THE LIVING-ROOM: BROWSING, ORGANIZING AND PRESENTING DIGITAL IMAGE COLLECTIONS IN INTERACTIVE ENVIRONMENTS

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Abstract

We present the Living-Room, an interactive application for browsing, organizing and sharing digital photos. The application runs in an instrumented environment on a wall display and an interactive tabletop, which is meant to simulate a future living room. We discuss the design rationale as well as the interaction techniques and the technical implementation. To asses how well our design goals were met, we evaluated the application in a study with 10 participants with mostly good results.

Keywords: Photoware, bi-manual interaction, hybrids, interactive surfaces, instrumented environments.

1 Introduction

The vision of ubiquitous computing promises that elements of our daily environments will become interactive and acquire new functionalities provided by computing capabilities embedded into them. One plausible assumption is, that planar objects, such as walls, doors or tables, will provide interactive surfaces, which can display information and accept input [7, 23, 28, 32] for example, enabling a coffee table to double as an interactive display area. The variety in scale, orientation and distribution of these interactive displays provides novel possibilities and challenges for social interaction and communication.

The practical replacement of analog photography with its digital successor has already become reality. With the rise of digital photography the costs of film and paper no longer apply. Also the costs for storage and duplication have been minimized. Furthermore, have both the time and steps of actions necessary to attain a picture from the moment of capture been greatly reduced. All of these factors help to explain the immense popularity of digital photography. The technological advancements have also caused massive changes in consumer behavior. People do not only take ever increasing amounts of pictures they also engage in different activities to store, organize, browse and share pictures then in previous times [6, 8, 24].

In response to this, a variety of software for browsing, organizing and searching of digital pictures has been created as commercial products, in research [2, 10, 14, 22, 27] and for online services (e.g., Flickr.com, Zoomr.com, Photobucket.com). Especially the online photo communities have greatly facilitated the remote sharing of pictures with family and friends. While existing approaches provide good efficiency in retrieving images from a digital collection [13] all these systems have been developed and optimized for single user interaction with standard desktop computers. However, standard PCs do not lend themselves very well for co-located sharing and manipulation of photo collections foremost because of their shape and orientation which does not support face-to-face communication (See Figure 1). Also do such systems lack the tangibility and flexibility of physical media which is essential for co-located and social consumption of media [8].

As large interactive tabletop and wall-sized displays [5, 29] become available novel possibilities for browsing and co-located sharing of photos arise. With these new technologies it is possible to mimic the flexibility and tangibility of physical media while coupling these qualities with the advantages of digital photography.

In this paper we present a novel photo browsing and sharing application for the FLUIDUM instrumented environment (See Figure 1) that allows users to browse, sort and organize digital pictures on an interactive tabletop display as well as the presentation of selected pictures to friends and family on a large vertical display. We have also implemented an interaction technique to annotate digital images with handwriting as well as a technique for searching specific pictures based on these annotations.

Although the instrumented environment as shown in Figure 1 is a rather artificial room, we are simulating an actual living room with it. The increasing use of large TV screens or projectors in actual living rooms as well as the recent announcement of an interactive coffee table by HP make it plausible that many living rooms might soon contain displays equivalent to the ones we are using in our instrumented environment.

Figure 1: (a) The FLUIDUM Instrumented Room equipped with an interactive table and wall-sized display. (b) A collection of physical photos spread out on a table. (c) Typical setup of several people crammed behind one laptop watching photos.

2 Design Considerations

In this Section we outline the design considerations that led to the development of the Living-Room Prototype (Section 4). Along these lines we will discuss previous literature and how it has influenced the presented system as well as to what extent our approach differs from previous work.

