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Potential of Augmented Reality in Optimization of Military Libraries Services: A Review

Pramod Kumar Singh* and Pooja Rana
University of Jammu, Jammu - 180 006, India
E-mail: pksingh22@gmail.com

ABSTRACT

Augmented Reality (AR) overlays the information of virtual objects on actual surfaces and enhances learners' experience. As AR is becoming an increasingly important part of military training, military libraries can provide a cohesive experience using the latest advent of AR and core library science components to meet the military community's ever-dynamic needs. Since augmented reality is in a developing phase, this paper aims to know the potential of AR Military libraries service by conducting a systematic review of papers published in the Scopus database. AR in military libraries can enhance learning interest, perception of situation awareness, and adequate decision support. AR can offer great solutions to facilitate the controlling capabilities of military trainees and reduce cognitive load and stress. Its application in military libraries includes information filtering, 3D visualization, and extending digital threads. However, despite many limitations of AR usage, its applicability in military libraries can improvise the extensive pool of knowledge and experience to deal with warfare situations to improve capabilities of reaction and response in real-time war situations to improve the controlling capabilities of military trainees include tactical simulation, judgment in operations, assignment, and military simulations.

Keyword: Augmented reality; Military libraries; Technology

1. INTRODUCTION

According to the Great Soviet Encyclopaedia[1], "the military libraries assist military personnel with professional development, personal education, and leisure. In military education, two programs are vital to improving the controlling capabilities of military trainees by the staff officers and commanders, and information specialists, one is instruction and the other one is training. This includes training in tactical simulation, judgment in operations, assignment, and military simulations[2]. Virca and Barsone[3], in the year 2021, found that ICT technology has steered the Fourth Industrial Revolution (4IR) and therefore at par will reshape many military operations and nits-bits of international security. The incubation of technologies like artificial intelligence, IoT, and even quantum computing has allowed defense sectors to achieve digital supremacy. But the talk of recent technology, i.e., augmented reality (abbreviated as AR), can revolutionize military domains like no other[4].

According to Spiegel[5], the military is one such sector that has fully realized many use cases that AR works for, enabling defense troops to work more accurately. The emerging use of AR in militaries significantly impacts the use and extraction of information[6]. Thus the alchemy of library tools with military necessity can eradicate the seclusion developed due to the lack of organization of workflows and arsenals.

Specifically, with regard to libraries, the recent advances in technologies have brought about various innovations in the functionality and services of libraries. Modern tech applications have equipped libraries with capabilities to optimize their operations and tactics. AR in libraries provides a space within the library where users get absorbed in virtual content. AR technology in libraries works to enhance information spaces to create, operate and manage their complex assets, including service and maintenance. Duncan[7] disclosed numerous benefits for libraries in the Caribbean on developing AR collections which include distance learning, the greatest access to library resources by its users, etc. Green & Groenendyk[8] in the year 2019 came across varying evidence supporting the emergence of AR in libraries, particularly ARL-member academic libraries. These libraries are now offering access to AR wherein they create spaces within the libraries that are AR-enabled and maximize content access through AR technology.

Roy, *et al.*[9] presented the implementation of WebAR services in the central library of IIT Kharagpur to deliver library e-resources information. This service proved to be beneficial for effective learning and information delivery with minimal risks. Kannegiser[10] in 2021 showed the use of AR in library orientation appeared to be a worthwhile endeavor for libraries in reducing anxiety among users. The transformation of recordings into AR content came out to be a powerful tool for disseminating information that leads to an effective way to seamlessly merge in-person, library-led tours with traditional orientations.

