ARBS: An Interactive and Collaborative System for Augmented Reality Books

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Abstract. Augmented Reality (AR) has been studied from different application fields since the early 60s. In particular, AR has been usefully applied in the educational field, specially based on a versatile AR application called Augmented Book. We introduce the *Augmented Reality Book System* (ARBS), an interactive and collaborative application for traditional books augmentation. The proposed system allows the incorporation of AR content to any pre-existent traditional book. Once the AR content is incorporated to the book, it can be shared and explored by other users, allowing collaboration among readers. The ARBS does not require special programming or previous technical knowledge from the user. To validate the proposed system, we designed and conducted a novel experimental study with novice AR users. Very positive feedback from participants confirms the usefulness of the ARBS.

Keywords: Augmented book · User evaluation · Augmented reality · Computer graphics

1 Introduction

Augmented Reality (AR) has been studied by the research community for more than fifty years. First contributions to this field can be tracked back to the 60s, with Sutherland's *"ultimate display"* [24]. Nevertheless, due to technological limitations, massive adoption of these features was pushed back. In fact, both widely accepted definitions of AR were introduced in 1994 and 1997, by Milgram and Kishino [18] and Azuma [3] respectively.

AR has been addressed in several different fields [5,6,29,33]. In particular, AR shows a huge potential in educational applications [15,23,30]. Indeed, the research community has focused on the exploration of different approaches to enhance students motivation [13]. AR environments allow students to interact with both the real and the virtual world, exploring objects, performing dedicated tasks, learning concepts, developing skills and carrying out collaborative activities. Moreover, the immersion, interaction and navigation features that enable

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AR technologies play an important role to raise the students motivation [23], allowing experimental learning [30] or supporting advanced spatial visualization and interaction. These possibilities have been the most important aspects that motivated different types of AR learning environments for regular classroom practices [7].

A very promising AR application for education is the *MagicBook* of Billinghurst et al. [4]. It uses special books with AR fiducials (i.e. special markers that can be recognized by a computer software) as the main interface objects. People can turn pages of the book, look at the pictures and read the text like they are used to. However, if they look at the pages through an AR display (e.g. computer screen) they would be able to appreciate virtual contents appearing over the pages. This approach works over special books shaped as an augmented book from scratch, making impossible the augmentation of a traditional pre-existent book.

Despite the fact that in the last years there was a great increment of e-books and its specific hardware (e.g. e-readers like Kindle, Sony Book Reader, Nook, etc.), as stated by Grasset et al. [9] the physical qualities of traditional books (i.e. transportability, flexibility, annotation capabilities, etc.) are still preferred by readers. Other studies tried to port physical characteristics of books to purely virtual versions of traditional books [14], arguing that capabilities like flipping quickly through pages or annotating pages should resemble a printed book as much as possible. In this way, Park et al [20] stated that besides the advantages and disadvantages, both e-books and paper books will coexist for several years to come.

Many researchers and companies [1,31] explored the experience around AR books, adding new ways of interactions [9,13] or introducing collaborative tasks [16]. However, most of these approaches involved special books conceived as augmented books from scratch and are not applicable to traditional pre-existent books. This limitation has been overcome by research works that proposed authoring tools to generate augmented books [16]. Nevertheless, there are still limitations on sharing the virtual contents incorporated to a given book. For instance, the specific book created with these tools has to be installed manually in other device. Moreover, the AR field already counts with authoring and deployment tools [17,27] that allow users to create augmented contents and share them in a seamlessly way. Although these tools have proved to be effective for commercial or advertising and promotional purposes, they are still a general approach around AR and therefore lack of specific features which are necessary to facilitate the reading experience of books.

In this paper we introduce the *Augmented Reality Book System* (ARBS), an interactive and collaborative application for traditional books augmentation. The proposed system allows the incorporation of AR content to any pre-existent traditional book. Once the AR content is incorporated to the book, it can be shared and explored by other users, allowing collaboration among readers.

To validate the proposed system, we designed and conducted an experimental study with novice AR users. The results obtained not only reflect how novice users interact with the ARBS but also present some interesting findings on how they interact with AR applications in general.

The contributions of this paper can be summarized as:

- The design and implementation of a novel, interactive and collaborative system for augmented books based on the augmentation of any pre-existent book.
- The evaluation of the proposed approach within a novice AR user context and the report of the results and conclusions of the experiment.

The rest of this paper is structured as follows. Section 2 provides the related work concerning to augmented books. In Sect. 3 details of the ARBS approach are presented. The design and procedure of the experimental study is presented in Sect. 4, and the results are provided in Sect. 5. Section 6 presents the discussion of the proposed approach based on the obtained results as well as future research directions. Finally, Sect. 7 states the conclusions of this research work.

2 Related Work

The first augmented book based on Azuma's definition [3] can be tracked back to Rekimoto's research work [22]. However, the first approach that formalized the idea of an augmented book is the *MagicBook* proposed by Billinghurst et al. [4]. This initial version featured a handheld display based interface. The great impact was the immersive virtual environment that the user could explore. The Billinghurst's Augmented Book paradigm was applied in several fields [2,28,32]. This approach is proven to be still effective, for example for spatial skills development [15] or for learning geometric shapes [13].

Grasset et al. [10] explored the design space of what they called the *Mixed-Reality Book* and discussed different interaction techniques including gaze interactions, finger interactions and tangible interaction.

