemap-like visualisation on top of a semantic file system which uses the Resource Description Framework (RDF) to encode relationships between documents. The leaves of the tree might contain concepts as well as documents. In addition, users can create links between concepts and documents across tree leaves. The work of Katifori et al. [12] takes a task-centered PIM system approach and applies the spreading activation theory to OntoPim in order to recommend closely related documents for a given task. The spreading activation theory abstracts how users organise information in their memory. Moreover, information gets linked when used in the same context. These links have a weight which is increased each time the association is used. Finally, ZOIL [10] takes an Object-Oriented User Interface (OOUI) design approach where user interfaces are just “views” on top of data objects such as documents, document fragments and emails. The advantage of this approach in an office workspace is that the user interaction with the information space becomes more intuitive. Users often see documents as first-class objects. Nevertheless, ZOIL only provides support for the design of so-called ZOIL user interfaces which are based on six design principles including zoomable user interfaces and other visualisation techniques to interact with a central data repository.

Besides PIM solutions for digital information, the combination of physical and digital media in so-called hybrid

surfaces has been investigated in various research projects. Hybrid surfaces have been extensively studied starting with the DigitalDesk [24] where overhead projection was used to digitally augment paper documents. In DocuDesk [5], tabletop user interfaces have been designed for linking digital and physical content whereas occlusion issues between digital and physical media have been investigated in Objectop [13]. Note that these solutions normally focus on supporting the task at hand and less on organising and re-finding activities.

In the context of PIM activities, a number of existing solutions digitally augment the physical space in order to help users in organising and re-finding their personal documents. By tracking physical documents, digital and physical user interfaces have been developed to indicate where documents are located and to provide additional metadata. Lawrie and Rus [17] designed one of the first augmented filing cabinets where users can digitally search through the physical filing cabinet. In order to provide re-finding functionality for document piles on a desk, Kim et al. [14] developed the digital pile browser where users can digitally navigate through physical piles. Since users might use various storage artefacts such as boxes, DrawerFinder [15] focusses on tracking physical documents and objects in storage boxes located in closets. By tagging the storage boxes with two-dimensional tags and monitoring a user’s interactions with the closet, digital search functionality can be provided for the physical space. Recently, SOPHYA [9] has been introduced for tracking documents across physical folders. While the folders are augmented with an electronic circuit, the bookshelves contain some conductive paths. Users can add documents to augmented folders and place the folder on one of the conductive paths. SOPHYA keeps track about which folder has been placed where in the augmented office environment. In order to re-find documents, SOPHYA augments the physical space with displays and LEDs. Furthermore, the same research team presented Metis [8] which adapted the electronic circuit and conductive path technology used in SOPHYA to support the tracking of other physical artefacts such as books. Metis also enables third-party applications to query the metadata of tracked physical artefacts. SOPHYA as well as Metis focus on the tracking technology and show some limitations in terms of usability since users have to add electronic circuits to every artefact that should be tracked.

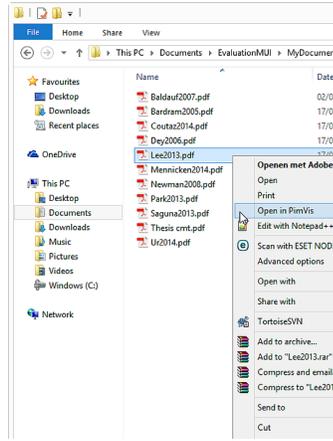
We can conclude that there is a broad range of related work focussing on advanced PIM solutions with no or limited support of physical documents. On the other hand, physical document tracking solutions offer limited support for organising and re-finding personal physical documents. There is clearly a need for cross-media solutions that go beyond document tracking and offer a combination of PIM solutions with physical document tracking and augmentation.

