In-place Annotation of Physical Objects with Pico-Projectors

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ABSTRACT

Just as we annotate digital documents with digital annotations for collaborative work, we frequently annotate physical objects using physical annotations (e.g. by using Post-It notes). In the physical world, we are limited by the size of the physical Post-It note, and further, too many Post-It notes clutter the physical space. In this work, we explore the use of handheld projectors combined with a tablet to create digital annotations for physical objects, and to visualize these annotations around such physical objects. Our design allows people to use a flashlight metaphor for visualizing digital "post-it" notes, which can be created in-place by pointing the projector at an object, and then adding the annotation using the tablet. We realized this design in a prototype to informally assess the effectiveness of the metaphors we used, and to gather suggestions for future work in this area.

1. INTRODUCTION

On February 4 2013, researchers at the University of Leicester announced that the skeletal remains they had discovered the previous September belonged to the monarch King Richard III. During the press conference, the researchers excitedly showed these precious remains to reporters, who would have likely been unable to tell the difference between King Richard III's skeleton, and any other skeleton. The researchers were convinced after observing injuries on the bones which corroborated with contemporary accounts of Richard III's scoliosis and fatal head wounds sustained in battle. Yet, the notes the researchers made of these observations, which are annotations, stand apart completely from the bones themselves.

We use this vignette as a motivating example for our work. This story is a representative example where the physical objects should not be manipulated—particularly by novices or inexperienced students—the objects themselves are precious or fragile. Yet, the annotations are still valuable: they provide additional information about the object, or they may serve as a communication medium for collaborators working with the object. In an anthropological context, for instance, scientists are called to analyze primate fossils, which illustrate changes in bone structure, facial features, or teeth over the course of evolution. Fine-grained annotation of these fossils, which describe and highlight important features and details on the remains, is an important learning and communication tool.

Using physical objects, such as Post-It notes, or pins, as is common in anthropological scenarios, has limits. In-place annotations are limited by the size of the annotation medium—only so much text can be shown; further, we can only put so many pins into an object before it becomes overly cluttered. Prior research has considered the use of augmented reality (AR) to digitally annotate physical objects. Yet, this approach generally requires the use of see-through displays such as glasses, tablets, or smartphones. This approach makes collaborative work difficult, as collaborators do not share a view of the space, precluding common actions such as gesturing at digital or physical objects difficult (Billinghurst & Kato, 2002).

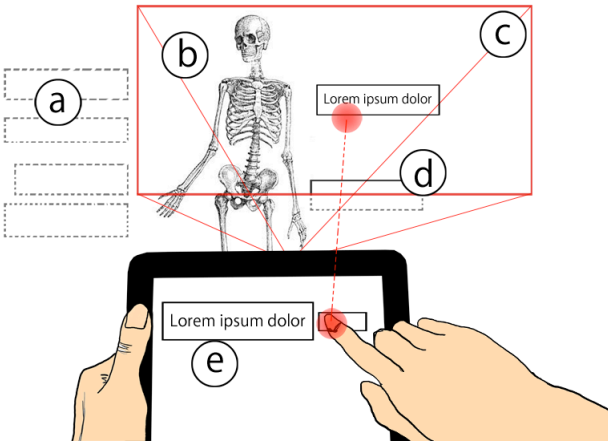

Figure 1: Projector-based annotation system allows user to view annotations. (a) Hidden annotations, not visible because projector is not shining on them. (b) Physical object. (c) Projection area of portable projector. (d) Annotations within projection area are displayed. (e) Tablet has controls for annotation control.

In this work, we explore the use of pico-projectors as a means to overcome many of these issues. Handheld projectors, or pico-projectors, have the advantage that they project onto an object, and into the world around the object, thus providing a single view that everyone in the space can see. This allows everyone to point and gesture unambiguously at both object and annotations as appropriate. We also combine a pico-projector with a tablet, allowing people to create annotations at distinct parts of the physical object. These could be selectively viewed by shining the projector at only some annotations and not others (using a flashlight metaphor), and in principle, could be filtered using toggles on the tablet (e.g. to filter out annotations of a certain type, or by a set of authors).

We realised this design in a prototype illustrated in Figure 1. The system allows people to annotate tagged real-world objects. Annotations are represented metaphorically as post-it notes containing text information, which can be attached to objects and surfaces and viewed in the environment with the projector. We implemented this prototype in order to explore the design opportunities presented by pico-projectors in tracked physical environments, and to gather feedback about the viability of the interaction design to determine how to proceed with future work in this area.

