TABLETOP FILE SYSTEM AND PERSONAL INFORMATION MANAGEMENT IN PERVASIVE COMPUTING

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Abstract

A key problem for pervasive computing is due to the challenges of limited interaction available in the broad range of places people need to access and work with digital information. When there is no keyboard or mouse available, we cannot rely on conventional hierarchical or search interfaces to our files. This thesis tackles the problem in the particular case of collaborative tabletop interaction: the goal is to find powerful and natural mechanisms for people to work together at the tabletop, easily accessing the relevant files from their personal storage devices. Our approach focuses on using content-based associative file system access to facilitate information retrieval from the tabletop.

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Problem Statement and Research Question

File system and personal information management is a task typically performed with a conventional personal computer, by a single user. Moving away from the desktop paradigm and its primarily single-user interaction methods allows new possibilities for both sharing personal information, and collaborating on the management process. The interactive tabletop – a novel medium that has attracted significant research interest – supports collocated collaboration with a large, shared workspace where people can sit face-to-face and interact with it simultaneously. While users may not perceive a tabletop interface as a conventional personal computer, a form of file system is important: a file system, and its interface, constitutes a core facility of an operating system. Hierarchical organisation and navigation of file systems has become the standard in conventional personal computers, although the properties and constraints of tabletop interfaces (where there is typically no keyboard or mouse present) call for rethinking standard approaches to file system interaction. The social nature of the tabletop interface also encourages people to share their files with each other, meaning that files on the tabletop often need to come from multiple file systems, and these file systems may need to be interacted with concurrently by multiple people.

In this research, we are exploring ways to support collaboration with personal file systems at a tabletop, as an important affordance of tabletop interaction is collaboration. In order to support

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seamless use of tabletops, we need to support pervasive file and personal information access, where information and its meta-data are available from a variety of devices with little prior configuration by the user. Due to the differing interaction primitives of tabletop interfaces, and the key goal of supporting collaborative interaction, we must support natural retrieval of information from multiple collections of related (and possibly overlapping) information. For example, colleagues may meet at a tabletop to share and discuss similar files that they have been authoring on their own personal computers. A tabletop is one example of the kind of interfaces in a pervasive environment that need to support collaborative access to information stored on personal devices.

Upon completion of this research, the central research question that will be answered is:

Can an associative file system interface provide a natural and effective means for collaborative file and personal information access at an interactive tabletop?

The key goal of supporting *natural* file system access is based on the need to support interaction with file collections through the semantics of the information, and rich contextual information associated with it, rather than the constraints of the underlying storage mechanism. For example, we aim to support retrieval of files based on natural queries such as "find me all files and e-mails related to the grant application that I accessed with Joe at our last meeting in the boardroom", rather than "on my work laptop, find me files with this list of titles… at this storage location… and on my desktop computer, find me all e-mails from Joe." Rather than requiring users to access their information based on which computer it is stored, and where on the computer it is stored, we aim to support associative file access based on file content, and useful meta-data (such as the project the file is related to, where the file was recently accessed, and who it was accessed with) in order to address the constraints and properties of collaborative tabletop interaction. Furthermore, the information accessed from the tabletop will be stored on other devices, and this information (with its associated meta-data) needs to be easily accessible regardless of where it is stored.

While associative access has the potential to improve collaborative information retrieval, users may prefer to use hierarchical access when they need to access specific files based on storage location. Consequently, we also need to explore ways to effectively support this from a tabletop when there is no keyboard or mouse present in the environment.

There is also the issue of providing users with sufficient control over their personal information. Users need control over which devices can access their information, and the specific collection of files that can be retrieved. When supporting associative access, users need control over how files are associated with others. Given the context of use of tabletops, which may often be used in shared, open environments, we need to ensure that pervasive information access systems sufficiently meet the privacy needs of users.

In addition to answering the central research question, we will investigate the properties and benefits of collaborative tabletop file system interfaces that have been designed specifically for multi-user tabletop interaction, compared to existing conventional file system interfaces. We aim to gain insight into best design practices for tabletop file system interfaces, and develop a heuristic evaluation framework for future collocated tabletop interface designs to support personal information access.

Our investigation is based on the hypothesis that through the combination of pervasive file system access, and a tabletop file system interface designed to allow natural interaction with multiple personal file systems, we can effectively support people sharing and collaborating with personal

files (authored with remote devices) in a collocated setting at a tabletop. Users should be able to collaboratively access their personal files from multiple devices, with little prior configuration.

The interactive tabletop has attracted significant research interest, with researchers focussing their efforts on exploring novel interaction techniques, support for interacting with small collections of files, and limited work exploring interaction with larger digital photograph collections. Research on interaction with files at the tabletop has been limited. Previous systems (such as [4]) have required users to explicitly copy files to the tabletop for collaboration, resulting in private file system interaction away from the tabletop itself. This is the first research on collaborative tabletop file system access, and we will investigate different usage issues that are not present in conventional, single-user file system interfaces. Upon completion of this research, we will have a greater understanding of how to effectively support collaborative information access from a tabletop.

