Contact Augmented Reality: Exploring its Design and Implementation

1st Author Name
Affiliation
Address
e-mail address
Optional phone number

2nd Author Name
Affiliation
Address
e-mail address
Optional phone number

3rd Author Name
Affiliation
Address
e-mail address
Optional phone number

ABSTRACT
We present Contact Augmented Reality (cAR), an approach to augmented reality where the display is mobile and on direct contact with the augmented object.

Author Keywords

ACM Classification Keywords

General Terms

INTRODUCTION
Augmented Reality (AR) enhances the real world by embedding digital content onto it. Bimber and Raskar list three challenges AR faces at its basic level: display technology, registration and rendering [2]. The display technology used determines the complexity of the other two. *Traditional AR* relies on mobile displays carried by the users (retinal, HMDs, smartphones and handheld projectors), allowing the augmentation of virtually any object within the display's field-of-view but requiring complex operations for registration (e.g. 3D location, object recognition) and rendering (e.g. field-of-view calculation, perspective correction). Moreover, mobile displays present limitations in terms of resolution, focus, lighting and comfort. On the other side, *Spatial AR* (SAR) relies on displays fixed in the environment (projections, transparent LCDs); requiring simpler operations for registration and rendering and offering solutions to the limitations of traditional AR, but limited to non-mobile applications [2].

Small-size transparent displays (e.g. TOLEDs) are an upcoming technology often portrayed in concept devices [3, 4, 6, 9]. In this paper we explore the use of such displays for augmented reality and leverage a property not available in other display technologies: they can rest directly on top of the augmented object while allowing such object be visible. This direct contact provides spatial alignment at very short distance between the digital content and the augmented object, allowing us to create a mobile augmented reality with the strengths of SAR. We call this approach *Contact Augmented Reality* (cAR). cAR simplifies the requirements for registration and rendering: registration is reduced to finding the *relative* 2D location and orientation of the cAR device on-top of the augmented object; rendering no longer requires perspective corrections.

By following an iterative and user-centric design approach, and taking Active Reading [1] as a sample application area[1], we built two prototypes which helped us identified and explore a series of interaction techniques for cAR devices: contact-based (e.g. annotations, scribbles), content-aware (e.g. UI orientation, content lookup), and off-contact (e.g. flipping, stacking). The first prototype is tabletop-based with transparent tangibles; it uses fiducial markers for registration and rendering is handled by the tabletop display. This prototype enabled rapid prototyping and testing of the interaction techniques. Our final prototype is a mobile device called the *tPad*. The tPad uses a 7" LCD displays on a light-table and addresses registration with a camera-based feature tracking approach (see Figure 1). tPad uses a resistive-overlay for touch/pen input and a controller board detects flipping and stacking. This prototype allowed us to explore the challenged for building a real cAR device.

Figure 1: tPad on top of a document showing highlights (green), text and free annotations, and off-screen pointers (arrows)

[1] Active reading is an activity which has been discussed as better performed in paper and that can benefit from digital augmentation for which several technologies have been proposed [REFERENCE].

For both cAR prototypes we implemented an active reading application allowing users to underline, highlight, scribble comments, search content, and look-up references. Users access special information by flipping the device, and two devices can share content when staked-up. We studied the use of cAR to support active reading with users in informal sessions. Initial feedback shows that using the tPad is highly intuitive and learn-able. Moreover, users highlighted the value of reading on paper, having the digital features when needed, and being able to access their annotations digitally.

Our contributions are at the conceptual, interaction design, and technical levels. First, we introduce cAR and differentiate it from existing AR approaches. Second, and propose a series of interaction techniques for cAR. Finally, we present two cAR prototypes and show how cAR can be applied to and benefit an every-day task such as active reading.

RELATED WORK [1 PAGE]

Augmented Reality
HMDs and Handheld

Spatial Augmented Reality
Fixed in relation to the object

Projectors, transparent displays

Virtual Lenses
Mackays ABook – say that we were inspired by this work and we generalize this initial exploration into the concept of cAR. However, we depart in several ways: first we use a camera based registration, second we explore off-contact and content-aware interactions, third we rely on transparent display technology.

CONTACT AUGMENTED REALITY – cAR [1/2 PAGE]

Definition: mobile device which augments when coming in close contact (overlay) with the augmented surface.

How is cAR different than traditional or spatial? 1) Activated upon contact, else the device works as a normal mobile device → it is not handheld as it needs the surface.

2) Spatially aligned -> registration problem is reduced to finding the location of the device in relation to the surface, no need to track the user.