Many researchers used augmented books to address improvements in what is called *markerless* capability. Although AR based on fiducials has proved its usefulness, some people argue that these markers distract readers or even worse, ruin the book's environment. Thus, several registration methods based on textures (i.e. a distinctive image) were developed and used in augmented books [12,25]. In this way, a more natural usage is achieved because there is no difference between the augmented book and the real book (e.g. there are no markers that expose the registration method used).

Recently, authoring tools that enable non programmers to create their own augmented books are emerging [13,21]. Thus, the process of creation of this kind of books does not require highly qualified skilled professionals of information technologies. Nevertheless, all these approaches are based on books shaped as an augmented book from scratch and the only interaction with the book consisted in observing the virtual content. It means that none of the mentioned approaches can be applied to traditional pre-existent books. In contrast, there are alternative approaches like [11] that allows the update of digital contents of the book and provide other interactions types (e.g. multisensory feedback).

However, its production only can be accomplished by developers or researchers with technical background.

As stated before, the potential of AR books is promising, but there are some limitations. With all these constraints in mind, our work tries to overcome them by introducing an interactive and collaborative system (ARBS) that allows incorporation of AR content to any traditional pre-existent book. Once incorporated to the book, the AR content can be explored, modified and shared. The present work includes an evaluation of the ARBS by a robust statistical experimental study. As far as we know, up to now there are no standardized methodologies to evaluate AR books [8]. This motivated us to design an experimental study to evaluate AR books by different kind of novice AR users. In order to evaluate the books, we propose a two-scenario task-based evaluation to study the ease of use and learnability of the approach under two possible conditions (i.e. creating a new augmented book or starting from an already created one).

3 System Overview

We propose an interactive and collaborative and AR system called ARBS. This novel system allows the integration of augmented contents to any traditional pre-existent book. Since the system was designed to be used by novice AR users, the ARBS provides interactions to easily transform a traditional book into an augmented book. Moreover, the AR contents introduced to the book can be shared with other users, enabling and facilitating collaboration among readers.

The ARBS environment is composed by three main elements, namely: (i) the user, (ii) the computer device and (iii) the physical book. In the ARBS environment, the reader is represented with a user profile, through which the user is able to explore, create and interact with the augmented contents. The system is deployed in a computer with the classical configuration for AR applications (i.e. a camera to capture real world and a display to show the augmented world). It is important to mention that the ARBS implementation does not require any special device (like augmented glasses or sophisticated displays). Finally, when the user incorporates augmented content to a traditional book he/she is creating an Augmented Reality Book (ARB), which is stored in the system, and later shared with other users. Thus, the ARBS allows users to perform the creation of a new ARB, as well as the exploration of an already created one.

The following sections describe these elements in the ARBS environment. We detail the ARB representation and design that supports the incorporation of AR contents to any pre-existent book, the usage of the application to enrich traditional books with augmented contents, and finally the implementation and architecture of the system that allows the collaboration among users.

3.1 Augmented Reality Book

In the ARBS a physical book has its virtual counterpart in the form of an Augmented Reality Book (ARB). An ARB contains some basic information related to the physical book (like title, authors, description and ISBN code), the augmented contents and AR facilities that enhance the traditional book. The ISBN code[1] is used to uniquely identify an ARB. In addition to these basic attributes, an ARB provides a structure to storage the augmented contents. This structure is arranged in containers, and each container is assigned to a page of the physical book. Therefore, each augmented content is located on a specific region of a given page, enhancing the original content of the printed page. It is important to remark that multiple containers can be associated to the same page. In this way, the containers not only serve as a structure to hold augmented contents, but also allows to group contents based on the reader's decision.

Multiple augmented contents can be introduced to an ARB, such as images, 3D-models, sounds and text. In order to show them as virtual contents, a specific *marker* must be attached. As an initial interface for AR contents we propose the black & white markers (i.e. standard fiducials of AR applications). In addition, regarding to content placement we propose a single marker approach called *fixed marker*. We defined different locations to place the markers (see Fig. 1). The

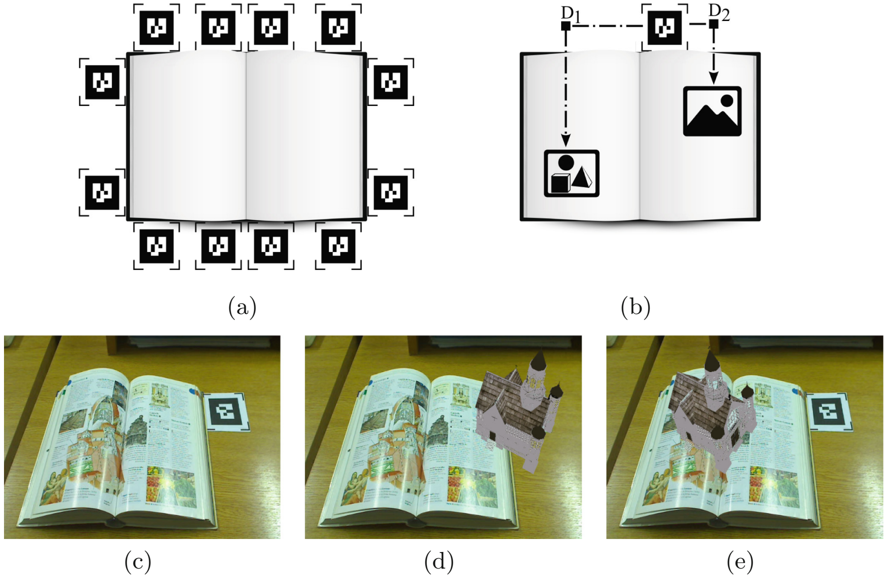


Fig. 1. Possible fixed positions for markers (a) and an example of the contents displacement concept (D_1 and D_2) from a single marker to situate two augmented elements over the book (b). Finally, an example of a book with a fixed marker at its right (c), an augmentation without any displacement (d) and the same augmentation with a transformation applied (e).

