

Review Article

Augmented Reality Interface for Complex Anatomy Learning in the Central Nervous System: A Systematic Review

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The medical system is facing the transformations with augmentation in the use of medical information systems, electronic records, smart, wearable devices, and handheld. The central nervous system function is to control the activities of the mind and the human body. Modern speedy development in medical and computational growth in the field of the central nervous system enables practitioners and researchers to extract and visualize insight from these systems. The function of augmented reality is to incorporate virtual and real objects, interactively running in a real-time and real environment. The role of augmented reality in the central nervous system becomes a thought-provoking task. Gesture interaction approach-based augmented reality in the central nervous system has enormous impeding for reducing the care cost, quality refining of care, and waste and error reducing. To make this process smooth, it would be effective to present a comprehensive study report of the available state-of-the-art-work for enabling doctors and practitioners to easily use it in the decision making process. This comprehensive study will finally summarise the outputs of the published materials associate to gesture interaction-based augmented reality approach in the central nervous system. This research uses the protocol of systematic literature which systematically collects, analyses, and derives facts from the collected papers. The data collected range from the published materials for 10 years. 78 papers were selected and included papers based on the predefined inclusion, exclusion, and quality criteria. The study supports to identify the studies related to augmented reality in the nervous system, application of augmented reality in the nervous system, technique of augmented reality in the nervous system, and the gesture interaction approaches in the nervous system. The derivations from the studies show that there is certain amount of rise-up in yearly wise articles, and numerous studies exist, related to augmented reality and gestures interaction approaches to different systems of the human body, specifically to the nervous system. This research organises and summarises the existing associated work, which is in the form of published materials, and are related to augmented reality. This research will help the practitioners and researchers to sight most of the existing studies subjected to augmented reality-based gestures interaction approaches for the nervous system and then can eventually be followed as support in future for complex anatomy learning.

1. Introduction

In modern computing world, the rate of increase in information is very fast. The role of Augmented Reality (AR) is obvious in different fields of life since 1990 [1–5]. AR is used to enhance the understanding of students in science, such as

biomedical sciences [6], microbiology [7], and environmental sciences [8, 9]. AR is a communicative technology, which integrates a real thing into virtual environment with interactions. The human interaction is a significant feature of AR. Apart from the interaction through language, the gesture interaction is the utmost body auxiliary interaction.

Researchers try to solve the problem of dynamic gesture, but yet no established and integrated approach is available to overcome this problem.

The role of AR is at first-hand and significant understanding in the field of multimedia technology. AR focuses on the improving and efficient real environment and conveying the contents by flawlessly supporting the computer-generated virtual information. The aim of AR is to bring simplification in user' life by fetching virtual information of the real world environment, and it increases the perception of user with interaction of the real world.

AR has application in the human body learning. Layona et al. [10] proposed application of AR for wisdom of the human body anatomy. The designed application helps the learner to gain knowledge of the human body anatomy with 3D object interactively. Ferraz [11] presented that the current interaction between child and computer is not a complete development paradigm. It is associated to different problems, such as mental and physical health problems, and is shown as not to be a well cognitive development for children performance. The authors proposed a synergy between the human body development, computing machines and neural environment. The technique focuses on the issue that the children should be motivated toward physical environment, which has diverse alternatives for stimulation of sensory and augmenting mental and physical stress to organism. Khademi et al. [12] combined the augmented reality with the haptics for the observation of stiffness of human arms. To measure the human arms impedance, a haptic handheld device is used. For tracking and recording, the computer vision system is used, while to show the impedance diagram, a screen is used. Janssen [13] presented a framework of three components for empathic technology to augment human communication, which is based on neuroscience and psychology, consisting of emotional convergence, cognitive empathy, and empathic responding. Cangelosi and Invitto [14] presented a review to analyse the details of communication of modern neuroprosthetics and human-robot applications. Brain and computer interface is focussed specifically, which is linked to the haptic system, interactive robotics, and autonomous system. Esquivel et al. [15] presented an approach to identify the gestures made by hands for the CAD control system with a Kinect sensor of Microsoft.

The proposed study contribution is to identify relevant studies associated to the current research. 78 studies that were selected and included on the basis of predefined exclusion, inclusion, and quality criteria. The proposed research carries the following research questions:

The current review concentrated on three research questions (RQ) given below:

R.Q.1. What are the applications of augmented reality in complex anatomy learning for the central nervous system?

R.Q.2. What research work is performed since 2009 in the area of gesture interaction-based augmented reality approaches for complex anatomy learning in the central nervous system?

R.Q.3. What are the available techniques/methods being used for gesture interaction-based augmented reality approaches for complex anatomy learning?

The paper sections are arranged as follows: Section 2 discusses the process of research, which uses the guidelines to conduct a systematic literature review (SLR) provided by Kitchenham et al. [16]. Derivations and discussions along with the answer of the research questions are discussed in Section 3. Limitations of the research are presented in Section 4. The paper concludes in Section 5.

2. Process of Research

Systematic literature review has several applications in different domains [17], and it is recognized as an established way to analyse and observe a problem area objectively. The applications of augmented reality are obvious in all fields of real life especially in the area of the central nervous system. The CNS has various features to be analysed. The reason behind using SLR is to thoroughly find out, measure, and assume the published research related to the predefined research questions to explore full information to community of research [17]. The implemented protocol [16] and the actions are divided into three phases including (1) development of protocol, (2) conducting the SLR, and (3) reporting. The following subsections in brief discuss the SLR protocol used and the process of data collection.

2.1. Research Definition. The objectives of the proposed study is to present a comprehensive understanding of the present published research related to the augmented reality-based gesture interaction approaches for complex anatomy learning in the central nervous system. The aim of using augmented reality applications in complex anatomy learning for the central nervous system, the research work performed in the area of AR-based gesture interaction approaches for the CNS, and the technique used for the CNS based on AR and gestures interaction will eventually support the practitioners to easily adopt the goal for which the AR is used. The SLR used by the current research provides a brief investigation of the applications of AR in order to make it easy to understand diverse methods followed in research and industries. The review further explores the research performed in the CNS based on AR.

A formal process of SLR is followed to make the procedure further objective and repeatable. The process of SLR conduction and phases involved in SLR is shown in Figure 1 [17].

2.2. Research Plan and Method. The guidelines [16] were followed as protocol for conducting the proposed research work. The first phase of the SLR is to describe questions which consist of three research questions. The second phase is the process of search in the mentioned libraries for the keywords defined. The next phase is the selection process in which the relevant papers are included while the irrelevant papers are excluded. In the fourth phase, the quality

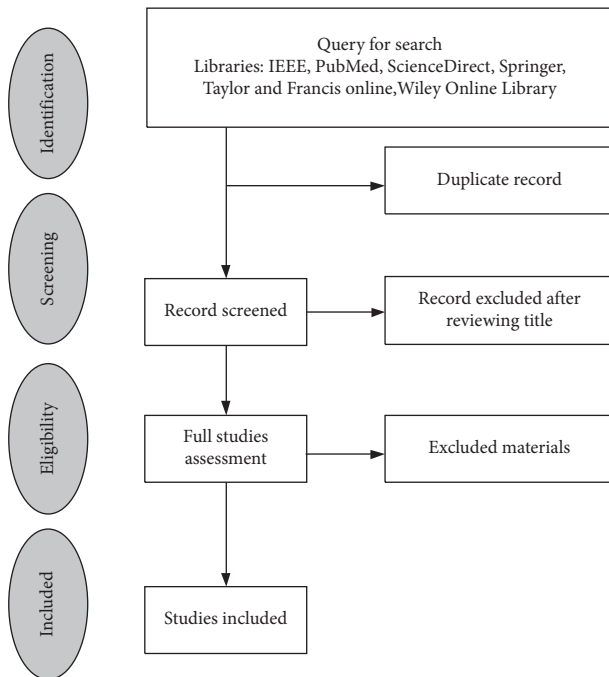


FIGURE 1: Phases of conducting systematic literature review.

assessment process is performed, and weights are assigned to questions. Last, data analysis of the obtainable data in included articles is done.

2.3. Search Process. A formal search process for conducting review of literature is an essential part of SLR to search each individual source. An organized process of search formulates to comprehensively excavate available materials to identify associated literature to meet the predefined criteria of search. To support this study, an appropriate search process has been carried out to find connected material published in the leading and apparent journals, books, conference proceedings, and other materials published online. The proposed research uses four keywords associated to the augmented reality-based gesture interaction approaches for complex anatomy learning in the central nervous system based on research questions searched in the libraries. The process of search for this study is shown in Figure 2.

Based on the predefined keywords, these libraries were searched and are given below:

- (a) IEEE
- (b) PubMed
- (c) ScienceDirect
- (d) SpringerLink
- (e) Taylor and Francis Online
- (f) Wiley Online Library

The proposed keywords selection for the process of search was determined by the authors of this research. The keywords were kept more specific, as by doing so, a huge list of articles was obtained, which were later on difficult to

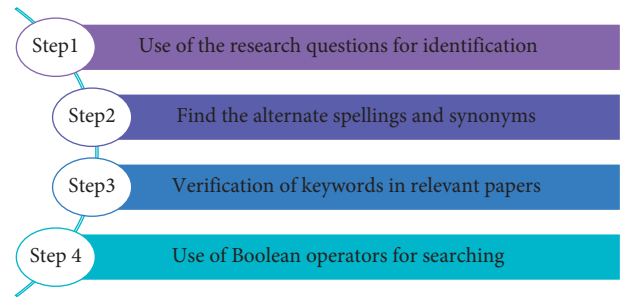


FIGURE 2: Steps of the search process.

analyse. Apart from this, the inclusion and exclusion process, analysis, and evaluation of the papers were a tricky task. To get rid of the issue of searching and to effortlessly include and exclude, analyse, and evaluate papers, the keywords were reserved explicit.