Murphy[11] in his research necessitated the use of technology in military libraries to improvise their work concerning the delivery of resources and materials. One of the main considerable

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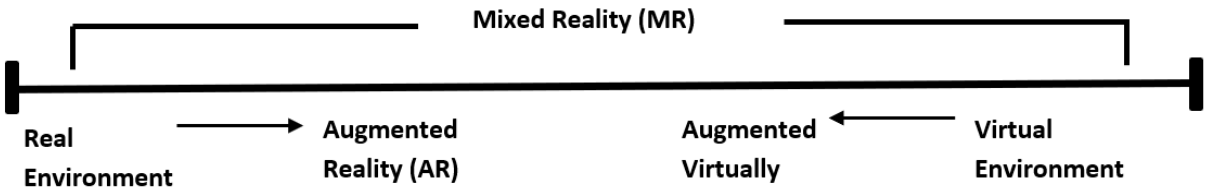

Figure 1. Milgram [18] Reality-Virtuality (RV Continuum).

features that distinguish military libraries from other types of libraries is its means of restrictions. The military library apart from conventional sources (books, pamphlets, and periodicals) contains documents that are subjected to secrecy and therefore have to be stored and circulated in a precautionary manner[12].

The task of the defense sector is sensitive and paradigmatic that needs attention in terms of its use and retrieval of information services. As we see world-renowned libraries are working in the field of defense for fulfilling the information needs of the military community such as the Institute of Defence Studies and Analysis Library which is one of the finest libraries in India dealing in the areas of nuclear issues, military affairs, international relations, and related subjects the United Service Institution of India founded in 1870 has a highly specialized library "Colonel Pyara Lal Memorial Library**"** for enhancing and enriching knowledge in the area of defense studies/science and many more military libraries still working on strengthening support to military community needs. The military libraries need to be efficient enough to deal with the ever-changing scenarios where war grounds are constantly evolving and the world has taken a shift by adopting AR and VR in defense to counter their enemies[13].

For a very noble cause, the military libraries require innovative strategies for security bases of every national infrastructure using technology in their work. The role of AR can effectively find a quick way to display the deluge of information available in a digestible format. The military libraries through AR can offer a solution to manage logistics and services in a manner that can transcribe the traditional ways of dealing with data to present users with experiential gains, thereby aiding military libraries in optimizing their work culture and focusing on the personal and professional education of the combatants efficiently.

Past studies have shown very little literature on its use in military libraries and urge a need to emphasize its seemingly endless list of possibilities in the context of military libraries, This study aims to synthesize the previously published literature on the application and benefits of AR and present the possible applications of AR technology in military libraries for optimizing military library services and prioritizing ways to elevate soldiers' situational awareness during military operations.

2. AUGMENTED REALITY (AR)

The contrivation of the term "Augmented Reality" (AR) was first minted by Tom Caudell in 1990 when he defined AR as a system where virtual elements are embedded with real-life objects to enhance the user's experience[14]. The first AR systems were discovered in the 1990s, which gave mixed reality experiences of virtual objects to users in the real world[15].

Azuma[16] conducted a survey in the year 1997 based on which he identified the three main characteristics of AR, which are defined as:

- It combines the real & virtual objects
- It is interactive in real-time
- It registers in 3D

These three characteristics of AR also highlight the technical requirements for implementing AR systems. The need for its implementation requires a display that can combine real and virtual objects, the second one is a desktop/PC-based system that can present interactive graphics and responds to user input in real-time, and the third essential requirement in the case is a tracker that allows virtual image to appear fixed in the real world using ideal points of key objects in the real world.

In the broader context, this can be elaborated by understanding other taxonomies, such as Milligram's Mixed Reality Continuum shown in (Fig. 1). Milgram and Kishino introduced the notion of the reality-virtuality continuum and the term AR as mixed reality in 1994. In Fig. 1, on one end of the diagram we have a real environment, and on the other end, we have a virtual environment, the objects in virtuality superimpose with the objects in the real world through the process of augmentation. According to Milgram and Azuma, the element that brings virtual content to reality is known as taxonomy[17].

In simple Augmented Reality (AR), the tracking component can be a camera that tracks the user's location in the real world and aligns the coordinate systems between real and virtual objects for the accurate placing of virtual objects on physical objects with the help of the registration component. There is a feedback loop between the human user and the AR system through which the user observes the AR display & controls the viewport[19]. AR has transformed the world of learning where just by tapping on the image with a mobile device, the e-contents can be accessed. AR technology was used mainly in entertainment and business. Still, this is becoming more prevalent in other fields, for example, sharing knowledge, education and managing information, etc. AR has now been implemented in the field of education to train and teach students using AR aids. AR is not just an aid in students' learning in the field of medical science for treating patients suffering from severe ailments by enhancing students' medical training. Many military tasks employ AR to simulate the virtual world in real life using computer-generated amplification to strengthen their visualization of the situations.

