Enriching Augmented Reality with Text Data Mining: An Automated Content Management System to Develop Hybrid Media Applications

Rocco Raso
IWi - German Research Center for Artificial Intelligence (DFKI)
rocco.raso@dfki.de

Dirk Werth
IWi - German Research Center for Artificial Intelligence (DFKI)
dirk.werth@dfki.de

Peter Loos
IWi - German Research Center for Artificial Intelligence (DFKI)
peter.loos@dfki.de

Abstract

Augmented Reality (AR) tools offer novel typologies of contents to generate Augmented Print (AP) systems. Compared with traditional print media, the development of AP applications requires additional efforts to identify thematic contents, which are suitable to be enhanced by AR systems. The generation of virtual contents represents a potential obstacle for developing AP applications. Motivated by the necessity to provide hybrid media applications with more efficient tools, in this paper we present a novel paradigm, which employs an automated framework to face the issue of content creation and content management. We propose a model for the automatic detection of specific textual contents in traditional print media. Using techniques from text data mining, we identify virtual contents which match the editorial contents. This aids in the process of content creation and management and, as a result, simplifies AR content delivery and shapes new perspectives for hybrid media applications.

1. Introduction

Since the beginning of its large scale diffusion, Augmented Reality (AR) has been perceived as a visionary tool addressed to revolutionize print media. The integration of AR tools and paper-based media enables the connection between virtual contents and real environment. Due to the presence of a physical medium with paper-based images and textual contents, traditional print media are certainly suitable to be extended with AR contents. The widespread availability of mobile devices with ubiquitous internet connection makes it possible to diffuse Augmented Print (AP) applications on a large scale.

Almost twenty years after the first academic definition of Augmented Reality [1], the integration of AR tools and print media seems, however, to fall through. The low offer of print media enhanced with AR systems, which are available on a regular basis, in comparison with the copious offer of special issues enhanced with AR systems, suggests peculiar difficulties in the integration of AR tools and print media. Although several AR applications for paper-based media have been created, the use of AR tools to enrich print media still does not lead to a persistent modification of the editorial content. The examples of integration of AR tools and paper-based media represent sporadic experiments and non-persistent modifications of the offer of contents for print media. The creation of AR applications for print media usually follows handcrafted and manual processes because AR applications must be tailored around the specificity of every release of a magazine. This lack of automated and industrialized processes imposes a large growth of cost and time for publishing companies which intend to offer AP applications. In particular, the excessive effort for the content creation and management of AR systems limits the diffusion of this technology for print media on a wider scale and the consequent development of hybrid media.

In this context, we identified a necessity to modify the traditional processes for the development of AR applications by means of the introduction of automated tools as well as text data mining techniques. In this paper we present a new paradigm of augmented print which is oriented to the integration of specific text data mining tools to industrialize the content creation process for hybrid media. We present a completely automated AR app generation system, which enables the industrialized development of AR apps for hybrid media. The methodology of our research identifies a specific scenario in order to design solutions useful to improve the originally inherited situations. Among other research purposes, the defined augmented reality environment will be the ground where we validate tools coming from different contexts, such as text data mining techniques.

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The structure of the paper can be summarized as follows:

- Introduction of our concept and motivation of the need to define a novel automated approach for the content management of augmented print applications. The model we propose is characterized by an automated approach to reduce the effort for the creation and management of content for AR applications and is based on the use of text data mining techniques.
- A brief exploration of the current state of research and technology in order to describe the state of the art of the application of AR tools in print media. We introduce examples of integration of AR applications in print media and we present specific AR tools for print media.
- Presentation of the possible theoretical approaches to face the proposed research questions. We used specific text data mining techniques and we analyzed their application to automate the content creation and management of AR applications.
- Application of the presented theoretical approaches to a specific use case and description of the prototypical implementation.
- The paper concludes with the synthesis of the achieved results, a short outlook and a discussion of future work.

