Evaluation of Picture Browsing using a Projector Phone

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ABSTRACT
It is expected that projector phones (mobile phones with an integrated pico projector) will hit the market in the next few years. So far no research exists regarding how mobile applications should be designed when using a projection and which applications will profit from such a large high-resolution display. This paper presents a comparative evaluation of picture browsing using projector phones. In a study we compared three different interaction techniques: phone display only, projection only and a combination of both. The results show that users prefer the projection-based interaction techniques and the large high-resolution projection leads to a reduced number of enlarge interactions. However, the task completion time results illustrate how familiar users are in using conventional phones with small screen size. The paper presents a comprehensive discussion of findings from our study and defines important guidelines which we consider as critical for the success of applications for projector phones in the future.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Input devices and strategies; Prototyping.*

General Terms
Measurement, Design, Experimentation, Human Factors.

Keywords
Projector phone, photo browsing, interaction design.

1. INTRODUCTION
We currently see huge industry interest in handheld projectors (classified as accessory projectors [1], a small battery powered projector that can be connected to mobile devices) and projector phones (mobile phones with an integrated pico projector), which allow projection of high-resolution information anytime, anywhere and potentially any size solving the burden of the small mobile phone screen. Texas Instruments [2], Microvision in cooperation with Motorola [3] and 3M [4] are some who are currently working on small projectors and their integration into mobile devices. It is expected that consumers shall see these devices emerge in the market place as soon as 2010 if not before [3].

University of Toronto and Mitsubishi Electronic Labs conducted pioneering work on the usage of handheld projectors [5-7]. This corresponding research lead to results regarding the projection of information on non-planar surfaces [5], the interaction with information displayed by a handheld projector [6] and the implementation of single and multi-user application scenarios [7].

This paper presents an experimental comparison of picture browsing on mobile phones using three different interaction techniques: phone display only; projection only and a combination of the phone display and projection. The keypad and joystick of the mobile phone were used for user input in all three interaction techniques. Through this we explored the following two research questions. What are the advantages and disadvantages of using projection when compared to the mobile phone screen? Whether and when should both displays, projection and mobile phone screen, be used in parallel or not?

Participants performed three different tasks which involved finding photos of three specific types, single (e.g., *Find the picture of a post box!*), event (e.g. *Find all pictures of a Water Polo game!)* and property (e.g. *Find all pictures of boats!*) as defined in [8]. We selected photo browsing as it is a very common task that requires many searching, zooming and panning operations to find the right photo and to see a photo in great detail when using a mobile phone. This leads to a relatively high task completion time, high mental demand and frustration level on behalf of the user. Because of this, many research projects have previously worked on optimizing the visualization and interaction with large picture sets on mobile phones [8, 9].

The results of the study show the advantages of using a projector phone when compared to a conventional phone when considering the number of task related user interactions, preferences of users and qualitative feedback. However, the task completion time results clearly show that people are very fast when browsing photos on their phones. We provide strong evidence which shows that mobile applications for projector phones have to be designed in a very careful way. Based on the experiences we gathered from this user study, we have defined guidelines that should be considered when designing applications for projector phones.

2. PROTOTYPE
A photo-browsing prototype was implemented in order to compare the three interaction techniques. Participants navigated through the pictures using the joystick and were able to enlarge pictures in order to see them in greater detail. The default layout of images for the three interaction techniques was a grid 3 x 5 (Figure 1a) in a thumbnail fashion.

Phone display only
A Nokia N95 was used which has a display resolution of 240 x 320 pixels (4 x 5.3 cm), an aspect ratio of 3:4 and portrait format. The mobile phone application was implemented in Java ME (MIDP 2.0, CLDC 1.1).

MobileHCI 2008, September 2–5, 2008, Amsterdam, the Netherlands.

Projection only
Figure 1b and 1c illustrate the experimental setup; the N95 was physically attached to a battery-powered projector (Samsung SP-P310ME) hanging from a frame using elastic and projected an image with a resolution of 606 x 768 pixel (portrait format, 76 x 60 cm, distance to wall 200 cm). This setup was chosen in order to simulate a projector phone, as these devices are not yet available. The setup intended to represent actual use in a realistic setting where the user would typically be unable to hold the mobile phone completely steady. The mobile screen displayed was not used and displayed a black rectangle.

