Escaping hierarchies and desktops: Associative, pervasive file access with user control

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ABSTRACT

There has long been recognition of the limitations of hierarchical file systems, particularly when people need collections of files, email and web pages for a new task. An associative file access mechanism offers promise in addressing these limitations. Such a mechanism is particularly appealing for personal file access at pervasive interaction devices, such as tabletops, providing an excellent means for collaborating with personal files. A key challenge for providing such a mechanism is ensuring effective user control over the associative access, so that it both achieves the potential to escape the limitations of hierarchies and it ensures the user can understand and control it.

We describe a user-controlled associative file access interface, *Focus*, and in particular the design of its *Inspector* interface which operates on a smartphone, making it a gateway to the user's files. We report a qualitative study designed to assess whether participants could use the phone's Inspector and Focus on a tabletop to readily access file collections for tasks requiring crossing the hierarchical file structure. We also studied how well participants *understood* the results of the associative access mechanism and how well they could *control* it, altering the particular search for the new demands of different tasks. All 12 participants were able to use the system effectively for all three aspects: finding the files needed; understanding why particular files were retrieved; and controlling the associative access. The key contribution of this paper is a new associative file access mechanism that users can control. A secondary contribution is Focus and its Inspector which provide a new means for pervasive file access, making tabletops and other embedded display devices useful for group file access.

Author Keywords

File system access, associative search, user control, tabletop interface, single display groupware

INTRODUCTION

Hierarchical file systems have long been dominant in personal computing, despite widespread recognition of their limitations, leading to research that has explored alternatives (for example, [8, 12, 15]). Notably, an undesirable cognitive load is imposed on users when storing and retrieving their digital information, particularly when that information is difficult to categorise [11]. Furthermore, with the diverse applications that people use to author and manage their digital information, it is likely that the information required by a user will be distributed across several locations in their hierarchy, requiring manual cross-hierarchy retrieval. There is also no support to dynamically restructure the stored information depending on the task at hand, which is particularly important when dealing with information that users may need to make use of in terms of several dimensions. These problems will only get worse in the future with increased storage capacities and people owning more devices, with their information distributed across them.

Interactive tabletop surfaces have recently seen rapid growth in terms of hardware technology. There is a real need for corresponding progress in the foundational software for exploiting the potential of these new hardware products. Of particular importance is a mechanism that can enable people to walk up to and use interactive surfaces to access and work with their own collections of files in a collaborative setting. There is recognition of the importance of associative storage models for these new pervasive computing devices [1], which need to support collaborative work with multiple — and in most cases uniquely organised — personal file systems. This has prompted our research exploring associative file access mechanisms for collaborative tabletop interaction [3, 4].

Consider the following scenario, illustrating associative file access at a tabletop:

> *Alice meets Bob over coffee. She learns that they are both planning a trip to London. Alice uses her mobile phone to control the access to the documents she has collected so far, stored on her computer at home, including: e-mail from her travel agent; web pages and other documents about hotels and attractions. Using the phone she controls the release of these onto the interactive tabletop. Bob also uses his phone to control the release of his information to the tabletop. Alice and Bob review documents about the Tower of London. Bob asks about hotels nearby. The associative access interface automatically retrieves all attractions and hotels that are near Tower of London, from both of their file collections, based on the text content of the documents and location keywords attached to them.*
>
> *Later, Alice wants to compare the dates that she and Bob intend to arrive in London, so that they can arrange to meet. Alice retrieves an e-mail from her travel agent with flight arrival details. When retrieving this*

information, the associative access interface automatically retrieves the flight arrival information for Bob (stored in a PDF document), and presents this on the tabletop (after he has permitted the release of this collection of information).

She had organised her documents, with one directory for hotels, another for attractions, another for useful maps. Her email is in a single mailbox, "London Trip." This structure is helpful for many tasks. However, when Alice needs to access files that cross this structure, existing hierarchical filesystems do not work so well. She would need to traverse each relevant directory, as well as her email to get all the files she needs. This is tedious and error-prone. An associative access interface can automatically retrieve the required information regardless of its storage location, bringing in related information from different storage locations, even from Bob's file system when he choses to share it with her.

Associative file access has the potential to provide a powerful new means for supporting access to collections of files that cross the hierarchical boundaries of the file system. It has particular value in the context of *Single Display Groupware (SDG)*, because of the limited interaction available, without a conventional keyboard and mouse, making it desirable to have a single interface action that will retrieve a whole collection of the files needed for a task, across hierarchical file and application boundaries. Moreover, the typical context of such SDG, where the user may want to share their files with another person, creates changing contexts and the need for the user to do new tasks that call for accessing *different* groupings of their files stored on their own devices. Notably, associative access is far less familiar than a traditional hierarchical interface. In addition, we want the associative mechanism to be flexible and powerful in its operation, ensuring it achieves the potential power of being able to bring together different collections of documents. The cost of this power and flexibility is the risk that the user will be unable to control it, to understand *why* it returns the results it does and to alter this as needed. Indeed, in the existing interfaces that provide associative access, such as Google's *similar pages* search, which presents other web pages that are similar to one of interest, it does not explain to the user *why* they are similar. More importantly, the user is not given control over how this search mechanism works. While this might be acceptable for web search, people need *understanding* and *control* over the mechanisms that provide access to their own personal file system. As individual's file systems are all very different, in terms of both content and organisation structure, it is particularly important that users can control and tune such systems to meet their needs.

To achieve this control, our approach is to leverage carried personal devices that people can use as a companion while interacting with the tabletop. This essentially makes the personal device a form of gateway to the user's file-space. For adjusting personal settings related only to one user's files, it makes sense that this be done on a personal device. It causes minimal disruption to other users of the tabletop. This also makes it easy for the user to transition between different devices and workspaces, while still having the same handheld interface to control the associative access mechanism for their files. The user can also control their privacy, by reviewing and controlling what will be displayed at the tabletop.

This paper addresses the problem of helping people *understand*, *scrutinise*, and *control* personal settings for a new class of associative file system interface in a pervasive context. These critical issues must be addressed if a new file system interface is going to be adopted and used to its full potential. We present a novel system where people use handheld devices to individually understand and control the retrieval system, while still being able to work with others around the tabletop.

The remainder of this paper is organised as follows. We begin by providing a background of related work, followed by an overview of our approach. Then, we describe our study where users conducted a set of file access tasks. We conclude with a discussion of our findings on user-controlled associative file system access at tabletops.

RELATED WORK

Our work builds on three key areas of existing research: novel associative approaches to file system access; accessing file collections from interactive tabletops; and using personal carried devices as a means for controlling associative file interaction.