2. Background literature

2.1. Augmented reality and print media

One of the first examples of an integration of an AR system into a print medium is represented by the "MagicBook" [2]. MagicBook is a prototype of an AR book that permits a reader with Head-Mounted Display (HMD) to explore 3D models during reading a print medium. Although this AR system has a considerable importance in terms of research, it also presents some limitations: the use of HMD reduces its large scale diffusion and the use of AR markers as trigger entities limits the printing area of the text; as a consequence, there is a considerable reduction of its business potential. With the improvement of the AR detection techniques, the application of AR tools for print medium started to avoid the use of AR-Markers in favor of images. The first example of AR application for print media triggered by an image printed on a paper-based medium is represented by an AR advertisement. The British automotive marque “Mini” ran the first augmented print advertisement on several automotive magazines [3]. Going on a specific website, the user could access related AR contents through a computer camera. The diffusion of mobile devices and smartphones simplified the access to AR environments. One of the first AR apps useful to integrate a release of the newspaper with virtual contents has been developed for the German magazine "Süddeutsche Zeitung Magazin" [4]. The reader can experience the enhancement of contents of some selected printed images just scanning the print medium with a smartphone. Several further experiences tested AR applications for print media (e.g., "Stern" [5], "Auto Bild" [6], "Welt der Wunder" [7], "Rheinische Post" [8], etc.). Although several implementations have been performed, all existing applications of AR tools in print media represent sporadic applications. They do not represent a persistent and continuous modification of the offer of contents for print media.

Even if the results are promising, very few paper-based magazines go beyond the testing phase of AR technology. The average reading time of a traditional printed advertisement is 3,9 seconds [9]. Researches demonstrate that the average reading time of a paper-based AR advertisement is 12 seconds [10]. It means that the users are generally more engaged and they are more available to pay attention to the proposed advertisements if they are involved into AR environments. It certainly represents an encouraging market potential but, surprisingly, print media are far from adopting novel augmented print approaches as business models. One of the probably reasons why augmented print applications are not prevailing is related to the technical difficulties that non-automated AR app generation processes must face. Without an automated, industrialized content creation and management framework, the creation of contents for AR applications is extremely complex and expensive.

2.2. AR app generation tools for print media

The use of AR technology to integrate print media is certainly dependent on the existing IT-tools which are useful to develop AR systems. The spectrum of technical possibilities and the offer of AR tools grow rapidly. Nowadays, several IT-tools offer the possibility to create AR applications (e.g. ARToolKit SDK [11], Vuforia AR SDK [12], Wikitude SDK [13], etc.). Since both paper-based AR applications and print media need physical support (e.g. printed paper), it is clear that they can be easily integrated. The necessary presence of a physical print medium, which is useful to transmit the information, enables the easy integration of Matrix Barcodes (e.g., QR-Code, Aztec Code, Data Matrix, etc.), AR Markers or textured images. In print-based AR systems, these items are defined “trigger entities”, since they permit to start the representation of virtual contents. Additionally, different typologies of

trigger entities permit to access virtual contents by means of AR applications. Trigger entities may be simple physical objects in feature detection based AR systems [14], for instance. Innovative techniques such as OCR-tools [15], encoded paper [16] or text patch recognition [17] may also be involved to create AR systems.

2.3. Research contribution

The creation of immersive and hybrid environments for print media enables the possibility to shape innovative scenarios. Even if the possibilities offered by the augmented print systems are not confined to the domain of augmented reality [18], we must consider that mixed and augmented realities represent a key tool permitting the development of augmented print applications. The analysis of the scientific literature shows that the integration of AR technologies in print media is sporadic or only partial and does not represent a persistent modification of the typology of the offered editorial contents [19]. Therefore, we designed a specific framework which is able to face the problem of the automated creation of an AR app. Our system describes an automated AR app creation process which creates an up-to-date AR app through a structured app creation process. This process is tailored to the needs of an existing publishing company and it enables the generation of a structured augmented print model. These presuppositions are necessary to depict the paradigm of hybrid media application which we introduce in this paper.

An AR environment is defined by the presence of three specific components: 1) medium (e.g., mobile devices, HMD systems such as Google Glass or HoloLens etc.), 2) AR trigger entities (e.g., matrix barcodes, markers and textured images for paper based AR systems, physical objects for feature detection based AR systems, spatial coordinates for location based AR systems etc.) and 3) virtual contents (e.g., images, 3D models, URLs, audio contents, videos etc.). Most of the current research questions related to AR applications are associated with medium and trigger entities. The study of new modalities of detection and the development of specific devices and applications for immersive technologies represent the core topics for developers and researchers who want to investigate this research field. In this paper, however, we take a novel approach and investigate the third component of an AR system: the related virtual contents and their generation process. One of the largest problems of AR applications is represented by a generalized lack of automation of the traditional AR app generation processes, in particular with regard to content creation. The creation of contents for AR applications still represents an excessive effort in terms of time and money and it is seldomly automated. It is thus necessary to investigate new possible solutions for the development of automated systems, which are useful to generate AR contents for hybrid media. In order to reach our target, we developed a framework to enable the automated and industrialized creation of AR applications. In particular, we focus our attention to media which include textual contents, such as the typical print media. Our approach is oriented to the extraction and elaboration of specific textual contents in order to enable the development of further virtual contents, which are suitable for augmented reality applications. We would like to demonstrate the possibility to use text data mining tools to support the creation of AR applications. As a result, we can contribute to the creation of a novel paradigm for hybrid media applications.

