

The Evolution of Azuma's Augmented Reality— An Overview of 20 Years of Research

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Abstract. Augmented Reality (AR) is no longer just a gimmick. 50 years after the development of the first head-mounted display, and approaching the 20th anniversary of the first conference dedicated to AR, it is time for a new review on the theme. As such, we present a bibliometric analysis of scientific literature since 1997, using as database the Web of Science. This allowed identifying the most relevant authors, their distribution by subjects, the evolution of publishing by year and the most frequent publications.

Keywords: Augmented reality · Bibliometric analysis · Marketing

1 Introduction

The idea suggested by Azuma in 1997 of a technology to allow overprinting 3-D elements from a virtual world onto the physical world, in real time interaction, is now reaching two decades of existence [2].

What started around 1960 as a see-through head-mounted display - “The Ultimate Display” [38] -, has evolved into a medium that is now established among the scientific community [41], and present in our everyday lives, in many fields, such as gaming, retail, architecture, health, and many others [3, 8].

Bibliometric analysis (BA) is “the application of mathematics and statistical methods to books and other media of communication” [32]. Therefore, among other aspects, this is a suitable method to assess the quantity and quality of the work developed in specific disciplines over the years, and their most influential authors [12]. Hence, BA offers researchers the means to assess the state of the art in a particular discipline, as well as a more efficient identification of new areas of research [35].

This article has the following structure: Sect. 2 presents the link between literature related to augmented reality and marketing; Sect. 3 presents the methodology, Sect. 4 shows the results and discussion, and finally Sect. 5 presents the study limitations and suggestion for future research.

2 Augmented Reality, a Marketing-Oriented Perspective

Augmented reality (AR) is a highly versatile technological application. Consequently, we have seen its application in fields such as surgery [40], marketing [19], journalism [29], tourism [6], and the treatment of phobias [34], to name a few.

This technology is contributing to improve how we interact and represent our knowledge. It is promoting productivity, once it creates more intelligent, context-aware and transparent immersive experiences for people, business and things [15]. Also, AR is impacting the economy as it is expected that the revenues earned by the AR apps market will grow tenfold, from \$ 515 millions in 2016, to \$ 5,7 billions by 2021 (in line with the forecast from 2015) [20, 21]. These forecasts are also fueled by changes in the marketing dynamics we are witnessing in some technological brands. Mergers and acquisitions illustrate it such as the Metaio¹ (an AR developer) integration in Apple and the rumors of Snap acquiring the AR Israeli startup Cimagine Media².

At the same time, we are witnessing an increasing use of AR as a medium with application in various areas. In marketing, it emerges as a means of communication between brands and consumers. Consumers interacting with AR are increasingly sophisticated, tech-savvy, demanding brands and companies to provide them experiences, not limiting their satisfaction to the utilitarian role of the offered products/services [4, 30, 31].

In addition, we verify a more complex and comprehensive consumer-brand interaction, using a multiple touch points approach [28].

Accordingly, AR emerges as a suitable medium allowing brands to interact and communicate efficiently (in due time, in the right context and with the adequate information) with their stakeholders, offering new experiences [5, 8, 10, 14, 27].

This explains the inevitability of the connection between AR and marketing, since this technological application fills the need for experience demanded by the consumers.

Because of the aforementioned ‘phenomenon’, major brands are currently using augmented reality solutions in their marketing strategies (e.g. IKEA’s catalogue³, Ralph Lauren’s presentation of Polo for Women Spring 2015 collection⁴, among others) [17, 37]. In addition, there is also the influence of AR in academic research, with special emphasis on how AR affects consumer behavior as a mean of communication [18, 19].

¹ “Apple buys German augmented-reality software maker Metaio”: <http://www.reuters.com/article/us-apple-metaio-idUSKBN0OEIRO20150529>. Accessed on January 3, 2017.

² “Snap reportedly acquired augmented reality startup Cimagine Media for up to \$40 million”: <http://venturebeat.com/2016/12/24/snap-reportedly-acquired-augmented-reality-startup-cimagine-media-for-up-to-40-million/>. Accessed on January 3, 2017.