There has also been limited research on supporting pervasive file system access that enables users to easily interact with their information from multiple devices in a pervasive computing environment. In this research, we will determine and provide insight into ways to design the technical infrastructure required for such facilities. Furthermore, there is the challenge of designing pervasive computing interfaces with constrained display size and interaction primitives to support personal information access. One example of existing research into this problem is "spilling" [5], an interaction technique to overcome the limitations of small-sized personal storage devices by using a tabletop display for an expanded view of files. Similarly, this thesis investigates ways to support collaborative file system access from a tabletop (one type of pervasive computing interface) with constrained display size and interaction primitives.

The challenge of supporting collaborative file system access, where the required information is stored across multiple remote devices, is one that many pervasive systems will face – how do you support seamless access to users' personal information across multiple devices? Additionally, how do you support both associative and hierarchical information access from pervasive computing interfaces with restricted display and input, while giving the user sufficient control over the process? These issues must be addressed to allow natural collaboration with collections of personal files at a tabletop.

Approach and Methodology

This research involves the exploration of different techniques for interacting with file systems from a tabletop through prototyping novel approaches and their evaluation in qualitative and quantitative user studies. These user studies will range from small-scale usability studies, to extended trials where groups of people use a tabletop to collaborate on genuine tasks they need to complete. For each of the prototypes, our methodology involves key stages of theory formation, interface design, theoretical analysis (using tools such as heuristic evaluation), prototype implementation, followed by thorough user studies.

Our plan is to develop two collaborative file system interfaces, one based on existing practices of file system interaction design, and another based on the current trend of content-based file system search. Our *hierarchical* prototype will be designed to support concurrent interaction with multiple hierarchies, at a multi-user tabletop where there is no keyboard or mouse present. Our *associative* approach will be to support associative access to multiple collections of personal information, also at a multi-user tabletop. A key feature of these prototypes is that they will utilise a pervasive file

system architecture, where files and meta-data are available from multiple devices (such as laptop computers and tabletop displays).

We will conduct thorough evaluations of the two approaches, and compare these with existing legacy file system interfaces. In our analysis of experiment results, we will focus on the issues of collaboration and cognitive awareness between users, and how these are affected by the different collaborative file system interfaces. Our data collection methods will involve software logging, video and audio recording (for post-experiment analysis), questionnaires, and semi-structured interviews. As this is the first work on tabletop file system access, this research will require a series of user studies to fully understand how tabletop file system interfaces are used under real conditions.

In order to validate our claims and answer the research question, our system must effectively support real world use. We will have succeeded if we determine how to best design tabletop interfaces to support collaborative file system access in a pervasive computing environment. The results of our evaluations will be distilled to a set of design guidelines that need to be fulfilled to effectively support collaborative file system access from a tabletop.

The experimental and mostly qualitative approach chosen is appropriate because it will examine the prototype interfaces under realistic conditions, and determine which file system interaction approach is most effective for supporting people collaborating with their files. Qualitative evaluation may allow identification of subtle properties of interaction that could be overlooked from a purely theoretical perspective. In our approach, qualitative analysis is favoured over quantitative, as we want to examine affective aspects of the interaction design, and the quality of the resulting collaboration that occurs in realistic scenarios (instead of measuring only the efficiency in task completion). Qualitative evaluation also has a formative role in the development of our prototypes.

Related Work

Study of the key problem of accessing personal file systems from a tabletop has been limited. *UbiTable* [6] allows users to share information from their mobile devices (such as laptops). These devices connect to the tabletop, and users selectively share information with the tabletop. Each file system is kept completely private (except for files explicitly shared), and the similarities between related documents are not highlighted across the individual workspaces. Each user must have an understanding of exactly what information is available on the computer that might be relevant for collaboration. Furthermore, the system does not support interaction with larger collections of files without requiring users to copy or transfer the files to the tabletop first.

The *Personal Digital Historian (PDH)* [7] aims to help people construct, organise and navigate digital collections in a collaborative setting using a pen-based tabletop. PDH provides an interface to a large collection of historical information that is navigated based on several dimensions. While PDH was positively received in a qualitative evaluation with 14 participants completing tasks with 1250 documents, “clutter” and “over crowding” within groups of information were identified as problems in the system. The concept of ‘associations’ presented in PDH (where similar items are presented around the tabletop) has strongly influenced the design of our associative access techniques. However, PDH is designed for a single, shared historical collection of information, rather than multiple personal file systems.

Stuff I've Seen (SIS) [3] provides a unified index to all personal information that a user has seen on their computer. The SIS interface combines separate information-spaces (such as e-mail, files and calendars) without relying on a hierarchical organisation structure, instead using contextual cues (such as dates and people) to facilitate retrieval. The qualitative responses from a 6-week field study with 234 participants indicated that SIS was often useful when only vague details (such as a timeframe or rough topic) could be remembered about an item that needed to be retrieved, highlighting the importance of supporting *episodic* information retrieval through integrating information with relevant contextual information (such as calendar appointments). The unified index approach to files and personal information was also found to simplify information retrieval.

