An Explorative Comparison of Magic Lens and Personal Projection for Interacting with Smart Objects

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ABSTRACT

One shortcoming of self-describing smart objects augmented with digital resources is the limitation of output modalities due to their long established physical appearances. To overcome this drawback intangible representations e.g., sound, video projection etc. are usually coupled with the tangible representations of smart objects that enable access and interaction with their value added features. In this paper, we explore two mobile interaction techniques that associate such intangible representation to smart objects using a pico projector augmented camera phone. The first technique utilizes a *Magic Lens* metaphor applying mobile augmented reality (contextual information is overlaid while looking at a smart object through camera) to uncover and interact with smart objects. The second technique, *Personal Projection* follows similar mechanisms in discovery and interaction, except information is projected onto the nearest surface. We report the implementation of these two techniques and a comparative qualitative study with three prototype smart object applications. The findings give us deeper insights on the positive and negative aspects of these two techniques and open up a range of stimulating research issues that we discuss in the paper.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Interaction styles; Prototyping.*

General Terms

Design, Experimentation, Human Factors.

Keywords

Mobile Interaction, Smart Object, Projected Interface.

1. INTRODUCTION

Pervasive computing is reshaping our physical space by embedding intelligence and digital resources into its fabric and transforming it into an interconnected and constantly aware information space. Our physical environment now hosts increasingly number of self-describing physical objects augmented with digital resources that enable them to provide rich information services [4]. However, due to their long established physical appearances, output dynamics of these smart physical objects are limited to certain modalities, e.g., tactile feedback, etc. and most objects do not provide an informed visual output. In addition, it is difficult to dynamically change the shape, color and form-factor of the tangible representation of these objects due to current technological constrains. As a consequence, it is hard to comprehend the digital resources offered by these objects and subsequently access and interact with them. To overcome this shortcoming, articulated intangible representations, e.g., sound cue, tactile feedback, video projection, etc. are generally coupled with smart objects to expose their smart services enabling us to access and interact with their information services [3,5]. In this paper, we have addressed this particular issue of associating intangible representation to smart objects to foster user interaction from a mobile device perspective. We present two mobile interaction techniques using projector augmented camera phone that enable us to browse, discover, interact, and control physical objects to realize personalized behavior within and across smart objects. In both cases, the mobile device acts as a remote interface for the smart objects' services.

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The first technique, *Magic Lens* (we have adopted the term from the see-through interfaces presented in [1]) transforms a camera phone into a real world browser by applying mobile augmented reality approach, i.e., contextual information and further service access mechanisms are overlaid into a mobile phone screen while hovering across the physical space with the phone camera (Figure 1(a)). Smart objects are labeled with a 2D barcode in addition to their smart services that acts as the cue for the *Magic Lens* to recognize them. Once discovered, users can further interact with the smart objects through the phone screen to access its services. The second technique, *Personal Projection* extrapolates the first technique by exposing the user interface screen to a larger nearby surface through a pico projector attached to the phone while switching off the phone screen and using it as a touch input device. (Figure 1(b)) The mobile phone in this case is used as the delegate between user's interaction with smart objects and their projected output. The latter technique of projecting information has been previously explored in [6,5] using hand-held and steerable projectors. In contrast to their approach of projecting onto objects, we have adopted a from-free design by enabling projection onto the nearest surface, and empowering users to interact with the physical objects through the phone.

(a) Smart object specific information and service interface is overlaid on the phone screen once an object is tracked in the camera preview screen.

(b) Smart object specific information and service interface is projected onto the screen and the phone screen is used as the track pad.

Figure 1: Conceptual and Real Time Schematics of the Two Interaction Techniques

This paper focuses on the design and implementation of these two techniques and three smart object applications designed to evaluate their usability. These applications use a smart kettle providing real time energy consumption, smart books offering access to their online reviews, and smart medicine boxes providing logistic information to support medication management respectively. A qualitative study was

Figure 2: Prototype Smart Objects and Screenshots of Applications' Browsing Overlay Views and Detail Views

performed on the two interaction techniques to analyze their relative advantages and disadvantages in terms of usability and task loads in the context of the smart objects mentioned above. Although the study result shows a clear preference towards *Magic Lens* approach for the context of accessing smart objects' services, it also gives us some insights on the situations where *Personal Projection* would yield a better result. Furthermore, the findings expose a range of intriguing issues related to decomposition of interaction space, fragmentation of attention, situational disabilities and relative cognitive loads associated with these techniques that we have discussed in the paper.

2. DESIGN AND IMPLEMENTATION

In this section we first describe the design of the mobile interaction device and the corresponding applications implementing the interaction techniques. This is followed by the explanation of the three prototype smart object applications.