3. Automated content creation for AR apps

3.1. A new paradigm for augmented print

We identified the lack of automation of the typical content management systems for AR as a key problem for hybrid media applications and we recognised the potential of text data mining as a tool to offer an original solution to the described problem. Our concept is based on the idea that print media already contain editorial contents which have the capability to become “augmentable contents”. An editorial article contains specific textual keywords which mentally link the reader to external fields of knowledge. An average reader who finds the words “Mona Lisa” in a text immediately draws a tangible representation of the famous painting of Leonardo da Vinci in her/his mind, because human beings are naturally able to link words and specific fields of knowledge. Our research aims at reproducing analogous mechanisms using Artificial Intelligence (AI) in order to detect specific editorial contents of a print media with the target to transform them into potential AR contents for the final user of a hybrid media system. The use of AI techniques has the advantage of enabling the automation of the creation process of AP applications. In this paper we aim at answering the following research questions:

- Is it possible to reduce the effort of creating and managing contents for AR applications by means of text data mining techniques?
- How can editorial processes and AR app development be integrated in offering a new perspective for hybrid media?

We conceived a framework where a publishing company creates a traditional print media and a component with AI is then able to detect specific contents in order to drastically simplify the creation of AR applications. Specific contents, such as addresses, dates, email addresses, phone numbers, websites/social media and much more can be mined in the text of an editorial article. This information can then be automatically transformed into AR contents. Our framework can transform the preview of a website into a superimposed and clickable AR content for an AP application. This process is able to automate the content creation of a hybrid media application. If, for instance, the AI component detects that the topic of an editorial article is the "Mona Lisa", the system finds a picture of the famous painting in a database and it generates a superimposed AR content related to the editorial article. Detecting different typologies of contents and mining the existing available textual content, the content management of hybrid media becomes more affordable and smarter.

3.2. Text data mining for hybrid media

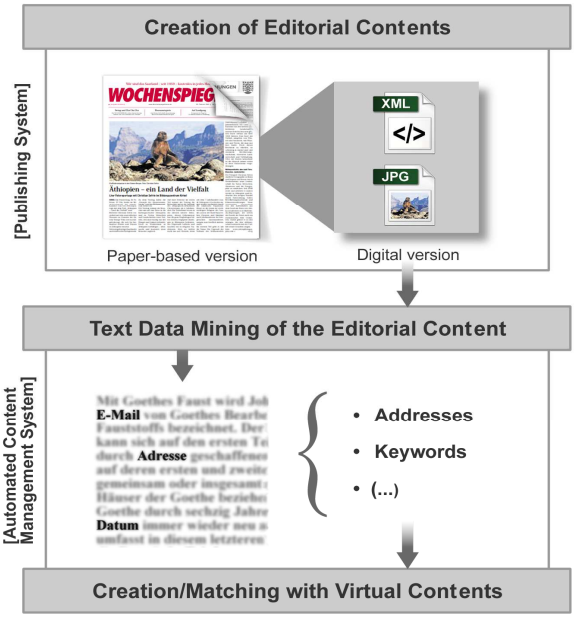

Figure 1. Schematic representation of the content creation process for the AR app development.

The first target of our research is to enable the automated extraction of information from textual contents. Thus, we analyzed different typologies of techniques of text data mining with the purpose of defining a wider range of possibilities. Every text data mining technique is absolutely dependent on the type of textual content we want to analyze. Therefore, we had to investigate different typologies of contents. The textual contents which we want to use are editorial articles of print media. These articles contain a large amount of textual information and, eventually, also pictures. We tested the use of Named-Entity Recognition (NER) [20] processes in order to transform the texts of common editorial articles into structured texts which enable an easier collection of information. Similarly, we considered Named Entity Disambiguation (NED) [21] processes to determinate the identity of specific textual contents during the creation of a text. We developed a prototype but we understood that this kind of solution requires an excessive effort for the preliminary preparation to the analysis of textual contents. We also tested the use of metadata to be added to the original textual content by means of Information Retrieval (IR) processes. This approach is useful to reduce the amount of irrelevant information but alone it does not enable to recall any piece of information, which is not preliminary differentiated. As briefly described earlier, we endorse solutions which permit the analysis of textual contents without adaptation or revision of the original text. Therefore, after different tests we understood that there is not a univocal solution rather the best approach requires a syncretism of different techniques. Combining different text data mining methods with the pattern recognition and syntactic parsing discerned via regular expression, we have been able to develop interesting solutions, in order to extract relevant information from editorial articles.