2.1 Scenario

The FLUIDUM Instrumented Room (Figure 1) contains an interactive digital desk and a wall sized display. These could – in a real living room – be a TV/projected screen and an interactive couch table. Consider the following scenario: a user has several friends as guests and they speak about past trips and vacations. The host wants to show some pictures of his recent trips but instead of gathering his friends behind his PC or laptop screen the host simply activates the display functionality of the interactive coffee table. Furthermore does the host activate a large display on the wall opposite to the sofa (e.g., a LCD screen or electronic wallpaper). His personal picture collection is displayed on the table grouped in piles. No mouse or keyboard is required to interact with the piles and the contained pictures. Instead the virtual information can be manipulated in a similar fashion as printed pictures could be – using both hands to move, unfold and flip through piles as well as to move, rotate, scale and view individual pictures. The host creates a new pile containing only those pictures s/he wants to present to the guests. When finished the stack can be dragged onto a proxy located at the display edge adjacent to the wall display. The pictures represented by the pile are immediately displayed on the wall and a slideshow starts. Speed and direction of the slideshow can be directed by simple gestures performed on the proxy (See Figure 3).

2.2 Related Work

Agarawala et al. present BumpTop [1] a new approach to the desktop metaphor using piling technology instead of filing (i.e., hierarchical folder structures) and a set of new interaction techniques to manipulate these piles based on a physics simulation. Our metaphor is also based on organizational structures found in the real world (i.e., piles) and some interaction techniques are similar to BumpTop. However, BumpTop has been designed for tablet PCs thus it only supports single handed user input with a stylus. While this is a reasonable approach for the limited screen real-estate on tablet PCs we had large interactive surfaces in mind which lend themselves to more natural interactions, possibly simultaneous multi touch and bi-manual interaction techniques.

Ever since Guiard postulated the model of the kinematic chain [9] bi-manual interaction has been explored as input technology in human computer interaction. According to Guiard's model the two hands function as a chain of asymmetric abstract motors thus the non-dominant serves as reference frame for the other (e.g., positioning a piece of paper to write on). In response to these findings Bier et al. proposed the Magic Lens/Toolglass technique [3]. This approach has been further developed and studied extensively in following years [12, 16, 17, 21]. Most of these systems where developed for standard desktop systems utilizing Wacom[1] tablets for input. We take this technology to a new level of directness by enabling users to utilize both hands directly on the displayed information.

This kind of interaction is afforded by our interactive table which provides space to rest the forearms on and a big enough display area so that both hands can move freely and cooperate with each other. This again mimics the real world where we frequently grasp and manipulate artifacts with both hands. In the presented system we directly apply Guiard's model as the non-dominant hand is used to position a toolglass which provides an area for handwriting to the user. The user can then annotate pictures by simply writing tags or descriptions onto it. In a later phase pictures can be retrieved by using the non-dominant hand to position a magic lens which only displays pictures according to specified search criteria. The dominant hand is used to specify these filters by hand writing tags or descriptions (See Figure 4).

[1] http://www.wacom.com/

Instrumented environments have been built in several projects [4, 29, 30] to simulate the vision of ubiquitous computing. Research goals have been to develop the hard and software that is necessary to enrich our everyday environments with computing power and information accessibility. In the past the major question was how this new technology can support and enhance formal office work. More recent studies have investigated how such environments can support semi-formal communication and creative collaboration [11, 25]. In this project we want to investigate which properties are important for systems in instrumented environments that support entirely informal and private activities, such as co-located consumption of media.

Several Studies have been conducted to understand how users interact with their photo collections [6, 24] both physical and digital. In general do these studies suggest that current PC based photo software is well suited for organizing and remote sharing of pictures, but does not support the co-located sharing of pictures which is highly appreciated by users [8]. The same study even reports that users are “turned off” by looking at photos on a PC screen. Kirk et al. [15] suggest to utilize interactive surfaces and natural interaction techniques to support co-located sharing of digital pictures.

Especially in the field of tabletop research several systems have been developed with photo browsing or sharing as scenario. The personal digital historian (PDH) [26] provides a circular tabletop interface that allows users to view and share pictures so that they are always correctly oriented. Morris et al. also present two studies that deal with photo collections on interactive table tops [19, 20]. While the PDH project mostly served to investigate the role of physical orientation of information artifacts in tabletop interfaces did the studies by Morries et al. investigate what role the positioning and orientation of control elements had on the collaboration around interactive tabletops. We take a more ecological, holistic approach by looking both at the combination of different displays across the entire room and also consider more of the peculiarities of the photowork process.

