Storybook Augmentation through Portable Projectors, 3D Augmented Reality and Anaglyph

Fadi Chehimi
Computing Department
Lancaster University, Lancaster LA1 4XH, UK
chehimi@comp.lancs.ac.uk

ABSTRACT
Many approaches have been proposed to enhance storybooks with some digital artifacts. Some used RFID tags, others used sounds, and many utilized augmented reality. This paper introduces a conceptual system that would augment storybooks with 3D and anaglyph content that is oriented according to the reader's posture and registered right on the paper rather than through intermediary displays by utilizing portable projectors. The system allows direct finger interaction with the projected graphics to create an immersive and entertaining user experience during reading

Author Keywords Paper computing, portable projectors, augmented reality, anaglyph, touch-based interaction

ACM Classification Keywords H5.m. Information interfaces and presentation

General Terms Design, Human Factors.

NTRODUCTION

For centuries, print has been the most reliable medium for documenting information, acquiring knowledge, and sharing thoughts [1]. With the advent of digital technologies however this role has started to drift. Although this is the case, reading printed books is still more preferable to reading digital ones, especially for recreational reading [11]. While digitized books often offer faster content retrieval/search, provide immediate dictionary look up, and encapsulate volumes of information with negligible footprint, they have notably failed to address the affordances printed books naturally deliver [11]. They require dedicated hardware which is generally expensive, not robust enough, and suffers from poor resolution or color contrast which makes reading from screen hard for long periods [10]. Physical books on the other hand are tangible with interactive feedbacks (e.g. turning a page), allow people to scribble on, are easier to navigate through, provide physical reference to depth of content, and so on [12,10]. They involve multiple sensory cues simultaneously (vision and touch) and this is what helps them retain their preference amongst the clutter of electronic alternatives.

For these reasons many trials to "completely replace" the physical artifacts of books with computer-based solutions, such as e-books, have failed so far [11,10]. As a result, the paramount consideration to keep in mind when designing electronic forms of books would be to enhance readers' experience with "real books" rather than to fully replace them digitally [6].

Many researchers have noted this and developed prototypes to overcome the issue. This paper extends their work and contributes to the current state-of-the-art of paper computing with a system that can augment storybooks, or paper in general, with 3D augmented reality and anaglyph[1] content registered and directly projected on the material in hand, rather than through wearable head-mounted displays (HMD) or on side monitors. Additionally, it allows for direct touch-based interactions with its projected content on the pages. The rest of this paper introduces the system we are proposing and highlights its features, the interaction concepts being designed, the possible implementation, and the future work to follow.

RELATED WORK

There are many research projects, and even commercial products, that augment storybooks with some sort of digital enhancements. Some have used spacial audio to create effective imagery and sense of place around books [10]. LeapFrog's LeapPad has utilized digital pens to interact with printed graphics on page [9]. Others have used mounted projectors to project content around books or on blank white paper for users to interact with [8,14] and many experimented with augmented reality (AR) for innovative storytelling approaches. The Magic Book [3] is the first prototype for this. It augments 3D content on markers printed on storybook pages through an AR handheld display or adjacent screen, and it provides a paddle with special marker as a mean to interact with this augmented content. Little Red [12] and The Haunted Book [13] are other two examples of this with the later augmenting 2D graphics instead of 3D that merge with the background illustrations on the marker-less pages of their concept storybook.

PAPER AUGMENTATION

The problems with using AR in its familiar form to digitally enhance physical storybooks can be summarized in the following:

UbiComp'10, September 26–29, 2010, Copenhagen, Denmark.
ACM 978-1-60558-843-8/10/09.

[1] Anaglyph is still or moving pictures where the red and blue channels have been split and then reassembled in slightly different perspectives so that the image appears three-dimensional when viewed through 3D glasses with red and blue lenses

- Using an HMDs or AR portable displays will limit the use of the system to one person at a time. This would eliminate the collaborative experience book reading usually offers.
- Showing the augmented visualization through a side monitor solves the above problem but introduces a flow in the interaction context: the reader's attention is either completely diverted onto the screen making the book void, or it constantly switches between the two spaces interrupting as a result concentration during reading.
- A paddle with a mounted marker is needed to interact with the augmented objects. No direct interaction with fingers is supported.
- The augmented content on the display occludes what is between the reader and the book. This is experienced for instance when the user tries to touch or point at a page or an augmented object but his fingers get covered by the augmentation.

