

# Interacting with Printed Books Using Digital Pens and Smart Mobile Projection

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## ABSTRACT

Even though the number of e-book readers is continually increasing, it can be assumed that books will still be printed for a long time. To solve the challenge of combining the benefits of real books with the power of digital computing, we propose the concept of *Projective Augmented Books* (PAB). The envisioned device works like a reading lamp which can be attached to a printed book. An integrated pico projector displays aligned information onto the book pages. To support active reading tasks, digital paper and pen technology is used for a variety of marking and annotations styles. Dictionary lookup, translation, and copying to a scrapbook are also provided. As early user feedback with our prototype suggests, a truly mobile PAB system could successfully bridge the realm of books and computers.

## Author Keywords

Digital paper and pen, gestures, interaction, mobile projection, sketching, books, Anoto, paper interface

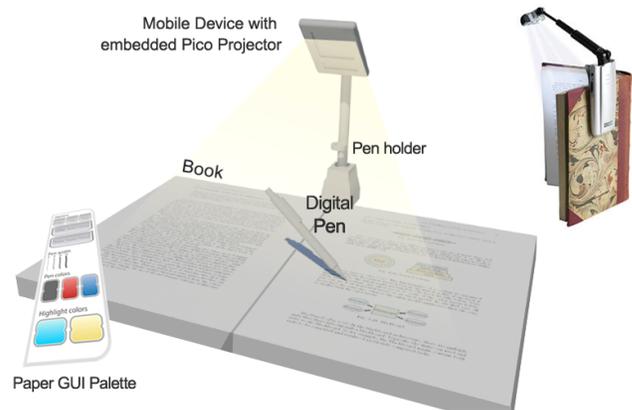
## INTRODUCTION

Trillions of books have been printed over the past six centuries. Therefore it can be assumed that books will still be printed in years despite the availability of lightweight electronic reading devices. Many people value the technology-free nature of books, their haptic affordances and sensory richness, as well as the ubiquitous availability and tremendous diversity of formats. Active reading tasks, such as highlighting text, marking graphics, annotating content or simply adding sketches can be easily done with printed books and pens. However, annotations are laborious to digitize. Additionally, the appearance of the book changes thereby and might be even damaged over time. Other functionality, such as looking up translations of words, linking to other content or retrieving additional information can be achieved far easier by using computer technology.

Digitally enhanced books can combine the best of both worlds. Augmented books and also desks (e.g., [17]) provide a natural way of interaction by enhancing physical books or other documents with digital features [12]. Previous research on augmented books can be divided into two groups. In the first, the information is projected as two- [19] and three-dimensional graphics [6]. These books always require special displays and often complicated technical setups. This limits the aspect of portability and

minimal system setup. The second group uses pens as an input device, but there is no projection of information onto the book or paper document [18]. Therefore, feedback is often insufficient if existent at all.

In our work, we are investigating alternatives of combining printed books, digital paper and pen technology as well as miniaturized projection technology to support active reading tasks. We propose the *Projective Augmented Book* (PAB) as a mobile solution combining a device like a reading lamp which can be attached to a printed book and project additional information on it (see Figure 1). On the input side, digital paper and pen technology (without ink) is used to recognize marks, to store annotations and to invoke commands associated with book content. Although the pen is used on the real book like we are familiar with, input is entirely virtual and immediately projected back onto the book. The cost-effective setup only requires printed books, an off-the-shelf digital pen and the projector lamp together with a mobile device for the computations.



**Figure 1. Basic principle of the PAB: A mobile device with a pico projector is used like a reading lamp to project dynamic content onto a book printed on digital paper. A digital pen and gestures are used for interaction.**

## RELATED WORK

Many researchers have tried to bridge the gap between digital and physical worlds [20]. One of the first attempts was the DigitalDesk [17], combining digital and paper documents on a physical desk. Other augmented desks include the EnhancedDesk and WikiTUI [19]. The latter projects multimedia elements on a book of choice. The multimedia installation Living Book employs a similar top-

projected setup and enhances books with additional content [7]. All approaches use a rather big, static setup with partly expensive components but inspired our system in terms of functionality. The recent LuminAR [9] system, a robotic augmented reality lamp, resembles the approach presented here, but again occupies a larger static space.