## 3. PIMVIS

Our PimVis solution consists of a graphical user interface for interacting with digital tools as well as the physical environment in order to explore and re-find digital *and* physical documents in cross-media information spaces. The PimVis backend consists of an Event-based User Interface Mechanism (EUIM) to enable interactions with third-party applications such as augmented user interface applications (e.g. for lighting up LEDs) and a document management component. We use the Object-Concept-Context (OC2) PIM framework [22] for storing a user’s personal digital and



(a) General PimVis setup



(b) Extended file explorer



(c) Ring binders with LEDs

Figure 1: PimVis user interface components

physical documents. The PimVis setup that has been used in the context of this paper is shown in Figure 1. The setup consists of the PimVis graphical user interface deployed on a tabletop as illustrated in Figure 1a in order that users can interact with PimVis via physical documents. Furthermore, we illustrate the interaction with digital tools via a Windows File Explorer context menu extension illustrated in Figure 1b and, as shown in Figure 1c, we have augmented ring binders with an LED for interacting with the physical information space. Note that various digital or augmented reality third-party applications can be integrated based on the PimVis EUIM component described later. We first introduce the graphical PimVis user interface followed by implementation details about PimVis and its related components.

### 3.1 Graphical User Interface

The graphical PimVis user interface provides three different views of a user’s personal digital and physical documents. The design of the graphical user interface is based on Shneiderman’s Visual Information-Seeking Mantra of “*Overview first, zoom and filter, then details-on-demand*” [20]. First, the Context View provides an overview of a user’s personal documents in the form of a bubble layout with each bubble representing a context as shown in Figure 2. When zooming into a context, PimVis switches to the Document View where documents relevant to the selected context (filter) are visualised in a graph structure as illustrated in Figure 3. When selecting a specific document in the Document View, PimVis switches to the Focus View shown in Figure 4, in order to provide details-on-demand. In the following we describe each of the three PimVis views in more detail.

#### 3.1.1 Context View

The Context View visualises the documents in their context since descriptive PIM research has shown that users use context as the main cue during re-finding activities [21]. A PimVis context can be a task or subject defined by the end user. For example, a user might define ‘Meetings with student Bob’ as a context.

In the Context View, the different contexts are represented by circular nodes (bubbles). This design for displaying contexts has been inspired by the the CAAD system [18] where each bubble represents a context. Nevertheless, the

scalability of the CAAD approach is limited since the view might quickly get cluttered when a context is defined for each task. Therefore, we have introduced context hierarchies. Each context group can include multiple other context groups or individual contexts. For example, a user can define a context group ‘Meetings’ which includes the context groups ‘Department Meetings’ and “Student Meetings”. In their turn, these sub-context groups can include a context such as ‘Meetings with student Bob’. Users can navigate through the context groups by using semantic zooming. Furthermore, each top-level context group has been given a distinctive colour. We have chosen this colour encoding approach instead of showing the name of the context group since otherwise the view might get cluttered. The context and context group names are shown when a user selects a particular context or context group (i.e. details-on-demand). Finally, the size of the context bubble represents the amount of documents for a given context. When a user zooms into a context group and selects a context, the Document View of the zoomed-in context is shown.