Mobile phone display and projections
Both the mobile phone and the projector were used to display the photos. Input capabilities were provided by the mobile phone as with the two previous techniques.

Figure 1. (a) Thumbnail layout mobile phone only (b) Nokia N95 attached to the projector (c) projection only

Table 1 illustrates the information showed by each display.

Table 1. Usage of the projection and mobile phone display

	Mobile phone display only	Projection only	Phone display and projection
Mobile phone display shows	Thumbnail and enlarged picture	N.A.	Thumbnail
Projection shows	N.A.	Thumbnail and enlarged picture	Enlarged picture of selected image

3. USER STUDY

The experiment used a repeated measure within participant factorial design 3 x 3. The independent variables were *interaction technique* with three levels (*phone display only*, *projection only and phone display & projection)* and *Task Type*. Task types were representative of typical photo browsing viewing characteristics with three levels, *Single* (searching for an individual photo containing a specific unique feature e.g., "Find the picture of a post box"), *Event (*searching for all photos of a particular event, implying that they were taken at the same time e.g., "Find all pictures of a Water Polo game"*)* and *Property (*searching for all photos taken at different events but sharing the same property e.g., "Find all pictures of boats"*)* as defined in [8].

14 paid participants mainly students, 9 males and 5 females took part in the experiment. The participants were aged between 13 and 33 with a mean of 26.6. All participants owned a mobile phone, 13 of them were camera phones. 12 participants had prior experience with photo browsing software on mobile phones.

The following hypotheses were predicted:

- **(H1)** The projection only interaction technique has the lowest task completion time.
- **(H2)** The combination of phone and projector will result in a higher number of context switches and will be the least preferred interaction technique.
- **(H3)** Using the phone display only interaction technique will result in a significantly higher enlarge count.

The dependant measures were task completion time, error count, enlarge count and number of context switches. Task completion time was the elapsed time between the user starting and stopping each task. Errors were counted when the user wrongly selected a photo. The enlarge count was the total number of photos enlarged per interaction technique.

Participants took part in the experiment individually, at the beginning they completed a short training phase using each of the three interaction techniques once. Prior to starting the task the description of the photo(s) the participant had to find was read to them.

For each interaction technique, the event and property tasks were repeated three times and the single task 10 times. This resulted in a total of 48 trials (3 interaction techniques x [3 event + 3 property + 10 single tasks]) per participant. Participants were made aware that the task completion time and error rate would be recorded and as a result they were told to complete the tasks as quickly as possible and were not made aware of how many photos to find in the event and property tasks. The order of the interaction techniques presented to each participant and the photo set associated with each technique were counter-balanced to prevent strict association between techniques and photo sets. Task order was also counterbalanced.

Three unique sets of pictures each containing 50 photographs (15 event, 15 property, 10 single and 10 random) were used. The photos were collected using the N95 camera, pictures obtained whilst at university, for example a Water Polo game and pictures taken by friends on their holidays.

Following the completion of each interaction technique, participants completed a post task subjective questionnaire. Following the completion of the experiment participants completed a post experiment interview; participants had to specifically rank the three interaction techniques in their order of preference and which one they believed to be the fastest.

4. STUDY RESULTS

4.1 Quantitative Results

Task Completion Time
Figure 2a shows the mean task completion time. One can see that there is almost no difference between the phone only (single M {mean in seconds} = 14.4, SE {standard error in seconds} = 1.6; property M = 34.4, SE = 0.93; and event M = 34.1 SE = 1.3 seconds) and projection only interaction technique (single M = 15.1, SE = 1.6; property M = 36.6, SE = 1.8; and event M = 35.8, SE = 1.3) however, the phone only interaction technique results in the fastest task completion time and thus H1 is proven to be false. A conclusive reason for this with subjective evidence also in favour is the familiarity of interacting with the mobile phone. The task completion time for the combination of phone display and projection for all three tasks is higher when compared to the other two interaction techniques (single M = 20.7, SE 2.3; property M = 40.1, SE = 1.26; and event M = 41.5, SE = 1.30) and thus proves H2 to be true.

