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Future Perspectives in Healthcare: An Analysis of Augmented Reality and Spatial Computing in Hospital Environments

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Abstract

This article investigates the applicability of Augmented Reality (AR) and Spatial Computing in hospital environments, exploring how these technologies can enhance interaction between patients and healthcare professionals as well as the efficiency of medical procedures. Through a systematic literature review using the PRISMA methodology, relevant articles highlighting the potential of these technologies in the hospital setting were selected and analysed. The results suggest a growing adoption of AR and Spatial Computing, driven by the advancement of 5G technology, with the potential to improve diagnostic accuracy, the effectiveness of surgical procedures, and the educational experience of healthcare professionals. The study concludes that the integration of these emerging technologies promises to transform hospital environments, emphasising the need to overcome technical, ethical, and privacy challenges to maximise their positive impact on health.

Keywords: Augmented Reality; AR; Spatial Computing; Helathcare

Nomenclature

AR Augmented Reality
VR Virtual Reality

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MR Mixed Reality

1. Introduction

Spatial computing is a type of system that is Spatial computing is mapping the digital into the physical world, where digital information is seamlessly integrated with physical spaces, enabling interaction and manipulation of digital content in real-world environments [3]. Such a type of systems are increasingly in vogue, largely due to its adoption by major brands of technological equipment for both household and business use. An example of this is *Microsoft*, which has already released two versions of the *Microsoft Hololens*, and *Apple*, which began selling the *Apple Vision Pro* on February 1, 2024, in the United States. In this sense, the use of such equipment by ordinary users will become more common as prices become more accessible. Through smartphones, whether *Apple* or *Android*, it is already possible to have immersive experiences in various contexts, such as e-commerce [2].

However, regarding the medical field [4], the study by Azuma already mentioned the use of AR in this area. However, nowadays, studies can refer to the context of spatial computing and MR for the medical field [6]. There are several studies addressing problems of clinical patients with traditional methodologies, regarding length of stay [14], improving communication between the elderly and clinical teams [8], or even in prediction systems [15]. However, with the availability of Head Mounted Display systems with spatial computing and MR, it would be interesting to understand what kind of applicability they could have in improving the relationship and experience of patients with healthcare professionals and healthcare institutions.

Therefore, the research question that arises is: How can Spatial Computing systems be applied to the Hospital Context?

Thus, to understand the trends that may lead to the adoption of these technologies by patients and healthcare institutions, a literature review study was conducted to understand what has already been developed and what may be developed in the future.

2. Method

For the selection of studies to be included in this article, the PRISMA methodology was used. *PRISMA* (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) is a method developed to assist in the preparation and presentation of systematic reviews and meta-analyses in scientific literature[13]. This methodology was designed to ensure transparency, clarity, and consistency in the reporting of studies that synthesise method. The appropriate use of PRISMA not only enhances the quality of systematic reviews but also facilitates the interpretation and replication of studies, promoting significant advancements in research.

2.1. Information Sources

As a data source, the SCOPUS database was used[1], due to its size, wide coverage in terms of publication areas, and quality assurance base. This research was conducted on January 22, 2024. It is worth noting that the impact of journals on the publications analysed here was obtained, and for this, the authors consulted the SCImago Journal & Country Rank[2].

This impact can be analysed in Table 1.

It can be seen that of the 7 articles analysed, 2 are in Quartile 1, 4 are in Quartile 2, and 1 is in Quartile 3.

[1] https://www.scopus.com
[2] https://www.scimagojr.com

Table 1. Table of articles analysis in SJR

Article	Journal	Quartil
[16]	International Journal of Communication Networks and Information Security	Q3
[5]	IET Collaborative Intelligent Manufacturing	Q2
[7]	ACM Transactions on Computing for Healthcare	Q2
[1]	Education and Information Technologies	Q2
[12]	Mathematics	Q2
[10]	Buildings	Q1
[11]	IEEE Internet of Things Journal	Q1

2.2. Search Strategies

To advance with the bibliographic search, several keywords were identified as starting points. The keywords used were:

- Spatial Computing
- Augmented Reality
- Healthcare

After that, a first keyword was created for advanced search in *SCOPUS*:

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ALL ( ”spatial computing” ) AND ( ”augmented reality” ) AND ( ”healthcare” )
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As can be seen in the keyword, the keywords are related by the **AND** operator. This decision was made to absorb as many articles in the area as possible, since these topics are considered new areas of study and there are few specific studies in the clinical areas. As a result, 64 articles were obtained for analysis.