The second target of our research is the definition of an automated framework useful to collect information to be transformed into virtual contents suitable for augmented reality systems. These kinds of contents are websites and URL links, images, videos or audio tracks. We conceived an automated AR app generation framework by means of a specific server-based platform. Accessing the platform, the content manager has the possibility to validate the AR contents proposed by the system. By means of the embedded AR toolkit, the AI of the described system is able to develop an automated and up-to-date AR application related to a specific release of a print medium, which becomes the trigger entity of the hybrid media. As soon as specific textual contents have been detected and isolated from the editorial articles, the framework identifies relevant AR contents. These contents can be extracted textual entities (if the system identifies directly in the text of the analyzed editorial content information like websites, phone numbers or similar) or related virtual contents, which are selected into databases associated to specific knowledge fields. Obviously, these databases can be internal or external

to the framework. An interesting opportunity is represented by the use of wikification processes to link textual contents and internet-based entities. When the AI of the framework detects a relevant textual content, the system identifies related virtual contents on specific websites or online-based databases. Certainly, as we already outlined, this approach needs the final validation of the content manager but the general cumulative effort for the creation and management of AR contents is drastically reduced.

Our framework is intended to be integrated into an existing workflow for the creation of editorial contents. New editorial articles for print media are created in form of digital texts by publishing systems and related images are also available as digital contents. Processing the textual information provided by a publishing company during the phase of creation of new editorial contents, it is possible to detect relevant data for the creation of AR contents. The use of text data mining enables the provision of potential relevant contents, which can be automatically transformed into virtual contents for AR applications (Fig.1).

4. Use case

4.1. Implementation Design

With the purpose of testing our concept on a concrete field, we identified a specific use case in collaboration with the editorial company "Saarländische Wochenblatt Verlagsgesellschaft mbH (Wochenspiegel)", which publishes a free of charge and weekly distributed publication covering an entire German region. We conceived a general paradigm which can be applied to every analogous publishing company and is useful to provide a novel model of hybrid media. The publishing company is a traditional print media company and creates new editorial articles every week. Having the target to provide the print medium with an up-to-date AR application every week, the publishing company evidently cannot use a traditional handcrafted process to create and manage new AR contents every seven days. The automated framework we conceived enables an interface between publishing company and AR app development process. Every editorial article created by the print media is available on our platform through a publisher system, which links the authors of the publishing company and our framework. It is basically a simple data exchange that enables to archive the new editorial articles, to analyze and process them. Text files, image files and an XML index of every new editorial article are uploaded in the system. The image files will be used to trigger the AR system of the application and the text will be used to detect relevant information suitable to automatically generate virtual contents for the AR application.

We designed an AR interface based on the AR toolkit "Wikitude", in order to enhance editorial contents of a print medium with virtual contents. Scanning a paper-based copy of the print media with the camera of a mobile device, the user can access AR contents which are superimposed directly on the print medium. Printed images trigger the augmented reality system and open the possibility to reach virtual links, which are useful to connect a specific editorial article with related virtual contents. The reader has the possibility to cross the boundary of the real environment to experience related virtual contents in a different hybrid context: the AR environment (Fig. 2).

Figure 2. The hybrid media system merges real and virtual environments by means of the AR app.

The available virtual contents may be divided into three different typologies:

- **Browser based contents.** They are virtual contents like external websites or, more in general, server-based services which may be visualized using a browser. Therefore, they lie in a "pure" virtual reality (VR) environment.

- **Contents "on the paper".** They are virtual contents which may be visualized directly and jointly on the print medium, such as 3D models or photo galleries which are related to the editorial content. According to the definition of Reality–Virtuality Continuum [1], they are visualized in an AR environment.

- **Functions of the device.** They are virtual contents which enable the interaction between the AR interface and specific functions of the mobile device. These functions enable the possibility to call a phone number and the possibility to save the date of an event on the calendar of the mobile device. Both the two kinds of information are identifiable in the text of the paper-based editorial content.