Enlarge Count
We would assume a direct relationship between enlargement count (Figure 2b) and task completion time. We would expect that the fewer enlarge operations as in the case for the projection interactions would result in a faster task completion time. However, this is not the case. Familiarity and confidence of using the mobile phone could possible explain the lack of a relationship. The results in Figure 2b significantly prove H3 to be true.

Error Count
The error count is negligible (M = 0.10) for all interaction techniques when considering the mean values for all three tasks per technique. This can be easily explained. The majority of errors were a result of participants accidently pressing the wrong button, this was more so when using the projection interaction techniques.

Context Switches
A context switch is defined as and occurs when the user switches from one display to the other. The projector only technique resulted in a total number of 1161 (45%) context switches. The high number can be explained by the user simply looking at the phone for the correct key press, confirmed by video footage. The phone projection combination resulted in a total number of 1402 (55%) context switches and thus proves H2 to be true. The higher number can be expected when considering the user had two displays to look at and also looked at the mobile phone to ensure the correct button press. Visualizing the key pres information in the projection could significantly reduce the number of context switches in both cases.

User Preferences
As depicted in Figure 2c, 9 participants (64%) preferred the projection based techniques compared to 5 (36%) who preferred the phone display only version. When comparing interaction speed, 7 participants (50%) agreed the projector based interaction techniques were the fastest. The relative high preference and speed results for the phone display only version can again be expected when considering how familiar users are with the mobile phone especially for the common task of photo browsing.

4.2 Qualitative Results

Phone display only
Participants expressed relatively few positive comments when using the phone display only version. In general participants appreciated the familiarity of interacting with the mobile phone, they commented that it felt more intuitive and comfortable to use. This can be expected considering participants use the mobile phone on a daily basis. Some participants also felt that the interaction was faster for two distinct reasons; familiarity, and only one device to focus on when compared to the phone display and projection combination. The majority of participants commented that the screen size and resolution were too small.

Projection only
The concept of using a projector phone to browse photos was greatly appreciated by all participants. The majority of participants described the interaction as fun, intuitive and straightforward to use. They found that it was easier to find photos as they were bigger when projected and found they had to perform less frequent enlarge operations. A couple of participants found the interaction a little difficult and confusing to use. They found themselves frequently looking down at the phone although nothing was displayed on the screen to physically check the navigation, selection and enlarge buttons they were actually pressing. As a result participants commented that they thought it took longer to complete the tasks. However, participants agreed that with further practice this issue would probably be resolved.

Phone display and projection
Similarly to the projection only interaction participants found the photos easier to find when projected due to the larger images. Some participants appreciated the use of two displays and found the ability to have a permanently projected enlarged image and a thumbnail view on the mobile phone highly beneficial. After observing participants, it was quite common that participants specifically viewed the thumbnail images for the most time and viewed the projected image for clarification. Others did not appreciate having two displays and commented how difficult, frustrating and slow the constant switching was, with a general dislike and difficulty. Video analysis confirmed that for the majority participants solely concentrated just on one of the displays as if they forgot two were available. A couple of participants complained of neck ache and motion sickness as a result of continually looking up and down rapidly. These negative subjective comments provide strong evidence in favour of H2.

5. DISCUSSION AND FINDINGS

Relationship of quantitative and qualitative results
Figure 2a does not support H1; however the qualitative data provides strong evidence in favour of projector phones. Although participants were informed to complete each task as fast as possible, it was interesting to observe that participants seemed to browse the photos in generally in a relaxed manor. This can be seen as normal behaviour, generally when we browse photos we take our time to look at the photo without the pressure of being rushed. Furthermore it was also interesting that participants favoured greater task completion time over error count and