The keywords for the proposed study include “augmented reality,” “gesture interaction,” “nervous system,” and “learning.” The search process was limited for the years range from January 2009 to September 2018. The process of search shows a large number of associated materials in the form of journal publications, books, workshops, conference, and many other published papers. The included repositories were manually searched by same and predefined keywords. All of the citations and bibliographic information were handled in the Endnote software [18]. The papers with duplication were excluded manually, and one source of similar paper was included.

Figure 3 shows the detail on the whole search process for the keywords in the mentioned libraries. The process includes initial search, exclusion and inclusion, filtering through title, filtering through abstract, and then filtering through full contents.

Individual folders were made for the libraries (mentioned above), and 1143 articles were identified. Initially, the entire folder of the library was checked manually, and all of the articles were renamed by their exact titles. Duplication in the papers was excluded. Manual process for filtering was performed manually for all the libraries through title, and 147 articles were obtained. The articles were then filtered through checking abstract of the papers, and 111 papers were included. Last, the papers were filtered through their contents, and 78 papers were included. Figure 4 shows the details of included articles through title, abstract, and contents.

Endnote library was used for the 78 included papers, and their references were managed. Some of the information were not available in the citation of the papers; so, the process of making the references was performed manually. Such information include author name, title, year, place of publishing, page no., and so on. The included papers were then reviewed and analysed in the proposed research.

2.4. Study Selection Process. A large number of articles were obtained after the search process. So, it was an essential part of the research to include only relevant papers according to predefined exclusion and inclusion criteria. This was

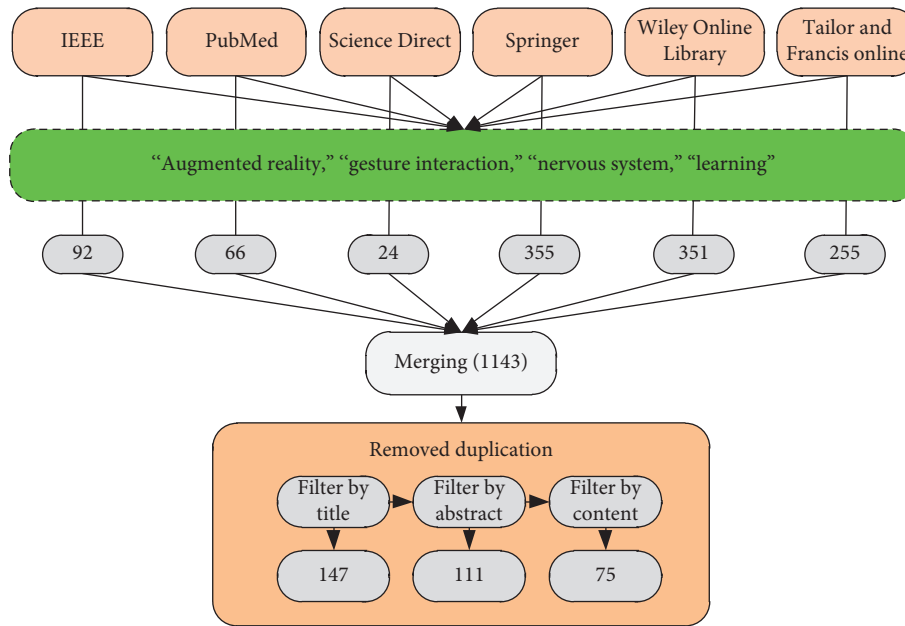


FIGURE 3: Search process, inclusion and exclusion, and filtering process based on the keywords for articles.

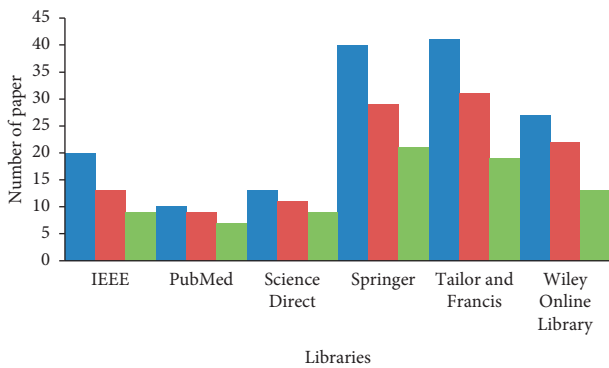


FIGURE 4: Filtering of papers by title, abstract, and contents.

performed to be capable to select only those papers which were precisely focusing on answers of questions. The collection of articles was complex job as it consists of numerous steps. For this reason, the paper selection was carried out in two steps: initially, process for filtering was performed manually for all the libraries through title, and then, the articles were filtered through checking abstract of the papers. Last, the papers were filtered through their contents, and relevant papers were included, while the papers that were not relevant were excluded. The inclusion and exclusion criteria were defined and are shown in Table 1.

Selected articles after removing of duplications and filtering process along with type of publication, year in which the article published, and citations are shown in Figure 5. This process resulted in retrieving only the most relevant papers, explicitly passed through the defined inclusion and exclusion criteria [19].

Figure 6 shows the details of papers categories of the papers published in the given years.

Figure 7 shows the details of other category (congress and report) of the papers published in the given years.

According to the trend in 2, there is an increase in the research and publications year-wise, marking the gaining importance and application of augmented reality in the field. Figure 8 shows the raise in number of publications in the selected year range.

2.5. *Quality Evaluation of Included Papers.* The quality evaluation process of included papers was carried out through selection of paper inclusion process completed. All the articles were read, and quality of these papers was evaluated for each research question. The quality criteria (QR) defined against each question was evaluated in the paper and is given below:

- QR1. An obvious depiction of augmented reality in the CNS in the given paper.
- QR2. The research work performed published in the range of year 2009 till September 2018 is given in the paper.
- QR3. The papers provide detail of different techniques to augmented reality used in the CNS.
- QR4. The papers focus on the applications of AR in the CNS.

All the included papers were analysed by the authors manually. Separate QR of each question supported the authors to objectively evaluate the quality of answers for the questions provided in included papers. The papers were assigned weights based on the question and quality against the criteria mentioned above. Weights were assigned in manner of 1 for a question fully described in paper, 0.5 for a question explained to some extent, 0 for the paper which does not provide information of the question.

To measure this quality for analysis, score in total shows the relevancy of paper to the proposed research. All the

TABLE 1: Criteria for inclusion and exclusion of papers.

Inclusion	Exclusion
(i) The paper published in the year 2009–2018.	(i) Papers not in the range of January 2009–September 2018
(ii) The contents of the article are available	(ii) Several versions of the paper
(iii) The article is written in English	(iii) Not associated to the defined research questions
(iv) The paper gives details about the use and application of augmented reality-based gesture interaction in the central nervous system	(iv) Not in English
(v) The paper provides background required to answer the predefined research questions.	
(vi) The article exists in the above databases	