Mixed reality books [6] provide a three-dimensional augmentation of real books and thus seamlessly combine the traditional medium with new media, new ways of telling stories and highly interactive content. In projects like the MagicBook [3], computer screens, head mounted displays, or handheld displays are used to display 3D objects based on 2D Augmented Reality markers. However, pens are not used and traditional reading tasks are not supported. The output devices are still too clumsy to wear and decoupled from the book.

A number of research projects and also commercial solutions exist in the domain of using digital paper and pens for convenient interaction with an extremely popular, flexible, ubiquitous, and cheap medium offering better readability [1]. Many approaches are based on the Anoto [1] technology. Interaction can be done by means of pen gestures [16,18], sketching, or interactive palettes (e.g., [13]). Typically, input and output space are separated (like with PaperPoint [13] and PaperProof [16]). The real domain of paper and ink is often decoupled from the digital world in terms of time and feedback (like with commercially available Anoto-enabled sketchbooks). Even though affordances of paper books are kept while adding electronic augmentations like with the ScrapBook in MEMENTO [18], the projection of additional information onto the printed document is often not provided or not portable. An approach improving on that is PenLight [14], introducing a digital pen with embedded projector. This approach differs to the one presented here in the set of supported interaction techniques and in targeting larger paper documents from the field of architecture. It also does not feature an overall display of available annotations at once.

### THE PROJECTIVE AUGMENTED BOOK

Typical scenarios for people working with real books are a student preparing an examination and borrowing books from a library, a researcher preparing a lecture based on a text book or a customer choosing products from a mail-order catalog at home. In any case of active reading, people browse through pages, read passages, mark and annotate them and later come back to it to re-read what they have marked. To enhance working with real books like these, we propose the concept of the *Projective Augmented Book*. As shown in Figure 1, a printed book is used to attach a device like a reading lamp. Instead of shedding light, it contains a pico projector attached to the top. This projector allows projecting any digital information on top of the book. Depending on technology, the device can be integrated into a smart phone on top. Alternatively, the projector can be separated from the phone, which could be stored in the base

of the construction. The short throw projector can be adjusted with the lamp-like construction to allow for covering the entire surface of the open book.

Pen interaction is the most dominant way of annotating real books, of highlighting text or graphics, of scribbling or writing comments. We therefore suggest to use digital paper and pen technology for interacting with the book. As a consequence, the PAB requires any real book which is printed on digital paper. The Anoto technology allows to capture the interaction of a digital pen with normal paper. A tiny and almost invisible dot pattern is printed on each sheet of paper. The infrared camera integrated into the tip of the pen sees this pattern and processes it using onboard image recognition. Since the pattern is unique, the absolute position of the pen on the paper can be tracked exactly. This can be either stored within the pen or transmitted via Bluetooth in real-time to a receiver (typically: a computer). Besides the position, pen and page IDs are also transferred.

For the PAB, people are using an Anoto enabled pen with a plastic tip to allow for virtual annotations of the book without marking or damaging the book. Instead of transferring real ink, the pen position is sensed and transferred to the mobile computer in real time. Digital ink is then projected down to the very same place where the pen tip moves. This allows all annotations to be entirely virtual and user-dependent, e.g. for books borrowed from a library. For private books, a ballpoint pen or pencil tip can also be used leaving real and virtual traces at the same time.