A wealth of research has explored novel desktop interfaces for file systems in an attempt to overcome the limitations of hierarchies for managing personal information. Quan et al. [15] explored the possibility of engineering existing file system interfaces to support multiple classification, thereby addressing a key weakness of hierarchical organisation. Their study showed multiple classification to have positive effects on people's efficiency for storing and retrieving information.

Other research has explored associative access as a replacement for hierarchies. The *Semantic File System* [8] and *Presto* [5] provide attribute-based file system interfaces, enabling powerful searching that hides the underlying hierarchical file organisation. Another approach has been to model file system access on relational databases [12], enabling flexible retrieval of information from different meta-data dimensions. *Haystack* [10] allows users to create arbitrary, meaningful relationships between stored information to aid retrieval. Karger et al. [10] discuss the concept of presenting "similar items" alongside user-selected items, like in the *Implicit Query (IQ)* prototype [6] where information relevant to the user's current context is presented in a peripheral interface. These systems provide a form of associative access, but they remain a "black box" to the user, with little focus on enabling users to understand and control the retrieval process. The search mechanism operates the same for all users, regardless of the organisation of their files and the task that they are currently trying to achieve.

We now consider work on accessing file collections from interactive tabletops. Tabletop file access has been explored from two perspectives: one concerned with moving information from between devices (e.g. a personal computer, tabletop and wall display); the other concerned with the navigation of file collections from a shared tabletop. *UbiTable* [17] had people sitting around a tabletop, each with their laptop computer used to privately locate files and move selected information to a shared region of the tabletop for collaboration. This is similar in nature to work on supporting visible transfers of information between devices, such as in *Augmented Surfaces* [16] and *MultiSpace* [7]. Hartmann et al.'s tangible drawers [9] allowed users to individually access files from a flat, unstructured collection and move selected files to the shared area of the tabletop. These interfaces require manual transfer of files, thereby limiting their appear for accessing broader collections of files stored on each user's personal storage devices.

Other approaches for browsing large collections of information at a tabletop have been explored, such as *TeamSearch* [13] and the *Personal Digital Historian* [18]. These took a faceted browsing approach to tabletop information retrieval, which provided additional flexibility to a hierarchical interface. Our previous work [3] presented an associative file access interface for tabletops that allowed multiple users to efficiently retrieve similar information from their file collections. While associative file access has the potential to overcome the limitations of hierarchies, a later study of this approach [4] — that compared their associative interface with the existing hierarchical Windows Explorer — highlighted the importance of helping users understand and control the unfamiliar associative retrieval.

We now consider work that looks at how people can use their personal carried devices (such as smartphone) in conjunction with shared devices for file interaction. Olsen et al. [14] created a new interface that integrated a user's carried device with the tabletop. Taking careful account of the security issues, users could interact with a single file by displaying parts of it on the table. Cheverst et al. [2] presented the *Hermes Photo Display*, a public display that allowed users to send and receive pictures with their carried mobile phone. People could contribute to and receive images from the public display, but not control the presentation of information on the display (which may be undesirable in a public setting).

USER-CONTROLLED ASSOCIATIVE ACCESS

Hierarchical file organisation has become dominant in modern personal computing, despite widespread recognition of its limitations, and it has a strong legacy. While associative storage and access models are desirable in future pervasive computing systems [1] — particularly tabletops and other embedded displays that must support multiple users — there are still challenges to overcome in helping users understand and control these systems to suit their file structures and the specific tasks they wish to achieve.

We build from an associative tabletop file access interface called *Focus* [4]. With a single interface action, Focus retrieves similar information from each user's file collection, regardless of how it is stored in the underlying file hierarchy. These on-the-fly associations are based on file meta-data, as well as any textual file content. A key challenge is that it requires flexible control for each user over which of their files are accessible from the tabletop, and how their information is calculated to be similar. While the associative access mechanism is designed to work well with default settings, there may be cases where a user needs to adjust it (while working at the tabletop), depending on the task at hand and the sets of files the user needs to access. Furthermore, if the user is going to employ the associative access at its full potential, it is important that they can understand *why* it returned the files that it did.

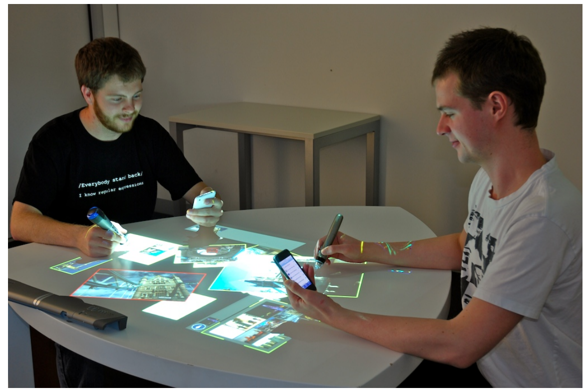

Figure 1. People using Focus in conjunction with their phones to collaboratively access their file systems.

We now explain the key components of our approach: an associative tabletop file system interface, called Focus, that multiple people can use to access and collaborate with their file systems; and Focus Inspector, a companion application for each user's carried personal device that is used to privately understand and control the associative retrieval system.

TABLETOP INTERFACE — FOCUS

Focus, shown in Figure 1, is an associative file system interface that retrieves all files related to the current *focus file*, across each computer of the users at the tabletop. To make their files accessible at the table, users run the *Focus Exporter* application on their personal computer: this allows them to make their whole file system, or specific parts of it, available for access at the table. For a more detailed description of the design and implementation of Focus' predecessor, see [3].

When Focus is first launched a broad *start view* shows the first file (alphabetically) in each exported directory of each remote file system on the tabletop. The files are presented either within a browsing 'widget', that can be easily reoriented, resized and moved to different parts of the table, or the results can be shown in a radial layout in the middle of the tabletop, to support people working at different orientations. From the start view, file navigation is based on the notion of a *focus file*. Once a user selects a focus file (by holding down on it), all other *similar* files (based on file content and other meta-data) across the file systems are loaded and displayed on the tabletop. The retrieved files are presented as a single file-space, regardless of which file system they are located in, or which application they belong to (for example, relevant e-mail is integrated with the file system). To find similar files, Focus co-ordinates searches on all users' exported file systems and applies *weights* to different meta-data attributes. These are the mechanism for users to customise how their files are determined to be similar to others. Our previous studies [3, 4] of Focus involved fixed settings of these weights so that other aspects of the approach could be explored. This paper describes the new interface for controlling them, the Focus Inspector.

PERSONAL INTERFACE — FOCUS INSPECTOR

Focus Inspector is a mobile application designed to be used in conjunction with the Focus tabletop. The Inspector allows a user to privately access their files. For example, a user may wish to check files first before sending them to the shared tabletop workspace. It also enables a user to scrutinise the associative retrieval system, to determine why it returned the results that it did. And, importantly, it provides the interface for controlling the associative access; it enables a user to adjust the weights applied to the meta-data attributes in the similarity calculation, allowing each user to customise the system for different tasks and different sets of files. The Apple *iPhone* was chosen as a platform due to ease of development, though other devices with a web browser are equally suitable. Future versions of Focus Inspector could be made to support a wider range of mobile platforms. We now describe the design of the functionality of Focus Inspector.