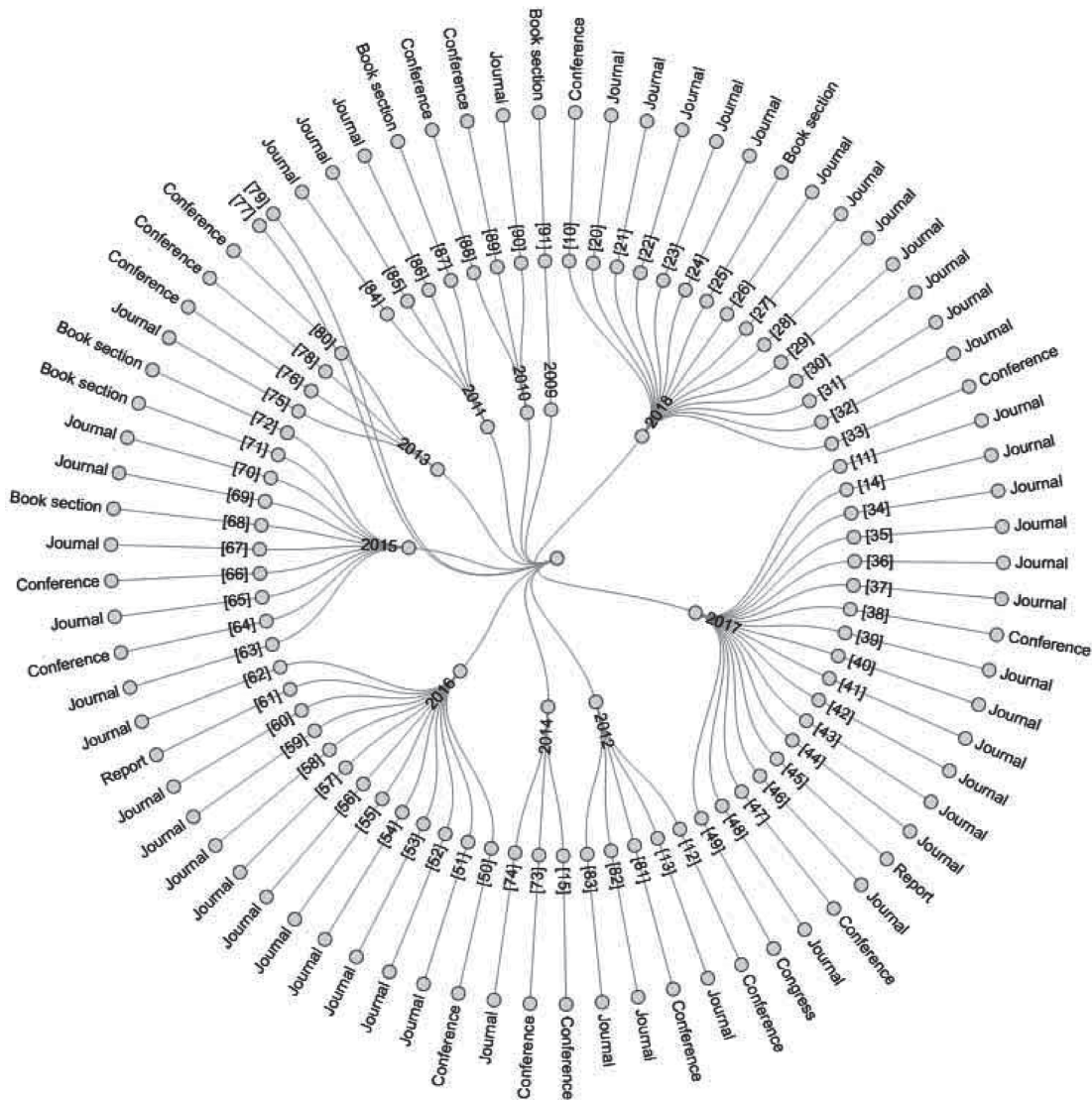


FIGURE 5: Details of the selected papers.

scores of the defined research questions are added. Details of QA for included papers are given in Figures 9–12.

2.6. Data Extraction from the Proposed Study. After the process of quality assessment, the data required associated to

questions defined above were derived from papers. Relevant data extracted from the selected papers are shown in different tables which are defined in Table 2;

(i) Figure 4 presents the filtering process of included papers from the search process.

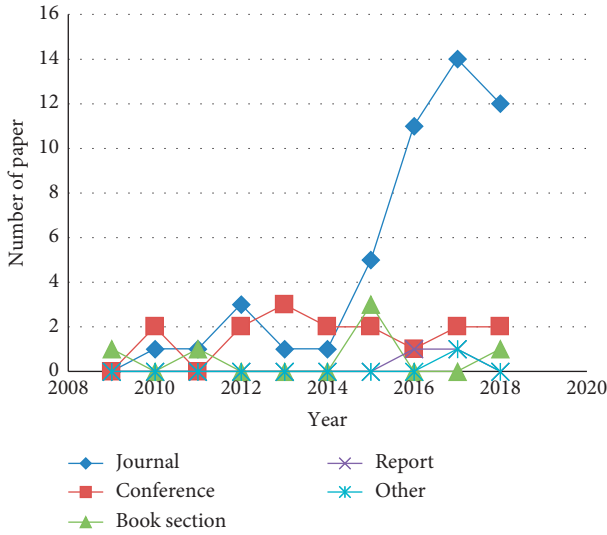


FIGURE 6: Details of journal category of the papers published.

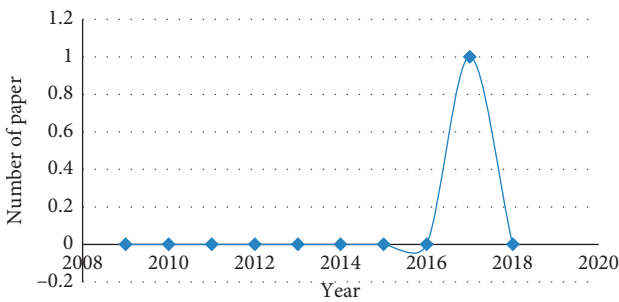


FIGURE 7: Details of other category of the papers published.

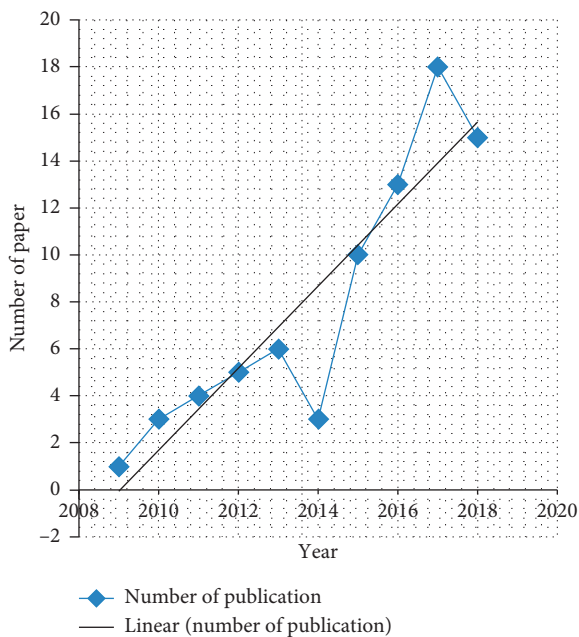


FIGURE 8: Number of publications for the proposed research from 2009 to 2018.

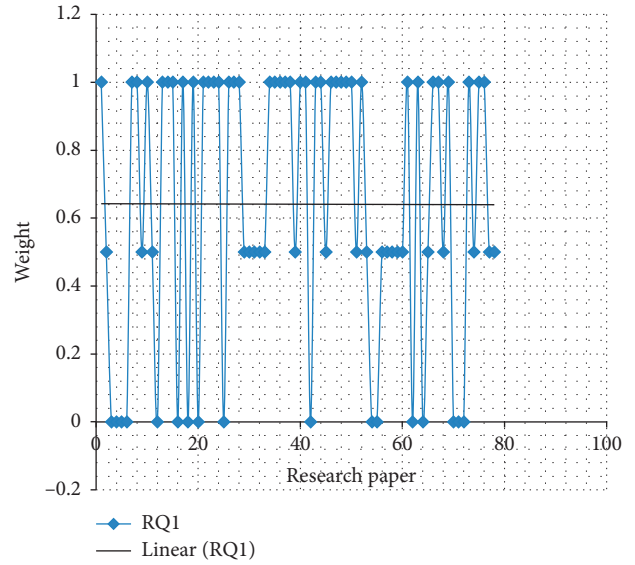


FIGURE 9: Quality scoring of research question 1.

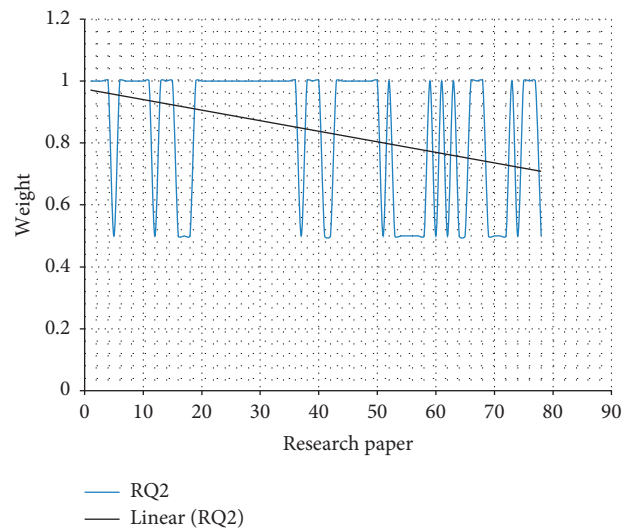


FIGURE 10: Quality scoring of research question 2.

- (ii) Figure 5 shows the final selected papers, which are given along with the paper type, reference, and publishing year.
- (iii) Figure 12 presents the overall QA of included papers.
- (iv) Table 2 shows the techniques/methods being used for gesture interaction-based augmented reality approaches for complex anatomy learning.

3. Results and Discussion

Below subsections briefly present the answers of the defined research question.

3.1. What Are the Applications of AR in Complex Anatomy Learning for the Central Nervous System. The role of

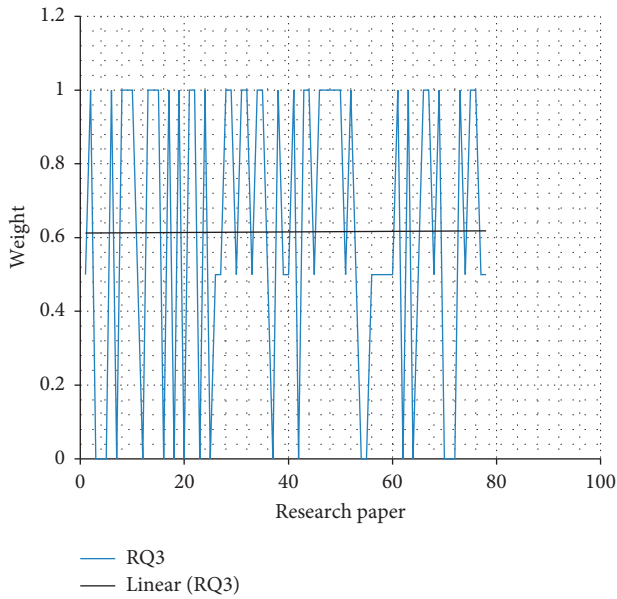


FIGURE 11: Quality scoring of research question 3.