[1] The International Standard Book Number (ISBN) is a unique numeric commercial book identifier.

reader can place augmented content on a given marker location and apply 3D transformations to move the content to a specific place over the book's page.

Despite this single marker approach, we considered another type of marker defined as *free marker*. This is the classical use of markers from the point of view of a tangible user interface, allowing users to move the marker freely throughout the book. Thus, there is no constrained location for this kind of markers.

Besides these two marker approaches, there is no restriction on the quantity of markers to be used by the readers. Users can add as much markers as they consider necessary.

3.2 ARBS Workflow and Interface Application

In order to enrich pre-existent books with augmented contents, we propose a usage workflow which involves two main stages (see Fig. 2): the creation/request of an augmented book and the incorporation/exploration of digital contents. The first stage consists in the creation of the ARB for a traditional book. However, if the ARB for that book already exists, this creation is not needed and the reader can just request the corresponding ARB. Thus, as a result of this stage an ARB is selected to continue with the next stage.

In the second stage, the reader can explore the contents included in the previously selected ARB as well as introduce new contents to it, such as images, digital text notes, sounds or 3D models. However, to proceed with these tasks there is an important step that must be carried out: the page selection. Therefore, the first step of the second stage consists in issuing the book's page that contains the particular augmented content the user wants to explore, or issuing the book's page where the user wants to incorporate new augmented content. Once the page is selected, the user can incorporate new augmented contents or explore pre-existent ones.

In the last step of this workflow, the reader can visualize, explore and interact with the augmented contents. The ARBS provides a rich set of interactions such as geometrical transformations for the augmented contents, markers selection and positioning, content sharing, etc.

Figure 3 shows the interface of the ARBS. In this session, the user interacts with an ARB exploring specific augmented content. The system interface allows searching an ARB and navigation through its virtual pages to explore the augmented contents associated to each one of them. Finally the user can select one augmented content in particular. When the user explores the selected content, the interface shows the type of marker that must be used, and in the case of a fixed marker it shows its corresponding location.

On the other hand, the user can create a container for a given page of the book in order to introduce a new content to it. Thus, the ARBS provides an interface to introduce a new content (see Fig. 4). The user can select the type of augmented content as well as the desired type of marker. Finally, using the geometric transformations in 3D (i.e. scaling, rotation and translation), the augmented content can be situated at some specific location over the book.

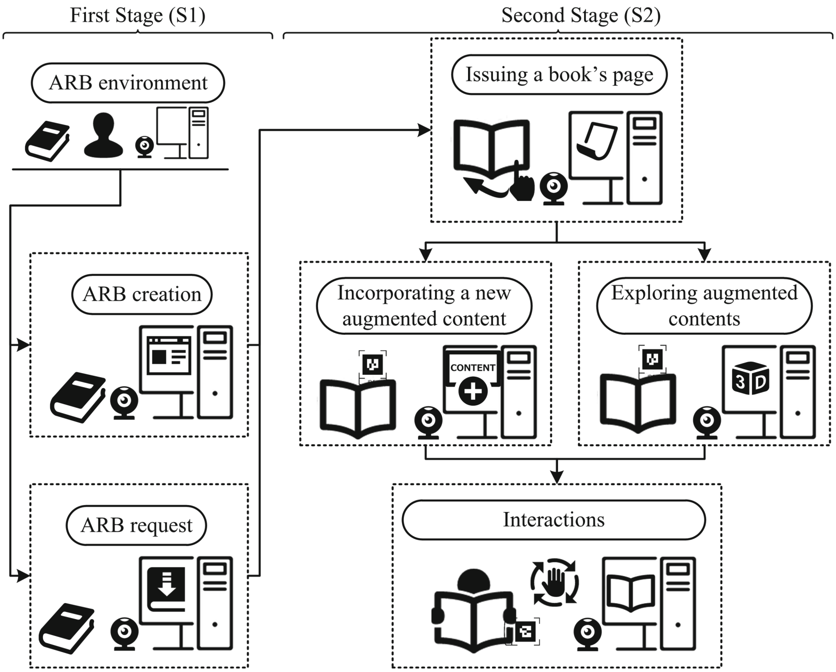


Fig. 2. The proposed workflow using the ARBS.

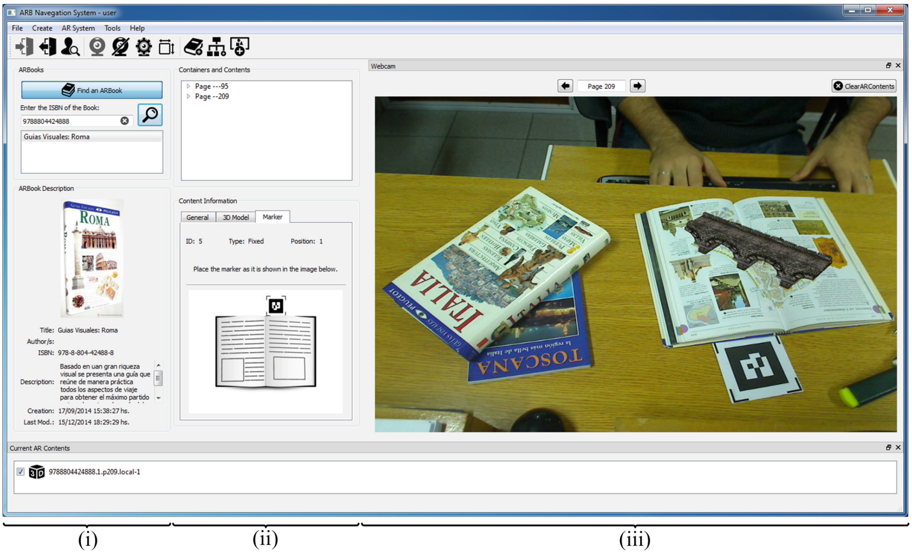


Fig. 3. ARBS interface showing (i) the search section with the loaded books and the information of the selected book; (ii) the corresponding containers and contents of the selected book, with the information of the selected content; and (iii) the viewport showing the frames captured by the camera with the rendered AR content.