When Focus Inspector is first launched on the phone, it displays a list of computers[1] belonging to the user on the local network. The user can then touch one to connect to it. They are prompted for their username and password. Once connected, the user is able to access their files. Our foundational study [4] indicated that associative and hierarchical file access mechanisms have complementary roles for tabletop interaction. As hierarchical file access is generally personal, relying on a user's knowledge of their own hierarchical file structure, it makes sense that this be supported on the personal device. So, Focus Inspector was designed to support both access mechanisms.

Associative browsing allows a user to access their file collection based on content, without reliance on where information is stored in the underlying file hierarchy. Just like the tabletop version of Focus, the Inspector first presents the *start view* (Figure 2a). File navigation is also based on selecting a *focus file* to retrieve all *similar* files. For example, if the user wishes to see more files that are similar to *Buckingham Palace 2.jpg*, they can select this as the focus file (by touching it), and all files that are determined to be similar are then presented (as shown in Figures 2a and b). The darkness of the filename text is also used to give a subtle indication of the different levels of similarity — the most similar files, at the

[1]This is automatically populated using Apple's *Bonjour* — a multicast DNS service discovery protocol.

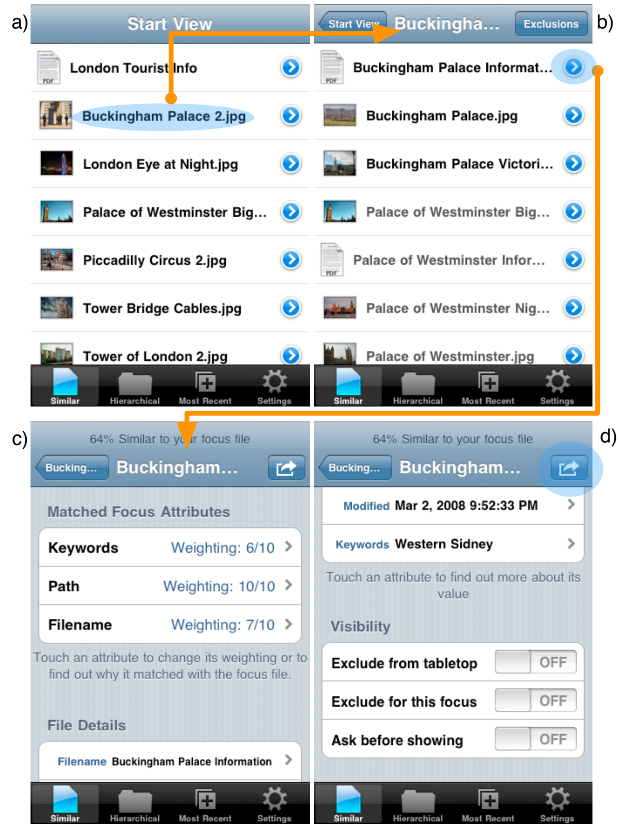

Figure 2. Associative file access using Focus Inspector. A user can touch a file in the list (a) to find any files that are 'similar' to it (the blue highlight shows the point of touch), and the similar files are then presented in a list of results (b). For more information about a file, a user presses the blue arrow (b), which opens the file information screen (c and d).

top of Figure 2b, have dark filenames, and less similar files, further down the list, have a lighter shade of grey. A user can go back to the previous screen of results by pressing a back button at the top left of Figure 2b. Touching the *similar* tab (bottom left of Figures 2a–d) again (while it is already the selected view) causes the interface to jump back to the start view, allowing the user to quickly return to it even after many *iterations* of focus selections.

For any of the similar files listed in Figure 2b, the user can press the *detail* button (a blue circle with an arrow) to be presented with more information about the file and why it is similar to the focus file. Figures 2c and d show the top and bottom parts of the detailed information screen, respectively. It is made up of three sections: *matched focus attributes*, *file details*, and *visibility*. In the matched focus attributes, the user can see that *Keywords* has a weight of 6/10, *Path* has a weight of 10/10 and *Filename* has a weight of 7/10. This means that the full path of the file is the same as the focus file (they are in the same directory) and this is most important, the filename is next most important and the keywords associated with the file are also used, but less important. The user can touch any of these matched attributes to see a screen with the attribute values for the focus file and the current result (Figure 3a), enabling the user to compare them. For ex-

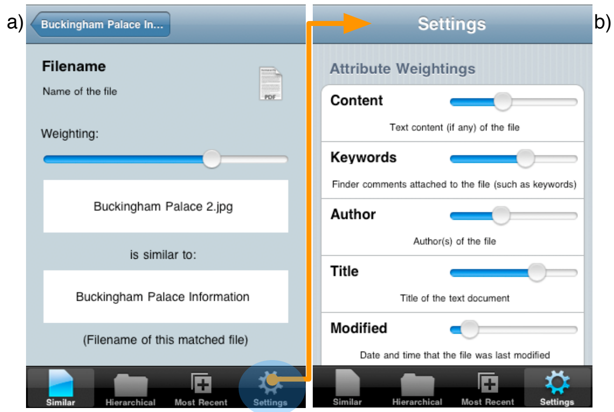

Figure 3. Scrutiny and control features of the Focus Inspector application. (a) shows the information about a matched attribute, and its weighting can be adjusted if desired. The "settings" tab can be selected (b) to adjust the weighting of any attribute.

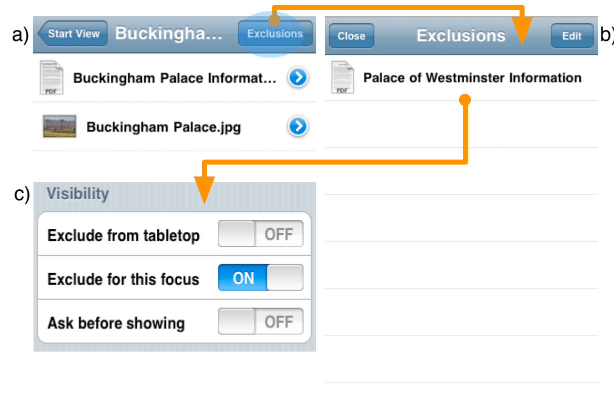

Figure 4. The file exclusion features of the Focus Inspector. If the current focus has exclusions, they are not presented in the list of results. Instead, the exclusions button (a) can be touched to view and edit the exclusions list (b). The exclude option can also be toggled from the file detail view (c).

ample, touching *Keywords* will present a screen that lists the keywords for the focus file and the keywords for the current similar file that the user is inspecting. The user's knowledge of their own filesystem and their own use of keywords, or the content of documents, would have driven their choice of these attribute weightings. The file information screen was designed to help the user quickly see what made the selected file similar to the focus file. In summary, the matched attributes section shows any similar attributes that the file shares with the focus file.