2. RELATED WORK

We briefly review related work in annotation systems, augmented reality, and handheld projector interaction design to situate and frame our work.

Annotation Systems. Hansen [5] describes challenges inherent in the design of object and location annotation systems, articulating three general strategies for creating them: augment the user with special I/O devices; augment the physical object with sensors and electronics; or augment the environment with projectors and cameras to detect and display object-specific data in the world. We primarily apply the third of these strategies, by using handheld projectors to display data in the world.

Augmented Reality (AR). In contrast, AR systems apply the first of Hansen's strategies [5], by augmenting users with special viewing equipment. In practice, AR has been used in museums to enhance exhibits by providing additional multimedia information. The Natural History Museum [4] in London created a multimedia theatre to view an educational film on the evolutionary history of humans. Occupants are provided specially designed tablets that use AR to display fully-animated 3D models of human ancestors, such as *Australopithecus afarensis* and *Homo erectus*, and various species of dinosaurs and fish. The tablets are also capable of displaying facts and additional information when not being used to view the 3D models. Similarly, the Museum of Fine Arts [8] in Rennes, France experimented with using an AR guide to evaluate how to immerse the visitor and encourage them to analyze the exhibits. Participants were provided mobile PCs fitted with cameras to view paintings with. The PCs played music and sounds to enhance user experience and displayed contextual information on the paintings, such as pointing out a curve composition in a Rubens' painting.

Both systems rely on viewing information through a device's camera, which keeps the user separated from the information around them and does not allow multiple users to share a viewing space. Our work addresses these concerns by using a projector to view annotations in place and in context, and allow viewers to share the same perspective.

Pico-projector Interaction Design. We are not the first to consider using projectors for viewing information. Cao and Balakrishnan [2] used a portable projector fitted with a handle and set of controls, a pen for drawing and interaction, and was tracked using a series of Vicon cameras. The projector was shined on physical surfaces to reveal virtual information, much like a flashlight would be used to explore a dark room. Their research studied and analyzed interaction techniques using this system, such as manipulating virtual objects and using the pen to annotate surfaces. Follow-up work by Cao et al. [3] built upon their system to include multi-user interaction and to analyze interaction techniques with multiple projectors.

Molyneaux et al. [7] examined techniques for creating virtual spaces in a physical environment. They described their techniques in regards to "infrastructure", or having a system of sensors around the test space to track the projector within it. One technique used a series of Kinect cameras mounted to the ceiling of their test space to create a model of the room for the virtual information to reside. Their other technique did not use such an infrastructure and relied on a Kinect mated to a projector to sense the surfaces of objects in front of it to display the projection on.

Cao's work laid the groundwork for the flashlight metaphor being used in this project and both his systems demonstrated it as a viable interaction technique for portable projectors. We extend this work by showing how it can be used to augment tracked physical objects in an instrumented space with annotations.

3. DESIGN

The purpose of this project was to create an annotation system for objects using portable projectors. Metaphors are used to display and create annotations in the system.

3.1 Interaction Metaphors

Flashlight Metaphor. The projector in the system uses a flashlight metaphor as described by Cao and Balakrishnan [2, 3]. The projector is shined in the physical environment like a flashlight. When it shines over a space containing virtual information, the projector displays the information (Figure 1d). The system places a white 'halo' around objects in the environment to indicate they are being tracked and may be selected to add annotations to. This halo is displayed by the projector when it shines over an object.

Post-It Note Metaphor. Information in the system is treated like real world post-it notes. Post-it notes in the real world contain information and can be attached to objects to imply association and context. For instance, when placing a note on an object, information on the note now describes or provides detail on the object. Placing a note on a wall creates a visible public display for the information. While information being attached to objects would ideally be attached directly onto the object's surface, this is not yet a feature of the current system or the Projector Toolkit. For now, annotations are displayed next to an object's halo to indicate they are anchored to it.

3.2 User interaction

Figure 2 illustrates an interaction scenario with our design.

Scenario. Larry and a team of anthropologists are studying newly-discovered fossil remains. The remains are fragile and the team is not allowed to move them. To work with them, the team members must make observations and annotate the remains with their findings.