3 The Living-Room: Prototype Overview

Starting from the Scenario described in Section 2 we have built and implemented a prototype for an interactive living room. Our system consists of an LCD monitor which is equipped with a DViT [28] overlay panel for interactivity embedded into a wooden table. A vision based tracking system with a camera mounted over the table and finally three back projected wall displays (See Figure 2). The table has an overall size of 1.6×1.2 meters and the display resolution is 1360×768 pixel. The wall display has an overall size of 5×2.5 meters and provides a resolution of 3072×768 pixel. The ceiling mounted firewire camera is used to track orientation (i.e., upside-down) and rotation of the toolstick which is used for the annotating and filtering activities. The application has been implemented in C# and the graphical user interface is based on the piccolo framework [2]. From an implementation point of view the application can be divided into three phases: browsing and sorting, annotating and filtering and finally presenting pictures. The transitions between these phases are designed to be fluid and for the user completely transparent. Since the implementations of the browsing and presenting interaction techniques are technically straight forward we restrain our selves to describe their functionality only (See Section 4). We will however describe the technology behind the annotation and filtering process.

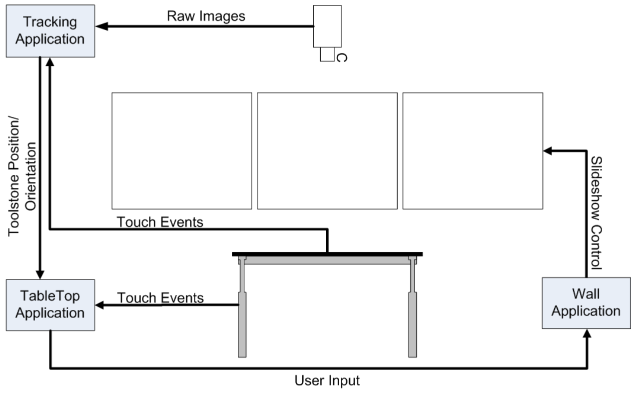

Figure 2: Architecture Overview of the Living-Room prototype.

We have adapted the magic lens/toolglas [3] metaphor for annotating and filtering pictures. We use a physical handle to position, orient and control the mode of the lens (See Figure 4). Since the table only provides position- but no orientation information we had to implement an additional tracking system for the missing information. With every touch that is detected on the table surface a two step cycle is triggered to 1) find the marker in the camera image stream and 2) compute it’s rotation relative to the table.

The toolstick has two different color-coded sides which are mapped to different functionalities of the lens. To identify these markers we utilize an adaptive thresholding technique to separate the marker colors (foreground) from the background colors. In order to distinguish the markers’ pixel from possible similar pixels in the background we apply a segmentation algorithm based on the region merging procedure (i.e., neighboring pixel of the same color are recursively merged into segments). Once we have identified the marker’s triangles we apply a canny edge detection algorithm and finally utilize a hough transformation to calculate the rotation of the marker.

4 Browsing, Organizing and Presenting Pictures

From the users’ point of view the above mentioned different phases are completely transparent and transitions between them can be made at any time without changing

[2] http://www.cs.umd.edu/hcil/piccolo/

Figure 3: Browsing and Sorting pictures on the interactive table. The inset shows the slideshow displayed on the wall.

the mode or the setup of the application. To ensure this flexibility was a important design goal in order to mimic the freedom users enjoy when dealing with physical media.

4.1 Single-Pointer Manipulation of Photos and Piles

Both single photos and entire piles can be manipulated directly with fingers or a pen (or even the toolstick turned upside-down). With a single pointer the photo or pile can be moved on the surface of the table in order to organize picture collections semantically (i.e., sorting pictures into piles) but also spatially. That is, putting piles into relations to each other via proximity/distance which takes advantage of users spatial memory capabilities. For example could one area of the table contain piles with pictures from different vacations while other areas contain pictures from family meetings. The possibility of arranging photos and piles freely on the table surface also fosters communication between people because items can be explicitly handed over to others in order to signalize that the recipient should, for example, look through a certain pile [11]. Finally this flexibility in spatial arrangement allows users to create temporal structures (e.g., pictures of one person from different occasions) which play an important role in story telling and informal communication.