3. METHODOLOGY

Since AR is still in a developing phase, even its implementation in libraries is one such theoretically driven

concept. The methodology chosen for this study is a systematic review[20], (a technique by Tranfield presented in the year 2003) to provide insight and guidance into operational needs and the application of augmented reality in military libraries. This paper aims to discuss the possible application of AR in military library services to optimize the conventional transparent layers of military operations. For this matter, the inclusion criteria have been specified to select the most relevant studies to be reviewed.

- English language and peer-review national and international journals indexed in the Scopus database, Ebscohost, and Google scholar
- Those specifically focus attention on the applications of AR solutions to military operations and libraries.

The papers to be reviewed are retrieved from the Scopus database published in the year 2014 to 2022 and others published in Ebscohost and Google Scholar. The search operators used for the study are "augmented reality" + "military" or "augmented reality" + ("library" or "military libraries") or "education" or "military operations". A total of 1091 papers appeared on the search. Further filtering the documents by limiting it to open access and time frame (i.e. 2014-2022), 176 papers are analyzed and synthesized using Cadima systematic review tool https://www.cadima.info/ by first going through the title and abstract and then full-text articles. The flowchart created with the help of Cadima for data extraction is shown in Fig. 2.

the possible applications of AR in the optimization of Military Libraries. Many studies reveal the possible application of AR in libraries and other sectors of society may it be medical, military, or education. In the context of modern military applications, Amaguana, *et al.*[22] opined on the working of the simulation system based on augmented reality by creating a simulated war environment using 3D objects and audio-visual resources for the pretense of actual war conflicts. This system allows users to simulate the virtual world in real life using a virtual button with acceptable performance and easy integration of the application. Also, Livingston, *et al.*[23] in the year 2018 followed the human-centered design paradigm to study both training and operational aspects of the AR system for its use in military operations. AR systems have a significant impact on the cognitive learning outcomes in educational research and strengthen the communication conditions between experts and improve the understanding of operative procedures[24]. AR is paving its way into military operations of countries like the United States, India, and China. There is a need to realize the potential of AR in military libraries to meet the dynamic information needs of the military community and sustain the ever-changing information requirements in warfare. A systematic review of the studies on the application of augmented reality is presented (Annexure 1) to drain out the possible aspects of augmented reality that can be applied to military libraries to optimize the working and efficiency at critical times.

