ABSTRACT

Image collections are a common interaction pattern for 2D interfaces, however mid-air user interaction with collections has received little attention. We present a controlled experiment (within-groups, n=24) comparing three sets of hand gestures for mid-air browsing and selection in image collections, that were identified out of an elicitation study, using MS Kinect. Each set includes cursor-less gestures for browsing (sideways hand extension, wheel and swipe) and for selection/deselection (hand-up/hand-down). Task success was universal with high accuracy and few errors for all gestures. Sideways extension outperforms swipe and perceived effort for this gesture is significantly lower. Both gestures outperform wheel. We suggest that from a usability perspective, sideways hand extension should be preferred for browsing image galleries, if no other contextual factors apply. Also, the results of the elicitation study, in which most users proposed the swipe gesture for browsing, were not confirmed by the controlled usability experiment. This suggests a combined use of elicitation studies with rigorous usability testing, especially when gestures for particular user interface design patterns are sought.

CSCS Concepts

Human-centered computing → Human computer interaction (HCI) → Interaction techniques → Gestural input.

Keywords

Mid-Air Interaction; Browsing; Selection; Image Collections; Kinect; Gestures; Usability; Elicitation.

1. INTRODUCTION

Image collections (or galleries) are a common user interface (UI) pattern, especially for multi-touch interaction. It is used to display a large number of images, each one pointing to a further description. Typically, image collections contain dozens of items and not all of them are visible at once. User interaction involves browsing the collection and selecting one of the images. Image collections have many variations (e.g. [8]) and are widely used in web sites, mobile apps, interactive TV apps, game consoles, the latest versions of MS Window and in large public displays (a most impressive image collection on a large display is the (multitouch) interactive wall at the Cleveland museum of Art that displays more than 4,000 items [7]). Image collections are a UI pattern that follows the tenets of flat design (web), metro design (MS Windows) and material design (Google, android) languages that provide for user interactions for multiple devices, promote responsiveness, lay out dynamic content (content lists, maps, etc.) and rest heavily on photographs instead of icons ("content for chrome"). Image collections are sometimes an alternative design option to menus, especially when users may want to explore content directly: collections present content directly and usually take up a large portion of the display, while menus present tags about content (usually in hierarchies) and are smaller in size.

Over the last few years, mid-air interaction (kinesthetic control or free space interaction) has been made more feasible with the release of affordable sensors like MS Kinect, Leap Motion and Myo. In this interaction style, users use their whole body to interact with a distant display, while many applications focus on hand movements or gestures. Mid-air interaction is suitable for applications where kinesthetic control is natural like dancing, exercising and types of (physical) gaming. It may also be useful for cases of public distant displays like in museum exhibitions and the TV because it affords for little content occlusion from users' bodies or hands. Indeed there are situations of interaction with distant displays in which touch interaction is unsuitable, for example if people are not able to touch the display surface or are required to stand at a distance.

In contrast to other long-lived interaction styles, there is not an established corpus of mid-air interaction techniques concerning 2D UI patterns like galleries, menus, content lists, maps, etc. These established design patterns are used in the design of 2D interfaces for distant displays. Therefore, the question arises of whether some gestures are more appropriate than others to perform basic manipulation of each of these interaction patterns.

More specifically, in this paper we present a study about mid-air interaction with image collections; in these collections users need to browse, select and deselect items. Image collections are needed for mid-air interactions, especially at the start of user interaction styles, especially at the start of user
sessions for example to browse and select available games, channels or music albums at the TV. The approach is as follows: First, we identified three gesture sets for browsing and selection out of an elicitation study: sideways hand extension, wheel and swipe for browsing, and hand-up / hand-down for selection / deselection (Figure 1). We implemented these (along with a fast-browsing mode) with MS Kinect. Then, we setup a controlled experiment to evaluate their usability. We found that the sideways extension is more usable in terms of both measured and perceived usability. The swipe presents lower but comparable performance to sideways extension, while the wheel is significantly slower and increases perceived effort. We discuss some qualitative remarks and draw on implications for design.

2. RELATED WORK

Earlier studies of mid-air interaction that originated from VR (Virtual Reality) focus on free-hand 3D object manipulations [3]; these lines of research continue up to now, like the ‘handle bar metaphor’ for two-hand 3D manipulations [20]. These works do not involve collections because they are a 2D ‘flat’ UI pattern.