The *file details* part of this screen, visible at the bottom of Figure 2c and the top of Figure 2d, shows additional information about the file. The user may touch any of these attributes to view a short description of the attribute and its full value. For example, after touching the *Modified* field a screen is presented that describes the field as *the date and time that this file was last modified on your computer*, and the value is a timestamp formatted according to the user's locale.

The *visibility* part of the screen, shown in Figure 2d, provides options for setting a file to be hidden from the table. If a file is incorrectly displayed in the results — for example, if a file has a similar filename to another but they are not semantically related in any way — a user can exclude it, so that the file is not presented as a similar file when the same focus is selected again. To exclude a file, a user can toggle the *exclude for this focus* option when viewing the detailed information about the file (Figure 2d), and an *exclusions* button will then appear at the top of the results for the current focus file (Figures 2b and 4a). Touching the button will present the exclusions list (Figure 4b), allowing them to view and edit the exclusions for the current focus file. There is also an option to mark a file as *private*, so that it may only be displayed on the personal device and not the tabletop, and an option to have the application prompt, on the phone, for permission if a particular file is about to be displayed on the tabletop.

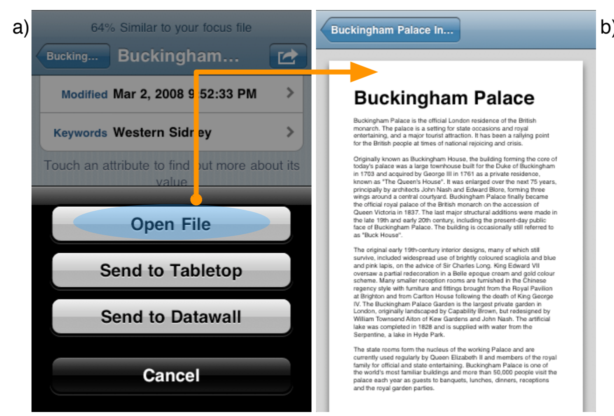

Figure 5. The file actions menu (a), allowing the file to be viewed on the device (b), or sent to the tabletop or a wall display opposite to the tabletop.

An *action* button at the top-right of the file information screen (Figures 2c and d) can be touched to bring up the actions menu (Figure 5a), where a user can choose to open the file on the device — enabling them to check the contents of the file before displaying it on the tabletop — or they can send it to the tabletop for immediate display.

The lower right of each screen enables the user to select the *settings* tab, shown in Figure 3b. This is where the user can move the sliders to adjust the weightings of any of the metadata attributes supported by the system. A description of each attribute is given to help the user understand its purpose.

Users may also access their files hierarchically when desired. Touching the *hierarchical* tab at the bottom of the interface switches to hierarchical mode, where a user can navigate through the folder structure on their computer. The state of each tab is retained, so that a user can easily switch between the two modes depending on their task. The hierarchical interface (Figure 6a and b) shows the contents of a folder in

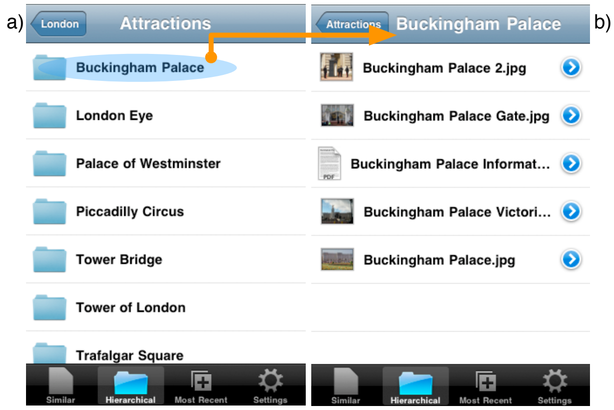

Figure 6. Hierarchical access using the Focus Inspector application. The folder (a) shows a number of subfolders. These can be touched to open the folder, resulting in the contents being being displayed (b).

Figure 7. The recent results list in the Focus Inspector application. After a focus selection is made on the tabletop (a), the user can select the "Most Recent Results" tab of the Focus Inspector to see a list of all files on the tabletop (b). From here, the user can view more information about a file, such as the "matched attributes" to understand why the file is similar to the focus file.

the same way that the similar browsing mode shows a list of results. Touching a folder will display its contents; touching a file will show its details (in the same manner as Figure 2c), where a user can open the file, see its meta-data, control privacy options, or send it to the tabletop.

Finally, it is also important that users can view more information about any of the files presented on the *tabletop* after selecting a focus item on there. The *most recent results* tab (Figure 7b) shows a list of all files presented on the tabletop (i.e. the tabletop in Figure 1, with a screenshot of its files shown in Figure 7a). From this list, the user can view detailed information about any file and adjust the settings outlined previously.

EVALUATION

The personal mobile interface, Focus Inspector, was designed to enable users to understand, scrutinise and control personal settings for our associative file system interface, Focus. Accordingly, the primary goal of the evaluation was to test whether the presented approach, and its implementation, met this design requirement. We chose to evaluate the approach in a qualitative think-aloud experiment, so that participants would verbalise their understanding of the associative retrieval mechanism while completing the tasks. We hypothesised that:

H1: Users can effectively locate files on the personal device using an associative access interface.

H2: Users can gain an understanding of why a particular file is returned by the associative access, thereby gaining a better understanding of the retrieval system.

H3: Users can effectively control the weightings used to determine the files returned by the associative access, and easily adjust these depending on the task at hand.

Experimental Procedure

We conducted the study one individual at a time. This was because we wanted to focus on the issues of user control of the associative file access mechanism, rather than collaboration aspects, which formed a key part of our earlier studies [3, 4].

We chose a travel planning scenario for our experiment that involved retrieving different types of information (such as e-mail, stored web pages, textual documents and images) that would typically be stored and managed with different applications. For example, e-mails will often remain in an e-mail client, instead of being saved to a folder in the file system along with any related files. Travel planning was chosen as it involves many classes of files, such as flight bookings, hotels, destination guides, itineraries, and information about attractions to visit. The scenario presented to participants was that they were spending a week in London, England, and they needed to access files to finalise their itinerary.

The experiment consisted of the following stages:

Preliminary Questionnaire This gained general information about the participant's computer and tabletop experience, and also experience using touch-screen devices like the iPhone. It also asked about the user's background, such as age, gender, and occupation.