Pictures and piles can be moved by simply touching them and dragging them around. To add a picture to a pile or in order to create a new pile pictures have only to be released over an existing pile or a second picture respectively. Two piles can be merged in analogy by dragging one onto the other. Finally piles and photos can be tossed around the table to cover greater distance by applying a movement similar to the dragging movement into the wished direction but with more speed than regular dragging.

4.2 Bi-Manual Manipulation of Photos and Piles

In order to carry out more complex operations than simple moving of items we employ bi-manual interactions. Again these interactions can be carried out with two fingers or one finger/pen of the dominant hand and the toolstick as pointing device in the non-dominant hand. Fluid and hassle-free scaling and rotating of pictures is very important for co-located consumption of digital media in order to present pictures correctly oriented to all users but also to enable communication about details in pictures (e.g., pointing out a single person in a group shot).

One can easily and fluidly scale or rotate a photo by placing two pointers onto the picture. To scale, one varies the distance between the two pointers. To rotate, one moves the two pointers in a circular motion around an imaginary axis. The picture is always rotated around the barycenter of the movement. Hence, the photo rotates around one pointer if that pointer is kept steady or the picture is rotated around the midpoint of the axis connecting the two pointers if both are moved on a circular path.

Piles can also be manipulated with bi-manual interaction. Similar to scaling photos one can place two pointers on a pile. Increasing the distance between the two pointers spreads pile items like a deck of cards on the user-drawn path, allowing pile contents to be viewed in parallel. When finished with inspecting the piles content it can be closed by pulling the leftmost and rightmost picture together with two pointers again mimicking a deck of cards' behavior.
Photos inside the open pile can be moved similar to photos on the workspace with one pointer which allows leafing through the pile's content much like flipping through the pages of a book. To further inspect individual pictures they can be dragged out of the pile by moving them to the top or bottom of the opened pile which causes the picture to be re-added to the workspace as an individual picture.

4.3 Presentation

To start a presentation, the user moves a pile to the wall-proxy located at the display edge of the table adjacent to the wall (See Figure 3). Once a pile is present on the wall proxy a slideshow of the pictures contained in that pile starts. The current photo is always shown at full resolution and size on the middle display. To increase orientation and ease navigation in the collection, predecessors and successors of the current picture are shown in decreasing size to the right and left respectively. In addition to initiating the slideshow the proxy serves another functionality. Once activated a jog-dial is displayed on the proxy which affords gestures to control the slideshow. A stroke to the right on the proxy will trigger one forward step, a stroke to the left will trigger one backward step. On the wall the photos are moved and scaled to their new position and scale in an according animation. To finish the presentation, the user removes the pile from the proxy.

4.4 Annotation and Filtering

Up to now we have only described the toolstick as an additional pointing device. However, the toolstick has a second functionality. Once the user turns the toolstick