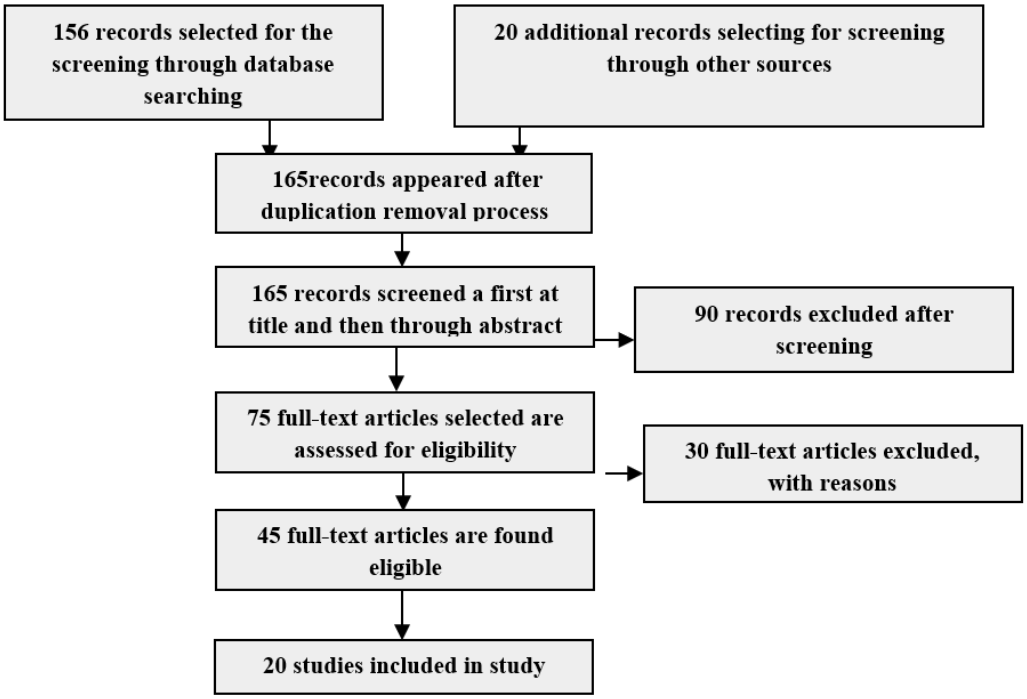

Figure 2. Flowchart showing the procedure of data extraction using Cadima systematic review software21

4. APPLICATION OF AUGMENTED REALITY (AR) IN DIFFERENT FIELDS

This section presents a review of the extent of usage and application of AR in several fields namely military, libraries and education. This analysis of the past studies includes examples of how AR is being implemented in the field of intelligence, military operations, libraries, medical science, etc. to drain out

5. APPLICATION OF AUGMENTED REALITY (AR) IN MILITARY LIBRARIES

The main focus of bringing this technology to the field of military libraries is to reduce the cognitive load of military troops and the community and to see the stress level go down by simplifying the process of information access and dissemination.

The AR system is beneficial in providing an overview of the military library and helps quickly identify resources available. Soldiers can browse through the collection and can find interesting books on techniques of warfare and dealing with equipment. The AR can be used in the location specifications of the collection and resources in military libraries where the librarians can filter out uninteresting information and enrich the military personnel with the information they need at the moment and removing the stress involved in the tiring process of information identification.

According to Morozov[45], locating and searching for books on the shelves can be simplified by developing an AR library management system. AR can help in assuring accuracy in locating the books and filtering the necessary information needs of the combats and military community by placing and highlighting any view in virtual spaces as in real spaces by maintaining a battle information management system. However, the traditional ways of dealing with data have led to the dramatic course of maintaining and keeping collecting historical records. With the advent of storage techniques, databases, and big data in the picture, military libraries, as equipped with sophisticated resources and training methodologies, can very well orchestrate real-world drills and training within library confinements. Here, AR can play a significant role in curating these training experiences.

With big data analytics, archives can serve as an excellent virtual playground for training military staff in such libraries. So that technicians can learn and execute the complex activities that will sustain assets for years to come. The process of tracking and navigation is one problem that exists in the scenario of information access. Several methods and applications are being used to track indoor items to provide robust directions to research material and other desired documents in libraries. For this purpose, a system developed by Behzadan, *et al.*[46] was used to track indoor items with wireless LAN and GPS tracking systems for outdoor position sensing. However, more successful ways for keeping track of the resources within the libraries were provided by LibrARi, and it is one such AR application in which interaction is done with the help of an image. Military libraries can incorporate AR in their work to keep track of the resources and equipment in the library for optimizing their services for better experience and learning of the military community. AR helps allow defense troops to search books with AR interaction. LibrARi allows interaction with the searched books and helps find related books on the subject. Augmented pointers can help to locate books.

The working of military libraries is very sophisticated and any delay in military operations can result in the big picture. It is a challenge for military librarians to filter relevant information from the collection and present this to the warfighter as it requires increasing capabilities from one to collect and deliver data in real time[47]. AR's characteristics can help overcome the problem of information overload as its distinctive features allow one to filter data faster and provide relevant information according to the need and situation. It enables information managers to disperse an increased amount of information to sustain combat situations and deal with defense activities at critical times. The issue of information overload can become quite a matter of concern when educating soldiers and making them aware of the potential threat of warfare situations. Keeping foot with the pace of military operations would require assistance from the military personnel engaged in the processes. The task of information filtering requires consistent training and capabilities of advanced technologies. In response to the issue of information overload, Livingston *et al.*[48] explained an algorithm restricting information displayed to the users. This algorithm-based information filtering uses semantic keys (location-specific filtering feature developed on top of rule-based filtering and spatial type interaction) and the concept of area of operations to limit the information shown. It enables a significant level of flexibility in the process of updating the area of operation and user interest. The ruler-based filters determine that the information is vital and support information filtering. This whole process enables the user to understand the situation more. With the help of AR capabilities to align graphics properly onto the physical surfaces, it removes the cognitive load to understand the meaning of the graphics.