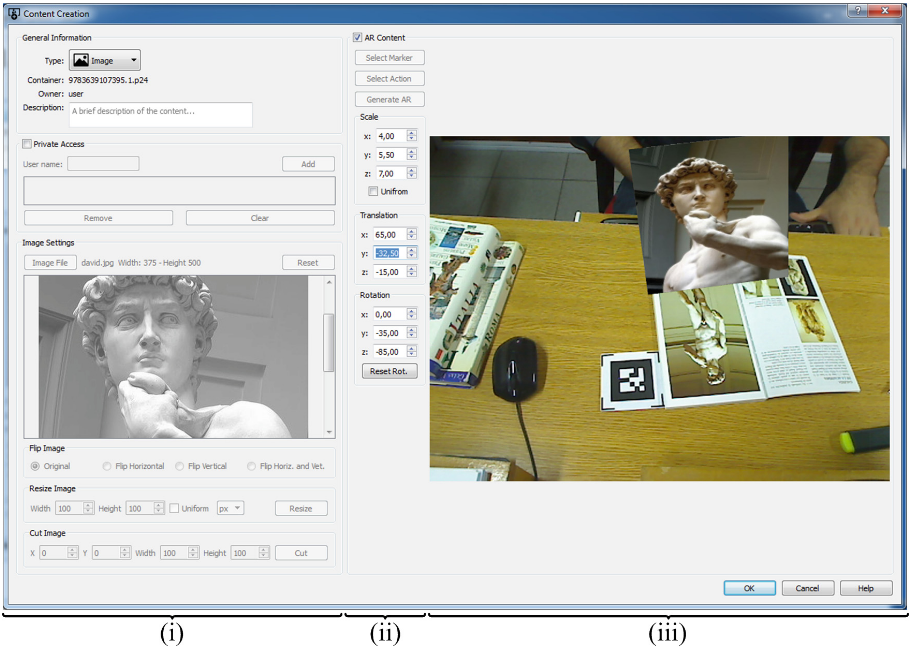


Fig. 4. ARBS interface for the content incorporation showing (i) content general and specific attributes; (ii) markers selection and transformations setup; and (iii) the viewport showing the current AR content.

3.3 ARBS Architecture

The ARBS Architecture is composed by two software components: a front-end application and a back-end server (see Fig. 5(a)). The front-end application is used for the creation and exploration of ARBs. It consists in three main layers components. The upper layer provides the functional modules to handle ARBs and its contents. The AR and Rendering modules are in the a middle layer, which handles the real-time requirements of this type of AR application (i.e. capture frames to process them and show the corresponding augmentations). Finally, the lower layer provides the support for the communication between the front-end application and the back-end application.

On the other hand, the back-end application consists of the server application. It has two main functionalities. One function is to store all the information related to the ARBs. The other main function is to response both ARBs and contents requests. Thanks to this client-server architecture the ARBS enables collaboration among users. Since all the ARBs are designed as shared elements, each ARB is unique and all its contents are accessible to other readers. Figure 5(b) shows the collaboration schema offered by the ARBS.

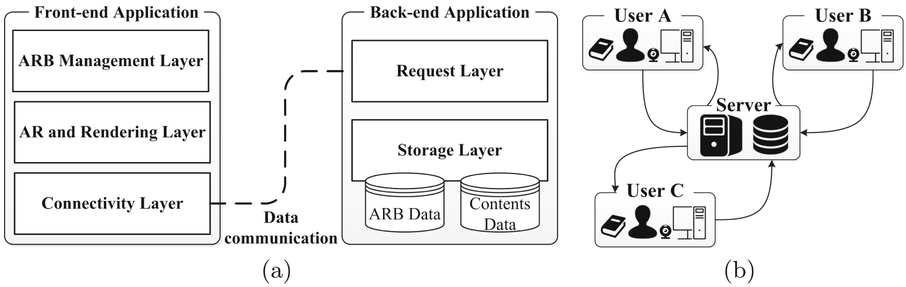


Fig. 5. The ARBS client-server architecture (a) and the collaboration schema among users (b).

The ARBS was implemented in C++ using the Qt Framework[2]. The rendering process was developed using the programmable pipeline of OpenGL[3]. AR features were developed using the ALVAR library1[4]. Finally, we used the OpenCV library[5] to capture frames with the camera. Both front-end and back-end software components were developed using a framework based approach. This allows to easily extend the ARBS with new features, such as more complex interactions or new types of augmented contents. Further customization can be done by adding new modules to the corresponding architecture layer.

4 Experimental Study

The overall goal of the experiment was to study how novice users interact with the proposed application in order to customize traditional books into augmented books. In addition, we intended to observe how different physical properties of books affect the augmented content incorporation.