Research on mid-air interaction with 2D design patterns can be grouped into: application studies for specific contexts and groups, elicitation studies of free-hand gestures for application domains or devices and controlled usability studies.

Application studies of mid-air interaction cover a wide range of domains, like the work of [11] on free-hand gameplay with leap motion for stroke rehabilitation, the work of [22] on Kinect-based touchless image control during interventional radiology procedures and the work of [13] on Kinect-based free-hand interaction with distant displays about academic information and events at a university site. These studies present a broad set of mid-air interactions with application content and report broadly on issues of usefulness and appropriateness rather than usability of specific gestures or interaction techniques.

In gesture elicitation studies, participants are shown a system action (the ‘referent’) and asked to propose a gesture to trigger it (the ‘symbol’). An obvious benefit of an elicitation study is that it enables designers to identify a set of non-conflicting gestures for the whole range of interactions with a device or an environment that most people agree upon. The study of [23] investigates a Kinect-based free-hand gesture set for remote TV control and the work of [12] investigates a gesture set for the smart home; here the gestures are applied holding a smartphone. These types of studies are important for identifying intuitive gesture sets but do not test these for usability (in some cases they test for memorability only).

In elicitation studies the concept of legacy bias refers to the phenomenon that “users’ gesture proposals are often biased by their experience with prior interfaces and technologies, particularly the WIMP (windows, icons, menus, and pointing) interfaces that have been standard on traditional PCs for the past two decades” [15]. Legacy bias can be addressed by applying the following techniques (either alone or in combination): producing multiple gestures per action; priming to think about system capabilities; and running group studies. In addition, the concept of ‘performance bias’ can arise in elicitation studies, i.e. “this is when the artificial, time-limited (elicitation) study setting biases participants against considering long-term performance”. Up to now there are not many studies that combine elicitation with usability testing which can rigorously test performance as well as user satisfaction in a way that may address these biases that arise in elicitation studies.

Controlled usability studies of mid-air interactions with 2D elements mainly involve free-hand control of menus, pointing gestures, navigation and manipulation of (large) data displays and collections. According to [17] research on menu selection is under-investigated even in VR (it is a 2D pattern, also) and includes comparative studies like the work in [2] that reports on the Kinect-based use of linear, marking and finger-count menus and the work of [5] who propose a body-centered menu interface and compare it with linear and marking menus (again with Kinect). Work on mid-air pointing gestures includes that of [18] who compare respective bimanual and unimanual gestures with Kinect and [24] who conclude that “if no hint is provided, people successfully use Point+dwell for selecting items” on a distant display. Regarding manipulation of data sets and collections, the work of [16] investigates several gestures for pan and zoom in large displays, the work of [15] proposes a bimanual interaction technique for remote pointing and manipulation of content in tabletops, while in [21] they combine gaze and touchphone gestures to control large image collections. In particular, mid-air interaction with image galleries has not been investigated in related work, although the image gallery is a fairly common and highly applicable design pattern for 2D interfaces.

In this paper we take the case of a cover flow gallery and investigate the usability of particular interaction techniques for browsing and selection in a systematic manner. To identify potentially interesting gestures for users, we did not reside solely on related work or our previous experience; instead we have first conducted a rapid elicitation study for the cover flow gallery that provided us with a limited set of gestures to test. Then we have conducted a controlled experiment to assess their usability.

3. IDENTIFICATION OF GESTURES: ELICITATION STUDY

The elicitation study aimed at the identification of intuitive gestures for interaction with image collections. 24 users participated in this study, all adults, age 25.4 (SD=7.48), ten women, two left-handed (but reported quite capable with the right as well, i.e. ambidextrous), academic staff (students from BSc and MSc, research and teaching staff), half of them had some experience with the Kinect. Exactly half of the users had some experience with the use of the Kinect by having played at least once a Kinect game, however no-one had extensive player experience with it (e.g. no-one owned a Kinect sensor at home). The same users participated in the controlled usability experiment, a couple of months later.

This was a ‘wizard-of-Oz’ study, in which users were presented with the system UI and were asked to think about, propose and apply up gestures in the mid-air in order to (a) browse the collection and (b) select a particular item. The system responses were handled by a researcher with the mouse and arrow keys. Each user was asked to provide at least three (3) gesture sets. All sessions were video recorded. Users were encouraged to talk during the elicitation and describe their gesture proposals. They were asked to replay each gesture a few times in order to reflect on it, explain their idea in their own words and possibly refer to other systems or previous experience.