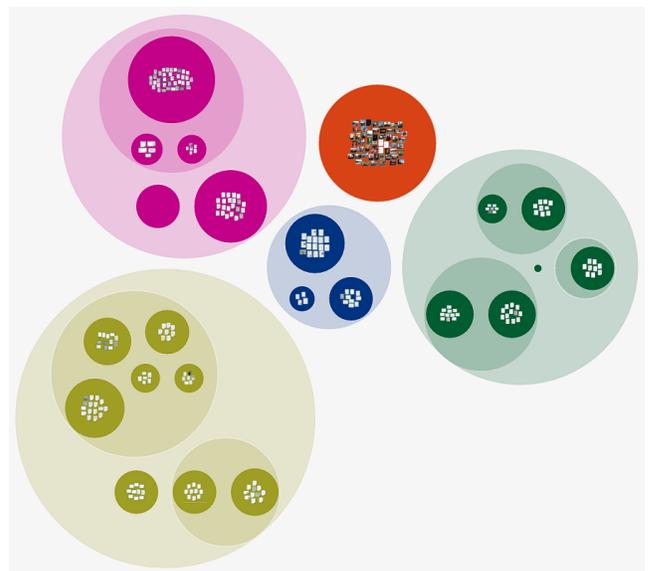


Figure 2: Context View

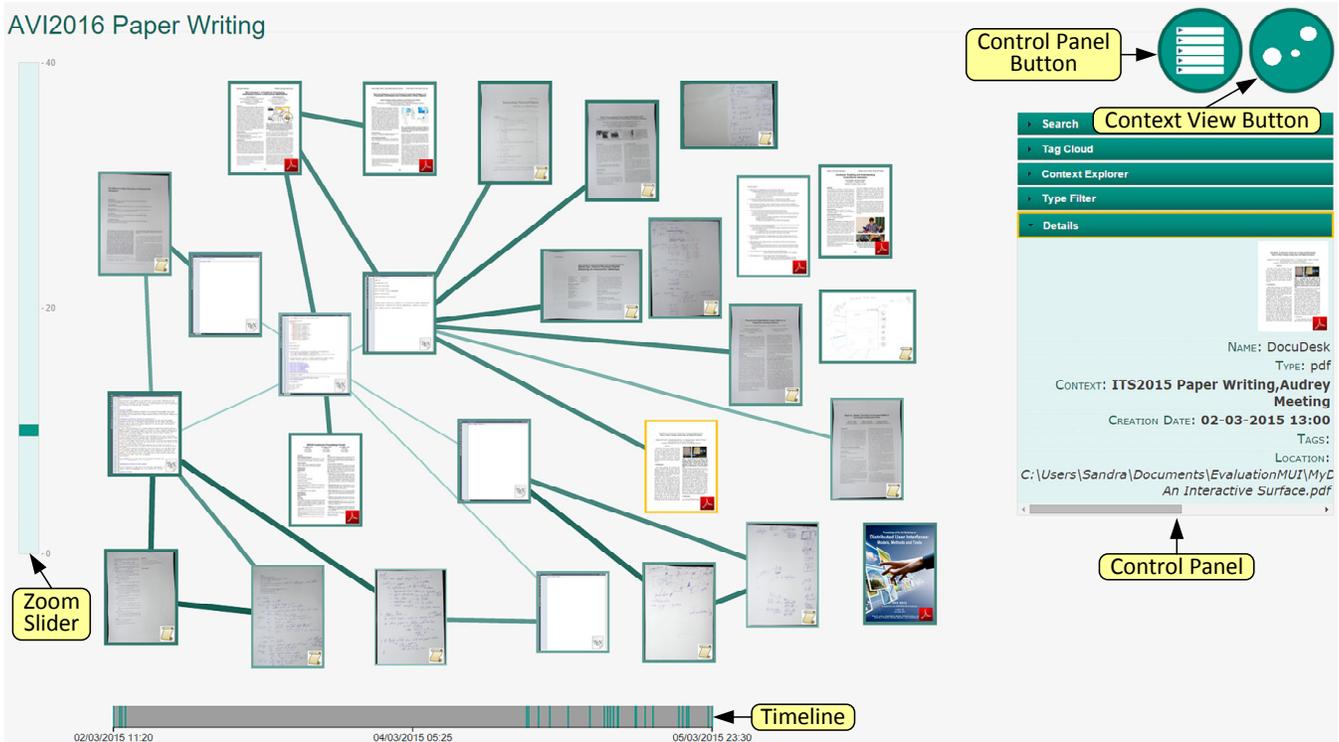


Figure 3: Document View

### 3.1.2 Document View

The design of the Document View is based on the fact that users naturally create associations between information items [12]. The Document View visualises the associations between documents within a certain context in a graph as shown in Figure 3. Each node of the graph represents a digital or physical document. The preview of the document and its format icon is used to graphically represent a specific node. The bidirectional associations between documents are represented by the edges of the graph. In our design, we allow users to allocate weights to documents and their associations. For example, a user might find a document or an association between documents highly relevant in a particular context. This relevancy is represented by the darkness and thickness of a node's border and edges between nodes.