Viewing annotations (Figure 2a). Larry is independently studying the remains and is interested in what his colleagues observed from the previous day. He shines a projector on the remains and reads the annotations that Phil left the day before. The projector allows Larry to see exactly where Wallace placed the annotation, and so Larry can see exactly what part of the bones that Phil was writing about.

Creating an annotation (Figure 2b). Larry sees something interesting that is contrary to what Phil saw the other day. As part of this ongoing discussion, he knows he will ask Phil to elaborate on his interpretation the next time they meet. Larry types in the annotation on his tablet to remind the others to discuss their findings.

Adding an annotation (Figure 2c). Larry then points the projector's cursor on Phil's annotation and presses the 'place' command. Larry's annotation is added to that part of the remains.

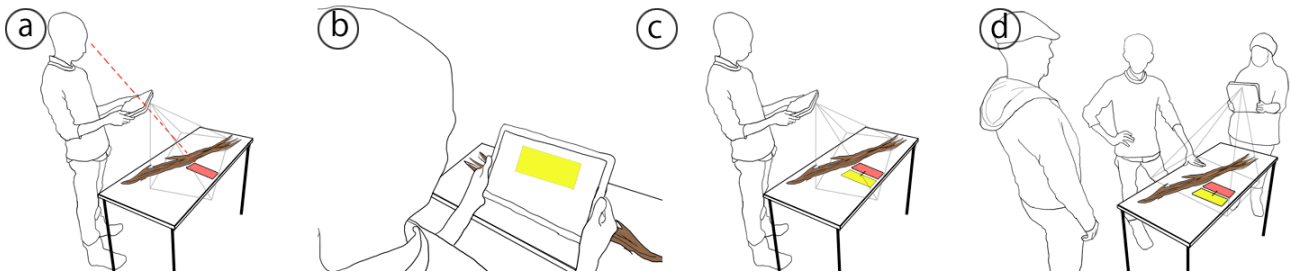

Figure 2: Example of user interaction with our system: (a) illustrates viewing an annotation associated with the object; (b) using the tablet, a person may add an annotation; (c) both annotations are now associated with the object; (d) multiple people can view these annotations with a shared view.

Viewing annotations as a group (Figure 2d). Larry meets with the other anthropologists the next morning. Phil shines the projector on the remains and notices Larry's note about his annotation. Larry asks Phil about his findings.

4. PROTOTYPE IMPLEMENTATION

The prototype was implemented as a custom-built C#/WPF application using the Proximity Toolkit [6] and the Projector Toolkit [9]. The Proximity Toolkit uses Vicon motion capture cameras to track silver markers attached to objects, which could be used to determine its location and orientation in a three-dimensional space beneath the cameras. Because our goal is to explore interaction design for such a system if it were built, the VICON system is intended to stand in for computer vision and sensing algorithms that would exist in devices with pico-projector technology.

Figure 3: Our system in use. Object halo and annotation is simulated due to poor lighting.

The Projector Toolkit [6] was used to create the basic environment for displaying virtual content with portable projectors. Both toolkits were used to quickly create and set-up the required infrastructure for tracking objects and using projectors. This infrastructure allowed more time and effort to be spent on developing and prototyping the annotation system, which was not a feature of either toolkit.

We used a MicroVision SHOWWX+ Laser Pocket Projector duct-taped to an Asus EP121 Tablet PC. The Tablet PC provided the touch interface for entering text for new annotations and switching between placing annotations on surfaces and anchoring to objects. Both were combined to create a single handheld unit for ease-of-use (Figure 4).

Because the system was intended as a sketch to explore how pico-projectors may be used, advanced functionality such as editing and selection are not provided.

5. FORMATIVE EVALUATION

We were interested in understanding how effective the interaction metaphors were, how closely the point-and-place interaction fit with user expectations, and to determine which parts did not meet expectations. To this end, we conducted a preliminary evaluation with HCI graduate students who have experience thinking about future technologies, and anticipating user needs and frustrations.

Method. Members of our HCI lab, including graduate students and professors, were demonstrated the system and asked whether the interaction made sense and whether they would use the system in a similar manner for placing annotations. Participants were also asked for general thoughts on the overall system to determine where other improvements could be made.

Feedback. The flashlight metaphor was easily understood and the action of shining or pointing the projector to find and view annotations was intuitive for the users. The public nature of projected content also facilitated group and collaborative work. The post-it metaphor was also understood, as the action of 'attaching' a note to an object to convey information was similar in concept to using a paper post-it note.