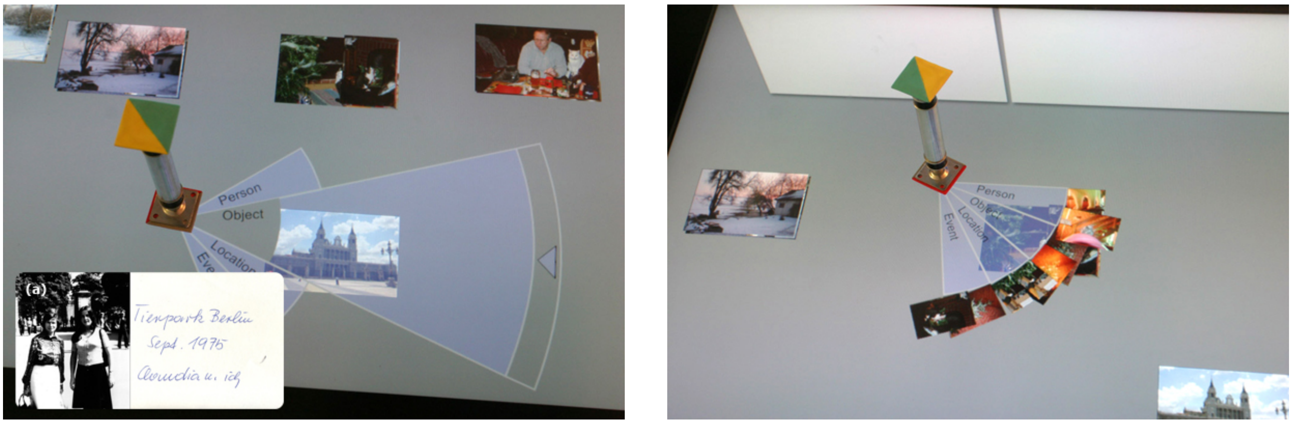

Figure 4: **Left:** Annotating a picture with the Toolglass. The extended region can be used for handwriting of annotations. (a) An old picture with handwriten annotation on the back. **Right:** Filtering the images of one pile. Previews of matching photos are shown on the outskirt of the toolglas; rotating the toolstick flips through the images.

upside down it serves as the physical handle to a hybrid bi-manual user interface to annotate and filter photos. The virtual part of the interface depends on the position and orientation of the toolstick. Furthermore, is the whole interface context sensitive in a way that it provides different functionalities depending on the information that is under the semi-transparent virtual part: annotation for individual pictures and filtering for piles (See Figure 4).

Before the rise of digital photography it was common practice to annotate pictures with additional information (e.g., people depicted and location. See Figure 4 a)) by writing on the back of the picture. In analogy to this in the presented system users can annotate pictures by writing onto them through the toolglas. The virtual extension consists of four segments labeled with “person”, “object”, “location” and “event”. To start the annotation process, the user moves the toolglas over a photo and taps through the desired category-segment onto the photo. Thus the segment is expanded and provides a writing area to the user. Once the user has finished writing an annotation the segment can be closed with a crossing gesture across the segment border (a little arrow in the boundary affords this gesture). Finally a handwriting recognition is started in the background. If the recognition process is successful a label occurs on the photo displaying category information and the tag itself.

Like photos and piles, annotations can be moved around, serving multiple purposes. Annotations can be copied to other pictures by dragging them onto an unlabeled picture, hence a copy of the annotation is added to that photo. Often several pictures have to be annotated with the same label, for example, if they all show the same person. To facilitate this kind of mass annotations one can drag annotations over a pile, which copies the annotation to all photos in the pile. Finally, all annotations are rendered in the vicinity of the picture they are associated with and they are connected through an anchoring line. By crossing out the connection between picture and label the annotation can be deleted.

To facilitate the searching and finding of specific pictures the toolglas can be used to create a filtered view of piles. Whenever the interface is placed above a pile a preview of the contained pictures is shown along the boundary of the virtual extension (See Figure 4 Right). Once this preview is being displayed one can turn the toolstick to flip through the pile and get an enlarged view of the consecutive images. If the user wants to search for a specific photo, once again s/he taps one of the four categories and writes a search term into the writing area. Matching images are again displayed along the boundary of the toolglas. Pictures can be dragged out of the result set to inspect them further. In the future we plan to extend this functionality by presenting a selection of available filters instead of solely relying on handwriting which proved to be cumbersome (See Section 5).

5 Evaluation

To assess our designs we conducted a qualitative user study. Ten participants (2 female 8 male), with a varying range of exposure to interactive surfaces (70% novices 20% experts 10% regular users of tablet PCs) and all of them right-handed, participated in think aloud-sessions and filled out post-study questionaires. Each session consisted of three phases. In the first part the participants received a short introduction to the system. The second phase was a discovery period where participants could explore the system on their own with following instructions on non-discovered functionality. Finally the participants were asked to complete five tasks with a given set of pictures constituted from car-, tree-, and landscape-shots (mostly beach scenery) .