To address the issue of legacy bias, we followed two out of three techniques suggested in [15]. We asked users to provide multiple gesture proposals for each referent in order to enable them to move beyond what came first to mind, i.e. to provide proposals with some reflection. During the elicitation process we also made use of the priming technique, i.e. we asked users to think about
the capabilities of the sensing technology by explaining to them briefly how the Kinect sensor works and how their skeleton is recognized. Users could also see their skeleton (i.e. a live drawing of connected joints recognized by the Kinect sensor) during interaction in a small window above the cover flow gallery.

The elicitation study produced several gestures for browsing and selection in the image collection (Table 1). For browsing, six unique gestures were identified from all 24 users, with a total of 48 proposals. Almost all users proposed the swipe gesture (22/24 users), while about half of them (10/24) proposed the sideways hand extension. For selection there were four unique gesture proposals from all 24 users in a total of 38 proposals.

We further reduced this set by leaving out the gestures that required the use of a cursor (point to swipe, push or point to select, thumbs up/down). The cursor is critical for the desktop UI paradigm but comes with a legacy that may not be pertinent for some mid-air interactions. For example, in mid-air interaction the cursor creates inevitable interaction delays; for example the hand travels for some time in ‘push to select’, while a delay time is required for selection with the ‘hover button’ gesture which is typically about half a second. Some highly intuitive, fast mid-air interactions may not require a cursor, like for example the menu selection at the dance central game user interface [6]. We also left out gestures that used fingers like the thumb or the pointer for reasons of technical implementation: we relied on version 1.8 of the SDK which does not recognize a point (joint) for any finger.

Table 1. Results of the Elicitation Study.

<table>
<thead>
<tr>
<th>Gestures</th>
<th>Explanation</th>
<th>Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Swipe</td>
<td>The palm of the hand is moved to the left/right from the wrist.</td>
<td>22/24</td>
</tr>
<tr>
<td>2. Sideways Hand Extension</td>
<td>The left or right hand is lifted sideways from the body.</td>
<td>10/24</td>
</tr>
<tr>
<td>3. Point to Swipe</td>
<td>The pointer finger points to the left or right of the display.</td>
<td>8/24</td>
</tr>
<tr>
<td>4. Wheel (by hands)</td>
<td>A wheel gesture is exercised with the use of hand palm and elbow around the arm.</td>
<td>2/24</td>
</tr>
<tr>
<td>5. Sideways Leg Extension</td>
<td>The left or right leg is lifted sideways from the body.</td>
<td>2/24</td>
</tr>
<tr>
<td>6. Turn Body Right/Left</td>
<td>The upper body is turned right/left.</td>
<td>2/24</td>
</tr>
</tbody>
</table>

Therefore, we have selected the following three (3) free-hand gesture sets for mid-air browsing and selection/deselection (Table 1): (a) hand sideways extension & (respective) hand up/down, (b) wheel & hand-down/up, (c) swipe & hand-down/up. For selection, the direction to select (up or down) depends on the previous navigation gesture, i.e. from the current hand position. These gestures were the most preferable for users after leaving out those that require a cursor or the use of a finger.

This elicitation study is not exhaustive since we are not investigating gestures for a large number of operations of a large-scale application or a device (like for example the use of the TV-set [23]); our level of analysis is the specific user interface design pattern of the cover flow gallery. The study served as a validation method for our initial design ideas, therefore we did not explore further formal analysis of the elicited gestures (like for example in [18]). Instead, we proceeded with an implementation of these gestures on a prototype system in order to provide an analytical and comparative usability evaluation.

For each gesture used for browsing, we also implemented a ‘fast browsing mode’, when users applied the gesture and hold their hand still, e.g. ‘swipe-left and hold’. This was a design decision that arose from the elicitation study: although we had not originally investigated a ‘fast forward’ mode, several users reported spontaneously that they would like to have this option.

4. USABILITY TEST

4.1 System and Apparatus

The apparatus consisted of a typical computer running a Windows 7 operating system, a Kinect sensor v1.8 and a 42” screen display, 1920x1080 (FHD). A camera was placed behind the user to monitor the users’ gestures and at the same time to capture the interaction with the image collection (Figure 2).