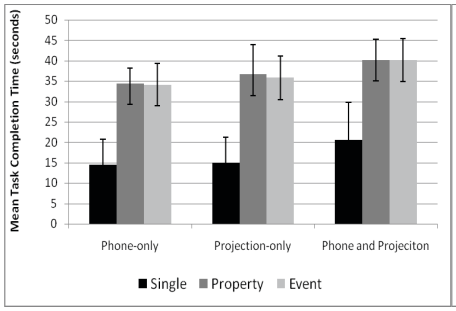

Figure 2a. Mean task completion

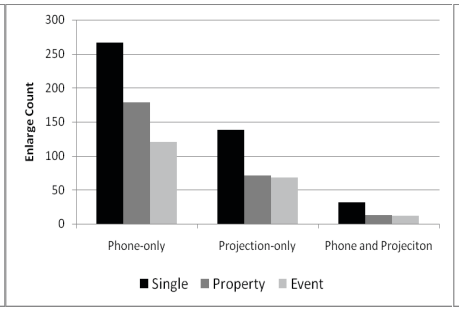

Figure 2b. Enlarge count

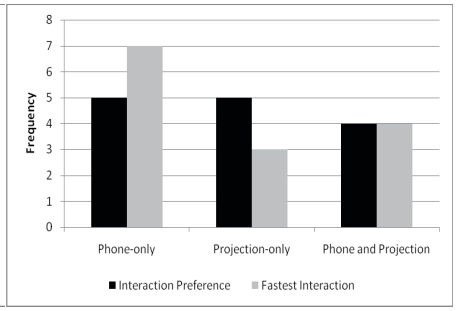

Figure 2c. User preferences regarding preferred and fastest interaction

typically spent the extra time checking for the correct photo and button press before making their selection. This explains the practically zero error count for all interactions methods.

Higher resolution and display size
Figure 2b and the qualitative results positively show that a higher resolution and display size clearly reduces the number of enlarge operations required and increase user satisfaction providing positive feedback for projector phones. The results in Figure 2b clearly prove H3 to be true. Several participants perceived the issue of the projector moving as a slight annoyance making it difficult to browse photos.

Applications
Participants suggested several applications that would benefit from embedded projectors in mobile phones this included: map browsing, video playing, multi player games, advertisements and presentations. Group based scenarios, especially media browsing would highly benefit from mobile projection when considering the current highly undesirable method which involves a group of people all trying to look at a photo on such a small screen or alternatively passing the phone from person to person.

Privacy
Participants were asked whether they would have any issues that would make them feel reluctant in using a projector phone in a public place. All participants commented that in the general application case it would depend on the context and content of the projected media relative to the environment and who was in the environment. The ability to easily project any type of content anywhere does have the potential for abuse of many natures, and may make others in the near vicinity feel very uncomfortable. It may be the case that with the adoption of projector phones we see visual pollution to an undesirable extent [10].

Other issues to consider
The affects that the projector imposes on battery power, the brightness of the projector and the ability to quickly and easily find a projection surface were other issues that participants commented on that need to be considered. The way in which people hold and interact with the mobile phone in relation to the position of the project also needs to be considered, for example will the projector be mounted in the same position and orientation as the camera and thus allow for dual interaction techniques.

6. CONCLUSION

The qualitative results, the ranking of interaction techniques and the enlargement count are in favour of the projection based interaction techniques. But when considering the task completion time one can see that the phone display only version was the fastest. The most important reason for this is that participants are used to photo browsing on the phone and in general used to interacting with the phone whilst looking at it, as a result performed not that well with the projection based interaction techniques. After analysing the study results we define the following guidelines to be considered by other researchers.

- The projection should explicitly show the current context (e.g. currently selected photo) of the application as when a context switch occurs the user may have forgotten on what she focused beforehand. The use of a flashing widget to attract the users and observers attention is one solution.
- The projection should provide additional information about the key assignments in order to reduce the number of context switches between phone display and projection.
- The key assignments should be as simple as possible to allow the user to focus on the projected display while interacting using the phone.
- The use of haptic feedback should be considered to inform the user when it is necessary to look at the phone screen.
- The mobile phone screen should be used to display private information that the user may feel reluctant in projecting.
- The application should be designed in a way that requires the minimal number of context switches between the phone screen and the projection.

In our future work with projector phones we aim to develop a rich set of novel interaction techniques focusing on multi user collaborative scenarios utilising more than one projector phone. The projection of media content we believe is highly desired using a projector phone. We aim to develop an intuitive collaborative sharing gesture to quickly and easily share media content. It is apparent that issues of privacy need to be addressed and also further longitudinal studies using projector phones need to be conducted.

ACKNOWLEDGEMENT

This work is supported by the NoE INTERMEDIA funded by the European Commission (NoE 038419).

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