However, participants complained the action of annotating an object by pointing at it with the projector was not ideal. The

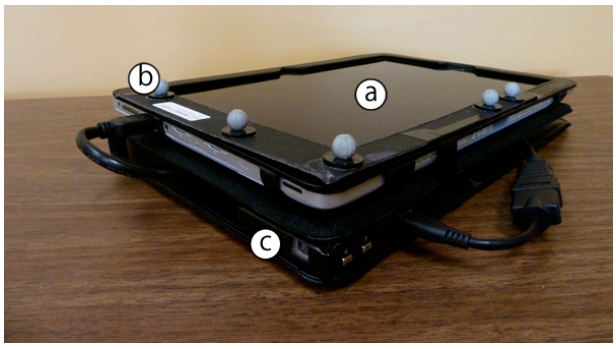

Figure 4: Combined projector and tablet unit: (a) tablet; (b) markers for Vicon cameras to track; (c) projector taped to the tablet.

preferred action was to approach the object and plant the annotation as though they were placing a physical post-it note. This action was considered more natural and also established a mental association between the annotation and the object.

Placing annotations on walls by pointing-and-aiming was better received, but participants raised concerns about the sequence of annotation steps. Our prototype used had users create text first before placing it/selecting an object, and while some participants thought this was the correct approach, others felt they should be able to select an object before creating the text. Future work should allow flexibility here, allowing either sequence of steps.

Other problems with the post-it metaphor was that since the virtual annotations disappeared once the projector was no longer shining on them, the annotations were said to lack the physical presence of an actual post-it note. The belief was that post-it notes also act as a physically distinct reminder in the user's environment, which virtual annotations did not possess.

Beyond the metaphors, participants also suggested that possible annotations should also allow for doodles/diagrams, or even attaching other images (e.g. photographs) or voice annotations, rather than allowing only text.

6. DISCUSSION

The issues with the post-it metaphor were not anticipated, and suggests its implementation is still incomplete. Adding an annotation was considered only in context to the flashlight metaphor's point-and-place interaction, and this neglected the other characteristics of real life post-it notes.

A possible redesign could focus more on studying how information is represented in the world rather than displaying information using the flashlight metaphor. In practice, we may also imagine dispensing with a strict "Post-It Note" metaphor, and appropriate the "attached comments" metaphor that Microsoft Word uses.

One of the issues with the implementation was the lack of features to demonstrate the capabilities of the system. While adding text to the world does showcase the potential for annotating a physical space, the choice of text or image was not fully considered and both were believed to convey just as much information. Future redesigns will focus on the ability to draw within a physical space, using either the tablet as a notepad of sorts, or pen techniques described and implemented by Cao [2].

Despite these issues, using portable projectors to annotate an environment is still a viable concept. Previous work requires users to remain separated from their environment while working. Pico-projectors allow users to create and interact with information in place in their surrounding environment and context. By displaying content directly into the world, the user is much closer to their surroundings and its relevant information.

User impressions of the technology were still positive, particularly with how it 'reveals' hidden information in their environment. Users believed the technology would also work for games where participants could be rewarded for finding hidden items or marking their environment to indicate successes. Future work may also explore and evaluate projector applications for interactive games.

7. CONCLUSION

In this paper, we present the basic concept and design of a prototype system for annotating information on objects. The system makes use of handheld projectors to display and create annotations, resulting in publically viewable information for group and collaborative work. The current implementation was developed using the Proximity and Projector Toolkits to quickly evaluate the viability of concepts and to determine potential applications and future tasks.

The system is not yet complete and the initial results from the informal evaluation indicate the problems, such as with the post-it note metaphor, still require investigation. However, portable projectors offer a very powerful model for interactions by allowing a user to annotate in place and in context to their surroundings. This prototype should serve to illustrate some of the potential applications for the technology.

Future work will expand on the usability of the system by adding drawing and tap-to-add functionality as indicated from the system evaluation, and tablet controls will also be refined. Work will also be performed on object and surface tracking so that annotations can be added directly onto the surface of an object instead of just around it. This will also allow for experimenting with different ways of displaying virtual information directly on or around objects. A formal user evaluation will be performed after these features are implemented.

8. Acknowledgements

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