³ IKEA Catalogue: https://www.youtube.com/watch?v=dwt-mgxq_ao&nohtml5=False. Internet. Retrieved April 5, 2016.

⁴ The Official Ralph Lauren 4D Holographic Water Projection: <https://www.youtube.com/watch?v=ugBbTiBmZ2g>. Internet. Retrieved April 5, 2016.

3 Methodology

Bibliometric analysis (BA) has the ultimate goal to provide a quantitative assessment of scientific literature state of the art, as produced in a given field of knowledge, being a method possible to apply in any area of research [1, 11].

This analysis allows a quantitative evaluation of the performance of scientific publications, such as the number of publications per author, citation analysis, and also detecting patterns in literature [13, 23, 33].

The main questions motivating our research are: (1) What is the state of the art after 20 years of the research in AR connected to Marketing? (2) Which authors contributed the most towards this development? (3) Where did this knowledge emerge from? And (4) What are the main streams for further research?

Thus, the main objective for the use of bibliometric analysis in the context of AR and marketing is to quantify the data concerning the evolution of the number of documents published per year; the type of document (article published in journal or conference articles – including Springer's Lecture Notes); the main authors and their productivity; and research areas [9, 36].

Our line of research was developed based on the work by de Bakker et al., Kim et al., and Schmitz et al. [9, 22, 36], from where we built our research strategy.

The process stages 1 and 2 correspond to document collection and the production of database for analysis; stage 3 comprises that analysis (see Fig. 1).

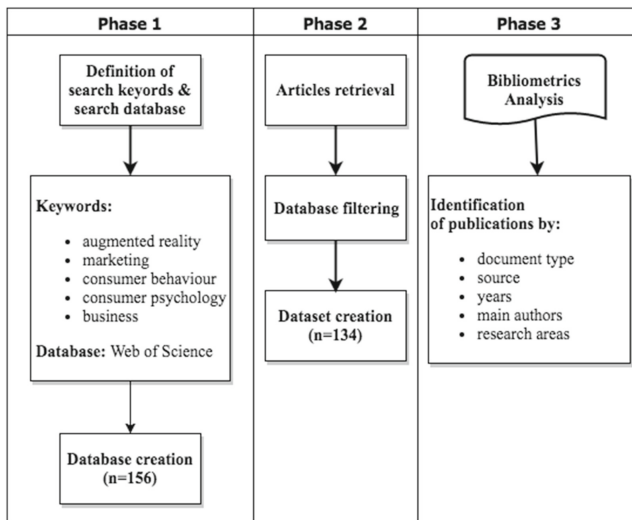


Fig. 1. Research strategy

3.1 Sampling

The bibliographic database used was the Web of Science (WoS), where we researched the following keywords: “augmented reality”, “marketing”, “consumer behavior”,

“consumer psychology” and “business. The rational that motivated this choice of keywords is described above, and it is related with the emergence of the use of AR applications in business, economics and management [15, 21], and with the so called research on new media [25, 28]. The research was further refined according to the following restrictions: the documents should be written in English, the type of document should be proceedings papers and articles, and the time interval considered was from 1997 until November 1, 2016 with a total of 156 documents.

In line with the established practice in BA [7, 16], two researchers carried out a review of titles, abstracts and keywords in order to eliminate documents whose subject diverged from the goals of the present research, which reduced the database to 134 documents.

To perform the statistical analysis of the data we used Microsoft® Excel for Mac [26].

4 Results and Discussion

After the analysis of the data resulting from 20 years of research on augmented reality in a marketing context, we verified there was a time span of three years since the publication of the survey by Azuma [2] and the emergence of the first article on the subject. In addition, the large increase in interest on the subject took place between 2010 and 2011, and 2013 and 2015, which were very fruitful years (concerning 2016 it is still too early for conclusions) (see Fig. 2). This may be because since 2010, the Marketing Science Institute (MSI) started to emphasize the importance of understanding consumer manifestations in the different media [24, 25].