4.1 Participants

Sixteen participants with ages ranging from 25 to 59 (M = 34.3, SD = 11.1) and comprising of 8 males and 8 females participated in this experiment. Nine participants informed they had used at least one 3D modeling application. Twelve had heard about AR but only ten stated they thought they knew what AR was. Only two participants informed they had used an AR application.

The computer experience of the participants was established from a three category scale, namely: novice, intermediate and advanced. Ten participants considered themselves as users and six as intermediate users. The main activities of the participants were BsC Students (5), PhD Students (5), Professors (3) and other activities (3).

[2] http://www.qt.io/.
[3] https://www.opengl.org/.
[4] http://virtual.vtt.fi/virtual/proj2/multimedia/alvar/.
[5] http://opencv.org/.

4.2 Design and Procedure

Since the proposed approach for augmented books tries to overcome the learning difficulty of this kind of systems, we decided to focus our experiment on two different cases: (i) when the participant uses the system for the first time creating an ARB from scratch; and (ii) when the the participant uses the system for the first time and interacts with an already created ARB. In this way, the experimental study followed a within-subject design where each participant was involved in two different scenarios.

Each scenario was conformed by several tasks pointing to interact with the augmented books including creation and visualization of different types of contents (e.g. text, images and 3D models). The evaluation also considered physical properties of books (i.e. how users perceive thickness, size or curvature of pages while positioning augmented contents) as well as how participants handle multiple books concurrently. Moreover, we studied the markers usage by introducing tasks where participants had to choose the type of marker (fixed vs free markers) or deciding how many markers to use.

Participants were evaluated individually performing an experiment composed of five phases (see Table 1). The first phase presented a questionnaire pointing to gather the background and demographic information of the participants. Secondly, the evaluator gave the participant a brief talk (about 10 min) of what AR is and the main uses of the proposed approach for augmented books. In order to avoid any bias, this brief introduction was structured to be explained in a similar fashion to each participant and without using or referring to specific features of the system.

Phase 2 and 3 consisted in the evaluation of the two scenarios. Each scenario was composed of 12 tasks that were provided individually and presented in a printed sheet of paper. Each task was defined as a description of what must be carried out without any explicit reference to the application's interface. We divided the evaluation in two groups of participants randomly assigned. Group A performed Scenario I in phase 2 and Scenario II in phase 3. In an opposite manner, group B performed Scenario II and Scenario I in phase 2 and phase 3 respectively. To evaluate the ease of use and learnability of this approach we measured the completion time [19,26] and also the success rate of each task. Both scenarios had similar but not identical tasks.

Finally, the purpose of phase 4 and 5 was to collect qualitative information. Phase 4 consisted of a subjective questionnaire, including questions about system's usability and the evaluation (five-level likert scale questions), opinions about AR technology (dichotomy and multiple choice questions) and information and feedback for future directions (open text questions). Lastly, phase 5 conformed a semi-structured interview, in which the evaluator asked open questions to obtain more feedback about the participants opinion.

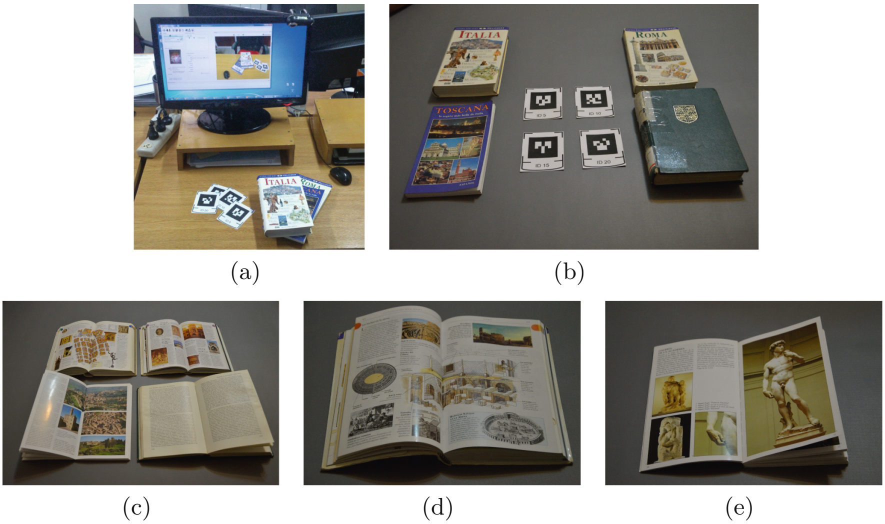
4.3 Environment Setup

The computer used for the experiment was a machine with AMD Phenom II X4 840 CPU, 4GB DDR3 memory and an ATI Radeon HD 5750 video card

Table 1. Description of the evaluation design. Group A and B consisted of 8 participants each. In Scenario I participants created an ARB from scratch and in Scenario II participants used an already created ARB.

	Group A	Group B
Phase 1a	Background questionnaire	
Phase 1b	Brief introductory phase	
Phase 2	Scenario I evaluation	Scenario II evaluation
Phase 3	Scenario II evaluation	Scenario I evaluation
Phase 4	Subjective questionnaire	
Phase 5	Semi-structured interview	

running Microsoft Windows 7 64-bit operating system. The display was a 22-inch LCD and the camera was a Logitech 9000 pro. We provided four markers and four books with different characteristics such as hardcover/softcover, size and quantity of text/illustrations (see Fig. 6).



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

Fig. 6. Evaluation environment (a); the four books and markers used in the experiment with different characteristics such as soft/hard cover and different thickness properties (b); different page layout of books used (c); example of curvature of pages (d); and influence of top-most pages of the book (e).