Having considered these limitations, we present in this paper a possible alternative that uses projection, through portable projectors, projector phones or even future wearable projection accessories, to display 3D and anaglyph content directly on book pages rather than through intermediary displays.

3D and anaglyph AR

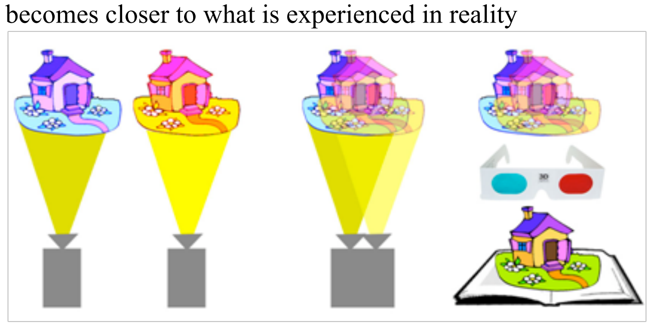
The idea of this is to have the 3D AR content projected straight on the piece of paper or book page that the user is looking at. This makes the augmentation visible on the exact surface of interaction and facilitates multi-viewer collaboration whilst reading. No need for HMDs or goggle-like displays to peek through at the augmented objects. Figure 1 demonstrates the possible look and feel of this technology with the aid of a wearable projector clipped to the ear of the reader.

Figure 1. Story 3D virtual content projected directly on the page in the orientation of the reader through an ear worn conceptual projector

All AR features are preserved here: markers are used to determine the orientation of the augmented content relative to the reader's posture; all virtual objects are registered on the paper in the correct orientation relative to his line of sight; objects can be static or animated and users may interact with them if the system allows; and users' experience with the medium in hand is enhanced by the use of augmentation.

By modifying the implementation of the 3D content being projected, it is possible to create anaglyphs that make the 3D content virtually come out of the page, creating thus a hologram-like effect. The OpenGL code responsible of the 3D environment can define two look-at views for each eye with one missing the red channel, Figure 2a, and the other missing the blue one, Figure 2b. Both then get blended into the final image with a distance corresponding to that between the eyes (approximately 4cm) applied, Figure 2c. The red-blue anaglyph glasses a user would wear for this will then compensate for the missing channels and feed the merged imaged to the eyes creating a realistic pop-up feel for the objects, Figure 2d.

With this we take the AR approach of enhancing books into another dimension that would add more entertaining factors into the reading experience. Also given that the reader will be able to interact with these contents with his fingers, as shall be discussed more later, the whole interaction becomes closer to what is experienced in reality



(a) (b) (c) (d)

Figure 2. Anaglyph implementation; a) left eye view without red channel; b) right eye view without blue channel; c) both views combined with horizontal offset; d) the hologram effect with 3D anaglyph glasses

Paper requirements

To achieve the experience sought after from our system the pages of the storybook we aim to design will be engineered to allow the system to detect its orientation and project content appropriately. The first thing will be to add markers at the upper left and right corners of the unfolded pages to allow the system to identify 1) the reference page and thus the material to project on it, and 2) the posture of the projector (or user) in relation to the book to project content in the right direction. Marker detection and pose estimation are very well established topics in the field of AR and thus we will be using the reliable approaches implemented in ARToolKit [2]. But instead of using black and white markers we will use colored ones to fit the artistic context of storybooks as Figure 3a shows. We will use dark colors (like red, blue, green, dark grey, etc) which would naturally convert to black during the binarization phase of the marker detection pipeline [4]. This will automatically generate the black boundary needed to identify markers, Figure 3b. Light colors like yellow and cyan would drop under the threshold value of the binarization algorithm and thus will be avoided.

The other requirement for pages is to have blank block spaces on them along with text to act as projection boards where the 3D content will display. The content will not necessarily be projected on the markers on page but on this blank space. If it is not present the projection will still take place but will be distorted by the clutter of text and graphical illustrations printed on the page.