Documents can be explored via different facets. The creation date of all documents is indicated on a timeline situated at the bottom of the graph. Users can select a time interval by sliding the handles. The graph automatically highlights the documents which have been created during the selected time interval. The control panel at the right-hand side of the graph can be hidden/shown via the control panel button and allows users to filter based on additional facets. The first tab of the control panel contains a search box with auto complete functionality for retrieving documents based on their name. In the case that a requested document is found, it is highlighted in the graph. The next control panel tab shows a tag cloud. By selecting a tag in the tag cloud, all documents in the graph containing the tag are highlighted. The following tab offers a context explorer. After selecting a context, PimVis highlights all documents in the graph with some relevancy for the selected context. The type filter tab can be used to filter the elements of the graph

based on different document formats such as PDF but also filter all physical documents. The different document formats are represented by thumbnails which are arranged in a grid layout in the type filter tab. The user can tap a thumbnail to highlight all corresponding documents. Finally, the details tab provides some details about the selected document, including its name, the creation data, assigned tags, relevant contexts and the location of the document.

The Document View can be zoomed by using the zoom slider on the left-hand side of the user interface or by using a double tap gesture on a specific document. Once the user zooms into a document, it is shown in the Focus View. In order to go back to the Context View, a user can always tap the Context View button.

### 3.1.3 Focus View

The Focus View shown in Figure 4 provides a detailed view of a document and shows all associated documents within and across contexts. In addition, the detail tab of the control panel is shown with the previously mentioned information. The Focus View also allows users to re-find a document in digital or physical space. When a user presses the re-find button represented by a magnifying glass, the corresponding application is notified. In the context of the presented PimVis configuration, specific re-finding application logic can be executed. When a digital document is shown in the Focus View and a user presses the re-finding button, the folder containing the selected document is shown in the Windows File Explorer. On the other hand, if the re-finding button is pressed when a physical document is selected in the Focus View, the LED of the ring binder containing the physical document lights up. Finally, users can go back to the Document View by tapping the rightmost button in the top right corner.



Figure 4: Focus View

### 3.2 Digital and Physical Interactions

We have implemented two examples of interactions between PimVis and the digital and physical environment. In order to re-find documents in the digital information space, we have integrated the Windows File Explorer. If a digital document is shown in the Focus View, users are directly forwarded to the folder containing the document in the Windows File Explorer after pressing the PimVis re-find button. In addition, users can go from the Windows File Explorer to the Focus View by selecting the ‘Show in PimVis’ entry in the Windows File Explorer context menu highlighted in Figure 1b. This context menu extension has been implemented as a registry entry which starts a small Java program to notify PimVis about the selected document. Our proof of concept application also contains interactions with the physical space. We augmented ring binders with an LED which lights up as shown in Figure 1c when a user selects the re-find button in the Focus View. In order to track which paper document is in which ring binder, we have developed a small tracking setup. Ring binders have been augmented with an RFID tag while documents are tagged with a fiducial marker. Furthermore, an RFID reader has been placed under the black desk cover at the left-hand side of the desk and a camera has been mounted above this area as shown in Figure 1a. When a user places a ring binder on the black desk cover, the tracking application identifies the ring binder and starts to monitor which documents are added to the particular ring binder. Documents are identified by using the reacTIVision framework which recognises the fiducial markers on the documents. In case the application detects a document in the monitored desk area but there is no ring binder present, the application will request PimVis to open the digital representation of the physical document in the Focus View. These examples illustrate that PimVis can be used to move from the digital to the physical as well from the physical to the digital information space.

