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Augmented Reality Assistance for Aging People:
A Systematic Literature Review

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ABSTRACT

The development of augmented reality (AR) is becoming robust and matured by the combination of real-time performance with virtual information. With the proliferating geriatric population, the benefits of AR systems can be suitably harnessed for supporting the elderly in home activities, mobility and entertainment, among others. Hence, the development of AR to assist aging population is now feasible, but an overview of the existing research is not yet attempted. The objective of this systematic literature review is to provide a detailed technical progress on the current situation of AR application and review the different domains using AR for supporting the ageing population. Search was conducted on five databases including Scopus, IEEE Xplore, Science Direct, ACM Digital Library, and Springer Link.350 papers were initially searched and after detailed study 71 were selected for the review. To conclude, the review proposed six components to be noted when developing new AR applications for the elderly.

KEYWORDS

Augmented reality, elderly care, design principles, mapping studies, systematic literature review (SLR)

INTRODUCTION

Augmented reality (AR) is becoming a heartbeat focus as AR enabled platforms are gaining importance in all domains of technology (Liarokapis & De Freitas, 2010). The ageing populace does not make up a homogenous entity (Rose et al., 2012). It is in this context that the success and integration of the AR system must be determined. There is an increasing trend of mobile usage among the elderly population. It acts as credible evidence that there is adequate scope for using AR system in ensuring greater independence and mobility among the elderly population (Arbeláez, Viganò, & Osorio-Gómez, 2019). However, there is an apparent lacuna in existing solutions that can meet the experience and requirements of such demographic. On a global scale, society as a whole faces a newer challenge with the rapidly growing elderly population (WHO, 2015). The demographic statistics reveal that population is aging rapidly both in developing countries (Shetty, 2012) and in developed countries (Vaupel, 2010).

As the elderly are not a homogenous or static group of people, also services and up-do-date solutions made for their well-being require understanding and skills from versatile areas of knowledge

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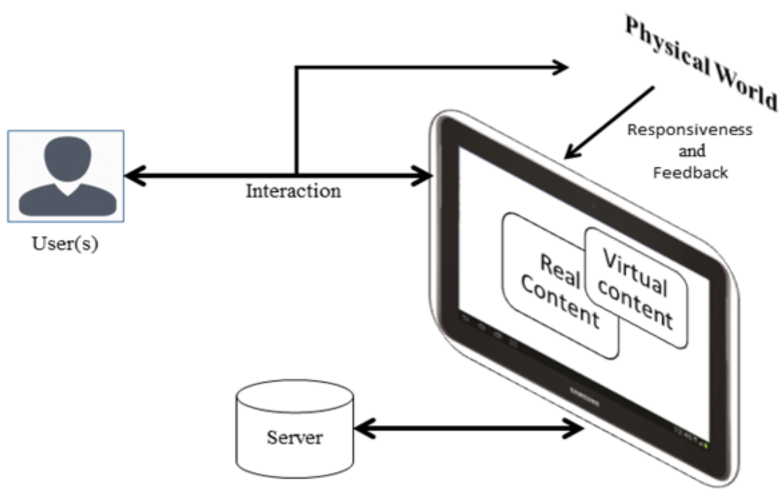
(Mäkimattila, Melkas & Uotila, 2017). The major problems that are faced include physical as well as mental deterioration, along with degradation of senses and loss of memory, among others. The combined effect of all these factors ends up exerting an adverse impact on the overall quality of life (Pandya et al., 2020). It is in this aspect that AR and other associated technologies can address the challenges that the elderly population face (Pulli et al., 2011; Azimi et al., 2017). It should be duly noted that there is a dearth of research which is necessary to zero in on a suitable theoretical framework or guidelines about human factors. Such a framework would have enabled AR designers to create appropriate applications addressing the specific issues faced by the particular population (Ahir et al., 2020). Internet of things (IoT) provides means to offer services remotely utilising novel technologies (Azimi et al., 2017). IoT enables smart ambient environment that is based on sensors, continuous detection and efficient information transfer between applications and devices. Smart ambient environment has increasingly been seen valuable when designing functional and safe living environments for elderly, where the role of AR is significant and can be applied with several every-day activities and functions (Yamamoto et al., 2010).