2.1 Hardware Design

As the primary mobile device, a 3rd generation Apple iPhone is used, which is equipped with a 3.5-inch (480x320 pixels resolution) wide screen multi-touch display and a 3 megapixels camera. A battery powered Optoma Pico Projector[1] (model PK101) with dimensions of 50 x 103 x 15 mm (w x d x h) and 640x480 pixels native resolution is attached to the bottom of the iPhone. The cumulative weight of the device including the cable and its holder is 280 grams. Figure 3 shows the device's top and front views.

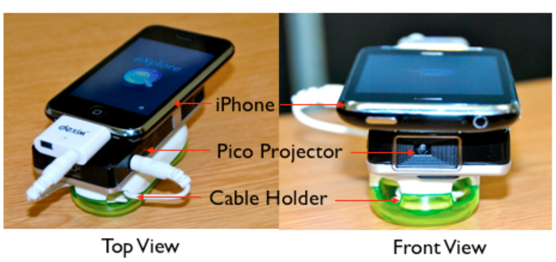

Figure 3: The Interaction Device

2.2 Software Implementation

In the following, we explain the two software components that implement *Magic Lens* and *Personal Projection* respectively.

Magic Lens: This application is implemented on top of iPhone OS 3.1.2 with Objective C. To enable real time 2D ID-Marker tracking a simplified C++ version of NyARToolkit[2] is ported on iPhone and is used with private Camera Controller API of iPhone SDK with a 12fps refresh rate. Once a smart object is tracked through hovering the phone over tagged smart objects, a tactile feedback is provided to the user and the ID-Marker is translated into corresponding interface pointer to load smart object specific interface and is overlaid on top of the camera preview giving the illusion of augmented reality notion as shown in Figure 1(a). From this point user can interact with the smart object using this phone interface as if it is a native iPhone application.

Personal Projection: The application is identical to the *Magic Lens* except two differences. First, instead of using the screen of the iPhone, the camera, tracking and subsequent smart object's interfaces are projected onto the nearest surface through the pico projector as shown in Figure 1(b). Although iPhone has a TV-out interface, it is limited to only photo and music applications. To enable custom application TV-out we have utilized private APIs of iPhone SDK's *MediaPlayer* framework, these APIs also enabled us to exploit the full 640x480 pixels resolution of the projector. Assuming the smart objects would be browsed vertically with camera facing downwards, the screen was projected horizontally on the nearest surface with an approximate angle of 90° from the object (Figure 1(b)). The second difference is the translation of touch input from mobile screen to projected screen, i.e., in the *Personal Projection*, the iPhone screen is switched off, however the touch inputs are captured and translated relatively onto the projected screen. To help navigating the screen and interface controls a cursor is shown on the projected screen relative to the phone screen, this effectively turns the iPhone screen into a multi touch track pad.

2.3 Prototype Smart Object Applications

To evaluate the usability of these two interaction techniques, three smart object applications were developed for three objects: a kettle, books and medicine boxes following [4]. These objects are tagged with ID markers that are tracked to recognize them as smart objects.

Energy-aware Kettle Application: A regular kettle is augmented with a software component that enables it to provide its real time energy consumption (Figure 2(a)). Users can interact with the application to estimate the approximate daily and monthly energy costs of the kettle by inputting speculated usage time.

Smart Book Application: A simple application that pulls all the digital reviews of the book in context from popular online bookstores (Figure 2(b)). Initially, the application only shows the average review rating and presents the detail reviews only when requested through secondary interaction.

Smart Medicine Box Application: This application aims to support medication management. It shows the category of the medicine in context and the corresponding locations in the cabinet (hypothetical) to enable quick medication preparation and arrangement (Figure 2(c)).

These applications extend the established purposes of three objects. However these objects natural physical properties, i.e., shape, size, color, etc. are kept intact and the augmentations are unnoticeable except the 2D code. Thus *Magic Lens* and *Personal Projection* could provide a seamless user experience to uncover these smart features associated with them and to interact accordingly. To assess this experience quality, we have designed a study that we describe next.

[1] http://www.optoma.co.uk/PicoNavigation.aspx
[2] http://nyatla.jp/nyartoolkit/

3. STUDY DESIGN

The prime objective of the study was to gain deeper insights on the usability issues of the two interaction techniques in context through qualitative assessments. Instead of finding a concrete research answer, we have taken an explorative approach to uncover some of the usability aspects that need to be addressed for fostering these techniques. We invited 12 individuals (7 Males, 5 Females, age range 22-38) through an open invitation in the university mailing lists. 10 of them are university students and 2 participants are marketing professionals. All participants own a mobile phone and none had previous experience using smart objects, mobile projected interfaces and mobile augmented reality applications. Each participant was paid £10 as a gratitude for participating in the study. Participants took part in the study individually. In the beginning we introduced the concept and purpose of the study and presented a small demonstration. For each interaction technique, a participant had to complete a total of three tasks involving three smart object applications in two successive sessions. Order of the interaction techniques was counterbalanced to avoid learning effects influencing the results. The three tasks were:

Task 1 - Sorting Medicine Boxes: The first task was a straight forward sorting activity. Participants were given 6 medicine boxes that were to be sorted and placed in a mock medicine counter. Once a medicine box comes into the interaction device's view finder, corresponding counters' position was overlaid or projected onto the screen and participant were required to put the medicine in the counter accordingly.