### 3.3 Use Case

In order to illustrate the benefits of PimVis, a simple use case of writing a research paper is discussed. When Alice starts to write her AVI paper, she opens the Windows File Explorer, navigates to the AVI folder and opens the corresponding  $\LaTeX$  file. After writing a few sentences, she needs a paper she used during a meeting with her student Bob. She switches to the PimVis tabletop visualisation or opens PimVis in her web browser and navigates to the context of meetings with Bob via the Context View. She immediately recognises the paper and wants to copy it to an AVI subfolder containing related papers on the desktop machine. By simply clicking the re-find button, the digital version is shown in the Windows File Explorer. She can now use the context menu of the Windows File Explorer to copy the file to the corresponding AVI subfolder or to open it. Note that in case the two applications would not have been integrated, Alice would have to manually navigate to the corresponding folder.

Furthermore, she wants to see which documents are related to a paper that she plans to refer to and which is already stored in the AVI folder. She remembers that she had used that paper when writing a research proposal. Alice can easily select the paper in the Windows File Explorer and select the ‘Open in PimVis’ context menu entry to show the selected paper in the PimVis Focus View surrounded by all related documents. In case there would be no extra context menu in the Windows File Explorer, she would have to navigate from the Context View to the context of writing the research proposal, select the corresponding document in the Document View and proceed to the Focus View.

When writing the implementation section a few days later, Alice needs her notes about the system architecture and some other details. These notes are stored in a ring binder labelled ‘Research Projects’. She navigates the PimVis Con-

text View and opens the digital representation of the note in the Focus View. After clicking the re-find button, the LED of the ring binder containing the note lights up. In case the ring binder application would not be integrated with PimVis, Alice would have to use the ring binder application which just provides a list of images or she would have to remember the ring binder's label provided by PimVis, go to the bookcase and search for the ring binder with the corresponding label.

### 3.4 Implementation

The PimVis graphical user interface is implemented in JavaScript in combination with the D3.js<sup>1</sup> library and can therefore be used on different devices while the backend is written in Java using a GlassFish<sup>2</sup> server. Applications can communicate with PimVis via a RESTfull interface or establish a WebSocket connection. The web server implements an Event-based User Interface Mechanism (EUIM) in order to allow various digital tools and third-party augmented reality applications to interact with PimVis. Furthermore, the OC2 PIM framework [22] allows applications to link digital and physical documents and to store document properties in terms of key/value pairs. Further, documents and their associations with other documents can be relevant in multiple contexts. This relevancy can be expressed by defining a context-specific weight (between 0 and 1) for a link or a document.

In order to not hardcode the interactions with third-party applications, we have developed the EUIM component. The EUIM component is implemented based on the publish-subscribe software design pattern guaranteeing a loose coupling of participating third-party applications. Applications can define their own channel on which they will publish specific data or they can publish to existing channels. At configuration time, developers specify these channels and define the JSON format of the transmitted data. Applications can also subscribe to different channels. For example, when the re-find button is selected in the graphical PimVis user interface, PimVis publishes an event on the `showInSpace` channel with the document's `objectId` and a state (e.g. `isSelected`). Any application subscribed to this channel can then use the `objectId` to send a request to the web server via the RESTfull interface. In that way we can, for example, receive extra information about a document such as its linked documents. The web server queries the OC2 PIM framework for the requested information. In the given use case, the LED application is listening to the `showInSpace` channel. When PimVis publishes the above-mentioned data after the re-find button has been selected, the LED application accesses the PimVis web server to determine which LED has been assigned to the ring binder containing the document. On the other hand, when the 'Show in PimVis' context menu entry is selected in the Windows File Explorer, the application publishes the document's `objectId` on the `ShowPimVis` channel. PimVis is subscribed to this channel and visualises the corresponding document in the Focus View.

The EUIM component enables dynamic PimVis configurations which is desired in a real office environment since users vary in their used storage artefacts such as filing cabinets or ring binders and often also use different digital tools. For example, let us assume that Alice buys a new augmented

document filing cabinet. The re-finding functionality offered by PimVis should also be able to light up the LEDs of the new filing cabinet. If the functionality in PimVis would have been hardcoded, PimVis would have to be re-deployed to support the new filing cabinet. However, due to the EUIM component, the new filing cabinet application only has to subscribe to the `showInSpace` channel.