The core objective of the technology of AR is to impart such artificial stimuli that would make any occurrence in the virtual world to seem real to the user (Craig, 2013). A good example is the Tesco store finder by Junaio AR browser. The goal of the application is to let users know opening time, location, website, and other relevant information about stores of Tesco (Madden, 2011). Naturally, users have a contribution to make in framing the architecture of AR. In the usual course of things, the architecture is framed in a single user's mind (De Sa. & Churchill, 2012; Olsson & Salo, 2011). However, as recent development suggests, the same may happen in the mind of two or multiple users. The mobile collaborative AR system "Studierstube" (Kaufmann & Schmalstieg, 2013) is inherently a geometric construction for the promotion of spatial capability. It is because that the same geometric entities can be determined from multiple sides. All geometric entities can be modified by multiple users by merely using an electric pen. It helps to determine the existing geometrical relationship, and subsequently use such input for further construction. The accommodation of multiple users is the cornerstone of collaborative AR system. This is elucidated in a game of senorAR tennis (Henrysson, Billinghurst & Ollila, 2006). In this case, the application engages two players who can sit across the table facing each other. The virtual court is seen through the phone. There is a common practice which is seen in various studies when those normal users are taken into consideration as opposed to a group (Woodward et al., 2004). Some of the examples of AR application design are for special needs' children having cognitive disability and autism (Bai, Blackwell, & Coulouris, 2012; Richard et al., 2007), but only a few for elderly users (Kim & Dey, 2009; Wood & Mccrindle, 2012). In the present study, 'user' is referred to as the immediate beneficiary having the option for manipulation and control of the system. For instance, AR systems can be utilised by doctors as a visualisation aid. It helps in the collection of 3-D dataset of patients undergoing surgery, on a real time basis (Azuma, 1997). The application becomes beneficial for both patient and doctor. However, it is the doctor who should be watching and controlling the system. The concept of interaction includes two dimensions, i.e., (1) inter, and (2) action. The aspect of 'Inter' relates to the existence of a particular state among different things. On the other hand, 'Action' pertains to occurrences. Within the ambit of interaction, one entity undertakes an activity, and the other provides a specific response to it. In the context of user-based AR system, research in this particular aspect focuses on the causal factors of a trigger, and the resultant response elicited. All those take place between AR device and user or virtual content and user. This point can again be elucidated with the Tesco store example. While trying to use the Tesco store finder, first, the app will have to be downloaded. It is followed by adjusting the device's position to access the virtual bubble. This adjustment of device vis-à-vis the physical position constitutes interaction between device and user. The result of such action is the identification of virtual target store through the device. For obtaining further information, say, distance, opening, or phone number – all those will be shown on clicking a virtual icon. Furthermore, a pop-up slide imparts other information. The interaction with virtual content takes place through a virtual Tesco bubble. There are, however, certain contrary instances as well. In some AR scenario, the interaction that takes place between AR device and user or virtual content and user ceases to take place. Such an example is elucidated in National Geographic. In such a case, visitors can participate with the augmentations on a large screen without having to interact with the device. Device, in such context, denotes an object or carrier that has the dimensions of being a repository of physical world information. It creates a favourable situation for initiating compelling augmentation.