augmented reality is obvious in all fields of life. Several studies are available in the field. The paper presented details of the mixed realities to elaborate the theories related to the use of technology for performance value and give precise explanation of efficient early use cases [61]. The techniques and approaches used for the recognition of facial emotion are briefly reviewed [62]. The design, deployment, and basic testing of the system, which is combination of smart devices, technology of AR, physical cube, and application of software, are developed to motivate social and cognitive functions of children in preschool [22]. A platform of an AR application design is presented for realizing natural human-computer interaction, which is based on gesture recognition [24]. The authors discussed the experimental design and compared the two types of system of optical tracking of augmented reality that is maker-based augmented reality and markerless augmented reality [25]. The paper presented an approach, and the AR marker is used for mobile computing platform [26]. The paper presented an approach of developing applications of AR for the anatomy learning of the human body with the interaction of 3D objects [10]. The authors proposed an approach of lightweight deep learning based on embedded devices or mobile [27]. The study presented has focussed on the past viewpoint of the progress of the technologies for VR and AR. The study has analysed the present applications and its relevant application in the neurosurgery [28]. The authors evaluated the learning structural anatomy using VR or AR as optional as application of tabletbased and showing that whether these modes enhance learning of student, performance, and engagement. Total of 59 participants were assigned to one of these three modes [29]. The study evaluates the feasibility of and performance of magnetic resonance imaging-guided paravertebral sympathetic injections by navigation of AR and 1.5 T and a magnetic resonance imaging scanner [30]. The paper focussed on the system and control as the core part of

information and communication technology and its application for upcoming humanity and research [63]. The paper presented research on two aims of the prototype augmented reality tool for mobile devices and to complete the assessment of designed prototype augmented reality [31]. The authors presented the compilation of novel applications of human-computer interaction in different areas. Such areas include VR and AR, input and output devices, wearable technologies, and so on [64]. A report on the 20 technologies to change the world is presented [65].

The authors presented the present interaction between child and computer in not a complete development paradigm. It is associated to different problems, such as mental and physical health problems, and is shown as not to be a well cognitive development for children performance. The authors proposed a synergy between the human body development, computing machines, and neural environment. The technique focussed on that children should be motivated toward the issues of physical environment, which has diverse alternatives for stimulation of sensory and augmenting mental and physical stress to organism [11]. The paper presented an approach of the gesture interaction between the driver and the vehicle. The approach was used for the driver to control the longitudinal motion and vehicle lateral. The gesture modality was used as input as it decreases the visual and cognitive demands of the driver. Experiments were performed on 20 drivers in a simulator of VR driving to identify the usefulness of the interface for control of the vehicle [35]. The paper presented an approach of AR-integrated simulation education in healthcare [36]. The authors proposed a hybrid method of egocentric VR and exocentric AR-based user experience and assessment of context aware smart home. Qualitative and quantitative experiments were performed to validate the approach [66]. A systematic review of the moment visualization of virtual reality-based rehabilitation therapy categorization for the conditions of neurological is presented. The present research in the area of lower limb applications is summarised [67]. The paper presented the usefulness of gestures as expanded encoding for the young learners by supporting the memorisation of target language and slowing attrition by implementing of teaching protocol and a bespoke pedagogical tool [37]. The proposed research work consists of the case study in which the students of different discipline at the undergraduate level interacted with industry agents to collect the data and suggestions at the starting phase of their projects. The disciplines included computer science, electrical, mechatronics, and telecommunication engineering [68]. The paper presented cognitive neuroscience perception affordances during the experience of interactive in VR. The proposed work was analysed by employing 10 subject samples matched by sex and age among the students of university [38]. The paper presented a method for location of brain lesions in 35 patients by using iPhone, and the lesion surface projection onto the skin of the head is shown [40]. The paper assessed the efficiency of a gesture recognition tool related to clinic, which are based on international biomechanical standards for the joint motivation of human reporting, design of the interactive AR treatment system

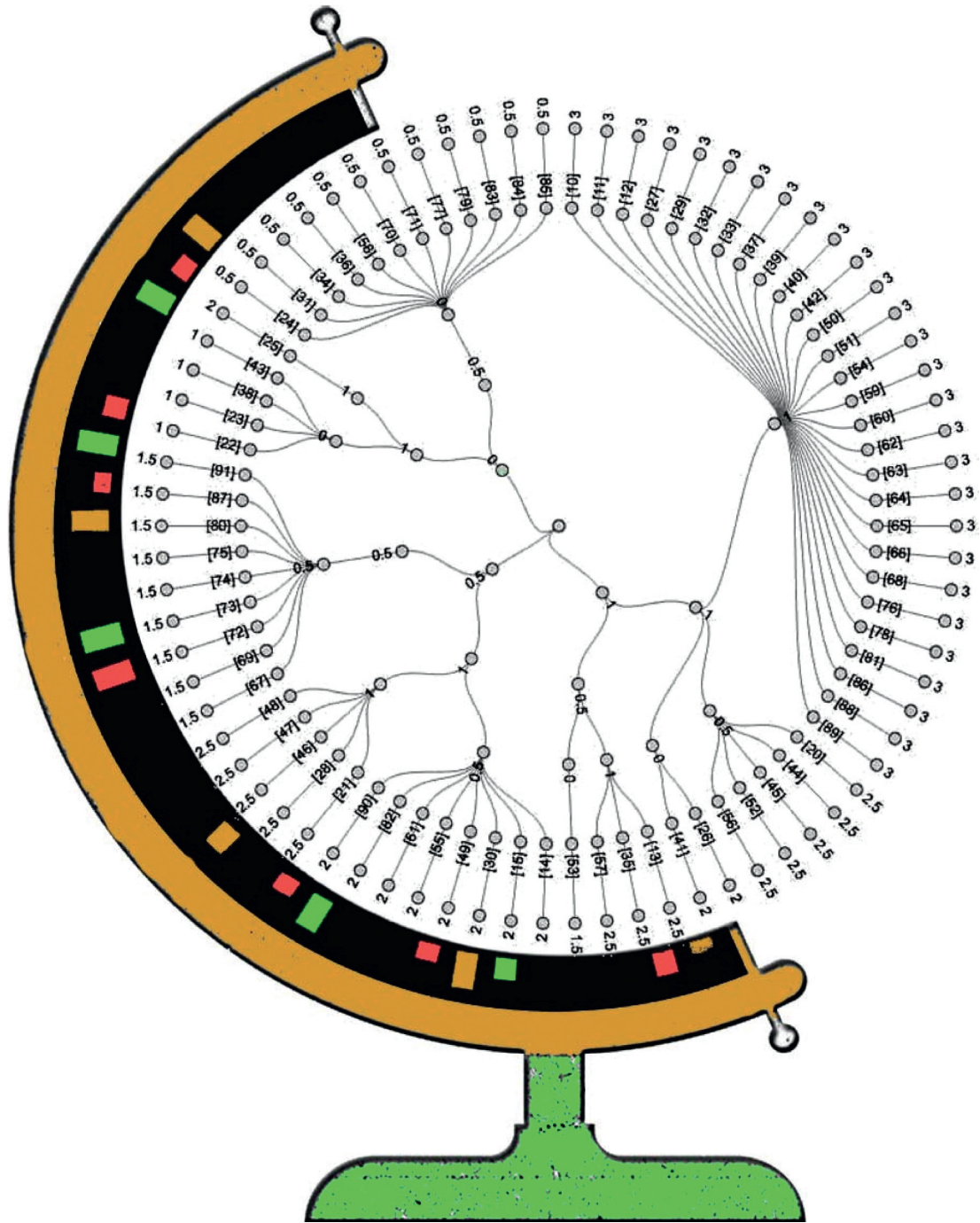


FIGURE 12: Overall quality assessment of the selected papers.

[41]. The authors assessed the success and recognition of the experiment involved with chronic stroke survivors [42].

The authors used multivariate pattern analysis as the decoding method for the analysis of magnetoencephalography to study the processing dynamics of social interaction. Total of 24 participants sighted the images of women which were doing actions, and the brain activities were recorded using magnetoencephalography [43]. An efficient, simple, and useful approach is presented for the visualization of patient brain by VR and AR using

application of smartphone [44]. The authors discussed the design of augmentative and alternative communication computer-based solution to act as complement for therapist for the activities of augmentative and alternative communication to support the better lives of disable children [45]. The paper presented a platform of AR for laser surgery of the eye. The study proposed an algorithm which automatically register images of multimodel, detect macula and optic disc regions, and demarcate these as protected areas from laser surgery. It supports the doctor to organise the presurgery

TABLE 2: Methods for gesture interaction based approaches in the nervous system.

