

Crossing Spaces: Towards Cross-Media Personal Information Management User Interfaces

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ABSTRACT

Nowadays, digital and paper documents are used simultaneously during daily tasks. While significant research has been carried out to support the re-finding of digital documents, less effort has been made to provide similar functionality for paper documents. In this paper, we present a solution that enables the design of cross-media Personal Information Management (PIM) user interfaces helping users in re-finding documents across digital and physical information spaces. We propose three main design requirements for the presented cross-media PIM user interfaces. Further, we illustrate how these design requirements have been applied in the development of three proof-of-concept applications and describe a software framework supporting the design of these interfaces. Finally, we discuss opportunities for future improvements of the presented cross-media PIM user interfaces.

CCS CONCEPTS

• **Human-centered computing** → **Pointing**; **User centered design**;

KEYWORDS

Cross-media PIM; paper-digital interaction; prosthetic memory

ACM Reference Format:

Sandra Trullemans, Payam Ebrahimi and Beat Signer. 2018. Crossing Spaces: Towards Cross-Media Personal Information Management User Interfaces. In *AVI '18: 2018 International Conference on Advanced Visual Interfaces, AVI '18, May 29-June 1, 2018, Castiglione della Pescaia, Italy*. ACM, New York, NY, USA, 5 pages. <https://doi.org/10.1145/3206505.3206528>

1 INTRODUCTION

People are overwhelmed with information and experiences over their entire lifetime. Memorising all that information is a burden since our organic memory (OM) is highly fallible over time. In the field of Personal Information Management (PIM), advanced solutions are designed for helping users in organising their information space and for making re-finding activities easier. We can observe

the design of a wide variety of applications aiming to help users to manage digital documents. For example, tools such as Presto [5] and Haystack [1] allow users to organise information by defining associations, while MyLifeBits [10] and Laevo [13] offer a temporal view over activities and digital documents. However, users are not easily adopting these solutions since the benefits are often not big enough to justify a change of their current organisational behaviour. Therefore, we see various augmentations of digital file explorers where, rather than shown in a search result list, the search results are visualised in the folder hierarchy by highlighting folders containing the documents which form part of the search result [9]. While these approaches are promising, digital and paper documents are frequently used together in certain tasks [21, 22, 24, 28]. Recently, the design of solutions that support the tracking of paper documents based on image recognition techniques is gaining interest. These applications often track the position of paper documents as well as their organisational units (e.g. piles and filing cabinets) and represent them digitally to the user in order that they can virtually browse the tracked organisational units [19, 20]. Nevertheless, users have to digitally search for the digital representation of the paper document and subsequently need to switch to the physical space to get the corresponding paper document. This transition between information spaces requires some additional effort. Ideally, paper and digital documents should be unified and be available in both information spaces. Prosthetic memories could then be designed in a way that users can choose in which space they want to search for a document.

In this paper, we propose the design of cross-media PIM user interfaces as a way of providing support to end users during the re-finding of digital and paper documents across the digital and physical information space. We start by discussing related work and then present a number of design requirements for cross-media PIM user interfaces. We then illustrate how these user interfaces can be designed in office environments and introduce our software framework enabling the design of cross-media PIM user interfaces. Finally, we discuss some potential future work.

2 BACKGROUND

Since the presented work informs the design of prosthetic memory (PM) for re-finding in both, the digital and physical, information space, we present a summary of related solutions helping users in re-finding digital or paper documents.