The presentation of digital information with the help of AR device leads to the creation of virtual content. This content plays a crucial role in AR architecture. Such a presentation could be in the form of 2D image, 3D animation, website, text, vibrations, and audio information. It is this virtual content that pulls the attention and attraction of AR users. It has been found out that participants are more likely to harbour a strong curiosity about the content generated from the device as opposed to the AR device itself (Odom & Pierce, 2009). The dynamic change of virtual information makes for a crucial feature of virtual content. Again, taking recourse to the Tesco example, while moving if customers use the app, automatically the virtual content pops up. However, the real content in the AR device may not be immediately apparent (Liang & Roast, 2014). Another way of the generation of virtual content involves tracking. In this case, there are three features which are at play – (1) synchronicity, (2) antecedent, (3) partial one to one (Liang & Roast, 2014). Any change on the real content leads to synchronous change on the AR virtual counterpart. An example is Word lens which is an AR translation application that displays translated foreign text on a real-time basis. Once the AR device is projected to another word, the display alters accordingly. However, if this process is not synchronized or takes a longer time, then it deprives the viewer to make use of the required information. In case of the aspect of antecedent, the physical text (real content) precedes the translated word (virtual content). Virtual element in the absence any real-world content becomes meaningless. It becomes devoid of any real-world interpretation. On the other hand, tracking feature of AR is reflected in a partial one to one. Any virtual content corresponds to only a solitary real content. However, the representation of virtual information can be through more than one component. Effectively, it indicates that there can be superimposition of real content on varying modalities of virtual content.

The AR architecture is better reflected through six major elements in some typical examples. Figure 1 shows the interplay among various elements. Users could be anyone engaged in the interaction of virtual content by merely clicking or adjusting the device. For the computer-generated virtual content to be shown on the AR device, tracking has to be undertaken. The relevant bits of

Figure 1. Interactive relationship between different elements of AR framework



information correspond to a real-world counterpart. The framework of AR means that designers have the benefit of a more detailed basis to articulate the criteria of AR, along with its classification and function. However, to make the potential benefit AR solutions to reach elderly population, the existing AR applications have to be reviewed to identify the lacunae that exist in making the system more amenable to the targeted populace.

Presently, the main focus of research in the domain of AR has moved towards putting forth easy and effective frameworks to be adopted for implementation (Shah et al., 2020). The final goal of the research is to design an appropriate AR application that would be beneficial for elderly people in their regular functions of life. So far, such attempts are quite limited (Malik et al., 2013). There have been prototypes and pilots to study how elderly can benefit from AR supported guidance when getting outdoors. For example, a mobile augmented teleguidance-based safety navigation concept was introduced to increase awareness of the elderly and their caretakers such as family members or other informal caretakers (Pulli et al., 2012). Similarly, there has been attempts to support visually impaired people to help them navigate with the help of smart ambient environment that allows voice or video to be transmitted between devices (Chaudary et al., 2017).

This study continues with reporting the research methods and application in Section 2. Next, the classification schemes using AR technology, assisting older people is discussed. The design challenges are described after that (Section 4). The findings of the study are discussed in Section 5, and the paper ends with conclusions, also introducing proposals for future work.

RESEARCH APPROACH

The research goal was to find scientific studies about how state-of-the-art technology in the form of AR can be used when providing care for elderly people. To find information, a theoretical study was carried out by applying a systematic mapping study (Evans-Lacko et al., 2014; Petersen et al., 2008). The objective of literature review is to present an overview of existing research in AR application for elderly people. The objective of review is defined in the following research questions.

In our approach, we focus on "How mapping studies contribute to the development of AR applications for aging people?". For the purpose we further sub divide our research focus on two sub questions,

(Q1) What are the advantages and disadvantages of using AR applications on elderly based on the previous literature?
(Q2) How do we consider the mapping study suitable for supporting future research activities?

The first sub-question addresses the importance of the research approach. It supports our main research question pointing out that there may be possible disadvantages of using AR applications for the elderly population. The second sub question finds out any issues in the mapping study which will be helpful to other researchers in this domain to pursue their future research in this direction.

In order to get an overview of the research on AR applications for aging people, a systematic mapping study is carried through. The mapping study consists of three stages (1) searching the related publications (2) design of a classification scheme with research focus (3) mapping of related publications.

INFORMATION COLLECTION STRATEGY

Scientific papers from data base Scopus, IEEE Xplore, Science Direct, ACM Digital Library and Springer Link were collected based on the above research questionnaires to conduct systematic literature review.