Preliminary Task The participant was told they were travelling to London and needed to access their files to finalise the arrangements. A worksheet explained the experiment scenario and the nature of the tasks they would be completing. At a desktop computer, participants were asked to first familiarise themselves with (open and look through) the files that they were assigned. They then had to organise this into a logical folder structure. This ensured they had some knowledge of where the files were stored and a rough idea of their content.

Interface Tutorials The participant sat at the tabletop beside the experimenter, so the experimenter could clearly see what the participant was doing on the iPhone. The experimenter explained the main interface elements of the tabletop and the iPhone interfaces. The experimenter gave a brief explanation of how the associative associative access works, and how to scrutinise and control the associative access. Participants were told not to use the *hierarchical* tab of the iPhone, as this was not studied in the experiment. For each interface, the participant was given two basic file access tasks to ensure they were confident using it.

Main Task The participant was given a sheet of paper that explained each task. The participant worked through the tasks, which involved accessing files, finding out why they were returned for a particular focus selection, and adjusting the associative access mechanism to retrieve different sets of files depending on the task. In two of the tasks the user had to *correct* the file access mechanism to retrieve the required files.

Post-Experiment Questionnaire This consisted of *closed* and *open* questions about the participant's experience using the tabletop and the iPhone companion interface. The eight closed questions were on a 7-point Likert-scale, to gather quantitative measures of effectiveness. The open questions were primarily used to elicit more details about each Likert-scale rating (eight questions), as well as general feedback and comments related to the interfaces and the associative access system (four questions). Essentially, the questions were designed to gather feedback on general usability and how well the participant felt that they understood the retrieval system.

We provided participants with a set of files to use in the experiment. While this lacked the authenticity of users working with their own files, it had several advantages. Importantly, it made it possible to conduct the trial with modest demands on participants' time, at the same time, ensuring that all participants tried a range of aspects of control, including some quite challenging ones. It also ensured comparability between all users. To compensate for this, the experiment incorporated a familiarisation phase, where the user had to organise the provided information. In the *preliminary task*, the participant started with a flat, unstructured collection (73 files) and ended with a well-organised file system that they had categorised themselves. A template hierarchy of 18 directories was provided for categorising the files. There was no time limit for this initial organisation task, to ensure the participant had sufficient time to familiarise themselves with the travel files.

The files were assigned *keywords* to link nearby hotels and attractions together, thereby providing an additional dimension of meta-data. A caveat is that a user is unlikely to manually assign such keywords for denoting geographic similarity. However, it added another level of complexity to the similarity calculation mechanism, and allowed the files to be retrieved from an important logical dimension. We believe that *geocoding* of files (something that is becoming common for digital photos) will form an important part of an associative access mechanism. Using the keywords field, for making close-by hotels and attractions appear related, allowed us to explore this natural way of retrieving files. Participants were told and reminded of the purpose of the keyword field during the experiment.

The *main task* was designed to exercise a range of typical operations with the tabletop and the Focus Inspector interface. At each stage, the participant was asked to explain how they navigated the file collection and why the results were presented to them (i.e. which meta-data attributes matched for the focus file they selected). For tasks that involved locating files for the nearest hotel or tourist attraction, a wall display next to the tabletop showed a high resolution map so they could check they have the right files. The task list was:

1. Assign weightings to the meta-data attributes so you can locate files through the *similar* search mechanism.
2. Locate information about *Big Ben*, and explain why you were able to find it through the similar search mechanism.
3. Choose a nearby hotel and locate the files related to it. Explain how you located the files.
4. Your friend is staying in *Hotel Cavendish*. Find the files about it, and adjust the settings so that the files about the nearest tourist attraction are displayed as the most similar.
5. Find the e-mail about flight quotes, and adjust the settings so that the reply to the e-mail is listed as the most similar file.

Task 1 called on the participant to set the attribute weightings on the iPhone based on their knowledge of the file collection they organised. Tasks 2–5 then required the participant to locate specific information about various tourist attractions, hotels, and travel booking e-mails (H1). Tasks 2 and 3 involved accessing files just with the iPhone, while Tasks 4 and 5 involved accessing files from the tabletop and then inspecting and changing the weightings on the iPhone as required. Before Tasks 4 and 5 the experimenter changed the weightings so that they were incorrect (so the required files could not be located in the tasks). Thus, the participant had to understand and fix the weightings so that the required information was returned (to test H2 and H3). As this was a single participant study, the tasks did not involve any of the privacy or exclusion settings discussed in the user view of Focus Inspector. These aspects will be evaluated in future work.

While the task list required users to adjust the system to behave in very different ways, we do not envisage that this would have to be done frequently while working at the tabletop, and certainly not something that is required before the start of every file access process. Rather, the system is designed to support transitions between different types of tasks that require the files to be structured or viewed from a different perspective. The system is also designed to be scrutinised in cases where it fails to operate as expected, possibly because the similarity mechanism is set to work with a different collection of files. As this form of control of a similarity-based access mechanism is novel, we ensured that the task list involved very different combinations of settings. We do not envisage that a user should have to make frequent

	Age	Gender	Occupation	iPhone Exp.
A	21	F	Student	Limited
B	21	M	Student	None
C	21	M	Student	Competent
D	23	M	Student	Limited
E	28	F	Accountant	Advanced
F	21	F	Student	Competent
G	21	M	Student	Competent
H	31	M	Researcher	Limited
I	22	F	Childcare Worker	Competent
J	25	M	Business Intelligence	Advanced
K	21	F	Student (not IT)	Limited
L	52	M	Singer	None

Table 1. Participant demographics and their iPhone experience level. Participants are identified A–L.

adjustments of this nature at the tabletop, which would be tedious. It is also worth noting that the system works sufficiently well without modification of its default settings, as demonstrated by its performance in our earlier studies [3, 4].

Hardware and Data Capture

The participant used a pen-based interactive tabletop, using the *mimio Interactive* whiteboard capture system, in conjunction with a top-projected display on a white table. The display had a resolution of 1024×768. The experiment dataset contained documents with a large font size, so that they could be identified at their default size, despite the resolution of the display. An iPhone was also provided for participants to use during the experiment. The main tasks were audio and video recorded and all computer and phone actions were logged for later analysis.

Participants

We recruited 12 participants for the study (5 female and 7 male), with an age range of 21–52. The background information for the participants is summarised in Table 1. Four had briefly used a tabletop interface before (none had used Focus or Focus Inspector), and their level of experience using an iPhone was varied, with 6 self-rating their experience level as *competent* or *advanced*. As the interface was designed to follow iPhone conventions, we considered it important to include a good sample of participants who were familiar with it, in case lack of familiarity with the iPhone caused problems. All students were undergraduates and six were studying IT. Participants were given a coffee/cake voucher for their time.