2.3. Inclusion and Exclusion Criteria

To enable a more exact filtering of the results produced, based on what is needed, whether it be inclusion or exclusion criteria, it was necessary to set the exclusion criterion to be applied prior to beginning the article selection process. As a result, the following selection criteria are now offered in the order in which they were used during the research:

- **EC1 - Subject Area:** Only articles in the areas of Computer Science, Engineering, Medicine, and Social Sciences were considered.
- **EC2 - Document Type:** Only journals were included for the study.
- **EC3 - Accessibility:** Only articles in Open Access were considered for analysis.
- **EC4 - Article Review:** Detailed analysis of the remaining articles.

In this sense, a final keyword was elaborated as presented below:

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ALL ( ”spatial computing” ) AND ( ”augmented reality” ) AND ( ”healthcare” ) AND ( LIMIT-TO ( OA ,
”all” ) ) AND ( LIMIT-TO ( SUBJAREA , ”COMP” ) OR LIMIT-TO ( SUBJAREA , ”ENGI” ) OR LIMIT-TO
( SUBJAREA , ”SOCI” ) OR LIMIT-TO ( SUBJAREA , ”MEDI” ) ) AND ( LIMIT-TO ( DOCTYPE , ”ar” ) )
```

A screening procedure was carried out on the 64 resultant articles. The authors carried out this procedure by going over the titles and abstracts that SCOPUS had provided during the search. The entire text was downloaded and reviewed when it appeared to be pertinent for additional analysis. As a result, 12 documents were included in the final set that came from the previously described research strategy for analysis.

Figure 1 presents a diagram illustrating the research process conducted.

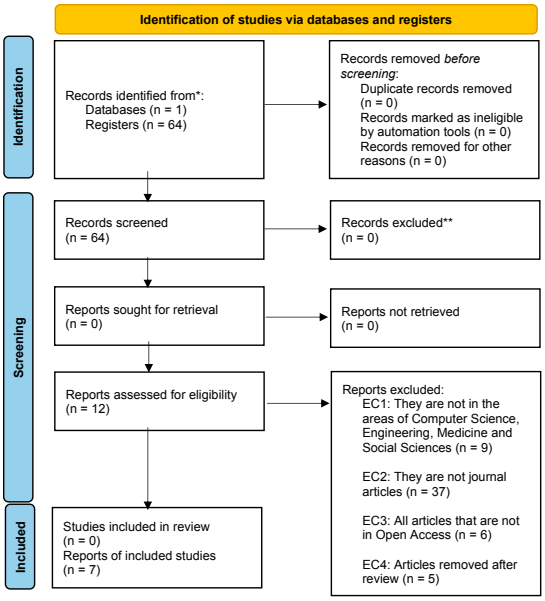

Fig. 1. PRISMA Flow Diagram (Created using [9])

3. Results and Discussion

As can be seen, after searching in SCOPUS, 64 articles were obtained. After applying the first 3 exclusion criteria, 12 articles remained. Thus, applying the fourth exclusion criterion, conducting a more detailed screening, reading and analyzing the remaining 12 articles, only 7 articles were included for analysis in this study. As the other 5 that were excluded did not fit with the theme under analysis.

Based on the research question, a summary of the analysis conducted on each article is presented.

The first article analysed was authored by Toding et al., which discusses the integration of 5G technology into intelligent healthcare and the development of smart cities, with an emphasis on Deep Learning architectures. This work highlights how 5G technology can transform the healthcare sector by improving the integration of AR, VR, and spatial computing technologies, enabling better real-time remote monitoring. This research also addresses how 5G technology facilitates healthcare services over long distances through an interconnected network of devices and high-performance computing, using Deep Learning techniques such as Deep Convolutional Neural Networks for disease detection and treatment based on dynamic data [16].

The second article analysed by the authors de Boer et al. investigates control methods in human-robot interactions, ranging from direct control to telepresence with virtual representation of a robot arm. Using AR technology, the study explores gestural teleoperation in simulated environments, highlighting how AR can improve accuracy and efficiency in robotic manipulation tasks. Although 3D teleoperation shows advantages over 2D video feeds, in terms of lower peak forces and less variation in gripper height, direct human interaction remains the highest performance standard. This article suggests that AR can offer smoother interactions in teleoperation environments, although it still does not completely surpass the effectiveness of direct human contact [5].

The third article analysed by the authors Elor et al. develops and evaluates BioLumin, an immersive MR environment that allows users to navigate and annotate reconstructed 3D images at the microscopic level. This system is

designed to facilitate the annotation of complex medical data by non-experts after brief training. The article discusses the usability and feasibility of BioLumin through a mixed evaluation approach, involving domain expert reviews and usability testing by non-expert users, indicating that the system is easy to learn and that non-experts can generate high-quality 3D annotations. This study suggests design considerations for future MR tools in broader medical and scientific contexts [7].