The questions we wanted to answer were how well the interface-free part (i.e., moving, scaling, rotating, presenting and inspecting) of our prototype performs and how well it is perceived by users. As well as how well the hybrid part for annotation and filtering performs and is perceived. Furthermore did we want to elicit on a higher abstraction level whether this kind of interaction style

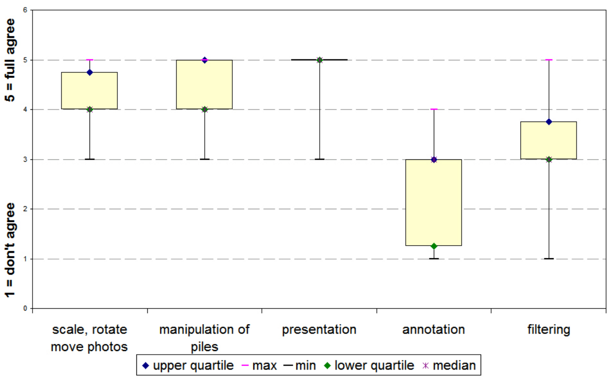

Figure 5: Appreciation of the different functionality groups.

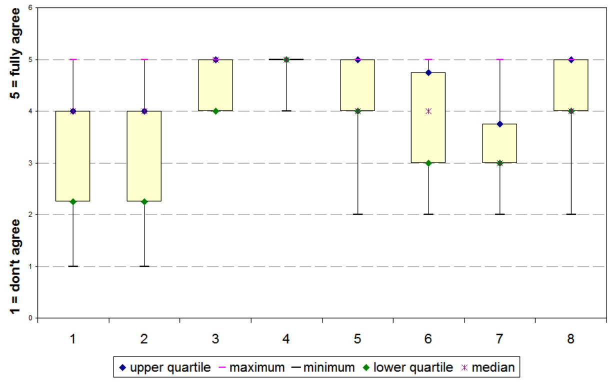

Figure 6: From left to right: *(1) Bi-Manual Interaction is well suited for annotating pictures. (2) The Bi-Manual Interaction is well suited for filtering. (3) Scaling and Rotating is pleasant and easy. (4) Starting and ending slideshows is easy (5) Controlling the slideshow is easy. (6) Copying of annotations eases mass annotation. (7) The two modes of the toolstick are easy to understand. (8) Interacting with photos and piles is fun.*

is appropriate for casual, informal communication and co-located consumption of digital picture collections.

Starting from one pile, containing all pictures, the participants had to create piles for each of the three categories. In the second task all piles had to be annotated, which includes the annotation of a single picture and copying the annotation to a pile. Also the participants where asked to unify the piles into one. In the third task they had to retrieve the pictures from one of the three categories by applying filter(s) to the unified pile. The fourth task was to choose one picture from the pile and to enlarge it on the table surface. Finally, at least four pictures had to be selected, grouped into a new pile and presented at the wall display.

After the participants had completed their tasks (all ten did without mayor problems) they filled out a post-study questionnaire. In order to assess the subjective appraisal of the different system aspects we performed Likert-Tests on three different thematic areas. First, we wanted to know whether the participants liked (or did not like) the different functionalities of the system (e.g., moving, scaling, rotating pictures). The results are encouraging for all aspects but the annotation of pictures. Figure 5 summarizes the participants responses. On average people liked the flexibility to move scale and rotate pictures (4.2/5) also they liked using piles (4.2/5) and the slideshow functionality (4.7/5). The appreciation levels for annotation (2.5/5) and filtering (3.2/5) are decidedly lower which we accredit to hardware difficulties (See Section 6). The comments that we gathered from free form text entries in the questionnaire and additional interviews support this interpretation since most participants said they did like the functionalities *per se* but as one participant put it “the annotation part does not work in a satisfactory way, yet”.

To further assess which conceptual design decisions influenced the perception of the system we asked participants to judge how well they thought certain interactions are suited for the respective task at hand. Figure 6 plots the results to the eight statements which we asked participants to judge on a Likert-Scale. Again the interactions with pictures and piles as well as the control of the slideshow were rated highly (See Figure 6 (3),(4),(5),(8)). For us it was very surprising to learn that participants had difficulties in distinguishing the two roles of the toolstick since its physical appearance was designed after a hourglass which we thought affords the intended functionality. When asked, people explained that they did understand that the toolstick has to be turned upside down to switch functionalities but simply could never remember which side meant what. In the future we plan to change the physical appearance so that both sides are clearly distinguishable and afford their specific usage. The results for the statements regarding bi-manual annotation and filtering were again mixed (3,3/5 for both) in contrast to the good results for the manipulation of pictures and piles, which are also bi-manual. This might at least partially be attributed to the technical problems with occlusion in our pen input, but this remains speculative.