The PAB is envisioned to be a truly mobile setup. People can take their book to any place, attach the virtual reading-lamp and start displaying stored annotations, editing them or adding new ones. By using the unique paper ID, a single touch with the pen transfers the book ID to the mobile device, which then retrieves the digital version of the book content from local storage or the Internet. A link between the printed and digital content is required. Since the book layout and specific Anoto pattern are known during printing, every element can be determined by just touching it with the pen (similar to [16]). Therefore, by underlining a sentence with a pen stroke, it is immediately known in the digital representation, which sentence was selected. A visual highlight can be projected at the precise place by using the pico projector. This only requires a simple four point calibration of the projection after attaching the device.

After turning a page, the reader simply needs to touch the paper at any point once to display all stored content for this page. Since the paper/page ID is immediately transmitted, stored annotations can be projected onto this page. For adding annotations, the first contact is sufficient to associate the pen strokes with the current page.

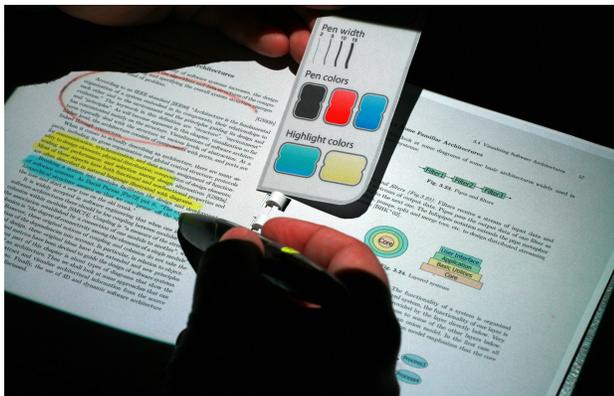
### INTERACTION TECHNIQUES

While developing interaction techniques for the PAB, we wanted to closely resemble the way people annotate real books with pens. In addition, enhanced digital functionality

which is not available with real books should be activated and used as smoothly as possible without interrupting the reading task. This requires mode switches or invoking special functions which can be achieved by two different basic methods. First, several pen gestures can be made directly on the book, which are not treated as annotations, but invoke a function such as the translation of a word. As a design principle, we suggest to provide alternative gestures for the same tasks to cater for a variety of users. Second, a separate tool palette made from paper can be used like a graphical user interface. These modes and the provided functionality will be explained in the following paragraphs.

### Basic Page Annotations

To annotate pages within the process of active reading, several marking styles can be realized [5]: marking by underlining, by using the margin (vertical line), by using crop brackets for a text block, by encircling content (lasso), and by highlighting (like with a text marker). Annotations can be graphical or textual as well as of eye-catching iconic nature, e.g. question marks. All these styles are straight forward and supported by the system. During a pen stroke, a line in the current color and width is drawn under the pen tip to provide visual feedback (see Figure 2).



**Figure 2. Annotating book pages by encircling and highlighting. Colors and pen width can be chosen from the paper palette. Annotations are stored for each page.**

In general, after doing a pen stroke and releasing the pen, the content is immediately analyzed. In the case of recognized pen gestures for issuing commands (see below), the strokes are removed after invoking the appropriate function. All graphical marking gestures, e.g. the corners of a text block to be marked (compare [16]) or the line encircling it, are automatically stored and interpreted. Marked text or graphics is internally selected in the digital copy. Thereby, any following command (e.g., copy) will be applied to the marked content. Any other form of textual or graphical annotation is simply stored with the page ID. In addition, text recognition can also be activated for this type of content to digitize hand-written text.

### Enhanced Functionality: Copy and Delete

Whereas the basic marking gestures and page annotations are stored as they are, all functionality described in the following uses single stroke pen gestures. After recognition, they trigger a certain command to be applied to selected text or graphics and vanish from the display.

Text passages and printed graphics can be transferred to personal diaries or scrapbooks (cf. [18]), which can be later managed on the mobile device or any other computer. After selecting content by means of margin bars, lasso or crop marks, a “c” symbol can be drawn to copy content.

To delete annotations, one can either use a crossing wipe gesture above the desired content or use an eraser. After choosing the eraser mode from the palette, the pen operates as an eraser. This allows deleting only small parts of an annotation.