AR can be a valuable asset to military libraries in dealing with the information needs of combatants in warfare and leading soldiers with battlefield injuries. Military medics can receive and deliver remote guidance in executing a procedure by collaborating with military librarians in assistance, saving time and even lives. According to Baily[49], the technology programming of AR can create a simulation of battlefield situations. Military librarians can help equip their libraries with these AR technologies to train the medic combats to learn from this technology to prepare them to deal with such situations in times of emergency. This technology can educate them to provide first aid for severe injuries like bullet wounds and shrapnel injuries and save the lives of the combatants on the modern battlefield. AR makes this possible for military librarians to help in remote assistance by extending the digital thread to the soldiers, technicians, and medics in the field through service and maintenance. By maintaining the task of organizing and managing data effectively, AR, in conjunction with the existing information database, allows librarians to visualize disseminating information efficiently, saving much time and even saving lives. Therefore AR proves to be a valuable technology for military libraries as with the help of augmented machinery; these libraries will be able can reduce the level of stress among the military community to an extent. The hands-off always-ready information presented through the AR helps improve decision-making and eases the users' cognitive burden.

6. LIMITATIONS OF AR AND FUTURE RESEARCH OPPORTUNITY

With the proliferation of smartphones, AR has gained the attention of almost all sectors; whether in the health department, entertainment, military, etc., there are still many challenges that this technology faces. Olshannikova et al.[50] explained important challenges related to the future agenda of using AR technology. This includes inconsistency in output resolution of scene, system lag, and inaccuracy in focus due to non-alignment of virtual and physical distance. A significant drawback is the lack of understanding and education on

oncoming interaction with this evolving technology. Other challenges include technological complexity, knowledge of the technology due to lack of skills of library personnel in computer application, maintenance of database, and dealing with times of information system failures are some of the barriers faced by military libraries in their implementation in libraries.

More to this, there are privacy issues and ethical issues. Privacy is always a concern in the military, even before its implementation. Who can access the information? What information is displayed? Who can these libraries collaborate with to equip the elements of AR in libraries? These are some of the possible challenges librarians must take care of while implementing AR in military libraries. Moreover, there are no standards and guidelines for AR. All these limitations highlight the lack of technological deficit professionals. There is a need to create training workshops for skill enhancements. These technical aspects of using AR must be worked on to improvise in the future for its successful incorporation into military libraries. The military is always at the pace of using the latest advents in technology. This new form of reality offers a great deal of knowledge and experience to the combats outside their known limits. Also, the literature on AR is growing rapidly and its usage in military libraries is still in its infancy, therefore there is a need to do more quantitative research on its usage in military libraries and its impact on strengthening the defense walls of the country.

7. CONCLUSION

Modern military applications can change the face of military operations. Using AR in military libraries can benefit information leaders and managers in assisting combatants in critical situations. AR offers some practical advantages over VR for military libraries and can enhance the working of libraries by managing and distributing information. They can help soldiers better understand large-scale missions with highly detailed and customized solutions. It seems inevitable that the future of armed conflicts will include technology to allow soldiers to enhance situational awareness and cognition. AR can help military libraries in scheduling data; it can ease the binding task and better recollection of learned things using remote data transfer capability by extending the possibilities of the digital thread. The 3D visualization and synchronization of virtual objects in physical spaces help to improve the process of learning new procedures. The capability of AR can create an imitation learning environment that enhances skills and aware combats the level of threat that exists in warfare situations comprehensively. Information superiority can ensure solutions to survive or avoid danger at difficult times. Situation awareness benefit of AR technology can help combat to identify and locate targets more quickly that the enemy by improving the capacities of reaction and response in real-time warfare situations which will influence and disrupt the opponent's capabilities. With all the efforts underway, AR will soon find its way into the standard working of Military libraries and be the reason for evolving our defense troops to the new age of computer and human interaction.