Finally we asked participants to judge whether they would use our system or parts of it at home if it was available for purchase. In analogy to the ratings of the individual functionalities (See Figure 5) participants stated they would use the photo (2.7/3), pile (2.6/3) and presentation (2.8/3) functionalities frequently, but they would use the annotation (1,7/3) and filtering (2/3) functionalities only seldom or never.

6 Discussion

In this paper we have presented our prototype for an interactive living room enabling the browsing, sorting and presentation of digital photo collections in an environment of several interactive, large displays. We have successfully implemented and evaluated the scenario described in Section 2. The feedback from the participants of our study and other users who have tried out the system are very encouraging and suggest that the usage of large interactive surfaces in combination with the presented interaction styles can leverage informal communication and is appropriate for the co-located consumption of media. Users also emphasized that the system was "fun" and "easy" to use. Especially the interactions to modify and inspect piles but also to scale and rotate pictures were greatly appreciated.

However, we did discover several limitations and shortcomings in our prototype. The most severe issue are the difficulties users had with the bi-manual interaction technique to annotate pictures. We modeled this interaction technique after an experiment described in Guiard's [9] work on the asymmetric kinematic chain. In that experiment it was observed how people constantly reposition a sheet of paper with one hand so that the other hand did not have to travel over great distance while writing on the paper. This lead directly to the idea of an area that can be positioned with the non-dominant hand to write on.

Unfortunately did this approach not work out very well in the current implementation due to hardware limitations. The DViT [28] technology which provides interactivity on the table relies on four cameras in the corners of the table. This technology unfortunately is less than ideal for bi-manual interaction, since whenever two input mediators (e.g., finger, pen, toolstick) are present at the same time in the cameras' field of view, occlusions are possible. This is specifically severe when the two pointers are on a trajectory close the bisecting line of one of the cameras' opening angle and/or if the two pointers are very close to each other. To make matters worse, humans are used (when writing on paper) to write on a rather small area in close proximity to the non-dominant hand which positions the paper so the currently written line remains in this area. Hence, users of our system constantly tried to write in an area that was very close to the pointer (controlled by the non-dominant hand) and consequentially very prone to displaced input or complete failure of input.

This made the writing process very cumbersome and forced some users to take several attempts at writing a single word. These problems are resembled in the ratings for the annotation and filtering (which also relies on handwriting) techniques. However, did users differentiate between the technical problems and the concept itself. Several participants of our study stated that they would like to annotate pictures with this technique given the technological problem was solved.

Another problem is related to the scalability of the system. In the current state the system performs smoothly with up to approx. 2000 photos with a resolution of 6 megapixels each. Current photo libraries already excel this number (5000-10000 pictures was the size range named by most users in our evaluation) and with ever decreasing costs for storage of digital information there is no reason why the growth of collection sizes should slow down or stop. With these amounts of pictures the screen real estate also becomes a limited resource and visual clutter can occur. Especially when there are many individual pictures, or many piles containing only a few pictures each, present on the table surface. To solve this issue one could think of applying automatic clustering techniques to narrow down the overall number of items or otherwise think of automatic adaption of visual zooming to minimize currently unused items.

Finally some users expressed their wish for hierarchical organization structures. While the piling metaphor is explicitly non-hierarchical [18] and studies suggest that this characteristic is beneficial [31] there are several possible improvements to the current application of the metaphor. For example could a interaction technique to move several piles at once be very useful. Or otherwise a more explicit way to to mark relations between piles than proximity. So that piles containing pictures from the same vacation, but different locations (e.g., beach, parties, sights) can be linked together both optically and in terms of interaction.

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