S.No	Reference	Title
1	[20]	TANGAEON
2	[21]	CNS anatomy and sexual desire neurochemistry
3	[22]	Giok, the alien
4	[23]	Avionics human-machine interfaces and interactions
5	[24]	Continuous dynamic gesture spotting algorithm
6	[25]	Marker versus markerless AR. Which has more impact on users?
7	[26]	Human anatomy learning systems through AR on mobile application
8	[10]	Web-based AR for the human body anatomy learning
9	[27]	A mobile outdoor AR method
10	[28]	Utilizing VR and AR for education
11	[29]	Effectiveness of VR and AR in health sciences
12	[30]	1.5 T augmented reality navigated interventional MRI: paravertebral sympathetic plexus injections
13	[31]	An AR tool for learning spatial anatomy on mobile devices
14	[11]	A biosymtic (biosymbiotic robotic)
15	[32]	Advanced, analytic, automated measurement of engagement during learning
16	[33]	An.—an interactive full body exercise experience for patients suffering from ankylosing spondylitis
17	[34]	Smart gait-aid glasses for Parkinson's disease patients
18	[35]	A hand gesture-based driver-vehicle interface to control lateral and longitudinal motions of an autonomous vehicle
19	[36]	AR-integrated simulation education in health care
20	[37]	A helping hand with language learning: teaching French vocabulary with gesture
21	[38]	Haptic, virtual interaction, and motor imagery: entertainment tools and psychophysiological testing
22	[39]	Exploring learner acceptance of the use of virtual reality in medical education: a case study of desktop and projection-based display systems
23	[40]	A low-cost iPhone-assisted augmented reality solution for the localization of intracranial lesions
24	[41]	MirrARBilitation
25	[42]	Effect of a mixed reality-based intervention on arm, hand, and finger function on chronic stroke
26	[43]	Rapid neural discrimination of communicative gestures
27	[44]	Visualizing the brain on a mixed reality smartphone application
28	[45]	An augmentative and alternative communication tool for children and adolescents with cerebral palsy
29	[46]	An AR assistance platform for eye laser surgery
30	[47]	Wearable computing background and theory
31	[15]	Gestures for Interaction between the software CATIA and the human via Microsoft Kinect
32	[48]	Healthcare system design focusing on emotional aspects using augmented reality—relaxed service design
33	[49]	Touching virtual agents: embodiment and mind
34	[50]	Core aspects of dance: condillac and mead on gesture
35	[51]	Immersive augmented reality: investigating a new tool for Parkinson disease rehabilitation
36	[52]	Using children's developmental psychology to guide augmented-reality design and usability
37	[12]	Haptic AR to monitor human arm's stiffness in rehabilitation
38	[53]	Augmented self-modeling as an intervention for selective mutism
39	[13]	A three-component framework for empathic technologies to augment human interaction
40	[54]	Smart wearable systems
41	[55]	Learning in a virtual environment using haptic systems
42	[56]	Augmented reality technologies, systems, and applications
43	[57]	On the use of augmented reality techniques in learning and interpretation of cardiologic data
44	[58]	Epione
45	[59]	Communication: the nerve system of construction
46	[60]	Human-computer interaction

laser treatment by using the registered images [46]. The chapter presents the correlations between nature and human relating to computation and network [47]. The paper demonstrated to study and discusses the diverse aspects of affective behaviour of the AmI system. The paper further outlined the role of affective computing in research of AI to AmI [69]. The paper presented an approach to handle the negative emotional health, which focuses on affective characteristics. The proposed system merges AR in displaying of virtual objects in real environment and Kinect, which let the user to communicate easily with virtual objects.

Biological sensors were deployed to measure and detect the emotions of the user [48]. The authors presented a review which tackle the potential of augmented unimodal and multimodal feedback in the framework theories of motor learning [70]. The authors presented the design and development of embodied conversational agent setup, which combine an AR screen and tactile sleeve. By this approach, the agent can touch the screen visually and physically [49]. The author examined the use of gesture by analysing different types of dance [50]. The chapter provides the detail of developing wearable tangible AR for the creation of several

interactive virtual environments, which can be used in Parkinson disease rehabilitation programs [51].

The authors presented a study focusing on children of age 6–9 years old for different ideas from developmental psychology and discuss how these relate to augmented reality. The study focussed on the children skills for spatial cognition, attention, motor abilities, logic, and memory, and then discussed the relationship of these skills to the present and hypothetical designs of augmented reality [52]. The authors combined the augmented reality with the haptics for the observation of stiffness of human arms. To measure the human arms impedance, a haptic handheld device is used. For tracking and recording, the computer vision system is used, while to show the impedance diagram, a screen is used [12]. The authors presented a framework of three components for empathic technologies to augment human interaction, which is based on neuroscience and psychology, consisting of cognitive empathy, emotional convergence, and empathic responding [13]. The paper surveyed the existing research work related to technology, system, and application in AR. The paper presents surveys about the challenges of the mobile AR system and the requirement for the effective mobile system [56]. The authors presented an overview of the augmented reality [71]. An AR-based responsive interface is designed for heart beating assessment and visualization. The cardiologic data are loaded from different sources and are processed to produce visualization within the environment of VR [57]. The authors presented an approach of the innovative pain management system (*Epione*), which pacts with three major pains. These pains include acute pain, phantom limb pain, and chronic pain. By using expression of facial analysis, the proposed system form a dynamic pain meter, which trigger biofeedback and AR-based destruction scenario, in an endeavour to enhance patient pain relief [58].

3.2. What Research Work Performed since 2009 in the Area of Gesture Interaction-Based AR Approaches for Complex Anatomy Learning in the Central Nervous System. There researchers try to come across a concise and efficient methodology for the applications of augmented in anatomy learning of the human body. The proposed research attempts an endeavour to find the available materials since 2009 to present about the use of augmented reality in the human body. The papers [10, 11, 13, 22, 24–31, 35–38, 41–52, 56–58, 61–71] are already discussed in Section 3.1. However, some of the other research works are given here. The authors presented TANGAEON, a tangible and embodied interaction approach that augment the AEON mobile application with an interactive container filled with water. Apart from this, the authors evaluated the TANGAEON with the help of two conventional techniques of mindfulness and with AEON. The proposed approach achieved good results to express mindfulness, apparent degree of difficulty, and level of pleasantness compared to the two conventional methods [20]. The paper describes a detailed study of the noninvasive techniques, their depth assessments, issues, and opportunities related to noninvasive sensory feedback techniques

[72]. The review of the algorithms of machine intelligence for healthcare applications is given in the paper. The review consists of the models of computational and algorithms. The applications of the algorithms discussed are viewed with several steps including extraction of feature, data acquisition, modelling, training of algorithms, aggregation, and execution of algorithm. A set of matrices is used for the assessment of performance of algorithms and modelling purposes [73]. The paper provides a survey of the techniques for education of anatomy based on the visualization and interaction. The background of education, model generation, fundamental data, and the component of textual are considered. The survey includes the studies assessments to analyse the effectiveness of learning [74]. The structure of the CNS and fundamental neurochemistry involved in sexual excitation, inhibition, and disinhibition, drawn mainly from essential preclinical research in animals are reviewed [21]. The authors reviewed the assessment interfaces of human machine and interactions for manned and unmanned aircraft. The study was specifically performed for the basic tasks of flight, which include aviation, navigation, management, and communication. A more focus is given on displays of safety critical and function of command and control. A high level description of the functionalities of the remotely piloted aircraft system is given for the real-time decision support system [23]. Some details are given in the proceedings of the 7th ICSC [75]. The paper reviews a detailed study of the present and future progress of haptic oral and maxillofacial surgery for the simulators in which VR is the main focus [76]. The paper described the application of VR as a clinical tool to tackle the evaluation, deterrence, and treatment of posttraumatic stress disorder for the projects of virtual reality, which were assessed at the University of Southern California since 2004 [77]. The authors presented a review of literature to examine available research on a virtual reality-based spinal procedure simulator, and furthermore, the quality assessment is performed for available studies assessing the virtual reality-based spinal surgery training [78]. The study presented a review of the real-time hand gesture recognition and the electromyography acquisition system [79]. The paper demonstrated the seven key sole needs for smart home in smart cities. These requirements are categorized, based on quality of the smart homes building blocks [80]. The paper presented a method of highly developed, analytic, and automated to determine the commitment at fine-grained temporal resolutions. Total of 15 case studies were used to for this purpose [32]. The paper presented a review to analyse the details of communication of modern neuroprosthetics and human–robot applications. Brain and computer interface is specifically focussed, which is linked to the haptic system, interactive robotics, and autonomous system [14]. The paper aims to develop a platform for an interactive experience for complete body exercise while catering the challenges of affordability, accessibility, and motivation for patient, who suffered from ankylosing spondylitis [33]. A system of smart gait-aid glasses for the patient of Parkinson's is proposed. The system is presented with an accuracy of 92.86% [34]. Some other research studies are available in computer-assisted radiology

and surgery proceedings of the 31st ICE, Barcelona, Spain [81]. The authors presented an approach to empirically evaluate the ASSESS MS, a support scheme to the clinical evaluation of multiple sclerosis using the Kinect. The study suggest three guidelines: standardization should be tackled in early development process, tools to support camera view and can help the progress of consistent data capturing in real environment, and the supported tool should preserve human interaction agency [82]. The paper presented the VR4MAX use, which is a highly effective and real-time software to construct a prototype 3D virtual reality learning system. To identify the attitude of a learner toward learning through virtual reality, a questionnaire was used for 167 university students [39]. The paper presented a method for location of brain lesions in 35 patients through iPhone, and the lesion surface projection onto the skin of the head is shown [40]. The paper presented a technique of outer ventricular drain insertion with the support of Android app into the frontal horn of the lateral ventricle and then reports on its clinical application [83]. The paper presented a study on the results analysis of two usability and user experience assessment research on applications of the treatment tool, gesture therapy, which was hired from the area of rehabilitation used as a cognitive stimulation and physical activation tool for elderly [84]. The paper presented an objective to concurrently compare the success and safety of different image management against surgery [85]. The paper surveyed the advances in Internet of thing-based healthcare technology and described the existing network architecture, applications, and industrial tendency in healthcare solutions for Internet of thing [86]. The chapter provides a theoretical context definition, to the associated ideas, theories, and present academic discourses to highlight the selected research methodology and to describe the related analytical techniques and strategies [87]. Authors have explored the interaction of gaming and prospective of sensory stimuli. The key objective of the paper is to talk about the significance of game development that is thoughtful of children with cerebral palsy [88]. The authors analysed the behavioural factors for the interactive difficulties and fatigue in interactive 3D virtual environments [89]. An approach is presented to identify the gestures made by hands for the CAD control system with the Kinect sensor of Microsoft [15]. The paper presented a therapeutic lamp as interactive projection, which is based on the system of AR for the treatment of small animal phobias [90]. Authors have combined the augmented reality with the haptics for the observation of stiffness of human arms. To compute the human arms impedance, a handheld haptic device is used. For tracking and recording, the computer vision system is used, while to show the impedance diagram, a screen is used [12]. The paper describes the present development in research and the issues and challenges faced by smart wearable systems for monitoring of health focussed on the multiparameter system of a physiological sensor and activity and mobility measurement system design [54]. The paper presented a review of state-of-the-art affecting viable healthcare systems which integrate features of autonomous and semiautonomous and work of experiments, which involve the automation of different