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CONTRIBUTORS

Dr Pramod Kumar Singh, obtained PhD in Library and Information Science from University of Jammu, Jammu in 2020. His research areas are as Bibliometrics study, Scientometric study, IT application to libraries and Library management. He edited the script, checked the plagiarism, validate the script, and prepared the final draft.

Ms Pooja Rana has obtained her master degree from DLIS, University of Jammu, Jammu in 2020. Her research area is Strategic management in libraries and scientometric studies. She collected the primary data and wrote the introduction, conduct a review of the literature, and prepared the first draft.

Annexure I

Author	Study	Year	Target/ Population	Design/ methodology	Applications
Boyce,, *et al.*[25]	Use of extended reality for enhancing military training by studying carious military tactics	2022	Military terrain simulations	A sample of 12 US military academy cadets used BVI on three different platforms (Sand table, Tablet, and HoloLens)	• AR tools such as sand tables and tablets performed well in this study to illustrate real field terrains. The technology performed well compared to HoloLens in accuracy, response time, cognitive load, and usability. • It reduces cognitive load relative to the flat interface.
Hussain[26]	Review of augmented reality in academic & research libraries	2022	Academic Libraries and Research Libraries	Qualitative research based on the content analysis	• Several libraries particularly in developed countries are using AR technology to provide a comprehensive experience of virtual content in physical spaces • This paper showed the need and adoption of advanced technologies as without these technologies no advancement is made in the library sector.
Huang,, *et al.*[27]	A framework for mobile augmented reality by providing an efficient map rendering platform	2021	Different platform-specific graphics libraries	Performance evaluation of platform-independent AR-GIS rendering engine; the augmented reality universal graphics library (AUGL) engine	• The AR universal graphics library engine implementation resulted in rendering performance thrice better than the average performance of ioS and Android. Moreover. • AUGL is two times more efficient than the AR-GIS rendering engine.
Pallavicini, *et al.*[28]	Systematic review approach for for reducing stress and anxiety by reviewing literature ib Commercial off-the-shelf video games	2021	COTS video games equipped with AR technology	A systematic review performed with PRISMA	• AR reduces stress and anxiety in children, adults, and older adults.
Tetiana, *et al.*[29]	Use of AR technology for education through computer vision mobile system	2021	Libraries	Analyzing algorithms of computer vision and features of existing software modules and libraries	• AR allows provides the real-world experience of virtual objects. • The computer vision mobile system for educational innovation facilitates more effective interaction between users and educational materials.
Jang, *et al.*[30]	Educational needs for simulation treatment of severe trauma using mixed reality	2021	Severe Trauma Treatment for patients in the medical field	Focus group interviews with military hospital nurses.	• AR can be applied for continuing education, securing safety, and debriefing through video conferences. • AR is beneficial in approaching realistic education reflecting actual clinical practices.
Saleh, *et al.*[31].	Augmented reality technology in libraries and medical universities	2021	Medical Libraries and University Libraries	Qualitative approach Semi-structured interviews of 20 experts in the field of AR.	• Libraries using AR can attract many users by enriching the content of resources and enacting effective policies. • AR assist in improving various professional activities including library management tasks.