## 4. FORMATIVE USER STUDY

In the presented formative user study we evaluated the user experience and explored the benefits and pitfalls of our PimVis solution.

### 4.1 Methodology

The previously described PimVis setup was used during the formative user study. Note that PimVis is not limited to interact with the Windows File Explorer and the augmented ring binders, but this setup was sufficient to evaluate the user experience and opportunities for cross-media PIM applications. Furthermore, the evaluation of systems dealing with PIM data is not trivial since information has to be personal to the individual participant. Therefore, we followed the best practice by the community and populated the setup with a co-worker's personal information whereas the organisation of documents was based on Boardmann's guidelines [2]. Participants were given enough time to get familiar with the documents in PimVis, the populated file system as well as the physical documents in the four augmented ring binders.

The participants performed six tasks. Similar to the given use case, the individual tasks are small activities that one might perform while writing a research paper. Furthermore, the six tasks were split into two parts. In the first three tasks the user did not necessarily have to switch from PimVis to the connected file explorer or physical space, whereas the remaining three tasks always used the Windows File Explorer as a starting point. This design allowed us to investigate whether users naturally switch between the different PimVis components. An example of a task from the first part is "You want to read the paper 'Reality Editor'. This paper is related to the paper called 'Objectop' which you have used in your current context and is stored in the 'Papers' folder in the current directory.". An example for the second part is "Find the image with the 'LED in a ring binder' that you have taken while working on the Cool Office project. Which documents are related to this image? Open the image on your desktop computer."

During the tasks, participants were observed and after completion a semi-structured interview was conducted. In addition, participants filled in a questionnaire to evaluate the user experience. We have used the standardised user experience questionnaire of Laugwitz et al. [16] which evaluates the attractiveness, stimulation, perspicuity, dependability, novelty and efficiency. Each factor's value represents the mean of four to six questions. Each question was rated on a 7-point Likert scale between opposites such as 'annoying' and 'enjoyable'.

Our eight study participants were pre-doctoral university students with an age between 20 and 31. All participants had experience in the writing of research papers or Master's theses. We opted for this specific population due to the fact that these participants would be familiar with the given use case.

<sup>1</sup><http://d3js.org>

<sup>2</sup><https://glassfish.java.net>

## 4.2 Results

We first report on the user experience results followed by the identified benefits and pitfalls for the design of combined cross-media PIM applications.

### 4.2.1 User Experience Analysis and Results

Before the construction of the six user experience factors, a reliability analysis was performed. By removing on average one question for each factor, all factors have a Cronbach Alpha above 0.7. Nevertheless, we could not reach this analysis requirement for the novelty factor which therefore was not further used in the evaluation. The resulting mean values together with the standard deviation are shown in Figure 5. Note that since all mean values are above the neutral value of 4 on the 7-point Likert with opposite statements, we rescaled the resulting mean values to a scale from 0 to 3 with 0 representing the neutral value.

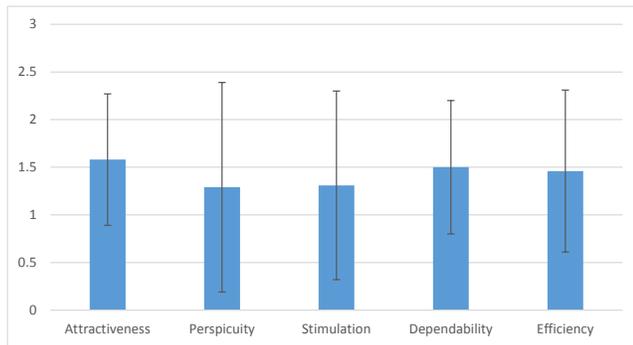


Figure 5: The means for each analysed factor (0 is the neutral value). The error bars show the standard deviation.

The results show a positive evaluation of all five user experience factors. The participants found PimVis attractive to work with and they all agreed that it would make organisation and re-finding activities more efficient. Nevertheless, we can also identify that the standard deviation of the perspicuity factor is quite large. From our observations we could see that users were sometimes confused when doing some tasks which included interactions with the context menu in the Windows File Explorer. While users understood the different interaction possibilities between the physical environment and PimVis, they often forgot about the interactions with the Windows File Explorer.