procedures of surgical [91]. The paper presented outlined the existing system available for training of ambulation and moment of upper extremity. The report of the proposed system NJIT-RAVR is presented [55]. The chapter elaborates in brief the engineering drawings, strategies of communication employ by organizations, and logistics of project information [59]. This chapter gives detail of the user interfaces and interaction for four widely used devices, hidden UI via basic devices, hidden UI via wearable and implanted devices, human-centred design, user model, and iHCI design [60].

3.3. What Are the Techniques/Methods Being Used for Gesture Interaction-Based AR Approaches for Complex Anatomy Learning. Since augmented reality applications are new in the field of the CNS and anatomy learning. However, the proposed research work is an attempt to find the available studies related to the augmented reality in the CNS. Table 2 shows the methods available for gesture interaction based approaches in the nervous system, while their details are given in previous sections.

The SLR has several benefits such as organizing the studies in a systematic manner, selecting the most appropriate studies, the filtering process of studies, quality assessments of the papers, and derivations of results [92–96].

4. Limitation of the Research

The following are the limitations of the proposed research work;

- (i) The research is inadequate to only the augmented reality-based nervous system, and may be, some papers are skipped due to this reason.
- (ii) The second limitation of the proposed research is that the search was carried out in only six of the most widely referenced libraries and skipped rest of the libraries. This was decided to focus on only high-quality peer-reviewed journals and conference papers in order to get justifiable results.
- (iii) The authors decided to evade searching of keywords in Google Scholar, as it provides access to most articles (mostly in mentioned libraries), and to avoid trouble of duplicate entries.
- (iv) There might be a chance that an article may have been ignored which talks regarding idea related to AR in the CNS and may not have used phrase at all.

5. Conclusion

The role of augmented reality is to incorporate real and virtual objects interactively running in real time and real environments. Augmented reality is having several applications in real life, such as game, transportation, medicine, and human body. Using gesture interaction approach-based augmented reality in the central nervous system has enormous impending for reducing the care cost, quality refining, and minimizing error and waste. A detail study report is dire

need to be present through which the researchers and practitioners can take help from the existing evidences and propose novel solutions. The proposed study uses SLR as protocol for conducting the analysis of study selection process, quality assessments of the selected studies, and the derivations from the selected studies. The proposed research was conducted for the published materials for the last 10 years. The papers were initially searched in the given libraries, filtered by title, filtered by abstract, and then filtered by the paper contents. Duplication of papers was avoided, such as a paper published in conference, and the updated version is published in journal; so, in this case, the journal paper is considered. The articles were included based on the inclusion, exclusion, and quality criteria defined. The study supports to identify the studies related to augmented reality in the nervous system, application of augmented reality in the nervous system, technique of augmented reality in the nervous system, and the gesture interaction approaches in the nervous system. Results of the study show that there is rise-up in published materials yearly-wise, and several studies exist related to augmented reality and gestures interaction approaches to different systems of the human body specifically to the nervous system. The study summarises and organises the available materials associated to augmented reality. The proposed research will support the researchers to sight most of the existing studies subject to augmented reality-based gestures interaction approaches for the nervous system and then can eventually be used as a support in research for complex anatomy learning.

Data Availability

The data used to support this study are not available.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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References

- [1] R. T. Azuma, “A survey of augmented reality,” *Presence: Teleoperators and Virtual Environments*, vol. 6, no. 4, pp. 355–385, 1997.
- [2] B. E. Shelton, “Augmented reality and education: current projects and the potential for classroom learning,” *New Horizons for Learning*, vol. 9, 2002.
- [3] J. H. Shuhaiber, “Augmented reality in surgery,” *Archives of Surgery*, vol. 139, no. 2, pp. 170–174, 2004.
- [4] C. Shin, H. Kim, C. Kang, Y. Jang, A. Choi, and W. Woo, “Unified context-aware augmented reality application framework for user-driven tour guides,” in *Proceedings of the IEEE. 2010 International Symposium In Ubiquitous Virtual Reality (ISUVR)*, pp. 52–55, Gwangju, South Korea, July 2010.
- [5] M. Hincapie, A. Caponio, H. Rios, and E. G. Mendivil, “An introduction to augmented reality with applications in aeronautical maintenance,” in *Proceedings of the 13th International Conference Transparent Optical Networks (ICTON)*, pp. 1–4, Stockholm, Sweden, June 2011.
- [6] C. M. Yusoff Rasimah, A. Ahmad, and H. Badioze Zaman, “Evaluation of user acceptance of mixed reality technology,” *Australasian Journal of Educational Technology*, vol. 27, no. 8, pp. 1369–1387, 2011.
- [7] Y.-C. Chen, “A study of comparing the use of augmented reality and physical models in chemistry education,” in *Proceedings of the 2006 International Conference on Virtual Reality Continuum and its Applications*, pp. 369–372, Hong Kong, China, June 2006.
- [8] K.-F. Hsiao, N.-S. Chen, and S.-Y. Huang, “Learning while exercising for science education in augmented reality among adolescents,” *Interactive Learning Environments*, vol. 20, no. 4, pp. 331–349, 2012.
- [9] K. Squire and E. Klopfer, “Augmented reality simulations on handheld computers,” *Journal of the Learning Sciences*, vol. 16, no. 3, pp. 371–413, 2007.
- [10] R. Layona, B. Yulianto, and Y. Tunardi, “Web based augmented reality for human body anatomy learning,” in *Proceedings of the 3rd International Conference on Computer Science and Computational Intelligence*, pp. 457–464, Normal, IL, USA, December 2019.
- [11] M. Ferraz, “A biosymtic (biosymbiotic robotic) approach to human development and evolution,” in *Symbiotic Interaction*, pp. 65–76, Springer, Berlin, Germany, 2016.
- [12] M. Khademi, H. M. Hondori, C. V. Lopes, L. Dodakian, and S. C. Cramer, “Haptic augmented reality to monitor human arm’s stiffness in rehabilitation,” in *Proceedings of the 2012 IEEE-EMBS Conference on Biomedical Engineering and Sciences*, Langkawi, Malaysia, December 2012.
- [13] J. H. Janssen, “A three-component framework for empathic technologies to augment human interaction,” *Journal on Multimodal User Interfaces*, vol. 6, no. 3-4, pp. 143–161, 2012.
- [14] A. Cangelosi and S. Invitto, “Human-robot interaction and neuroprosthetics: a review of new technologies,” *IEEE Consumer Electronics Magazine*, vol. 6, no. 3, pp. 24–33, 2017.
- [15] J. C. R. Esquivel, A. M. Viveros, and N. Perry, “Gestures for interaction between the software CATIA and the human via microsoft kinect,” in *Proceedings of the Gestures for Interaction between the Software CATIA and the Human via Microsoft Kinect-HCI International 2014—Posters’ Extended Abstracts*, pp. 457–462, Las Vegas, NV, USA, July 2018.
- [16] B. Kitchenham, O. Pearl Brereton, D. Budgen, M. Turner, J. Bailey, and S. Linkman, “Systematic literature reviews in software engineering—a systematic literature review,” *Information and Software Technology*, vol. 51, no. 1, pp. 7–15, 2009.
- [17] A. S. Albahri, R. A. Hamid, J. K. Alwan et al., “Role of biological data mining and machine learning techniques in detecting and diagnosing the novel coronavirus (COVID-19): a systematic review,” *Journal of Medical Systems*, vol. 44, no. 7, 2020.
- [18] Endnote, 2020.
- [19] T. Dyba and T. Dingsøy, “Empirical studies of agile software development: a systematic review,” *Information and Software Technology*, vol. 50, no. 9-10, pp. 833–859, 2008.