Due to the wide range of PIM tools, we focus on the most relevant solutions. A first approach is taken by researchers who enabled users to create associations between information items, including the Semantic File System [11] and Presto [5]. After the introduction

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AVI '18, May 29-June 1, 2018, Castiglione della Pescaia, Italy

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ACM ISBN 978-1-4503-5616-9/18/05...\$15.00

<https://doi.org/10.1145/3206505.3206528>

of the Resource Description Framework (RDF), we could witness a major effort in the design of RDF-based PIM solutions [1, 17, 23]. Another approach is taken by so-called lifelogging applications such as Lifestreams [8] and MyLifeBits [10] where every document interaction is recorded and offered to the user in the form of a temporal stream. A disadvantage of the presented approaches is that users have to change their current organisational behaviour. Therefore, significant efforts have been made to augment the tools currently used for organising digital documents. Often, the File Explorer is augmented with additional search functionality. For example, TagFS [2] allows users to construct tags in the File Explorer and enables them to categorise documents with these tags. Another approach is the use of the File Explorer for offering users task-related digital documents. In Laevo [13] documents related to a user's current task are grouped in a folder situated under the Windows library folders. In contrast, TaskTracer [6] shows the user's tasks in the Windows Start Menu and when a user selects a task, related documents are shown in a context menu.

While significant work has been carried out to help users in organising and re-finding digital documents, some effort has also been made to provide users the search functionality for paper documents. A first approach is to augment paper documents on an interactive surface where users can link digital media to a paper document as seen in DocuDesk [7] and ObjectTop [18]. Second, the position of paper documents in a filing cabinet or pile can be tracked and users can digitally search for the tracked paper documents [19, 20]. While these systems focus on the tracking of paper documents in a specific structure or setting, paper documents usually flow between organisational structures. Therefore, systems such as the Human-Centered Workplace [4] and PaperSpace [26] have been developed. They track paper documents within an office space by tagging them with Quick Response (QR) tags which are then monitored by multiple cameras. As a result, users can digitally browse their office space. A disadvantage of both solutions is the fact that they do not model and track the individual organisational structures. This issue has been addressed by the SOPHYA [12] framework where the position of physical folders containing the paper documents is also tracked by augmenting the folders and bookshelves with electronic circuits. In contrast to other related work, SOPHYA [12] and PimVis [27] augment the physical environment with the current position of the paper document which is searched digitally. We can observe that most PIM applications for paper documents mainly focus on the tracking functionality and often only foresee basic search interactions such as browsing digital representations of tracked paper documents in the digital space. While SOPHYA and PimVis address the fact that augmenting the physical environment with re-finding functionality can be of some additional value, the augmentations are still limited to the indication of the position of required folders. While applications have been designed for either digital or paper documents, we should provide users a unified view of their documents across the digital and physical space.

3 CROSS-MEDIA PIM USER INTERFACES

In order to advance the field of PIM solutions crossing the digital and physical space, we propose the design of cross-media PIM

user interfaces. The design of the user interfaces of our proposed solution is based on three main design requirements:

REQUIREMENT 1. *Enable a seamless transition between the digital and physical information space.* Due to the nature of digital and paper documents, they are stored and organised in their appropriate information space. This fragmentation introduces an extra cognitive load when re-finding documents since, similar to the use of multiple tools such as email or cloud services, users construct different organisational structures with varying folder schemas across platforms [3]. By unifying digital and paper documents, and enabling cross-media interactions at the level of information spaces, we can decrease the cognitive load and users can seamlessly move between the digital and physical space [25].

REQUIREMENT 2. *Support for the three re-finding cues of the organic memory.* Previous work argues to place emphasis on designing technology which works in unison with the human organic memory instead of building systems which aim to replace our powerful intellect [16]. Existing PIM studies further revealed that users re-find documents by remembering contextual, temporal and spatial metadata of the searched document [14, 15, 24, 28]. For example, users squeeze additional contextual information into the label of a document or folder in order to ease future re-finding. While users extensively apply the three re-finding cues, the constructed physical organisational structures as well as the digital tools do not provide enough support to trigger the used cues [28].

REQUIREMENT 3. *Augment the tools which users currently use to organise digital and paper documents.* While we have seen the raise of PIM solutions augmenting the File Explorer or MacOS Finder, similar augmentations of the physical space are rare and often show some limitation.