Reading a paper-based editorial article, the user has the possibility to reach several typologies of contents which are related to the editorial content. The framework that we conceived is able to depict preferences and profile of the user according to her/his behavior and to provide specific recommendations about editorial contents which may be appreciated by the user. These contents can be expressed as browser based contents or AR Contents "on the paper".

4.2. Automated content creation

As soon as the trigger entities start the augmentation of the print medium, the user sees related virtual links superimposed on the articles. Print medium and links are univocally correlated and scanning a specific article, it is possible to automatically detect its own links. The user experiences the contemporary presence of virtual entities (browser based contents and device interactions) and AR entities (AR links and virtual objects superimposed "on the paper") using a smartphone during the reading of an editorial article. The described hybrid media system can be generated thanks to the definition of a structured and automated framework. A correct definition of the interfaces between the different components of the system is fundamental. When a new article is generated by the publishing company, it is added to the platform and the AI of the framework provides a parsing of the text, in order to detect potentially relevant textual contents (Fig.3).

The textual contents which are mined within the text of an editorial article are:

- *Addresses* (e.g., the address of a shop which is described in an editorial article).
- *Cities* and *point-of-interest* (e.g., specific buildings or points of interest of a city which are described in an editorial article)
- *Dates* (e.g., the date of a concert which is the topic of an editorial article and will take place in the future).
- *Email addresses* (e.g., the contact of a person who is cited in an editorial article).
- *Phone numbers* (e.g., the phone number of an association which is described in an article).
- *Websites/social media* (e.g., the webpage of an event which is presented in an editorial article).
- *Weblinks* (e.g., the link to the online version of an article).
- *Proper nouns of persons* (e.g., persons cited in an article)
- *Themes and keywords* (e.g., the content and the general themes of the editorial article)
- *Author of the article*, *title* and *images*.

When a textual content is detected in an editorial article, the platform starts the matching with related virtual contents. The virtual contents which are recommended by the system are different for every typology of content. In particular, according to the textual contents resulting from the text data mining procedures, the framework generates the following related virtual contents:

- AR link of a web mapping service, according to the extracted *address* and *point-of-interest*.
- AR link of the function of the mobile device, which enables the user to save the extracted *date* on the calendar.
- AR link of the email provider of the user to write an email to the extracted *email address*.
- AR link of the function of the mobile device, which enables to call the extracted *phone number*.
- AR link of an internet browser, which visualizes the extracted link to *web-page/social media* or *weblink of the online version of the article.*

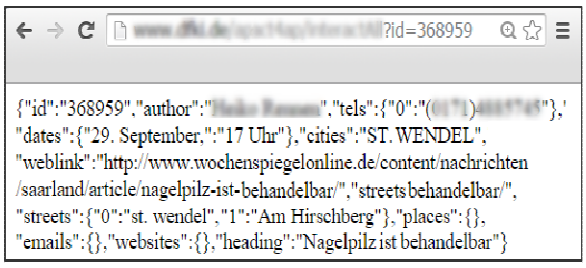

Figure 3. Detection of textual contents for a specific editorial article.

Further virtual contents for AR are researched according to specific wikification processes. It means that if the platform finds proper nouns of persons or themes and keywords, the system proofs the presence

of potential virtual contents through an internal database, which represent a matching with the detected textual content. In this way, virtual contents such as images and videos are included as AR contents for the AR app. Of course, this procedure can also be applied to every typology of detected textual content.

4.3. Prototypical implementation

We have created a prototypical implementation of the framework in order to demonstrate the feasibility of the artifact and to show our proof-of-concept. The prototype has a back end component and two different front end components. The back end component represents the AI of the framework and it enables the extraction of relevant textual contents from the articles and the matching with potential virtual contents for the hybrid media application. The back end component creates an up-to-date version of the AR application, combining extracted information and AR toolkit. The first front end component is an interface for the content manager where s/he can accept or refuse the recommended AR contents which have been generated in the described automated process. The second front end component is the user interface of the AR application, which is automatically generated (Fig. 4).

Figure 4. Screenshot of the prototype.

The back end component has been created through the platform Java EE and the user interface through the AR toolkit "Wikitude". Both user and content manager have the possibility to personalize and enhance their experiences adding functions and selecting preferences. The component responsible of the AI of the framework is server-based and it is reachable through HTTP request/response. It is possible to send requests to the server in order to interrogate the editorial content which has been parsed and to receive relevant information about detected textual contents and possible AR contents. The process is completely automated and the request only has to be referred to a specific article-ID, which identifies a specific editorial content.