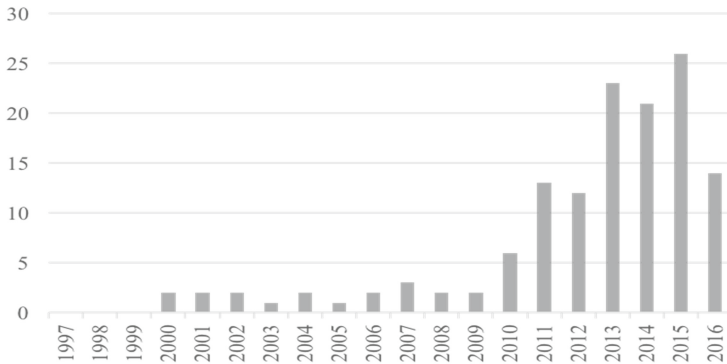


Fig. 2. Evolution of documents published per year

With regard to the sort of documents, we found that most of the scientific knowledge produced in this area is published in the form of conference papers (see Fig. 3). This result seems to indicate that this is an area essentially depending on technological developments, and as such, its life cycle is not befitting the timings the journals require to publish the articles. Nevertheless, analyzing the 10 most cited articles in the database,

we identified that 8 in 10 were published in top journals (journals rated Q1 by Scimago Journal & Country Rank in 2015), one was published in a Q2 journal and only one was a conference proceeding.

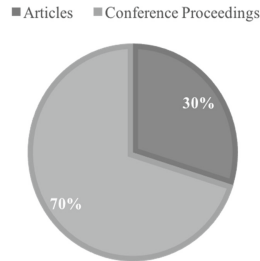


Fig. 3. Percentage of articles vs. conference proceedings

Concerning the authors, this is an area of knowledge where, on average, three authors write each article, being that there are articles with 26 and 12 authors. About 36% of the articles have more than three authors, and another 36% have one or two authors.

The most productive authors are Anna Javornik (with 2 articles and 1 proceeding) and Bernard Kress (with 3 published proceedings). It should be noted that only the second author was quoted (one of his proceedings was cited 8 times), while the first was not. This derives from the dates of the documents, the ones from Kress are from before 2014, while Javornik published her articles in journals (Q1 and Q2) more recently, in 2016.

Analyzing publications distribution by topics, there is a predominance of publications in marketing and business, whereas consumer psychology (CP) and consumer behavior (CB) only achieve one publication each (Fig. 4). This is because the first two topics are broad ranging, compared to CP and CB, and because the articles classified as CP and CB also belong to the topic “marketing”.

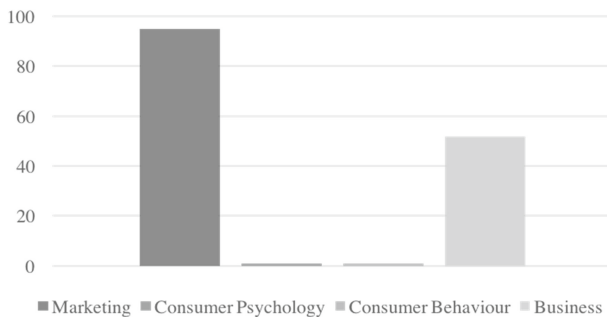


Fig. 4. Distribution of documents per research keyword

It is also worth mentioning that the major breakthroughs found among the existent literature are concerned with technical aspects of the augmented reality. The research

area relating AR and Business, Economics and Management categories are still in an embryonic state, therefore it is important to emphasize what is known, to organize in a more structural way such findings.

5 Limitations and Future Research

Pioneering the use of bibliometric analysis addressing both augmented reality and marketing, there is still a long path to follow, and consequently the goal of this study is specifically to assess the state of the art, instead of conducting an exhaustive study of the field of augmented reality.

The approach made by this study only used one single database, the Web of Science, which in itself, according to [39], has a limited scope, when compared for instance with Scopus (whose results are wider, and focus more on specific technical aspects). This suggests further research should employ other databases, such as ABI/INFORM and Google Scholar, namely.

Another aspect that may bring a new sort of insights is the use and establishment of the platform ResearchGate as a source of dissemination of scientific knowledge.

Concerning the methods employed in a bibliometric analysis, we underscore it allows citation and co-citation analysis, as well as textual analysis, both in the form of content analysis and in the form of text mining, through data mining algorithms.

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