5 Results

5.1 Completion Time

The completion time of each task was measured. The total average time of scenarios from each group is shown graphically in Fig. 7. These results were submitted to an initial analysis which consisted of a paired t-test revealing a significant statistical difference for the scenarios of both groups (Group A $t(8) = 6.978$, $p = 0.0002$ and Group B $t(8) = 7.749$, $p = 0.0001$). From this prior analysis we can infer that the second scenario performed by each group reveals a faster operation. Thus, we can consider this as a first indication of knowledge transfer between scenarios.

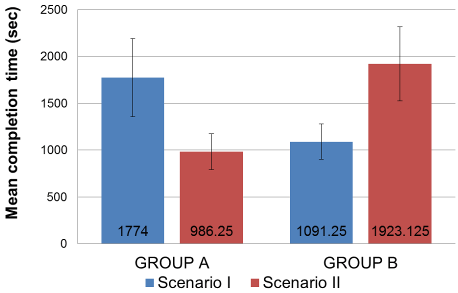
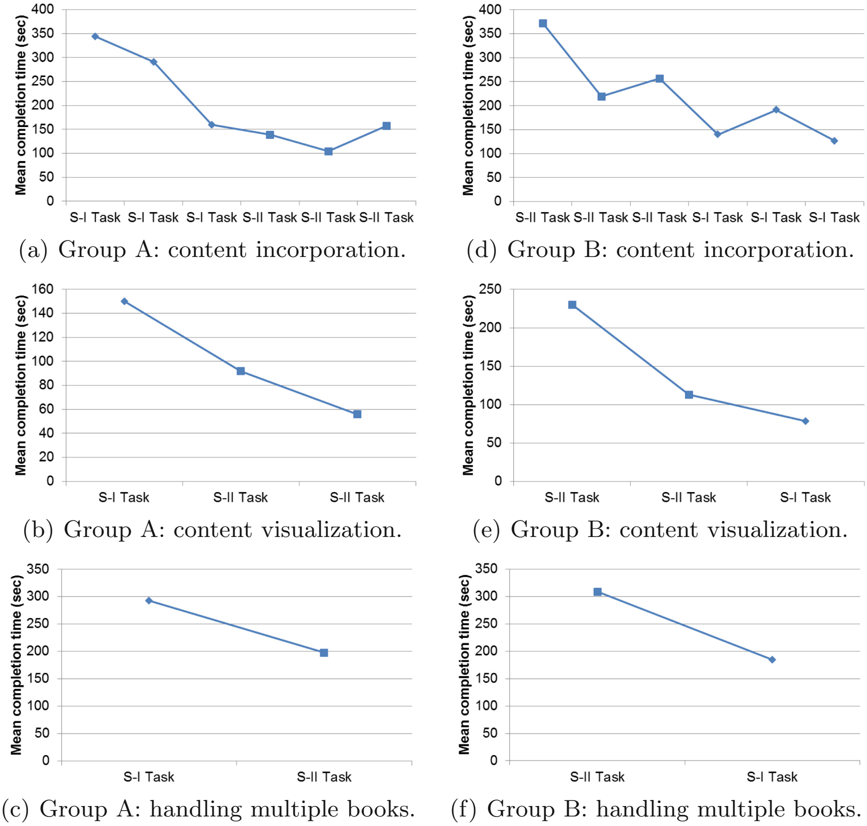


Fig. 7. Total average time of scenarios performed by both groups of participants. Note that Group A performed Scenario I first and then Scenario II, while Group B performed Scenario II first and then Scenario I. Error bars represent 95 % confidence interval.

A deeper analysis of the measured time also reveals a decrease in the average completion time of related tasks. Figure 8 shows the average time that participants of Group A spent on three different types of tasks. Among the six tasks that involved augmented content incorporation there is a highly significant statistical difference as determined by one-way ANOVA ($F(5, 42) = 11.03$, $p < 0.001$). The same analysis showed that there is also a statistically highly significant difference in the three tasks related to visualization of contents ($F(2, 21) = 24.14$, $p < 0.001$). In the case of using concurrently multiple books, the comparison of the two tasks only reveals significant statistical differences ($F(1, 14) = 6.29$, $p < 0.025$).

Participants belonging to Group B, which performed in first instance the Scenario II and secondly Scenario I, also reveal a general decrease in the time spent on the different tasks (see Fig. 8). An one-way ANOVA test determined highly statistical differences on the six tasks related to augmented content incorporation ($F(5, 42) = 14.26$, $p < 0.001$). For the case of tasks that involved augmented content visualization we also found highly statistical differences ($F(2, 21) = 32.29$, $p < 0.001$). Finally, we found significant differences ($F(1, 14) = 5.56$, $p < 0.033$) between the only two tasks based on handling multiple books.



(a) Group A: content incorporation. (d) Group B: content incorporation.

(b) Group A: content visualization. (e) Group B: content visualization.

(c) Group A: handling multiple books. (f) Group B: handling multiple books.

Fig. 8. Average completion time of tasks from both scenarios performed by Group A and B of participants (tasks are shown in performing order).

Based on the exposed statistical results of the two groups of participants we can confirm significant differences in the time spent to perform tasks. On the basis of this analysis, we have concrete evidence supporting both ease of use and learnability of the proposed approach.

5.2 Success Rate

We have measured how effectively participants were able to complete the tasks in both scenarios. We decided to use a level of success model [26] instead of the binary success rate model, in order to capture the learnability of the system. Thus, we defined four levels of success based on the degree of the tasks completion and the assistance needed to complete them (see Table 2).