RESULTS

To test the hypotheses presented in the previous section, we processed the data against several key *aspects* for each of the tasks. We then analysed cases where a participant did not fulfil a particular aspect, and compared these results with the pre- and post-experiment questionnaire responses. In all tasks, participants were asked to *think-aloud*. Thus, all of the reported observations are based on the participant verbalising their thoughts. In cases where the participant was silent, the experimenter encouraged them to state what they were thinking. The next section outlines the main observational findings from the experiment tasks, which are summarised — along with the key aspects — in Table 2.

Task	Aspect	Notable
1	**a.** Understood and made appropriate choices for initial weightings.	
2	**a.** Located required attraction files through the shortest path from the start view.	E
3	**a.** Located a nearby hotel by exploiting the *keywords* in an associative search.	C, D, F, L
	b. Understood why the hotel files were related to the attraction files.	D
4	**a.** Located required hotel files through the shortest path from the start view.	B
	b. Understood which attribute(s) should be changed to retrieve the nearby attractions.	C
	c. Correctly adjusted the attributes and located the nearest tourist attraction.	C†
5	**a.** Located required e-mail through the shortest path from the start view.	
	b. Understood why the e-mail reply was not listed as the most similar result.	
	c. Correctly adjusted the attributes to show the reply as the most similar result.	E†, I†

Table 2. Summary of aspects identified in observations of the participants. For each aspect, all participants succeeded for that aspect, unless they are listed in the *Notable* column.
† indicates success but with some additional effort (i.e. the participant needed to adjust the weightings multiple times, or they needed to make additional focus selections to finish the task)

Experiment Tasks

In Task 1, we observed participants making informed choices for their initial settings. The average weightings assigned by participants, in descending order, were filename (5.9), keywords (5.1), path (2.8), and text content (2.1). All participants assigned values to these *core* meta-data attributes. Only one participant (PD) chose to assign values to additional attributes: e-mail recipients (2), e-mail addresses (6) and creation date (1). Eleven participants chose not to assign values to any e-mail specific attributes, instead relying on the text content attribute to retrieve relevant e-mails. Participants explained that they gave a strong rating to filename and keywords, as it was clear while organising the files that the filenames were accurate, and the keywords gave useful information about nearby attractions and hotels. Path was not perceived to be as important.

We now step through the findings for Tasks 2–5 — the main access, understanding and control tasks. In Task 2, where participants had to first locate files about *Big Ben*, eleven participants took the shortest navigation path of *Start View* ⇒ *Palace of Westminster* ⇒ *Palace of Westminster — Big Ben* to locate the required files, involving matches between the filename and path attributes. One participant (PE) was initially unsure where the required files were stored, and made a random focus selection before returning to the start view and then succeeding (shown in Table 2, aspect 2a).

In Task 3, participants were asked to locate files for the nearest hotel. Eight participants realised that the nearby hotels would be presented further down in the list of results for the current focus file (Big Ben from Task 2), and so just scrolled down the list because they understood that the system would retrieve items with matching keywords (Table 2, aspect 3a). Regarding aspect 3b, PD did not realise that the hotel would be similar to Big Ben because of the assigned keywords, and so went back to the start view and located the files from there (involving additional focus selections). PC/F/L knew about the keyword matching, but intentionally chose to go back to the start view — they knew exactly where the required information was in the file hierarchy, and conceptually found it easier to navigate to that specific part of the hierarchy from the start view. However, after completing this task, PF and PL stated that it would have been easier to exploit the keywords association.

In Task 4, participants were asked to locate a set of files on the tabletop. Before they began, the experimenter altered the weightings, assigning them incorrect values, making the task more difficult than the previous. Eleven participants found the initial set of hotel files with the shortest navigation path from the start view (Table 2, aspect 4a). PB was unsure of which hotel to select as a focus file from the start view (as they all looked similar). They chose to focus on an e-mail from a travel agent about flight quotes, hoping that it mentioned the hotel in the text. This failed to retrieve the specified hotel, and so they returned to the start view and then selected the right hotel. From the hotel, the participant needed to retrieve the closest attraction — the keywords weighting was incorrectly set to zero, so no nearby attractions were retrieved. Eleven participants immediately went to the *Settings* screen and adjusted the keywords attribute to have a value between 7 and 10 (Table 2, aspect 4b/c). PG also chose to set the path attribute to zero, as they knew they were accessing files across different parts of the hierarchy. PJ decided to also set the text content attribute to zero, as they wanted to access information only based on keywords, and not the actual content of the documents. PC did not realise that they should adjust the keyword attribute (which they also did not realise in aspect 3a). Instead, they increased the text content attribute in case the information sheet for the hotel mentioned the nearby attractions. After this failed to locate the required files, they tried again and succeeded by raising the keywords weighting (Table 2, aspect 4c).

Task 5 began with the experimenter initialising the system with incorrect weightings. This time, participants were required to locate a specific e-mail, and adjust the settings so that the reply to the e-mail was listed as the most similar result (at the top of the list). All participants located the required e-mail through the shortest path from the start view (Table 2, aspect 5a). We then observed two strategies for solving aspects 5b/c. The first, used by ten participants, involved going through the whole list of settings and making adjustments to many attributes that could be important to the task. For example, PD increased *subject*, *path* (mailbox), *date* and decreased *keywords* and *filename*. The other strategy, employed by PE and PH, involved making one adjustment and then checking the result by performing the focus selection again on the tabletop. PE and PI needed to go back to the settings to make a second adjustment before the results were returned in the desired ordering (Table 2, aspect 5c).

Question	Med. (SD)
1. I was able to easily find all the files I needed using the iPhone interface. *(H1)*	6 (.62)
2. I was able to easily find all the files I needed using the tabletop interface. *(H1)*	6 (.83)
3. It was clear why a similar file was related to the current focus file. *(H2)*	7 (.67)
4. I understood how to change the similarity mechanism when I was required to. *(H2/3)*	7 (.67)
5. I knew which changes I should make to improve the similarity mechanism. *(H2/3)*	6 (.60)
6. The changes I made to the similarity mechanism made finding the files easier. *(H3)*	6.5 (.78)
7. I was able to understand how the system and the similarity mechanism works. *(H2)*	6.5 (.67)
8. I feel confident in using such a system to locate files at the tabletop. *(H1/2/3)*	6 (.87)

Table 3. Likert-scale responses from the post-experiment questionnaire summarised by median (7 being strongest agreement).