Author	Study	Year	Target/ Population	Design/ methodology	Applications
Chen, *et al.*[32]	The analysis of AR and multimodal interaction for command and control systems in Air forces	2020	Air Force environment based on augmented reality technology	This study incorporates analysis HoloLens Hardware as a carrier to realize the battlefield situational information	• AR has great significance and accuracy. • It provides operational simulation as well as evaluation verification
Wang, *et al.*[33]	AR in Maintenance Training for Military Equipment	2020	Augmented reality in the Civil and Military field	Analysis of the present situation of augmented reality technology	• AR has the optimum potential in developing the tendency of this technology in maintaining AR military equipment in the future.
Chmielewski, *et al.*[34]	Using analytical tools for accessing tactical situations in military operations	2020	Military combat decision support	A set of combat potential evaluation methods and algorithms in specialized mCOP application	• AR supports situational awareness of various crisis scenarios and helps to evaluate threat levels in advance. This can help in managing various military operations ahead of real war situations.
Chmielewski, *et al.*[35]	Application of AR for situational awareness development, decision-making support, and combat entity	2019	Combats support and Military operations	Development of application design utilizing augmented reality used for the production of contextual data delivery.	• AR improves the combats support, and implements the algorithm for path-finding and situational awareness. • AR is well effective in scheduling movement tasks, assistance, analysis, and military potential evaluation.
Karambakhsh, *et al.*[36]	Deep gesture interaction for augmented anatomy learning	2019	Medical education through augmented reality	Design of user interface featured AR for gesture recognition	• AR helps in installing deep convolutional learning with more accurate gesture recognition. • AR comes as a rising field combined with neural networks and applied to medical learning and education system.
Hannah, *et al.*[37]	Collecting virtual ad augmented reality in 21st-century library	2019	Academic libraries	Discuss possible pedagogical applications for AR and VR	• Building infrastructure to support AR/ VR collections to collect and curate 3D objects. • Supports the use of innovative pedagogies.
Ruiz, *et al.*[38]	Geolocation in a library using augmented reality	2019	Libraries and Digital Environments	AR-based Model View Controller system, prototype development, and its assessment	• AR allows users to take virtual tours of the library and be aware of various services and spaces within the library. • AR provides a way to observe and interact with library resources more effectively, leading users to their desired documents through its novel navigation capabilities.
Iftene and Trandabăț[39]	Enhancing the Attractiveness of Learning through Augmented Reality	2018	Learning innovation through AR	Analysis of applications of augmented reality in various domains	• AR improves collaboration and communication skills among students through an innovative learning environment. • Providing ease of learning biology and geography. • Enhances interest in classes by making them more interactive and attractive. • More precisely the users can retain new knowledge and information. • Reduces the stress among students by providing visualizations of tests as games

Author	Study	Year	Target/ Population	Design/ methodology	Applications
Lund and Agbazi[40]	Augmented Reality for browsing physical collections in academic libraries	2018	Academic libraries at Emporia State University in Europe	Use of AR for browsing physical conditions	AR can be utilized in academic libraries to reach out to patrons, remarkably those unaware of the library's collection with the appropriate designs. Their primary mission was to launch this application as a piece of information for the pursual of the users.
Baumgartner-Kiradi, *et al.*[41]	Potential of Augmented Reality in the library	2018	Academic and Special libraries	Qualitative research by interviewing libraries and experts working in public and scientific libraries in Austria	AR has great capabilities in creating imitation learning and identifying critical aspects of library operations. Its implementation in the medical sector helps in simulating critical conditions facilitating medics to learn various surgical procedures.
Avila[42]	Implementing augmented reality in academic libraries	2017	Academic Libraries	An exploratory study that explains the use of AR applications for libraries	Provides new ways to interact with library patrons. AR in libraries outreaches vital services to the users. AR-enabled libraries can be integrated with library flyers where access to AR content can be provided. It also goes well with signage.
Champney, *et al.*[43]	Augmented reality training of military tasks: Reaction from subject experts	2015	Military officials and subject matter experts. The critical parameters undertaken for the study	They built an Augmented Immersive Team Training (AITT) system for understanding subject matter experts' reactions.	The study revealed the need to superimpose virtual computer-generated imagery into an actual physical environment, considered. AR is an excellent tool for teaching and showed the appropriateness of fidelity of the AITT system with certain refinements in the system
Malhotra, *et al.*[44]	Context-aware library management system using augmented reality.	2014	Academic Libraries and Research Libraries	Design and development of GUI i.e. AR software to allow users, especially students in Universities/Colleges to view the content of the books physically which is available online.	The implementation shows AR is a promising tool for library management. Provides abilities to recognize a missing item in libraries. Library users can choose the best books by reading the reviews about the book using AR software.