4 THE AUGMENTED OFFICE

We first illustrate the advantages of the proposed cross-media PIM user interfaces by presenting three proof-of-concept applications that we have developed. We then elaborate on our framework enabling the design of these user interfaces.

4.1 Augmenting the Digital and Physical Space

Three proof-of-concept cross-media PIM user interfaces have been implemented. We first present the augmented filing cabinet shown in Figure 1a, followed by the Android application shown in Figure 1b. Finally, the File Explorer extension presented in Figure 1c is discussed. All three applications integrate support for the three re-finding cues by means of different interface components. The contextual related metadata of documents or folders is foreseen by the green component, the yellow component includes functionality to browse temporal metadata and the blue component integrates search functionality which triggers the spatial cue. The colour coding and functionality offered by these interface components is consistent across the three presented cross-media PIM user interfaces. The use of components for each re-finding cue enables us to compare the usefulness of each re-finding cue as well as the synergy between them in a future user study.

4.1.1 Augmented Filing Cabinet. We have augmented a physical filing cabinet with a tangible user interface which enables users to

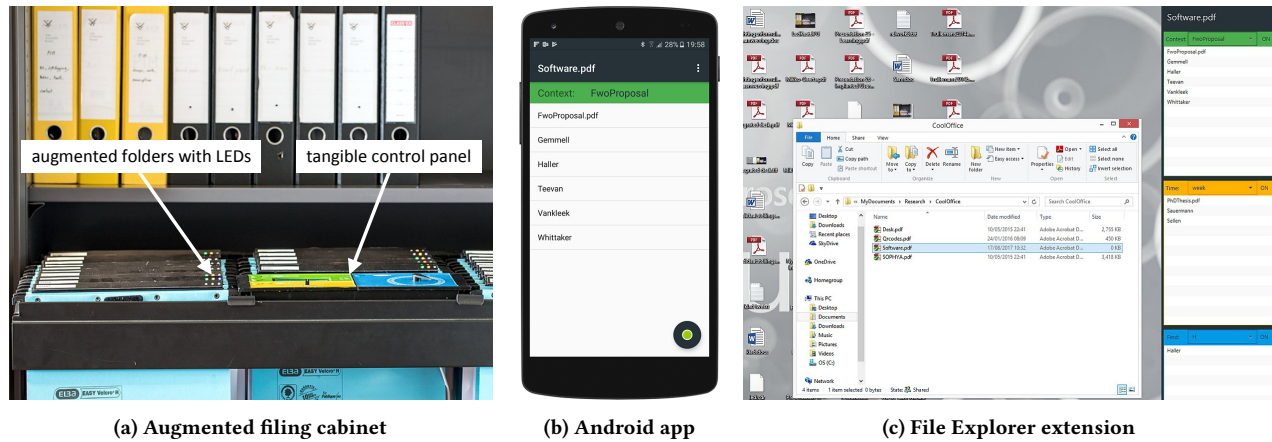


Figure 1: Different cross-media PIM user interfaces

explore the content of the filing cabinet by means of contextual, temporal and spatial metadata. The filing cabinet consists of 26 augmented folders organised in three columns consisting of ten, six and ten folders and a tangible control panel which is mounted in the centre column as shown in Figure 1a.

At the beginning of a search activity, users have to be able to indicate to the system about which physical folder they want to receive additional information. The filing cabinet foresees this interaction by registering a user's touch of the top of a folder. We augmented the top side of folders with an Interlink 24 inch 100N force sensing resistor (FSR) sensor¹. The FSR sensors are connected to Phidgets I/O boards². When touching a folder, the augmented filing cabinet application is notified and sends the newly selected folder's ID to the UIM component on the server. Furthermore, each folder has been augmented with a green, a yellow and a blue coloured LED. This LED interface provides users feedback about related folders.