Overall, participants completed the tasks with ease. However, there were some usability problems identified while participants were completing the tasks with the Focus Inspector interface. In particular, five participants accidentally selected a new focus file (performing a new query), when they wanted to see more information about a particular file instead. For example, in Figure 2b, participants pressed the filename (which performs a new focus selection), instead of the blue arrow to see more information about the file. PF stated *"by instinct I assumed pressing on the filename would show details about the file and pressing on the blue arrow would do the similarity search, but it was the other way around."*

Questionnaire Responses

The post-experiment questionnaire collected free form comments and closed questions with Likert-scale responses, to assess participants' perceived understanding of the associative access mechanism. Table 3 summarises the Likert-scale responses. Overall, the responses were positive, indicating that participants felt confident locating files, understanding why they are similar, and adjusting the similarity mechanism to operate differently. Responses were slightly more consistent for finding files with the iPhone (Q1) than the tabletop (Q2), due to the fact that the iPhone presents the filenames of all files in the list. By contrast, Focus shows the filename only when a file is flipped. PG stated *"I liked the way files were presented and manipulated on the tabletop. However, the amount of information (text) available on the iPhone was more useful for actually finding things."*

The broad notion of using a handheld personal device in conjunction with the tabletop was also positively received. For example, PE stated *"I liked the send to tabletop action. It was great to have immediate visual feedback from the ta-*

ble when interacting with the iPhone." Similarly, PD stated *"Having a private device to select the stuff I want to share is a great idea! Also having the same kind of search on both the iPhone and the tabletop is very good because it doesn't confuse you."*

When asked about understanding the similarity mechanism, PA responded *"This was very intuitive. The explanations under the attributes were helpful."* PB thought *"It was clear on first use what mechanisms contribute to the search."* However, PH thought *"keywords was a bit of a black box... geographical similarity (like time) should have its own attribute."*

For adjusting the attribute weights, PG stated *"it requires some thought but [it's] fairly easy to know which things might have impact in the similarity search, although the values I selected were low/medium/high weightings rather than 0–10/10."* Similarly, PA stated *"with the information about the files, it was easy to know which attributes [to change]. I was a little unsure of how much to change them but my guesses worked out."* PD related the system to their own files, stating *"I generally know how my files are tagged and sometimes where they are. But a possibility for presets (e.g. e-mail, non-tagged files) would help me being lazy."*

Regarding overall confidence using the system (tabletop and iPhone together) to retrieve files, PA stated *"yes, I would be confident to use this system. Now there is nothing I dont understand, it would just be a matter of doing it a few more times to feel comfortable."* However, PG stated *"I feel that I could find a file required although in some cases a text search may be useful."*

DISCUSSION

We set out to address the problem of helping users understand and control a novel associative file access mechanism. Our experiment involved observing participants as they performed a series of access tasks that required scrutiny and control of the similarity calculation mechanism, depending on the file structure and the specific tasks they were completing. It involved a range of file access tasks, relying on different parts of the file hierarchy and e-mail collection, and some tasks involved working with the information from different perspectives that the underlying file structure did not accommodate. For example, the participant had to view tourist attractions near a particular hotel, and the underlying file hierarchy was not originally organised to support this. This section discusses the results of these realistic file access tasks, combined with the questionnaire responses, in terms of our original hypotheses.

H1: Locating Files by Associative Access

Associative access is inherently less predictable than hierarchical, as it provides a dynamic view of a file system, but it has benefits for supporting multi-user file system access at a tabletop, as demonstrated in our foundational evaluation [4]. At the core of this work, it is important that users can effectively locate the information they need using associative access, both on the tabletop and on a personal device. The experiment results indicate that, with the provided collection of files, participants could easily locate the required information with no assistance.

The tasks given to participants were representative of the kinds of tasks that an associative access mechanism will support well. The tasks involved *realistic* access needs, requiring the retrieval of a range of file types. There are cases where associative access will not be appropriate, and so hierarchical access is provided as an alternative, particularly for locating specific files from a well known location. As we wanted to test whether participants could understand and control the associative access, we told them to only use the associative access. Even so, we observed that users were able to readily jump to different parts of the file collection — a feature that a hierarchical file system can support well if the hierarchy is logically structured and the user knows its layout.

We analysed both basic file system access (in aspects 2a, 4a and 5a of Table 2, where a participant located a set of files by selecting a representative focus file in the start view), and more novel, dynamic file access (in aspects 3a, 4c and 5c, where participants were presented with *similar* information based on a number of dimensions). While some participants did not utilise the similar file results to their advantage in earlier tasks (for example, Task 3), these participants made better use of this functionality in subsequent tasks (for example, PD/F/L in Task 4). Of particular importance is how users *perceive* the difficulty of locating information. In the post-experiment questionnaire, responses were positive for easily locating information (such as in Q1 and Q2 of Table 3). Thus, H1 is supported by the collective results regarding people's effective file access.

These results are dependent on people's knowledge of their file system. Indeed, when performing the tasks with their own files, users will remember more about each file, and they may need to exploit the associative access mechanism in ways not evaluated here. Furthermore, we studied a scenario where a user had just organised a set of files before coming to the tabletop, and so the information was fresh in their memory. Even so, the results show that people could readily grasp the unfamiliar access mechanism, with no major obstacles preventing them from using it in the same way as a more familiar hierarchical file interface. They were able to exploit their knowledge of this to access the files in ways poorly supported by a regular hierarchical file access interface, which would have forced the users to manually restructure the collection. Even though a file collection was provided for users, this ensured a high degree of comparability between trials. The study is an important first step to determining the effectiveness of using a personal device to understand and control the novel access mechanism of Focus. It is also realistic that some information in a file system has been forgotten about, which the experiment did not test, but associative access is potentially valuable for helping people locate information without specifying many details about it.

The results highlight some interface usability issues that need to be addressed. Most important is to resolve the confusion arising from touching a file's name in the list of results. Some users expected this to show more details about the file (and they were confused when a new list of similar files was returned); others expected this to conduct a new associative search, with the blue arrow beside it showing more information about the file. The interface needs to make the function of each touch point clearer.

H2: Understanding the Associative Access

An important prerequisite for effective user control of the associative access (H3), is that the user can first understand how the system works, enabling them to make informed adjustments to the system. The experiment tasks required participants to verbalise their thoughts about *why* information was presented to them after performing each retrieval, so that we could assess their understanding of the associative access system. While they inspected each file looking at the matched attributes, participants were confident in explaining why the results were returned. After just a couple of tasks, participants built-up a mental model of how the matching system works. After very little use of the system, users exploited their knowledge of the files and meta-data to improve their searching. For example, from aspect 3a of Table 2, eight participants knew that nearby hotels would be automatically retrieved because of the keyword weighting. Similarly, from aspect 4b, eleven participants knew that the keywords attribute should be adjusted to retrieve the desired files. Overall, participants gained a better understanding of the system during these experimental tasks.