### Enhanced Functionality: E-Mail, Translation, Encyclopedia

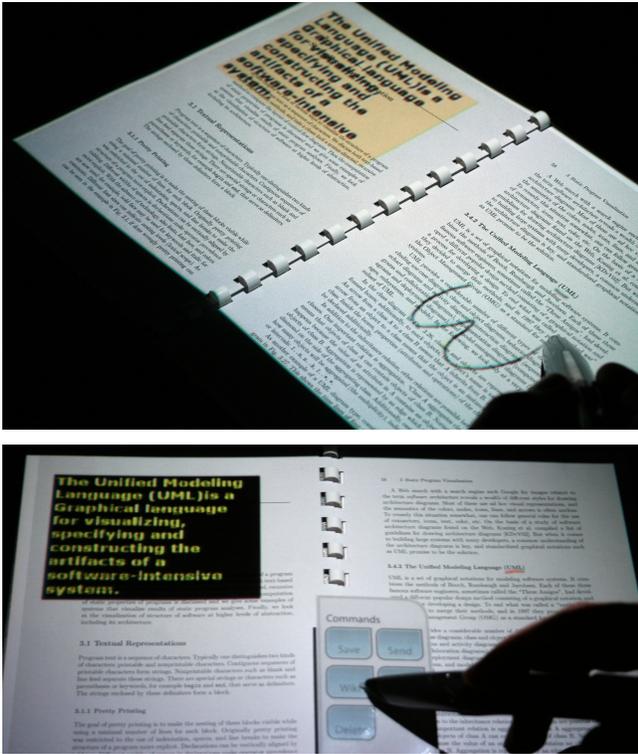
It is also possible to share content with other people by sending an email. For this option, the pen gesture “e” is used followed by a written email address, which is recognized by standard text recognition. To actually send the email, the user needs to finish the sequence with a checkmark pen gesture. Alternatively, she or he can touch the “Email” button on the paper palette.

After selecting a single word or group of words, the reader can translate it into another pre-defined language. This can be done using the single stroke gesture “D” (for dictionary) or the multi-stroke pen gesture “T” (for translation). This results in the translation being displayed on top of the book.

It is also possible to look up a word in an online encyclopedia such as Wikipedia. For that function, the “W” gesture needs to be done (see Figure 3, top). Both functions, translation and retrieving explanations, can also be activated using the appropriate button on the paper palette.

In the case of the encyclopedia, larger additional information is displayed as can be seen in Figure 3. This raises the problem of text visibility given the underlying printed content below. Even if a camera would be used to spot empty spaces on the page for displaying the content, there might be many cases, where white space will not be sufficient. Therefore, projection onto the text cannot be avoided entirely. With several tests concerning colors and brightness of the displayed content we found out that a dark background and light font color (not white) works best in terms of contrast and readability.

Assuming an audio capability which almost all smart phones and the LeapFrog [7] digital pen have, the translations and word explanations could also be read aloud as opposed to or in addition to visual feedback. The palette as displayed in Figure 4 right allows to explicitly choose this output modality if not provided by the pen already.



**Figure 3.** Using the pen gesture W for retrieving a short explanation of the underlined word (here: UML) from Wikipedia (top). Content is projected onto the book. The same can be done by tipping a palette button (below).

*Design of the Graphical Palette*

Command invocation can be performed directly on the book by means of graphical pen gestures. As an alternative, we propose a paper tool palette containing all described interaction modes, i.e. erase, copy, email, Wiki and translation functionality (see Figure 4, right). In addition, the palette contains buttons for choosing graphical attributes such as pen colors and stroke width. The tool palette was developed in an iterative design process. It is printed on Anoto paper, which allows an easy assignment of functions to active paper regions. Thus, the design and layout can be easily changed and adapted to particular tasks and required sizes. For invoking commands, the palette can be held in the user’s non-dominant hand or placed anywhere. It can also be thought of an interactive bookmark. Alternatively, it can be attached as a flap to the book cover or be an integrated part of the book jacket.