Figure 2. A user interacting with mid-air gestures with the cover flow gallery during the test.

We have developed a gesture recognition engine for MS Kinect and programmed the required gestures. The engine was written in C# and implements an algorithmic recognition of gestures, based on temporal and spatial relationships among selected joints of the human skeleton as identified by the Kinect SDK 1.8 skeleton API. The gesture recognition engine was integrated with an image collection (cover flow gallery, Figure 2) that consisted of 40 images (band covers, five for each band) in band name alphabetical order. The UI also included visual feedback of the user’s skeleton. When an image was selected a new window popped up with respective information.

4.2 Procedure

The within-groups design required from participants (n=24) to perform four tasks with each gesture set in counterbalanced order (regarding the gesture sets) following a Latin square. We did not ask users to carry out particularly difficult manipulations. All tasks were rather easy to perform, which was intentional by
design because we focused on user performance and workload rather than success, therefore. The tasks were:

1. Go to cover no 5; (all users started from cover no. 1); select it; deselect it; move back to the beginning.
2. Go to any cover of the band Metallica; select it; deselect it; move to the end of the collection.
3. Go to the cover of Nirvana with title ‘Smells like Teen Spirit’; select it; deselect it;
4. Move to the cover with title ‘Aerials’ by System of a Down; select it; deselect it; move at the beginning to finish.

The test process involved the following steps:

1. Welcome: participants were introduced to the aims and content of the test.
2. Demonstration: on how to perform the first gesture set for this user (counterbalanced). The researcher demonstrated the gesture and performed some browsing and selection.
3. Familiarization: participants were allowed some time, at their disposal, to get familiar with the gestures by applying them without a task at hand. This familiarization time was video-recorded and measured for each gesture.
4. Task performance: after the participant reported she was ready to begin, she was asked to perform the first task. Task execution was video recorded.
5. Post-task questionnaire: after completion of all four tasks for a gesture set, participants filled in the NASA-TLX questionnaire [9] that measures mental and physical effort.
6. Steps 2-5 were repeated for each gesture set.
7. Post-test questionnaire: at the end of all tasks for all gesture sets, participants filled in a self-developed post-test questionnaire to provide their retrospective view on perceived usability.

All user tests were video-captured by a camera that was located behind the participants to capture the gestures and system responses (actually behind-right not to occlude gesture performance). Four videos for each participant were produced, one for familiarization time and three for each gesture set, i.e. a total of 96 videos were analyzed retrospectively, ranging from two to five minutes each. The videos of familiarization time were used to record gestures identified as well as to perform some analysis on how users performed each gesture (e.g. duration, amplitude). The videos of task performance were analyzed on task success, speed, accuracy and errors.

5. RESULTS

5.1 Familiarization Time
The familiarization time (FT) was measured for all gesture sets with retrospective video analysis. Users required less time to familiarize themselves with sideways extension (average FT=46.08 sec, SD=17.31), much more time for swipe (av. FT=51.13, SD=46.40) and even more for wheel (av. FT=88.58, SD=48.46). The repeated measures ANOVA test showed a significant difference in familiarization time (F(3,12 = 7.72, p < 0.05). The pairwise comparison among each pair of gesture sets was conducted with a post-hoc Tukey’s test and showed a significant difference for all pairs (Table 3).

5.2 Task Success
Task success was universal: all users succeeded in every task. Sooner or later, all users adopted “fast browsing mode” to navigate through the image gallery.

5.3 Accuracy and Errors
Accuracy was calculated as the ratio of the minimum user gestures required for all tasks divided by all user moves made including error moves. Error moves were of three types: false negatives (unsuccessful attempts to perform a gesture), false positives (system activation by accident, i.e. the ‘Midas touch’) and back (unnecessary) steps. For example the first task required from the user to browse the gallery until the fifth record (starting from record no.1) then to select and deselect it and then to get back on record no.1. This required ten user moves and four (types of) gestures in total (navigate right, select, deselect and navigate left). Any more user moves or accidental system responses were regarded as errors.

The number of errors was low with regard to the total number of moves required to complete all tasks, which was 109 moves x 24 users (2,616 moves). Table 2 shows the error moves made for all users and tasks. Resulting accuracy was very high for all gesture sets: wheel =98.72%, swipe = 98.38%, sideways extension = 98.31%. The wheel gesture was slightly more accurate than the other two.