(a) (b)

Figure 3. Page layout; a) colored markers and blank space on pages; b) binarized image of what the camera sees with the colored markers converted to black

Having markers printed on pages might look obstructing to their layout coherence and therefore we could explore the possibility of utilizing natural feature detection as in [13] for page recognition and 3D registration. The authors have reported very reliable performance results when using this technique for the purpose of book digital augmentation.

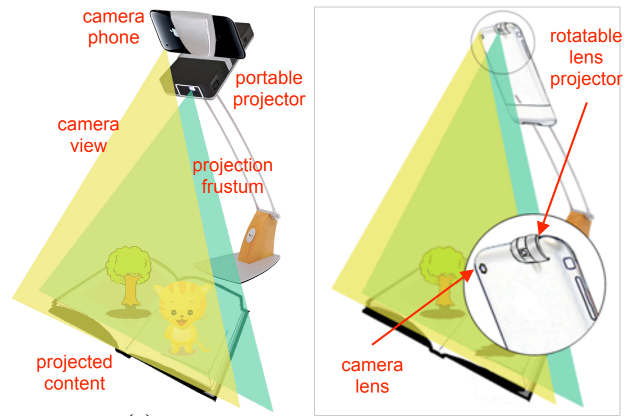
Facilitating hardware

Given that portable and pico projectors are still in their infancy and their capabilities are still limited many researchers have developed substitute prototype devices [14] and even proposed futuristic mobile phone projection accessories [7] to do the job projectors are envisioned to claim. Here we show the prototype we would develop and two other future implementations.

Desk lamp stand

This is our potential hardware implementation and the one possible with the available technologies. It is composed of a lamp stand altered to hold a portable projector and a mobile phone as in Figure 4a, (this could be used in place of a normal reading light). The phone is placed so that its camera points at the surface the projector is pointing at. It then can be used for marker detection and touch tracking on the book pages. Also the accelerometer sensor on the phone could be utilized to help determining the orientation of the projector relative to the book, and hence to the reader.

This design was inspired by the work in [13] but the difference here is that we are embedding the projector and the camera (on the phone) onto the lamp stand. When technology permits it will be possible to replace the two separate pieces of hardware with a composite phone that has an adjustable throw angle projector and a camera both built-in as Figure 4b demonstrates. A potential implementation of this has been introduced in [5].



(a) (b)

Figure 4. Hardware assembly; a) implementable prototype consisting of light stand holding a portable projector and a mobile phone; b) a visionary prototype with a phone embedding a rotatable lens projector and a camera

Ear-clip form factor

Another future design would be having the projector and camera in the form of a wearable ear-set device (as described in [7]), similar to Bluetooth hands-free sets, as Figure 5 shows. The device would (wirelessly) connect to the wearer's mobile phone which would play the role of the computer processing camera images and track fingers and printed markers. The phone also generates the 3D content to project onto paper and communicates it to the wearable device's pico projector for projection. The advantage of this design would be that interaction models based on such projection would become ubiquitous in the future.

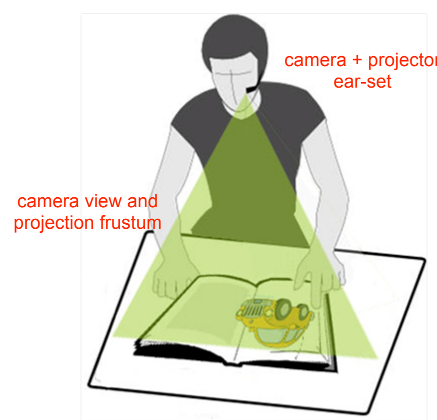


Figure 5. Ear-clip projector/camera form factor [7]

INTERACTION

Unlike existing solutions for AR-based storybooks our system will support direct finger-based interaction with the projected content. The user will be able to select an object for example or move it and drag it from page to page. This is achieved through tracking changes in shadow appearances as fingers move and point. The shadow shape can identify the position, direction and height of fingers and inherently touches. These shadows are naturally enforced by the light emitted by the projector and their varying sizes would determine the distance of the finger from the surface it is aiming at. This is a common technique in projection vision-based systems such as [14] which is found to be very relative to the detection and tracking methods we are planning to implement.