AnySpot [8] is a pervasive document access system, where users can access their file systems from a variety of devices (with a user interface designed specifically for each type of device). A web-services-based architecture supports hierarchical file system access from a variety of devices. This research explores an important issue to address in pervasive systems, though it only explores hierarchical access mechanisms, instead of mechanisms to facilitate collaborative information retrieval (such as by calculating similarities between the information collections being shared).

Preliminary Results

We have conducted an initial study comparing two prototype tabletop interfaces that we developed. The hardware for these interfaces consists of a normal white table, which is projected onto for a display surface. We use whiteboard capture technology, where each user is given a digital whiteboard pen to interact with the artefacts on the tabletop. To rapidly prototype each file system interface, we use the existing Cruiser tabletop platform (evaluated in previous user studies), which provides an interface with the hardware, and core facilities to interact with artefacts on the tabletop.

A hierarchical file system interface, called the *Browser,* supports concurrent interaction with multiple, remotely stored hierarchies, at a multi-user tabletop where there is no keyboard or mouse present. An associative file system interface, called *Focus* (shown in Figure 1) supports associative access to multiple collections of personal files, where users 'focus' on a file of interest to be presented with similar files (based on file content and any associated meta-data). Our study [1] showed that Focus (referred to as OnTop in the publication) provided valuable support for collaboration on the overall file access process – participants were more social and cooperative when using it than with the Browser, where participants were private with their file system interactions and selectively shared information with their partner once they had found it.

Focus was enhanced to support collaborative Personal Information Management (PIM). Personal information such as e-mail and web pages were combined with a file system in a single interface. A small-scale usability study was conducted [2] to determine the appropriateness of using a view of e-mail on the tabletop as a starting point for navigation to other types of personal information (such as files). The results highlighted important issues to address in future revisions to our prototype, such as additional techniques for clutter management, and facilities for strict control of privacy settings. Privacy is a key factor that will affect the uptake of tabletop interfaces that enable sharing of personal files and information – all participants stated that they would need complete control over which information is accessible at the tabletop, and that they are likely to only access a specific subset of their information in a collaborative setting.

All results have been calculated by thorough qualitative analysis, involving post-experiment video reviews where interesting features of interaction are coded for each participant. These analyses are

performed multiple times at varying levels of detail, and colleagues and supervisors review the results.

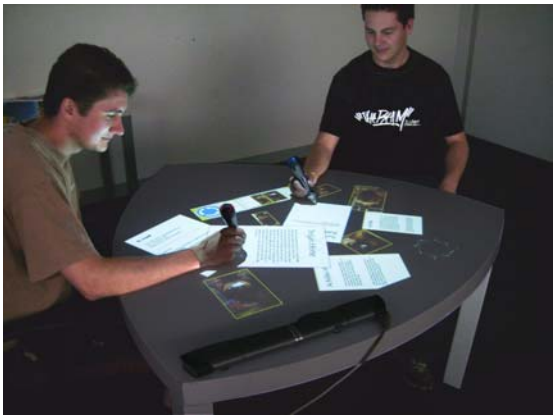

Figure 1. People using Focus to share and discuss their personal files at an interactive tabletop.

Conclusions and Future Steps

There is significant development still to be done with our prototype file system interfaces. Focus currently supports PDF documents and e-mail, though we are currently working on adding support for Microsoft Office documents, calendar appointments, address book contacts, and multimedia content. Including support for additional file types will allow more interesting ways to navigate personal file collections (through selecting 'focus' objects), and these issues will be examined in future evaluations. Participants suggested usability enhancements (such as improved clutter management) in our initial evaluation of the Browser, and these will also be incorporated into a future version. We will also explore new hierarchical file access prototypes to better exploit the interaction constraints of the tabletop.

A key area of development is the creation of a pervasive file system architecture that can provide access to files and meta-data across multiple personal devices, while ensuring sufficient user control over privacy. There is also the possibility of using existing context-aware systems developed in our research group to attach rich contextual meta-data about what the user was doing when they were accessing files, and who they were sharing them with at the tabletop.

The main area for future work is thorough evaluations. We are currently planning a detailed study comparing Focus with a conventional single-user file browser, in order to better understand the issues and dynamics of supporting collocated collaboration with file systems at a tabletop. After the planned revisions of the Browser and Focus are complete, we will conduct thorough studies of these interfaces where participants use their own files (stored on their own devices) to complete real tasks.

For prototype development, additional expertise in supporting fast, content-based, pervasive access to file collections would be valuable. In particular, we would benefit from working with people with expertise in semantic document similarity measures to improve the relevance calculation performed in the Focus system. We would also benefit from working with others with expertise in the capture of useful contextual information in a pervasive environment. In our evaluations, guidance and advice would be appreciated with experiment designs for evaluating collaborative information access using the pervasive file system access architecture.

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