Table 2. Types of errors, for all users and tasks.

<table>
<thead>
<tr>
<th></th>
<th>Sideways</th>
<th>Wheel</th>
<th>Swipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>False negatives</td>
<td>2</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>False positives</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Back steps</td>
<td>40</td>
<td>19</td>
<td>37</td>
</tr>
</tbody>
</table>

Table 3. Post-hoc pairwise comparisons according to Tukey’s test of gesture sets on familiarization time, speed and effort.

<table>
<thead>
<tr>
<th>Tukey’s Test(s)</th>
<th>Family Conf. Int.=95%, Individual Conf. Int.=98.07%, q(a,f,p)=3.3891</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comparisons</td>
<td>Diff. Means</td>
</tr>
<tr>
<td>Familiarization time</td>
<td></td>
</tr>
<tr>
<td>Sideways - Wheel</td>
<td>-42.50</td>
</tr>
<tr>
<td>Sideways - Swipe</td>
<td>-35.04</td>
</tr>
<tr>
<td>Wheel - Swipe</td>
<td>7.46</td>
</tr>
<tr>
<td>Time to task (speed, for all tasks)</td>
<td></td>
</tr>
<tr>
<td>Sideways - Wheel</td>
<td>-49.92</td>
</tr>
<tr>
<td>Sideways - Swipe</td>
<td>-11.29</td>
</tr>
<tr>
<td>Wheel - Swipe</td>
<td>38.63</td>
</tr>
</tbody>
</table>

5.4 Speed (Task Time)
Task time differed among gesture sets (Figure 3). The sideways extension was faster than wheel for all tasks and also faster than
swipe in three out of four tasks. The wheel gesture set was slower than the other two for all tasks, but the first. The repeated measures ANOVA test showed a significant effect ($F_{3.02} = 37.51$, $p < 0.05$) when all three gestures were considered. No significant effect between sideways extension and swipe was observed according to the post-hoc Tukey’s test (Table 3). We did not observe significant differences in performance between experienced and novice users. This can be attributed to that experienced users still have sporadic experiences with mid-air interaction.

Figure 3. Average time to task (speed) for each gesture set (error bars for 95% confidence interval).

Figure 4. Mental and physical effort for each gesture set according to the NASA-TLX questionnaire (perceived workload is rated in a 20-point Likert scale).

5.5 Mental and Physical Effort
Perceived mental and physical effort was assessed with the NASA-TLX questionnaire (Figure 4, please note that value 20 is the maximum value for perceived workload according to the NASA-TLX scale). Users reported that the sideways extension required less effort for all questions. The ANOVA test showed a significant effect ($F_{3.87} = 34.10$, $p < 0.05$). The pairwise comparison among each pair of gesture sets was conducted with a post-hoc Tukey’s test and showed a significant difference for all pairs (Table 3).

5.6 Perceived Usability
Perceived usability was assessed with a self-developed post-test questionnaire containing four five-point Likert scale statements for each gesture set: easy to apply, easy to learn, appropriate for the specific gallery, credible. We present user responses in Top-2, Neutral and Bottom-2 boxes. We present user responses in terms of grouping their answers in Top-2 (Strongly Agree, Agree), Neutral and Bottom-2 boxes [1]. For all questions, users perceive the sideways extension set as more usable in comparison to swipe which is in turn consistently perceived more usable than the wheel gesture set.

Figure 5. Perceived usability of each gesture set.

6. DISCUSSION
6.1 Comparative usability of investigated gestures
The sideways extension gesture is faster, requires less effort and it is perceived more usable when navigating in image collections. Users need only to move their arm to apply this gesture and not their elbows or wrists. However, it requires extra space around the user, which might not be desirable in some contexts of use. Some users reported that performance for this gesture would be improved, if the extension of the hand would control the velocity of the image browsing.

The swipe gesture was second in usability for almost all aspects examined. Regarding speed it was close to sideways extension, however users reported that it required considerably more effort. Perceived usability was also lower. Some users were confused with swipe-left and swipe-right but this was resolved over time.
Others would like to use either one of their hands to swipe (we implemented the gesture for the right hand only).

The wheel gesture was third in usability. It was slower, especially when navigating to a large number of images. Users reported increased fatigue because they need to move their elbow and wrist, while some also tended to use their shoulder as well. Some users also reported confusion with wheel-right, wheel-left. Notably, wheel was the gesture with the least errors, because users had better browsing control.