Given that the projector would be either mounted on a stand or worn by the user, hands will be free for gestural interactions on book pages. The fact that shadow-based tracking is capable of identifying multiple fingers at once makes multi touch interactions with projected content possible. As a result the user may pinch a 3D model with two fingers to zoom it in/out, can touch multiple objects simultaneously, and can collaborate with multiple users around.

CONCLUSION AND FUTURE WORK

The concepts presented so far are based on thorough inspection of the portable projection, mobile augmented reality and interactive surfaces research domains. It has been concluded that with the currently available technologies it is possible to implement and deliver most of the ideas introduced in this paper. And once implemented, we believe that it would considerably contribute to AR and paper computing as using animated 3D and anaglyph AR for paper enhancement up to our knowledge has not been discussed before.

Applying this to storybooks is a great way to demonstrate the potentials of the technology and its possible imagination stimulation. As discussed, physical books still dominate when it comes to reading for entertainment and therefore our approach emphasizes their physical characteristics and does not aim to fully transition the reader to a digital reading environment.

It is expected that some challenging issues will arise related to implementing the interactions, to the robustness of the shadow tracking system, to assembling the hardware,, or even to designing the book (having lots of blank space and the need to wear 3D glasses for instance). Usability of the system will be judged and evaluated when implemented and tested. But generally, it is possible to envision the potentials and usefulness of such prototype when used to augment the reading experience.

ACKNOWLEDGMENTS

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

REFERENCES

1. Ahonen, T. and Moore, A., *Communities Dominate Brands*, futuretext Limited, London, UK, 2003.
2. ARToolKit, http://www.hitl.washington.edu/artoolkit
3. Billinghurst, M., Kato, H., and Poupyrev, I., The Magic Book–Moving seamlessly between reality and virtuality, *IEEE Computer Grapics and Applications 21,1*(2001), 6-8.
4. Billinghurst, M., Poupyrev, I., Kato, H. and May, R., Mixing realities in shared space: An augmented reality interface for collaborative computing, *Proc. International Conference on Multimedia and Expo,* (2000).
5. Cauchard, J. R., Fraser, M., Alexander, J. and Subramanian, S., Offsetting Displays on Mobile Projector Phones. *Proc. International Workshop on Personal Projection UbiProjection* (2010).
6. Grasset, R., Dünser, A. and Billinghurst, M., Edutainment with a mixed reality book: a visually augmented illustrative childrens' book, *Proc. International Conference on Advances in Computer Entertainment Technology*, ACM Press (2008), 292-295.
7. Greaves, A. and Rukzio, R., Interactive phone call: exploring interactions during phone calls using projector phones. *Workshop on Ensembles of On-Body Devices at Mobile HCI* (2010).
8. Koike, H., Sato, Y., Kobayashi, Y., Tobita, H. and Kobayashi, M., Interactive textbook and interactive Venn diagram: natural and intuitive interfaces on augmented desk system, *Proc. SIGCHI conference on Human Factors in Computing Systems* (2000), 121-128.
9. LeapFrog, http://www.leapfrog.com
10. Maribeth Back, M., Cohen, J., Gold, R., Harrison, S. and Minneman, S., Listen reader: an electronically augmented paper-based book, *Proc. SIGCHI conference on Human Factors in Computing Systems*, ACM Press (2001) 23-29.
11. Marshall, C., Reading and Interactivity in the Digital Library: Creating an Experience that Transcends Paper. *Proc. of CLIR/Kanazawa Institute of Technology Roundtable,* 2005.
12. Saso, T., Iguchi, K. and Inakage, M., Little red: storytelling in mixed reality, Abstracts SIGGRAPH, ACM Press (2003), 1-1.
13. Scherrer, C., Pilet, J., Fua, P. and Lepetit, V., The haunted book, *Ext. Abstracts nternational Symposium on Mixed and Augmented Reality* (2008), 163-164.
14. Wilson, A. D., PlayAnywhere: a compact interactive tabletop projection-vision system, Proc. symposium on User Interface Software and Technology, ACM Press (2005), 83-92.