Task 2 – Searching Books: The next task was a searching one, where three books were given to the participants and were asked to find the book that has at least one review lower than two stars. So, they had to interact with each book through the interaction device and read the reviews to find the book. Here also, once a book comes into the interaction device's view finder, corresponding book information was overlaid or projected onto the screen and participant were required to tap the screen to get the detail review accordingly.

Task 3 – Estimating Energy Cost of a Kettle: The third task was more complicated where a participant had to understand how energy cost is calculated and accordingly put their approximate usage data to get a daily and monthly cost estimation. Like the other two tasks, once the kettle comes into the interaction device's view finder, the real time energy cost was overlaid or projected onto the screen and participant were required to tap the screen to estimate future costs.

Following the completion of three tasks with each interaction technique, a post task interview occurred requiring each participant to answer a series of subjective questions. After completion of both the interaction techniques, a post experiment interview was conducted with each participant. Each session was video taped for later analysis. Figure 4 shows some snapshots from the study sessions.

Figure 4: Participants completing the study tasks with *Magic Lens* (top row) and *Personal Projection* (bottom row).

4. STUDY RESULTS

After each interaction technique, the participants had to express their agreement to a subjective questionnaire designed following the IBM Computer Usability Satisfaction Questionnaire. These questions were structured using a 5-point likert scale from strongly agree to strongly disagree. Figure 5 presets the summary of the results. In general, participants favored the *Magic Lens* over the *Personal Projection*, however all the participants appreciated the simplicity, intuitiveness, quick learn ability, fast recognition, tactile feedback, instant information presentation, hovering metaphor, and joyful experience offered by both the techniques. On the other hand, the bulkiness of the device (due to the attachment of the projector and cable) was pointed as a common drawback. Their qualitative assessments revealed some distinct positive and negative aspects of these techniques. In the following we summarize them:

Magic Lens: The primary criticism that this technique received in comparison to the projection approach is the small screen size of the phone which yields poor experience when large amount of information is presented, e.g., book review etc. In addition, a few participants pointed out that looking at the phone screen downwards for a longer period of time is ergonomically more stressful than looking straight at the projected screen. On the positive note, participants found it to be very simple and user friendly. It offered them a crisp, smooth, and faster interaction experience. Also, a few participants pointed out the natural intuitiveness of the lens metaphor, which enabled them to apprehend the technique instantly.

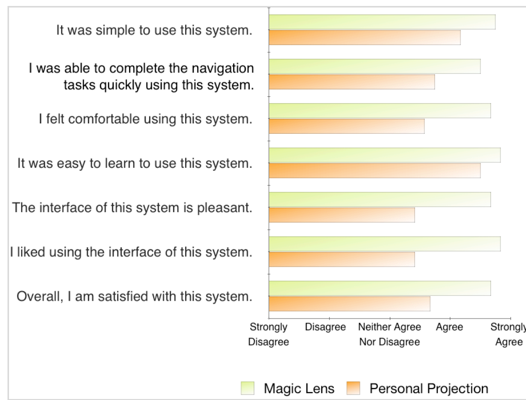

Figure 5: Average User Feedback

Personal Projection: The larger display was the main positive aspect of this technique, which a number of participants described as a strong point for different user groups e.g., visually impaired people etc. and for different environment settings, e.g., in public space to foster social interaction through information sharing. Among the negative aspects the shaky screen, difficulties in interacting with the projected screen using phone screen and demanding hand-eye co-ordination were highlighted primarily. Specifically, participants mentioned that due to the fragmentation of the input and output space, this technique demanded more attention, and put higher degree of cognitive load. These issues are further discussed in the next section.

During the post-task questionnaire session, the participants were also asked about physical and mental demands, frustration level and needed effort following the NASA Task Load Index. Figure 6 summarizes the participants' responses. *Personal Projection* required slightly higher physical and mental effort due to demanding hand-eye co-ordination. It also caused a relatively higher frustration level than *Magic Lens* because of the difficulties in navigating the projected screen using the phone screen. Nevertheless, both the techniques yielded similar results in terms of required effort.