- [20] A. Vianello, L. Chittaro, and A. Matassa, "TANGAEON: tangible interaction to support people in a mindfulness practice," *International Journal of Human-Computer Interaction*, vol. 35, no. 12, pp. 1086–1116, 2018.
- [21] J. G. Pfaus and S. L. Jones, *Central Nervous System Anatomy and Neurochemistry of Sexual Desire*, A. T. Goldstein, N. N. Kim, and S. A. Kingsberg, Eds., Wiley, Hoboken, NJ, USA, 2018.
- [22] M. Lorusso, M. Giorgetti, S. Travellini et al., "Giok the alien: an AR-based integrated system for the empowerment of problem-solving, pragmatic, and social skills in pre-school children," *Sensors*, vol. 18, no. 7, pp. 2368–2416, 2018.
- [23] Y. Lim, A. Gardi, R. Sabatini et al., "Avionics human-machine interfaces and interactions for manned and unmanned aircraft," *Progress in Aerospace Sciences*, vol. 102, pp. 1–46, 2018.
- [24] Q. Li, C. Huang, Z. Yao, Y. Chen, and L. Ma, "Continuous dynamic gesture spotting algorithm based on Dempster-Shafer theory in the augmented reality human computer interaction," *The International Journal of Medical Robotics and Computer Assisted Surgery*, vol. 14, no. 5, p. e1931, 2018.
- [25] P. Q. Brito and J. Stoyanova, "Marker versus markerless augmented reality. Which has more impact on users?," *International Journal of Human-Computer Interaction*, vol. 34, no. 9, pp. 819–833, 2018.
- [26] M. H. Kurniawan, Suharjito, Diana, and G. Witjaksono, "Human anatomy learning systems using augmented reality on mobile application," in *Proceedings of the 3rd International Conference on Computer Science and Computational Intelligence*, pp. 80–88, Normal, IL, USA, December 2018.
- [27] J. Rao, Y. Qiao, F. Ren, J. Wang, and Q. Du, "A mobile outdoor augmented reality method combining deep learning object detection and spatial relationships for geo-visualization," *Sensor*, vol. 17, no. 9, p. 1951, 2017.
- [28] P. E. Pelargos, D. T. Nagasawa, C. Lagman et al., "Utilizing virtual and augmented reality for educational and clinical enhancements in neurosurgery," *Journal of Clinical Neuroscience*, vol. 35, pp. 1–4, 2017.
- [29] C. Moro, Z. Štromberga, A. Raikos, and A. Stirling, "The effectiveness of virtual and augmented reality in health sciences and medical anatomy," *Anatomical Sciences Education*, vol. 10, no. 6, pp. 549–559, 2017.
- [30] D. R. Marker, P. U. Thainual, T. Ungi et al., "1.5 T augmented reality navigated interventional MRI: paravertebral sympathetic plexus injections," *Diagnostic and Interventional Radiology*, vol. 23, no. 3, pp. 227–232, 2017.
- [31] N. Jain, P. Youngblood, M. Hasel, and S. Srivastava, "An augmented reality tool for learning spatial anatomy on mobile devices," *Clinical Anatomy*, vol. 30, no. 6, pp. 736–741, 2017.
- [32] S. D'Mello, E. Dieterle, and A. Duckworth, "Advanced, analytic, automated (AAA) measurement of engagement during learning," *Educational Psychologist*, vol. 52, no. 2, pp. 104–123, 2017.
- [33] J. Bandyopadhyay and G. Dalvi, "An -an interactive full body exercise experience for patients suffering from ankylosing spondylitis," in *Proceedings of the IEEE 5th International Conference on Serious Games and Applications for Health (SeGAH)*, pp. 1–8, Perth, Australia, April 2017.
- [34] D. Ahn, H. Chung, H.-W. Lee et al., "Smart gait-aid glasses for parkinson's disease patients," *IEEE Transactions on Biomedical Engineering*, vol. 64, no. 10, pp. 2394–2402, 2017.
- [35] U. E. Manawadu, M. Kamezaki, M. Ishikawa, T. Kawano, and S. Sugano, "A hand gesture based driver-vehicle interface to control lateral and longitudinal motions of an autonomous vehicle," in *Proceedings of the 2016 IEEE International Conference on Systems, Man, and Cybernetics SMC*, pp. 1–6, Budapest, Hungary, October 2016.
- [36] K. J. Carlson and D. J. Gagnon, "Augmented reality integrated simulation education in health care," *Clinical Simulation in Nursing*, vol. 12, no. 4, pp. 123–127, 2016.
- [37] A. Porter, "A helping hand with language learning: teaching French vocabulary with gesture," *The Language Learning Journal*, vol. 44, no. 2, pp. 236–256, 2016.
- [38] S. Invitto, C. Faggiano, S. Sammarco, V. D. Luca, and L. de Paolis, "Haptic, virtual interaction and motor imagery: entertainment tools and psychophysiological testing," *Sensor*, vol. 16, no. 3, p. 394, 2016.
- [39] H.-M. Huang, S.-S. Liaw, and C.-M. Lai, "Exploring learner acceptance of the use of virtual reality in medical education: a case study of desktop and projection-based display systems," *Interactive Learning Environments*, vol. 24, no. 1, pp. 3–19, 2016.
- [40] Y. Hou, L. Ma, R. Zhu, X. Chen, and J. Zhang, "A low-cost iPhone-assisted augmented reality solution for the localization of intracranial lesions," *PLoS One*, vol. 11, no. 7, Article ID e0159185, 2016.
- [41] A. E. F. D. Gama, T. M. Chaves, L. S. Figueiredo et al., "A clinically-related gesture recognition interactive tool for an AR rehabilitation system," *Computer Methods and Programs in Biomedicine*, vol. 135, pp. 105–114, 2016.
- [42] C. Colomer, R. Llorens, E. Noé, and M. Alcañiz, "Effect of a mixed reality-based intervention on arm, hand, and finger function on chronic stroke," *Journal of NeuroEngineering and Rehabilitation*, vol. 13, no. 1, p. 45, 2016.
- [43] E. Redcay and T. A. Carlson, "Rapid neural discrimination of communicative gestures," *Social Cognitive and Affective Neuroscience*, vol. 10, no. 4, pp. 545–551, 2015.
- [44] J. Soeiro, A. P. Cláudio, M. B. Carmo, and H. A. Ferreira, "Visualizing the brain on a mixed reality smartphone application," in *Proceedings of the 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, pp. 5090–5093, Milan, Italy, August 2015.
- [45] C. E. Saturno, A. R. G. Ramirez, M. J. Conte, M. Farhat, and E. C. Piucco, "An augmentative and alternative communication tool for children and adolescents with cerebral palsy," *Behaviour & Information Technology*, vol. 34, no. 6, pp. 632–645, 2015.
- [46] E. P. Ong, J. A. Lee, J. Cheng et al., "An augmented reality assistance platform for eye laser surgery," in *Proceedings of the 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, pp. 4326–4329, Milan, Italy, August 2015.
- [47] S. M. Mishra, "Wearable computing background and theory," in *Wearable Android*, Wiley, Hoboken, NJ, USA, 2015.
- [48] S. Tivatansakul and M. Ohkura, "Healthcare system design focusing on emotional aspects using augmented reality—relaxed service design," in *Proceedings of the 2013 IEEE Symposium on Computational Intelligence in Healthcare and e-Health (CICARE)*, pp. 88–93, Singapore, April 2013.
- [49] G. Huisman, M. Bruijnes, J. Kolkmeier, M. Jung, A. D. Frederiks, and Y. Rybarczyk, "Touching virtual agents: embodiment and mind," in *Proceedings of the International Summer Workshop on Multimodal Interfaces, Innovative and Creative Developments in Multimodal Interaction Systems*, pp. 114–138, Berlin, Heidelberg, 2014.
- [50] J. M. Hall, "Core aspects of dance: condillac and mead on gesture," *Dance Chronicle*, vol. 36, no. 3, pp. 352–371, 2013.