### 4.2.2 Benefits and Pitfalls

From our user study, we could derive some benefits and pitfalls in the design of cross-media PIM applications.

#### *The starting point is mostly the current application*

Participants commonly started to solve the tasks in the component (i.e. PimVis visualisation or Windows File Explorer) they were busy with from the previous task, even if that was often not the fastest way to solve a task. For example, if the previous task finished with some interaction using the Windows File Explorer, they would first search for a document in the Windows File Explorer when starting the next task. Only after spending on average 25 seconds without a result, participants decided to switch to the PimVis visualisation in order to explore the content via contexts. The same phenomena was observed the other way around. For some tasks where it would have been possible to, for example, just nav-

igate to the picture folder in the File Explorer, participants first navigated through the PimVis context hierarchies.

#### *Differences in hot and cold documents*

Most participants were very pleased with the small ubiquitous user interfaces such as the Windows File Explorer extension or the ring binder augmentations with LEDs and the way they are integrated. Furthermore, they came up with interesting use cases how they might use these types of ubiquitous user interfaces in their own workplaces. Often users indicated that it would be nice to have small Windows File Explorer extensions for so-called hot documents. These are documents which are used in short term tasks. For example, related documents could be shown in a side panel of the file system when selecting a document instead of opening it in the PimVis visualisation. In contrast, for archived documents a more supportive application such as PimVis is desired. For physical augmentations this might mean that pointing to a specific ring binder is not sufficient but also the exact location within the ring binder should be indicated. Designers should take into account for which kind of documents they design ubiquitous user interfaces.

#### *Self-development and configuration*

Going beyond the presented PimVis setup, users came up with real-life use cases. They were often willing to spend time to augment their artefacts such as books. A customisable augmented environment where users can augment arbitrary artefacts would therefore be ideal for most participants. Furthermore, they would also like to be able to control the triggered actions. Nevertheless, the level of control is very user dependent. Users indicated that if there would be a possibility to configure which user interface has to do what action, this might depend on the task they are doing. For example, for some tasks the PimVis re-find button would open the Windows File Explorer folder and highlight the document while in another task the user would like that the document is immediately opened.

## 5. DISCUSSION AND FUTURE WORK

While most existing PIM solutions only support the organisation and re-finding of digital information, there is a need for the integration of physical documents. On the other hand, physical document tracking systems normally provide limited features for organising and re-finding the documents they are tracking. This results in isolated applications where users have to switch between tracking applications in order to re-find physical documents. With our PimVis solution which can be integrated with third-party applications such as document tracking systems, users get a single application for re-finding activities in cross-media information spaces. Currently, the graphical PimVis user interface mainly consists of exploratory features. Based on feedback from our user study, we are currently extending the Context, Document and Focus Views with additional features for managing the links between documents, allowing users to add their own document properties such as annotations and enable them to allocate a subgraph of specific context to other contexts. Furthermore, we are currently integrating PimVis with the DocTr [23] physical document tracking framework which will automatically update PimVis when physical documents are created or removed and offer automatic document tagging. Note that we plan to extend the DocTr framework to also monitor user interactions with

digital documents. Finally, we plan an in-situ evaluation to evaluate the scalability and feasibility of PimVis in real office settings and to investigate concrete design guidelines for PIM applications in cross-media information spaces.

## 6. CONCLUSIONS

We have presented PimVis, a solution for the organisation of digital and physical documents. PimVis offers some re-finding features for cross-media information spaces and enables users to explore their personal documents through context hierarchies as well as associations between documents. Furthermore, PimVis supports the integration of third-party applications such as the Windows File Explorer or augmented reality solutions in order to have a unified interface for cross-media information management. The results of our formative user study are promising and outline some opportunities for future cross-media PIM applications.

## 7. ACKNOWLEDGMENTS

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