The experiment task list enabled us to ensure that users performed several different kinds of associative access, employing a range of meta-data attributes in the similarity calculation. This allowed us to examine how well users understood the similarity mechanism when it performs more complicated matchings, across five or more attributes at a time. The questionnaire results, particularly Q3 and Q7 of Table 3, indicate that participants found it easy to understand how the associative access mechanism works, even in the more complicated matchings. This is an important step towards helping users understand this new, unfamiliar file system interface that provides dynamic, and possibly unpredictable views of file systems. Thus, H2 is supported by these results.

H3: Controlling the Associative Access

Our foundational study [4] identified *user control* as a critical aspect for an associative access interface like Focus. People organise their files differently, and they use very different sets of files depending on the task. Consequently, it is important that users can easily adjust the similarity calculation mechanism to meet their current needs. The settings interface could be enhanced to be more powerful and streamlined, enabling users to save and load settings for different sets of files, for different tasks. In our evaluation, such facilities could complicate the interface, and so at this stage we chose to keep the interface simple, allowing a user to adjust the settings with a slider, with the adjustment taking effect immediately.

The tasks involved several adjustments to the settings. We asked participants to set the initial weightings from scratch. All participants made appropriate choices that enabled the retrieval system to work effectively in the subsequent access tasks. We then examined cases where the settings were incorrect — to represent a scenario where the weightings were set for a prior task with a different set of files. In aspects 4c and 5c of Table 2, participants adjusted the settings and found the required information with little cognitive effort. We observed two interesting strategies — some chose to spend a little more time adjusting multiple settings at once, and others adjusted just one, observing the effect, and adjusting more if necessary. The latter points to the importance of conducting further work on providing live previews to indicate what impact each change will have on the current list of results. Questions 3–6 of Table 3 indicate that participants understood how to change the settings, and they understood which settings they should change to improve the retrieval. Indeed, we observed participants quickly identifying which attributes to adjust in the tasks where they were incorrectly set (e.g. aspects 4b and 5b of Table 2). Thus, H3 is supported by these results on effective user control.

One could argue that users should *not* be able to control such an associative access mechanism, because it might be cognitively hard or that users might not do a good job of it. However, the Focus associative access system is designed such that it can be controlled, and adjusting the importance of the meta-data attributes causes it to behave in different, potentially useful ways. It is natural that people will need to access their files from different perspectives, which hierarchies do not support well. In these cases, users may need to demote or ignore certain file properties, relying on a different set of properties to define what is *similar* or relevant to them. From the findings related to H2 and H3, we have seen that having *sliders* for the user to express the relative importance of the attributes is cognitively simple, and a worthy approach to solving the problem. Another approach might be having the user select which attribute to use for retrieving similar files, at the time that they select the new focus file. For example, the user could select to find all similar files just by keyword. However, we aim to support users having particular settings for a whole group of files, or a task involving them. The experiment results show that users did succeed in making these adjustments, making such controllability worthy of study in associative access systems.

The results highlight some areas for improvement in the associative access control. There might be cases where participants set the system to behave in a way only suitable for a specific task or set of files. This might cause the associative access mechanism to not work as expected for more general file access. Thus, if people are to have a high level of control over the associative access mechanism, it is important that they can easily reset it to a default state. This is needed to ensure that the added power of the control mechanism does not make general associative file access less predictable or less effective. The *slider* control mechanism worked effectively, but it is clear that users are not concerned about the specific values of the sliders — what matters is the *relative* importance of each meta-data attribute. Future interfaces could explore having a two-level rating (*important* or *unimportant*), or a three-level rating (*low*, *medium*, *high*, as suggested by one participant) assigned to each attribute to express its importance. However, in this particular experiment, the sliders were effective for setting relative levels of importance.

For user control, there are several aspects remaining that need to be evaluated. We have not evaluated the *exclusions* mechanism, nor have we tested the other privacy features, such as marking a file as *private* to exclude it from the tabletop. As these features are most interesting to explore in a small group setting, they are left for future work.

CONCLUSION

We are approaching a time when most people will carry powerful mobile phones that can hold large collections of their information and can also access their personal file collections on other devices and computers. At the same time, we are seeing the emergence of surface computing devices, such as tabletops. These have the potential to serve as a large screen interface that complements the mobile phone. This could make it possible to do tasks such as collaborative planning as described in our introductory scenario. This could be valuable in many contexts. For example, during a medical consultation, the patient and the doctor might exploit this combination of smartphone and tabletop to review and discuss documents for tasks like reviewing progress on a problem and planning the next stage of action. It has many other potential uses, for example, in learning contexts.

One of the fundamental requirements for such synergistic use of phone and embedded interaction device is that people should be able to access their personal files effectively. We have been tackling this problem by exploring and evaluating both conventional hierarchical and new associative file access mechanisms [3, 4]. That work showed that the Focus associative mechanism offers real advantages for helping people find collections of files that they need for the series of tasks involved in activities such as planning. At the same time, those studies pointed to key problems to overcome. The associative retrieval mechanism is inherently less predictable than hierarchical access. To address this, we need to ensure that the user can understand it well enough to control it and to *feel* in control of it.

This paper described our approach to this core problem for associative file access. It is based on the Focus Inspector application that runs on a smartphone, enabling the user to access their files from their remote personal computers. It was designed to ensure that the user could scrutinise all aspects of the file access and could control them. The mobile phone is an important part of the approach since it provides a relatively private interface for managing the file access control. We have described how we designed functions: the associative file access on the phone, a new and potentially valuable facility in its own right; the hierarchical file access on the phone, ensuring the availability of this mechanism when it is appropriate; a *scrutiny* interface supporting scrutiny of the reasons that a file was deemed similar to the current focus file; the *control* interface for altering the weightings on each of the meta-data attributes. We explicitly designed the core mechanism, and the associated interfaces, with user control as a key driver.

We designed the study reported in this paper to assess whether the combination of our associative file access mechanism and its scrutiny and control interfaces actually met their goals, to provide *user control* and a *sense of control*. Our study was small but carefully designed to test whether we had achieved these core goals. The study involved one set file collection of 73 files that each user organised into directories. While this is small compared with complete personal file systems, it was meaningful and representative of the numbers of files that a person might have for the tasks set. Furthermore, a person is likely to only share a specific collection of information with others at a tabletop. Our study involved 12 participants. Half were students in IT related degrees, a softer test of the system and interfaces. The other half were from diverse professions and were more representative of a broader, but still educated population. All participants were able to perform the range of tasks, including the more difficult ones, demonstrating that they could find files effectively, understand why a file was selected and control the associative file access mechanism. This indicates that Focus, with the Focus Inspector, provides effective associative file access that the user can control. This is an important step in enabling people to access their files for use at emerging embedded displays, enabling people to work beyond the desktop. At the same time, this work indicates that we have succeeded in creating an associative file access mechanism that can break the boundaries of the hierarchical filesystem, at the same time ensuring the user is in control and feels in control.

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