The fourth article analysed and authored by Alblehai investigates how avatar homophily in virtual environments influences users' flow experience and exploratory behaviour online. Using an avatar-mediated environment like Second Life, the study explores the relationship between avatar homophily (similarity in attitudes and backgrounds) with users' flow experience and exploratory behaviour. The results indicate that the perception of homophily can enhance users' immersion experience, leading to more exploratory behaviour. This finding suggests significant implications for the design of virtual learning environments, highlighting the importance of avatar customisation to promote social interaction and engagement [1].

The fifth article studied, authored by Nagy et al., addresses the integration of global value chains with Industry 4.0, focusing on improving business performance through digital readiness and workforce competence in V4 countries. It examines how Industry 4.0 technologies, including spatial computing and AR technology, can accelerate operational activity in global value chains, emphasizing the importance of technological innovation and technical-scientific knowledge in all spheres of business activity. The article suggests that digital adaptation and organized education in scientific research are crucial for expanding the digital adaptability of V4 countries, linking these advancements to the need for lean processes and digital integration to improve business performance. It is noteworthy that this article is not directly related to the medical field; however, it may be interesting in the creation of such technologies to enhance medical performance similarly to that of industry [12].

The sixth article, presented by Lee and Park, conducts a bibliographic analysis of embodied experience in virtual environments, highlighting the growing academic attention to this perspective. The research emphasises how Industry 4.0 technologies, including VR and AR, transform human-computer interactions, particularly in architectural and design contexts. The study maps scientific productivity, intellectual collaborations, and emerging themes in the field, revealing the importance of embodied experience in enhancing interaction and immersion in virtual environments [10]. In this sense, this article, like the previously mentioned article [12], can be interpreted to include such human-computer interactions in the medical field.

The seventh and final article, authored by Li et al., analyses and explores the convergence between the Internet of Things (IoT) and the Metaverse, highlighting how this intersection can enrich cyber-virtual experiences in MR environments. It presents six typical applications of IoT in the Metaverse, including collaborative healthcare education, entertainment in smart cities, real estate, and socialisation. The study addresses key technologies enabling AR and VR in the Metaverse, such as responsible artificial intelligence, high-speed data communications, cost-effective mobile edge computing, and digital twins. The need to address outstanding issues to achieve full integration of physical and cyber worlds is emphasised [11].

4. Trends

Based on the analysis conducted, emerging trends in the hospital context and in the interaction between patients and healthcare professionals may include the increasing adoption of AR and spatial computing, driven by the advancement of 5G technology. Significant improvements in diagnostic accuracy, surgical procedure efficacy, and healthcare professionals' educational experience are expected. The integration of the Internet of Things (IoT) with the Metaverse may also open new possibilities for virtual interaction between patients and doctors, offering immersive and personalised healthcare experiences.

5. Limitations

The analysis was conducted based on a specific selection of articles available in the SCOPUS database, which may limit the representativeness of the findings regarding the global research landscape. The research primarily focused on academic and scientific articles, which may exclude valuable insights from non-conventional sources such as technical reports and industry practices.

6. Conclusions and Future Work

Through the analysis of the seven provided articles, it can be concluded that the integration of emerging technologies such as AR, spatial computing, and 5G infrastructure promises to revolutionise hospital environments. These technologies have the potential to significantly improve diagnostic accuracy, surgical procedure efficiency, and overall patient experience, while also offering new methods for medical training and hospital resource management. However, successful implementation requires overcoming technical, ethical, and privacy challenges. Future work should focus on developing innovative solutions to these challenges, conducting more case studies in real environments, and exploring new applications for these technologies to maximise their positive impact on healthcare.

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