6.2 Comparison with prior work and the findings of our elicitation study

These results are interesting in terms of prior work, which suggests that a user-defined gesture set is rated as easier to perform, easier to remember, and a better match for its intended use [14]. In our elicitation study we found a strong user preference for the swipe gesture for browsing, however this was not validated by the usability test, which showed that users perform better and perceive the sideways hand extension gesture as more usable. This result is also interesting given the effect of gesture bias; however, we indeed limited this phenomenon during this research.

This result is interesting if we also consider that the cover flow gallery requires horizontal browsing, in which we found that it is easier for users to extend their hands sideways than perform swipe gestures. This result is different with respect to findings about vertical menu browsing and selection, where a (vertical) swipe-based gesture set is better, e.g. in [6] a vertical swipe is applied to navigate the menu with a hand move inwards to select.

6.3 On the combined use of elicitation study with controlled usability testing

We have made a combined use of an elicitation study as a method that contributes to designer awareness and may enrich insights or ideas with a rigorous usability test of most pertinent gestures. We have made an uncommon use of the elicitation study method because it concerned a particular user interface pattern (image collection) rather than a wider context like the use of interactive TVs [23] or several manipulations in smart homes [12].

For usability testing to be combined with elicitation studies, the gesture set to be tested needs to be small for practical reasons of user recruiting and data analysis. A large number of gestures would create methodological issues in the controlled usability test. In particular, a greater learning effect would appear that would require a methodological change if particular user groups, like older people and children can be considered. Future tests can include objective measurements of fatigue as well as other aspects of the user experience; the latter, if tests are carried out in the field.

6.4 Limitations of the study

We have used a subjective measure of workload (NAS-TLX), however there is recent work on objective measures of fatigue in mid-air interaction like the consumed endurance [10] or ‘distance measured by hands’ [5], which require additional coding. We plan to extend our gesture recognition library so that it calculates hand distances.

Another limitation is of a technical nature. Kinect skeleton tracking (v.1.8) provides joints (points) for hand, wrist, elbow and arm, so it is not possible to directly use other joints; however the latest v.2.0 of the sensor and software has added points for hand tip and thumb. This allows for implementing finger gestures in principle, however tracking finger movements or gestures with Kinect is yet not very reliable in version 2.0.

Also, we have followed an algorithmic implementation of gestures, which is not very flexible in comparison to machine learning and neural network approaches which however require a more in-depth approach in programming [25].

Last but not least, the prototype supported a swipe gesture for application with the right-hand, and this is why right-handed users (as well as two ambidextrous) participated in the study.

7. CONCLUSIONS

In this paper we presented a comparative study evaluating three different gesture sets for mid-air browsing and selection in image collections. We found that the sideways extension gesture is more usable than both the swipe gesture that is generally used, as well as a wheel gesture. We also found that all gestures had high accuracy and low error rates and that the users liked the fast forward gestures.

More specifically, the results of this study have the following implications for interaction design of cover flow galleries:

1. All gestures examined have high accuracy and few errors.
2. If no other contextual factors apply, browsing image collections is more usable with the sideways extension gesture than swipe or wheel.
3. The swipe gesture is consistently more usable than wheel, which causes more fatigue.
4. Fast forward browsing can be achieved by applying a gesture and hold; this function is preferred by users.
5. The swipe and wheel gestures may generate confusion between right and left navigation, which does not apply for sideways extension.
6. Cursor-less selection and deselection of images in collections are fast, intuitive and error-free.

At a wider context, this work contributes to the application of elicitation studies to the design of a gesture set for mid-air browsing and selection in an image collection. Despite the value of elicitation studies for identifying intuitive gestures for mid-air interaction, they should not be used alone to determine the appropriateness of a gesture. We presented a controlled experiment designed to compare the efficiency and adequacy of three gesture sets for the task of browsing image collections; to our knowledge there is not another systematic investigation of this sort up to now.

Future work includes experimentation with other types of image collections and gesture sets. Also, particular contexts of use or applications can be examined in a field setting. Furthermore, the investigation of usability with regard to particular user groups, like older people and children can be considered. Future tests can also include objective measurements of fatigue as well as other aspects of the user experience; the latter, if tests are carried out in the field.

8. REFERENCES


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