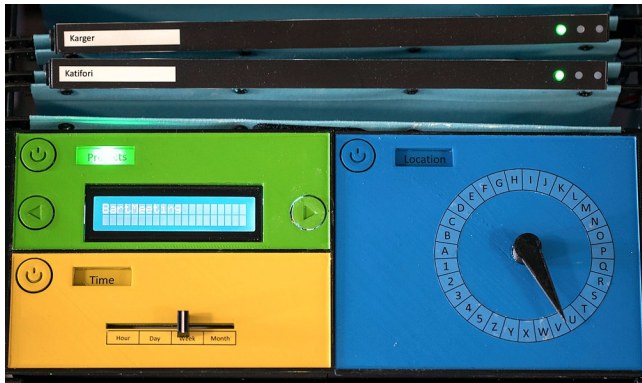


Figure 2: Tangible control panel with contextual, temporal and spatial re-finding user interface components

Once a user has selected a folder, the three components of the control panel shown in Figure 2 are updated with the relevant information. The related contexts where the selected folder has been

used are shown on the display of the green control panel component. Users can browse the related contexts by using the buttons with the left and right arrows. When a context is selected, the green LEDs of the folders which are also used within the particular context will be highlighted. Furthermore, users can explore temporal relationships by using the physical slider in the yellow interface component shown in Figure 2. By placing the slider on a specific time interval, the yellow LEDs of the related folders which are used in the same hour, day, week or month will light up. Finally, the spatial re-finding cue is supported by the blue interface component. Users can move the arrow to a specific letter and as a consequence the blue LED of the folders starting with the particular letter will be highlighted. We used Phidgets sensors and a Phidgets display to enable the tangible interactions with the control panel. Note that interactions with the filing cabinet, such as changing the values of components or selecting a physical folder, will invoke updates in the Android application and the File Explorer extension.

4.1.2 File Explorer Extension. Besides the augmentation of the physical environment, we have also augmented the File Explorer. The sidebar application shown in Figure 1c consists of three components similar to the ones of the augmented filing cabinet. When a user selects a digital document in the File Explorer or a physical folder in the augmented filing cabinet, the components are updated with the appropriate metadata of the selected artefact. Each of the three component consists of a combo box and a list of related digital documents and physical folders. For example, the combo box in the green component includes all related contexts. When a user selects a context, the digital documents and physical folders used in this context are shown in the list of the component. In a similar way, users can choose a time interval (same hour, day, week or month) in the yellow component and a letter in the blue component. If the user wants to re-find a digital document or physical folder given in one of the component lists, they can select the particular digital document or folder. In case that the selection is a digital document, the File Explorer is opened at the hierarchical level of the digital folder including the selected digital document. We choose for this feedback since it has been shown in related work that folder structures contain additional contextual information. However, if the

¹<https://www.adafruit.com/product/1071>

²<https://www.phidgets.com/?tier=3&catid=2&pcid=1&prodid=1035>

selected item is a physical folder then the three LEDs of the physical folder will be highlighted in the augmented filing cabinet.

4.1.3 Android Application. In order to enable a seamless transition from the augmented filing cabinet to the digital information space, we also designed an Android application consisting of a Swipe View layout where each view offers search functionality for one of the three re-finding cues. The design of the application is similar to the File Explorer extension. Moreover, each view has a spinner which contains the particular metadata of the supported re-finding cue and a list of digital documents as well as physical folder which are related to the selected digital document or physical folder. The context view of the Android application is shown in Figure 1b. Similar to the File Explorer extension, the selection of a digital document opens the File Explorer at the hierarchical level of the digital folder containing the selected document whereas the selection of a physical folder in the view's list will highlight the three LEDs of the corresponding folder in the filing cabinet.

4.2 System Architecture and Implementation

In order to enable the design of cross-media PIM user interfaces, we developed a software framework for the tracking and storage of contextual, temporal and spatial metadata of digital as well as paper documents and their organisational structures.