5. Discussion of results and evaluation

According to a design-oriented methodology [22], the presented research has been evaluated against following evaluation criteria:

- **Usability of the system.** The system has been validated according to ISO 9241-110.
- **Validation of the quality of the extracted contents.** Validation of the relevance of the detected contents according to recall and precision [23].
- **Integration into the existing system.** Evaluation of the integration of the automated AR app creation process into the existing publishing system, from the creation of the editorial contents to the development of the AR app.

The evaluation has been performed according to qualitative and quantitative methods:

- **Interviews of focus groups.** We identified three different focus groups: *advanced users* (people with experience and relevant IT expertise), *common users* (people without specific IT competencies) and *professionals* (users who work in the editorial field).
- **Usability tests with users in order to test specific features of the AR app.** The features that we tested are related to the ergonomics of the AR interface and they are evaluated by means of a final survey.

We evaluated our research in two different steps. In the first step, we filmed and observed users using our AR application (Fig. 5) and in the second step, we analyzed their feedback and their reactions to the use of our AR application. We selected a group of 16 people and we filmed every single person during the test phases of our AR application. Thus, it was possible to focus on their behaviors and to compare the reactions with the information about the use of the application, which we monitored and tracked in parallel. At the end of the test, every user completed a User Experience Questionnaire (UEQ). The questionnaire is a standard survey developed by the SAP AG and it is used to evaluate software in terms of usability to determine the experience of the users.

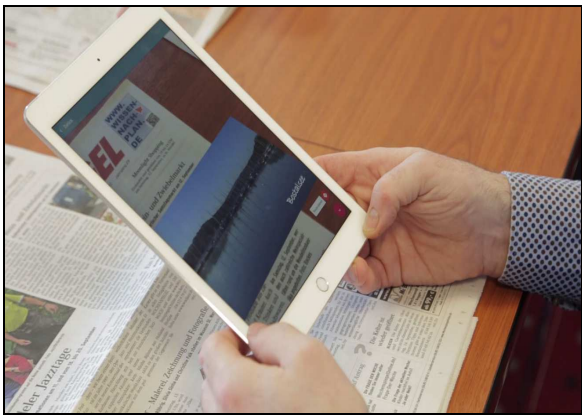

Figure 5. A user during the evaluation of the application.

The evaluation of our research has shown interesting results. In general, the test persons evaluated the AR application positively. The UEQ has a scale from 1 (positive feedback) to 7 (negative feedback) for 26 different items. To summarize the perception of the test persons, we calculated the average values for every question. These average values are in a range between 1,1 and 4,6. It means that the average value to summarize the feedback of the test persons is 2,6. Some test persons were enthusiastic about the hybrid media model we showed, whereas some other persons were, of course, more critical. Therefore, it has been possible to collect interesting feedback to modify and improve our artifact. In particular, the test persons identified interesting and very specific suggestions. Thanks to the evaluation we learned, for instance, about the necessity to label the image of the print medium with a visible mark, which triggers the AR implementation, as well as the necessity to add control functions (start/stop/pause/volume) to video AR contents.

6. Conclusion and outlook

This paper has shown a novel concept for the use of AR technologies in print media, with the purpose to offer a novel paradigm of hybrid media applications. This concept permits a reduction in the distance between internet-based media and print media, opening new scenarios for augmented print systems which need a high rate of automation for the content generation process. The presented concept is not merely an application of augmented reality in the editorial field but it defines a novel possibility to integrate complex instruments with traditional media. Our research designs a structured and persistent modification of the offer of contents for print media through the definition of a new hybrid media environment, where the issues of content creation and content management are faced with an innovative approach. This approach implicates the integration of AI tools in the framework. In particular, we demonstrated the opportunity to integrate text data mining methods to automate the expensive, in term of money and time, content creation process. Moreover, we propose a different approach for the management of virtual content in hybrid media applications.

Different aspects represent a large potential in terms of research and can be further implemented. The use of text data mining techniques to detect relevant virtual contents for AR offers an interesting outlook to extend our research to very different paper-based AR systems. Not only the editorial field but every domain that uses print-based media (e.g., learning, advertisement, marketing and communication, etc.) may take advantage of the research presented in this paper to define new directions for further research projects. The automated content management approach presented in this paper can be useful to define new areas of researches useful to shape models which are able to offer a holistic vision of the different components of the app development process, in order to integrate AR technologies into existing industrial systems. In terms of research, it contributes to the definition of an advanced concept of automated AR system for hybrid media applications to foster the industrialization of the app development process.

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