**IMPLEMENTATION**

Most of the described functionality was implemented as a prototype (currently: without text recognition and audio feedback). The system is shown in Figure 4. Due to the required projection distance of the DLP pico projector from Optoma, we require a tripod for mounting it. Therefore, the prototype does not allow true mobile usage yet. We expect this to improve with the next generation of steerable laser projectors with wide-angle lenses.



**Figure 4.** Setup of the running prototype used for the evaluation (left). Paper palette with GUI elements (right).

The software is written in C#, runs on a typical laptop and uses a modified version of a free gesture recognition library intended for mouse devices [4]. Data for each opened page is saved in a separate file. The pen stroke is partitioned into small segments and stored as a polyline.

**EVALUATION AND DISCUSSION**

Our initial prototype was evaluated formatively by using a usability inspection method. Five expert evaluators from our department were given typical test tasks of an active reading session. Their written responses were evaluated afterwards. Concerning the alignment of pen tip and projected stroke they were pleasantly surprised – even though misalignment by several millimeters occurred due to slightly offsetting the book (the projector was not attached). We conclude that pixel precise alignment is not required in typical quick annotation task, where roughly choosing a few words, pictures or paragraphs is the dominant activity.

The evaluators also found the suggested gestures to be memorable and especially the Wikipedia option desirable and pleasant to use. On the downside, the typical problem of distinguishing a command gesture (like the tick mark) from an annotation (looking similar) was raised. This is one of the reasons to provide the interactive paper palette. We also received valuable feedback, which has already been integrated in the current system as presented above. To provide an example: the first version required the user to actively save the annotations, which does not match our real world experiences with books, where annotations simply remain on the paper.

The hardware setup also needs to be improved to be truly mobile. Projection distance and calibration issues still need to be solved. The page recognition could be improved in the way that pages are automatically recognized after turning

without the need for touching it once with the pen. A combined projector camera system and (possibly invisible) markers on the pages would allow for optical recognition.

A major problem to be mentioned is the bending of the book, which can be considerable with paperbacks. By now, only planar surfaces were assumed. First, the bend in the middle needs to be taken into consideration. One solution would be to calculate an image for each slightly angled side of the book and combine it within a single image projected by the system. This is similar to the technology used in the magic lens system [15], where different information is projected onto multiple tilted lenses by a single projector. Second, the curvature of a page can be roughly estimated by continuous tracking the book's shape using a camera. The image to be displayed can be distorted accordingly.

Another important issue is the usage of the PAB approach for the majority of existing books, which are not printed on Anoto paper. One of the solutions we propose is to use a sheet of transparent foil with the Anoto pattern printed on it. This can be permanently attached to the book jacket and overlaid to a page as required for interaction. In any case, the book needs to be available in digital form.

## CONCLUSION

In this paper, we presented the concept of using a printed book as a projection surface for a pico projector which is attached to it like a reading lamp. For the proposed *Projective Augmented Books*, digital paper and pen technology is used to recognize marks and annotations and to invoke commands by means of simple pen gestures or by using an interactive paper palette. Thus, it is possible to look up words, to copy content to scrapbooks, and to share information by sending emails. Continuous graphical feedback is provided by the projected image aligned with the input. In contrast to many existing research approaches, PAB does not require fixed locations and expensive hardware and can be used almost everywhere. We also combined well-known pen interaction as a natural mode of interaction with a visual augmentation of real surfaces. This is related to the SixthSense approach [7] which uses touch gestures instead of pens. The PAB also supports multiple users by distinguishing their input and being able to display it user-dependently and combined.

For future work we will tackle some of the limitations and issues discussed above, i.e. technical improvements, better gesture recognition and disambiguation, as well as improved ubiquitous use cases. Especially, the usage of a camera projector system needs to be further investigated.

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