We analyzed the same group of tasks described in the previous section. The degree of success in each task can be expressed as a percentage, shown graphically in Fig. 9. In neither of both groups participants gave up on any task, being able to

Table 2. Categories utilized to evaluate the level of success rate of tasks. It is important to note that the evaluator only guided the participants when they asked for assistance and the evaluator did not explicitly solved their difficulty.

Level of success categories	
Category	Description
Complete success	Successfully completed the task
Partial success	Successfully completed the task but needed assistance
Partial failure	Successfully completed the task but had major problems
Complete failure	Participant gave up and did not finish the task

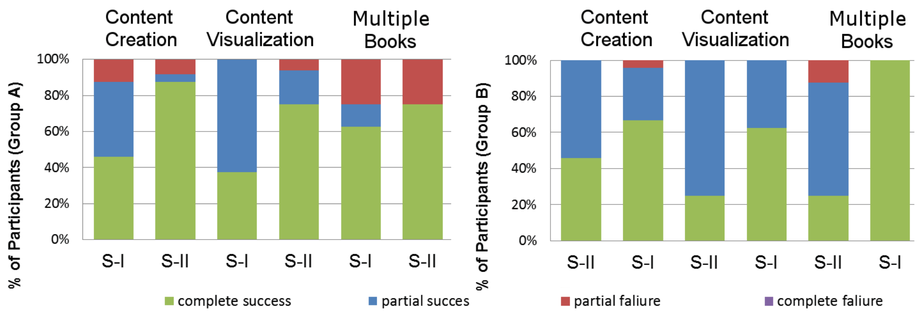


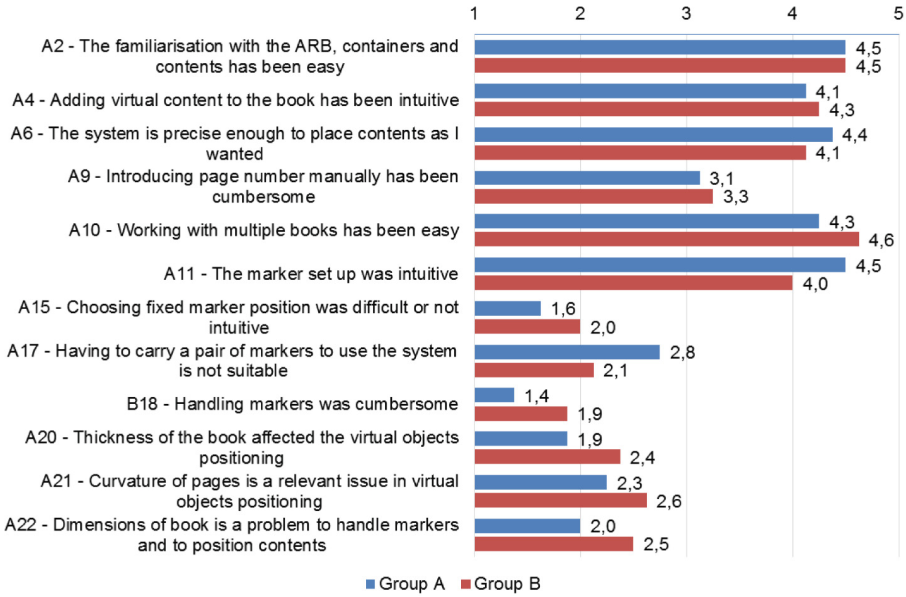
Fig. 9. Level of success rate of tasks from both participants groups.

complete all the tasks. Some degree of assistance was needed in the first scenario, however the second scenario performed by each group showed an increase in the success of the completed tasks. These results also empower the research findings about the learnability and ease of use of the ARBS.

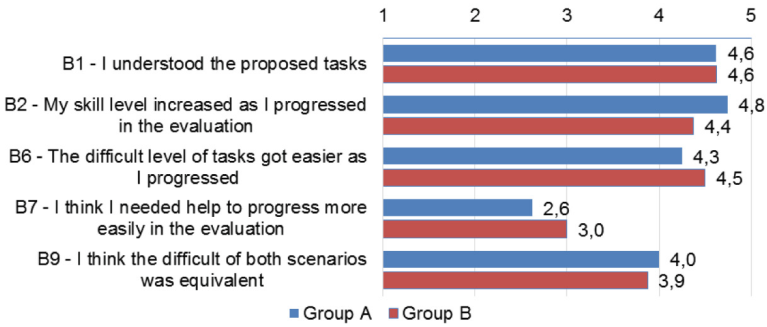
5.3 Subjective Results

Results regarding to the ARBS approach are shown in Fig. 10(a). In general both groups informed similar opinions about the usage of the system. Marker positioning was not perceived as an issue by both groups of participants. They also did not considered a problem to deal with printed markers. The feedback obtained suggests that participants did not noticed books' characteristics as an issue.

Survey about the evaluation showed that both groups of users agreed on the fact that Scenario I and II seemed equivalent and participants got more skilled as they progressed in the evaluation (see Fig. 10(b)). These results were submitted to a two-sample t-test analysis which outcomes are grouped in Table 3. From this analysis emerges that there are no significant statistical differences in the answers of both groups. Therefore, we can conclude that starting to use the system with an already created book or creating it from scratch, was conducted similarly.



(a)



(b)

Fig. 10. Subjective questionnaire results from the usability of the ARBS (a) and the evaluation (b). The scale used was *totally disagree(1), disagree(2), neither agree or disagree(3), agree(4)* and *totally agree(5)*.