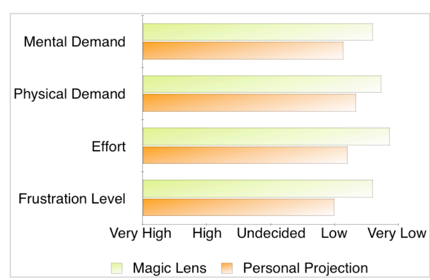

Figure 6: Avg. NASA Task Index User Feedback

5. DISCUSSIONS

Post-study interviews with the participants revealed several interesting issues regarding their preferences and qualitative assessments of the two techniques. We discuss these issues here.

Decomposition of Interaction Space: The *Personal Projection* technique essentially separates the input and output space, as the input, i.e., hovering across the physical space, and then interacting with the selected smart object is performed in the mobile space where as the output is projected in the external surface. This contributes in increasing the cognitive loads of the users, as they need to formulate a suitable hand-eye co-ordination to synchronize the interaction. Furthermore, in the current implementation the interaction introduces multiple orientations as the output is projected with an angle of 90° (approximately) from the actual physical object (Figure 1(b)). This turned out to be one of the major drawbacks for *Personal Projection*. On the other hand, interaction through *Magic Lens* is unidirectional (Figure 1(a)), leading to a better user experience. It is unclear from the current study that if the output is projected on the same direction as the phone's camera view, i.e., on the bottom surface, or on the object itself, whether that would influence user experience and with what granularity.

Fragmentation of Attention and Situational Disability: Related to the previous issue is the context switch of the users. Due to the decomposition of the interaction space, with *Personal Projection* users had to switch their attention in three dimensions, i.e., mobile phone, projected screen and the actual physical object. On the other hand with *Magic Lens*, the fragmentation of attention is reduced due to the elimination of the external screen. Although, this seems reasonable to argue that this contributes significantly towards the clear preference of *Magic Lens*, there are situations identified during the study where *Personal Projection* could yield superior experience. Particularly, for tasks where both hands are involved in manipulating physical objects, having a projected screen on the immediate surface has the potent to offer a better user experience. Another aspect of situational disability is the fluctuation of the projected screen, this is particularly important while users are on the move. So during the hovering process to discover smart features it is preferable to present the information on the mobile screen as *Magic Lens* does, however for secondary interaction depending on the scenario it might be useful to exploit projection. This dynamic switching of output modality depending on the context is an interesting research issue that we would like to extrapolate soon.

Dual Modes of Information Presentation: In our prototype, we have employed two levels of presentation mode: during the browsing phase only summarized service information is presented in a passive fashion where as detail service presentation is only invoked through active interaction with the initial presentation. This secondary interaction is not always necessary considering smart objects have their per-established purposes, and initial information only can make users aware of their value added features, making sure users can continue focusing on the primary task, i.e., manipulating the physical objects per se. From this perspective, *Personal Projection* acts like a peripheral display, and a number of participants pointed out these dual mode presentations positively. Conversely, the secondary interaction requires active user input, which in our implementation was provided by touch input on the mobile screen. This caused additional complexity for the *Personal Projection* due to the demanding hand-eye co-ordination and relative mappings of touch input.

Application Context: In the current study, we have used simple smart objects linked to digital information. Also, the interactions were straightforward and did not involve multi object interactions. Consequently, it is difficult to understand the complexity and subsequent user experience with both the techniques for applications involving multiple objects and multiple tasks. Another limitation of the study was that we have not utilized any multi-user scenario, and this influenced the preference towards *Magic Lens*. In the post-study interviews, several participants concurred that public and collaborative spaces are the ideal application contexts for *Personal Projection* to foster social interaction, e.g., photo sharing, discussing map during site seeing, etc. This also conforms to the implications mentioned in [2]. A further interesting application context for projection is the trivial routine tasks like sorting. In the study we have not measured the application specific user performances, however qualitative assessments revealed that user actually showed better interactivity in the medicine sorting with *Personal Projection* than *Magic Lens***.** Informal discussion exposed the fact that *Personal Projection* is preferable for tasks that involve relatively lower cognitive processing, e.g., looking at the screen and placing the object at hand in the prescribed location without further details. Similarly, for pipelined tasks involving multiple persons *Personal Projection* is expected to offer a better user experience.

Privacy: The final issue that we would like to put forward is the awareness of privacy. All the participants expressed their concerns in exposing their private information with *Personal Projection.* However, they also stressed their comfort with both the techniques for only uncovering the smart features that an object offers. For personalized interaction it is reasonable to assert that participants preferred *Magic Lens*, this actually confirms what Hang et. al. concurred about privacy concerns with projector phones [2].

6. CONCLUSION

We have presented two mobile interaction techniques, *Magic Lens* and *Personal Projection* that enable interaction with smart objects. A small-scale usability study with three prototype smart object applications is reported that showed *Magic Lens* provides better user experience due to its simplicity, better hand-eye co-ordination, and relatively lower cognitive loads. The study also exposed a range of interesting issues that formulate our future avenue of research work.

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