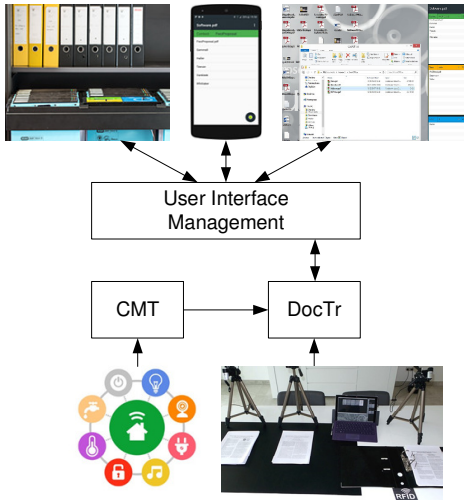


Figure 3: Cross-media PIM architecture

As shown in Figure 3, our framework uses the DocTr [31] framework and the Context Modelling Toolkit (CMT) [30]. The DocTr framework tracks the position of digital and paper documents as well as the access or move of documents and organisational structures. According to the DocTr data model, metadata about digital and paper documents is stored in the OC2 PIM [29] framework. In order to also store the contextual document information, we have extended the DocTr framework with CMT. CMT has been designed to enable end users to program complex context rules in the form of “*IF this THEN that*” statements. The framework also implements a context server which reasons over the defined rules to detect a user's current context. For the solution presented in this paper, we have integrated CMT with the DocTr framework in order to

query CMT for a user's current context when they interact with or move documents. When a user's context is received from CMT, it is stored in the OC2 PIM framework as contextual metadata of the particular digital or paper document. Note that it is up to the end user to define and model the contexts or tasks in CMT.

Besides the tracking and storage of document metadata and the corresponding organisational structures, the framework also consists of a user interface management (UIM) component. The UIM component ensures that all cross-media PIM user interfaces display a consistent search state. For example, if the user selects a physical folder in the filing cabinet and uses the contextual facet as search functionality, then the File Explorer extension should also display contextually related documents. In this way users can easily switch between cross-media user interfaces without search interruptions. In order to enable such consistency across user interfaces, we used the Model-View-Controller (MVC) design pattern in the UIM component. Furthermore, a user interface can notify the UIM component that a user selected a digital or paper document or an organisational structure. The UIM component will query the DocTr framework for the necessary metadata which is then sent to all other user interfaces. Next, a user interface can notify the UIM component that the value of a facet has been changed, for example if a user wants to change the time interval of related documents to be shown. Subsequently, the other user interfaces are notified by the UIM component to also update their particular component. Finally, user interfaces can request to find a particular digital or paper document. In this case, the UIM component queries the DocTr framework for the positional metadata which includes the knowledge of which user interface is responsible to show the document. Note that due to the separation of concerns, the object-driven approach and the simple interface to communicate with the UIM component, third-party applications such as SOPHYA [12], PimVis [27] and SDN [9] can easily be integrated.

5 FUTURE WORK AND CONCLUSION

In the future, we might see whether users increasingly rely on the provided aid and whether their organisational behaviour changes as a consequence of the used prosthetic memory. Further, the design of cross-media PIM user interfaces can be further explored by integrating support for the three re-finding cues in a more subtle way than presented in this paper. Alternatives to the three context, temporal and spatial components might be investigated and the use of mixed-reality solutions be further explored.

We proposed the design of cross-media PIM user interfaces to deal with the fragmentation of information across digital and physical documents. Cross-media PIM user interfaces help users in re-finding documents by providing a seamless transition between information spaces. They are in unison with the re-finding mechanisms of the organic memory and integrated into a user's currently used tools and organisational physical artefacts. We further presented three proof-of-concept applications and discussed the underlying software framework.

ACKNOWLEDGMENTS

The research of Sandra Trullemans is funded by the Agency for Innovation by Science and Technology in Flanders (IWT).

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