- [51] D. B. Boucher, A. Roberts-South, A. A. Garcia, M. Katchabaw, and M. S. Jog, "Immersive augmented reality: investigating a new tool for parkinson disease rehabilitation," in *Proceedings of the 2013 6th International IEEE/EMBS Conference on Neural Engineering (NER)*, pp. 1570–1573, San Diego, CA, USA, November 2013.
- [52] I. Radu and B. MacIntyre, "Using children's developmental psychology to guide augmented-reality design and usability," in *Proceedings of the 2012 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, pp. 227–236, Atlanta, GA, USA, November 2012.
- [53] T. J. Kehle, M. A. Bray, G. F. Byer-alcorace, L. A. Theodore, and L. M. Kovac, "Augmented self-modeling as an intervention for selective mutism," *Psychology in the Schools*, vol. 49, no. 1, pp. 93–103, 2012.
- [54] M. Chan, D. Estève, J.-Y. Fourniols, C. Escriba, and E. Campo, "Smart wearable systems: current status and future challenges," *Artificial Intelligence in Medicine*, vol. 56, no. 3, pp. 137–156, 2012.
- [55] A. S. Merians, G. G. Fluet, Q. Qiu, I. Lafond, and S. V. Adamovich, "Learning in a virtual environment using haptic systems for movement re-education: can this medium be used for remodeling other behaviors and actions?," *Journal of Diabetes Science and Technology*, vol. 5, no. 2, pp. 301–308, 2011.
- [56] J. Carmigniani, B. Furht, M. Anisetti, P. Ceravolo, E. Damiani, and M. Ivkovic, "Augmented reality technologies, systems and applications," *Multimedia Tools and Applications*, vol. 51, no. 1, pp. 341–377, 2011.
- [57] E. Lamounier, A. Bucioli, A. Cardoso, A. Andrade, and A. Soares, "On the use of augmented reality techniques in learning and interpretation of cardiologic data," in *Proceedings of the 32nd Annual International Conference of the IEEE EMBS Buenos Aires*, pp. 610–613, Buenos Aires, Argentina, August 2010.
- [58] S. Georgoulis, S. Eleftheriadis, D. Tzionas, K. Vrenas, P. Petrantonakis, and L. J. Hadjileontiadis, "Epione: an innovative pain management system using facial expression analysis, biofeedback and augmented reality-based distraction," in *Proceedings of the International Conference on Intelligent Networking and Collaborative Systems*, pp. 259–266, Thessaloniki, Greece, November 2010.
- [59] L. E. Bernold and S. M. AbouRizk, "Communication: the nerve system of construction," in *Managing Performance in Construction*, L. E. Bernold and S. M. AbouRizk, Eds., Wiley, Hoboken, NJ, USA, 2010.
- [60] S. Poslad, "Human-computer interaction," in *Ubiquitous Computing*, S. Poslad, Ed., Wiley, Hoboken, NJ, USA, 2009.
- [61] S. W. Volkow and A. C. Howland, "The case for mixed reality to improve performance," *Performance Improvement*, vol. 57, no. 4, pp. 29–37, 2018.
- [62] D. Mehta, M. F. H. Siddiqui, and A. Y. Javaid, "Facial emotion recognition: a survey and real-world user experiences in mixed reality," *Sensor*, vol. 18, no. 2, p. 416, 2018.
- [63] F. Lamnabhi-Lagarrigue, A. Annaswamy, S. Engell et al., "Systems & control for the future of humanity, research agenda: current and future roles, impact and grand challenges," *Annual Reviews in Control*, vol. 43, pp. 1–64, 2017.
- [64] M. S. Hasan and H. Yu, "Innovative developments in HCI and future trends," *International Journal of Automation and Computing*, vol. 14, no. 1, pp. 10–20, 2017.
- [65] T. Fryer, "20 technologies to change the world," *Engineering & Technology*, vol. 12, no. 9, pp. 40–45, 2017.
- [66] D. W. Seo, H. Kim, J. S. Kim, and J. Y. Lee, "Hybrid reality-based user experience and evaluation of a context-aware smart home," *Computers in Industry*, vol. 76, pp. 11–23, 2016.
- [67] L. F. d. Santos, O. Christ, K. Mate, H. Schmidt, J. Krüger, and C. Dohle, "Movement visualisation in virtual reality rehabilitation of the lower limb: a systematic review," *BioMedical Engineering Online*, vol. 15, no. 3, pp. 75–88, 2016.
- [68] M. J. W. Lee, S. Nikolic, P. J. Vial, C. Ritz, W. Li, and T. Goldfinch, "Enhancing project-based learning through student and industry engagement in a video-augmented 3-D virtual trade fair," *IEEE Transactions on Education*, vol. 59, no. 4, pp. 290–298, 2016.
- [69] S. E. Bibri, "Affective behavioral features of AmI: affective context-aware, emotion-aware, context-aware affective, and emotionally intelligent systems," in *The Human Face of Ambient Intelligence, Atlantis Ambient and Pervasive Intelligence*, pp. 403–489, Springer, Berlin, Germany, 2015.
- [70] R. Sigrist, G. Rauter, R. Riener, and P. Wolf, "Augmented visual, auditory, haptic, and multimodal feedback in motor learning: a review," *Psychonomic Bulletin & Review*, vol. 20, no. 1, pp. 21–53, 2013.
- [71] J. Carmigniani and B. Furht, "Augmented reality: an overview," "Augmented reality: an overview," in *Handbook of Augmented Reality*, B. Furht, Ed., pp. 3–46, Springer New York, New York, NY, USA, 2011.
- [72] B. Stephens-Fripp, G. Alici, and R. Mutlu, "A review of non-invasive sensory feedback methods for transradial prosthetic hands," *IEEE Access*, vol. 6, pp. 6878–6899, 2018.
- [73] O. R. Shishvan, D.-S. Zois, and A. T. Soyata, "Machine intelligence in healthcare and medical cyber physical systems: a survey," *IEEE Access*, vol. 6, pp. 46419–46494, 2018.
- [74] B. Preim and P. Saalfeld, "A survey of virtual human anatomy education systems," *Computers & Graphics*, vol. 71, pp. 132–153, 2018.
- [75] T. Hunefeldt and M. O. Belardinelli, "Spatial cognition in a multimedia and intercultural world," *Cognitive Processing*, vol. 19, no. 1, pp. S1–S76, 2018.
- [76] X. Chen and J. Hu, "A review of haptic simulator for oral and maxillofacial surgery based on virtual reality," *Expert Review of Medical Devices*, vol. 15, no. 6, pp. 435–444, 2018.
- [77] A. S. Rizzo and R. Shilling, "Clinical virtual reality tools to advance the prevention, assessment, and treatment of PTSD," *European Journal of Psychotraumatology*, vol. 8, no. 5, pp. 1414560–1414621, 2017.
- [78] M. Pfandler, M. Lazarovici, P. Stefan, P. Wucherer, and M. Weigl, "Virtual reality-based simulators for spine surgery: a systematic review," *The Spine Journal*, vol. 17, no. 9, pp. 1352–1363, 2017.
- [79] N. M. Patil and S. R. Patil, "Review on real-time EMG acquisition and hand gesture recognition system," in *Proceedings of the International Conference on Electronics, Communication and Aerospace Technology ICECA*, pp. 694–696, Coimbatore, India, April 2017.
- [80] T. K. L. Hui, R. S. Sherratt, and D. D. Sánchez, "Major requirements for building smart homes in smart cities based on internet of things technologies," *Future Generation Computer Systems*, vol. 76, pp. 358–369, 2017.
- [81] H. U. Lemke, "CARS 2017—computer assisted radiology and surgery proceedings of the 31st international congress and exhibition Barcelona, Spain, June 20–24, 2017," *International Journal of Computer Assisted Radiology and Surgery*, vol. 12, no. 1, pp. S1–S286, 2017.
- [82] C. Morrison, K. Huckvale, B. Corish et al., "Assessing multiple sclerosis with kinect: designing computer vision systems for

- real-world use,” *Human-Computer Interaction*, vol. 31, no. 3-4, pp. 191–226, 2016.
- [83] B. Eftekhari, “App-assisted external ventricular drain insertion,” *Journal of Neurosurgery*, vol. 125, no. 3, pp. 754–758, 2016.
- [84] A. L. Morán, C. Ramírez-Fernández, V. Meza-Kubo et al., “On the effect of previous technological experience on the usability of a virtual rehabilitation tool for the physical activation and cognitive stimulation of elders,” *Journal of Medical Systems*, vol. 39, no. 9, pp. 1–11, 2015.
- [85] H. J. Marcus, P. Pratt, A. Hughes-Hallett et al., “Comparative effectiveness and safety of image guidance systems in neurosurgery: a preclinical randomized study,” *Journal of Neurosurgery*, vol. 123, no. 2, pp. 307–313, 2015.
- [86] S. M. R. Islam, D. Kwak, H. Kabir, M. Hossain, and K.-S. Kwak, “The internet of things for health care: a comprehensive survey,” *IEEE Access*, vol. 3, pp. 678–708, 2015.
- [87] S. E. Bibri, “Conceptual background, theoretical framework, academic discourses, and research methodologies,” in *The Shaping of Ambient Intelligence and the Internet of Things: Historico-Epistemic, Socio-Cultural, Politico-Institutional and Eco-Environmental Dimensions*, pp. 27–81, Atlantis Press, Paris, France, 2015.
- [88] E. Oliveira, G. Sousa, T. A. Tavares, and P. Tanner, “Sensory stimuli in gaming interaction: the potential of games in the intervention for children with cerebral palsy,” in *Proceedings of the 2014 IEEE Games Media Entertainment*, pp. 1–8, Toronto, Canada, October 2014.
- [89] Y. Kim and J. Park, “Study on interaction-induced symptoms with respect to virtual grasping and manipulation,” *International Journal of Human-Computer Studies*, vol. 72, no. 2, pp. 141–153, 2014.
- [90] M. Wrzesien, M. Alcaiz, C. Botella et al., “The therapeutic lamp: treating small-animal phobias,” *IEEE Computer Graphics and Applications*, vol. 33, no. 1, pp. 80–86, 2013.
- [91] G. P. Moustiris, S. C. Hiridis, K. M. Deliparaschos, and K. M. Konstantinidis, “Evolution of autonomous and semi-autonomous robotic surgical systems: a review of the literature,” *The International Journal of Medical Robotics and Computer Assisted Surgery*, vol. 7, no. 4, pp. 375–392, 2011.
- [92] B. Liao, Y. Ali, S. Nazir, L. He, and H. U. Khan, “Security analysis of IoT devices by using mobile computing: a systematic literature review,” *IEEE Access*, vol. 8, pp. 120331–120350, 2020.
- [93] A. Hussain, S. Nazir, S. Khan, and A. Ullah, “Analysis of PMIPv6 extensions for identifying and assessing the efforts made for solving the issues in the PMIPv6 domain: a systematic review,” *Computer Networks*, vol. 179, Article ID 107366, 2020.
- [94] S. Nazir, M. Nawaz Khan, S. Anwar et al., “Big data visualization in cardiology—a systematic review and future directions,” *IEEE Access*, vol. 7, pp. 115945–115958, 2019.
- [95] S. Nazir, M. Nawaz, A. Adnan, S. Shahzad, and S. Asadi, “Big data features, applications, and analytics in cardiology—a systematic literature review,” *IEEE Access*, vol. 7, pp. 143742–143771, 2019.
- [96] S. Nazir, S. Shahzad, and N. Mukhtar, “Software birthmark design and estimation—a systematic literature review,” *Arabian Journal for Science and Engineering*, vol. 44, no. 4, pp. 3905–3927, 2019.