Table 3. Two-sample t-test of the evaluation questionnaire's results.

Two-sample t-test					
Questions	B1	B2	B6	B7	B9
sig.	–	0.15	0.51	0.52	0.80

Regarding to the subjective opinion about this technology all the participants agreed that AR technology has been really interesting to use with books. They also considered that the ARBS results in a useful complement to traditional books making them more engaging. In addition, participants acknowledged that learning to use the system was not a problem or a restriction. Moreover, 70 % (11 out of 16) of participants considered this technology suitable to be used in a library, a university or at home.

Finally, from the semi-structured interview we obtained more detailed opinions about the evaluation. All of them explained that the scenarios seemed similar and they stated that the second scenario was easier due to the previous knowledge obtained from the first one. Most of them (15 out of 16) considered this technology capable to improve attention or motivate reading books. Although 70 % (11 out of 16) said that the types of contents provided by the system were enough, they also suggested more contents or technologies to be added such as videos or even more complex interactions like games.

6 Discussion and Future Directions

6.1 System Usability

The results obtained expose that ARBS is easy to learn. The participants' opinions supports this statement, since they acknowledged that the lack of technical knowledge was not an impediment to learn AR, and in particular the ARBS. Moreover, results from questionnaires show it was easy to become proficient with the System and AR.

We expected to find difficulties in the incorporation of augmented contents, however this was not an issue for novice users. Nevertheless, we observed some issues on the system interface. For instance, it was not clear how to start the camera the first time (requirement that was imperative to create augmented contents). Consequently, the first task carried out by the participants demanded evaluator's assistance. The open questions also revealed that the needed assistance was not due to AR features such as markers handling or virtual content positioning, supporting the research objective.

During the final interview, the feedback around the learnability of the approach was very positive. In general, novice participants were really surprised on how easy they get used to the technology. Opinions such as *"I though it would be harder"* or *"I did not expected to enjoy the evaluation"* remark the positive aspect of easiness of the approach. However, based on the observed interface difficulties and opinions about the interface, we believe that including automatic guidance in the system would solve most of these issues.

6.2 Book Physical Properties

Observations during the evaluation revealed that the different physical properties of the books did not negatively influenced the usage of the ARBS. We expected to find some negative reactions from participants when they had to incorporate augmented contents in situations were curvature of pages or thickness of the book could affect the task. However, it was really surprising how natural users handle these situations. We can conclude that this behavior is due to the natural interface that offers the book, since every participant used them as they were used to.

Other interesting finding is how participants dealt with multiple books. In general each participant handled multiple books in a particular way. For instance some participants used different markers for each book allowing to use books in parallel. Other users used books concurrently changing them as they needed or even keeping always one book on top of the other. Finally, another case we observed is that some participants did not changed books at all since they worked only with one marker. We conclude that this last situation, although it was not a standard practice, is due to the lack of page recognition (because it is not required to keep visible the issued page).

Finally, we proposed the possibility of implementing an automatic page recognition feature. Opinions were diverse. All of participants agreed that incorporating such automatic system would be a benefit. However, they also agreed that introducing the page number manually on the system was not cumbersome. These mixed opinions need further research to draw a conclusion on which option results more convenient.

6.3 Markers

In general participants were not distracted with the marker location, however they had to be careful not to occlude the marker. We did not notice difficulties on the usage of fixed markers over free markers. Nevertheless, we observed that in tasks where participants were suggested to choose a marker, the preference was even.

Nevertheless, most participants (14 out of 16) agreed on using several markers and not just one. During the interview the general opinion was that only one marker is too restrictive. They did not perceived as a problem carrying a couple of markers either.

We observed that users get used to the markers' positioning quickly. The subjective results confirm this, since participants did not revealed negative remarks on the proposed locations for fixed markers. Moreover, some participants stated they understand the use of fixed markers, however free markers resulted more engaging. We think this is due to the possibility of the direct manipulation of markers, allowing more interaction.

6.4 Future Work

Although promising feedback was obtained, the ARBS system still has other features to be taken into account. The ARBS provides several augmented contents and interactions for them. However, there are still other contents to be considered (e.g. videos) as well as other kind of interactions (e.g. multimodal interactions).

Though the single marker approach is effective, we plan to improve the existent AR features adding *Markerless Registration and Tracking* in order to obtain a more natural interface with the book. Since the ARBS was implemented using a framework approach, these new features can be easily added to the system. We also plan to port our system to mobile devices. A mobile system could be useful in environments where it is difficult to have a desktop computer for each reader (e.g. a library).

There are other research possibilities to explore around the evaluation. To evaluate learnability we conducted the experiment in two scenarios with only 15 min of difference. We would like to study how this is affected with longer trials, such as after a week or even a month. Since ARBS system allows to share contents with other readers, it is interesting to design tasks oriented to study how readers can interact using this feature. This might involve performing the evaluation of more than one participant at the same time. We also would like to evaluate the system with greater number of participants with advanced knowledge in order to make a comparison to novice users.

7 Conclusions

In this paper we presented a novel system for augmented reality books. The ARBS allows readers to incorporate augmented contents to any pre-existent printed book. This novel application facilitates the generation of new augmented books by users without technical background, enhancing their books with information that a conventional book does not provide.

The application has been evaluated by 16 participants who created and edited augmented books under two scenarios. Quantitative and qualitative measures suggest that this technology is easy to learn and use, and opens up great possibilities to enrich the traditional reading experience. Participants were able to enhance four books incorporating different types of augmented contents. We summarized future directions for this approach and we expect to use this technology in different environments such as libraries and classrooms.

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