3) Simplified rendering

4) Operation both as a mobile device, and as an augmented lens.

5) Rests on the table (not as tiring)

6) Not always present – as a support tool rather than focal, as an ambient display

Why does it need a transparent display: 1) because it preserves the appearance (texture, colors, lighting, age, wear) of the object being augmented.

2) Because if maintains visible the physical modifications done in that object.

APPROACH [1/2 COLUMN]

We used Active Reading as an application scenario and an inspiration tool to brainstorm and elicit features and interaction techniques.

Features for active reading – literature review

Design sessions

Prototype 1 - Tabletop

Prototype 2 – tPad

ACTIVE READING [1/2 COLUMN]

cAR INTERACTION TECHNIQUES [1 PAGE]

Describe design sessions – first round:

- Winnipeg, interviews with 6 participants, each had a mock device
- Winnipeg, focus group
- Germany, brainstorm session 1

Second round:

- Winnipeg, brainstorm session 1
- Germany, brainstorm session 2

Results

Contact-based

- Horizontal Translation
- Horizontal Rotation
- Freezing
- Gestures (flipping, shaking)
- Direct Pointing (pen, touch)
- Adding digital content (highlights, scribbles, notes)
- Interacting with digital content (opening/moving note, remove highlight and scribble)
- Stacking

Content-aware

- Extracting content from object (word look-up)
- Anchoring content to object (highlight search results)
- Orient UI to content flow

Off-Contact

-

Implementation Requirements

TABLETOP PROTOTYPE [1 PAGE]

Implementation Details: registration, display and render details.

Features

Feedback

Limitations

tPad PROTOTYPE [1 PAGE]

Implementation Details: registration, display and render details.

Features – features that are not contact, reinforce the need of paper

Software architecture

Hardware

Registration efficiency (graphs by Sophie)

Limitations: LCD and light-table, FPS, single-side touch input, attached to the computer

Feedback

DISCUSSION [1 PAGE]

Model

- Model-based registration: model creation and distribution
- Model-based –vs– ad-hoc registration

Optimization Strategies

- Server-based
- Tagging at the document and page level
- Scaffolding: actual page -> next page -> previous page -> document level -> database
- Accelerometer triggered
- Button triggered

Simplified rendering

- Lower entry barrier: authoring tools and programmers readily available

Color mixing:

- Transparent displays on mobile devices – perhaps not for mobile phones, but convenient for cAR.
- Color correction
- LCD + OLED: can show both real white and real black

Issues of Camera-based Interface

- Potential recognition errors
- Delay for processing
- Dependence on lighting conditions
- Needs lots of computational resources

CONCLUSIONS [1/2 PAGE]

Actual conclusions

Future work

REFERENCES

1. Adler, M. J. and Van Doren, C. How to Read a Book. Revised edition, Simon and Schuster, New York, 1972.
2. Bimber, O. and Raskar, R. 2005. Spatial Augmented Reality: Merging Real and Virtual Worlds. A. K. Peters, Ltd., Natick, MA, USA.
3. Concept Phones. (2013, March 17). Transparent Phones. [Website]. Retrieved from http://www.concept-phones.com/tag/transparent-phone/
4. Corning Incorporated. (2013, March 17). A Day Made of Glass 2: Unpacked. The Story Behind Corning's Vision. (2012) [Video file]. Retreived from http://www.youtube.com/watch?v=X-GXO_urMow
5. Doshi, OR A., Cheng, S. Y., and Trivedi, M. M. 2009. A novel active heads-up display for driver assistance, IEEE Trans. Syst., Man, Cybern. B, Cybern., vol. 39, no. 1, pp. 85–93, Feb. 2009.
6. Iwabuchi, M., Kakehi, Y., and Naemura, T. 2008. LimpiDual touch: interactive limpid display with dual-sided touch sensing. In ACM SIGGRAPH 2008 posters (SIGGRAPH '08). ACM, New York, NY, USA.
7. Japan's transparent display vending machine. http://techcrunch.com/2011/12/20/video-japan-vending-machine-2-0/
8. Karnik, A., Mayol-Cuevas, W. and Subramanian, A. 2011. MUST-D: multi-user see through display. In Proceedings of the 24th annual ACM symposium adjunct on User interface software and technology (UIST '11 Adjunct). ACM, New York, NY, USA, 77-78.
9. Wigdor, D., Forlines, C., Baudisch, P., Barnwell, J., and Shen C. 2007. Lucid touch: a see-through mobile device. In Proc. UIST '07. ACM, New York, NY, USA, 269-278.

The columns on the last page should be of approximately equal length.
Remove these two lines from your final version.