The **search engines** that we used and assigned to the information resources are as follows:

Scopus (http://www.scopus.com),
ScienceDirect (http://www.sciencedirect.com),
Springerlink (http://www.springerlink.com),
Portal ACM (http://portal.acm.org),
and IEEE Xplore (http://ieeexplore.ieee.org).

The **keywords** used for search include, ‘AR’, ‘elderly disabled physical mental’, ‘older adults independent living, ‘technologies to support healthy aging’, ‘systematic reviews’, ‘mapping studies.

Initially 350 scientific papers were from the database search and 150 records through references were downloaded. Further after removing duplicate papers total 250 records were considered for title screening process. In title screening record’s title that were not focusing on systematic reviews, mapping studies and evaluation framework were removed. After title screening total 200 records were selected for further abstract screening. In abstract screening papers that were focusing on ubiquitous service system, game engine, living process detection and middleware building were removed hence after abstract screening 140 papers were selected for full-paper review. Finally, after full- text review 70 papers were selected for review. The process of information collection and exclusion is shown in Figure 2.

The databases and string searches used in this study are shown in this Table 1.

Figure 2. Process of search with exclusion reason

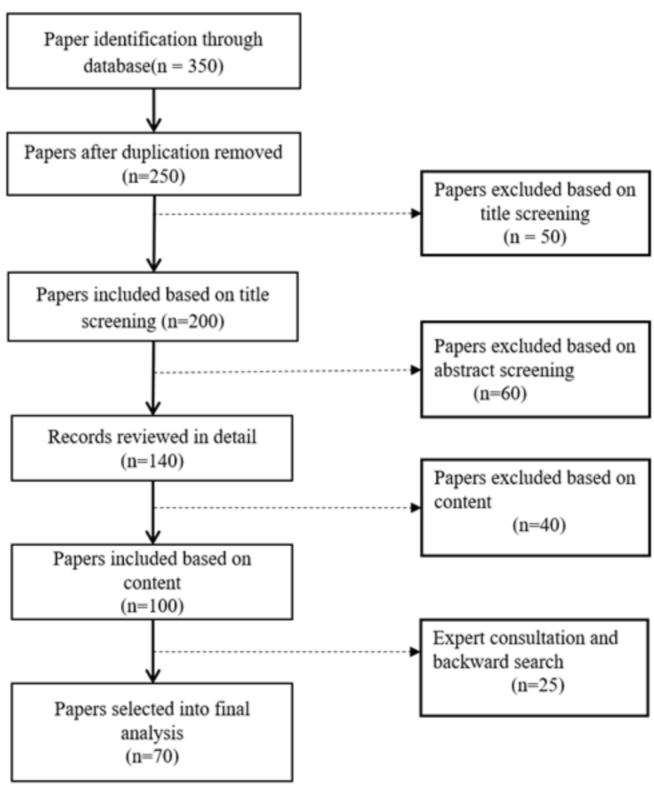


Table 1. Sources and search engines used in the study

Sources	Url	Search String
Scopus	http://www.scopus.com	(“Augmented Reality “AND “elderly disabled physical mental “)
ScienceDirect	http://www.sciencedirect.com	(“Augmented Reality “AND “elderly disabled physical mental “AND “technologies to support healthy aging’)
Springerlink	http://www.springerlink.com	(“Augmented Reality “AND “elderly disabled physical mental “)
Portal ACM	http://portal.acm.org	(“Augmented Reality “AND “elderly disabled physical mental “AND “technologies to support healthy aging”)
IEEE Xplore	http://ieeexplore.ieee.org	(“Abstract”:” Augmented Reality”) AND “Abstract”:” elderly disabled physical mental “)

INCLUSION AND EXCLUSION CRITERIA

Inclusion Criteria

Scientific papers that were peer-review articles in journals, conferences and workshops, published from 2011 to 2020 were considered. The scientific papers which focused on real-time AR based applications, virtual experiences, AR devices and interaction methodologies were considered for review.

Exclusion Criteria

Scientific papers that were cases focusing on only technical aspects to realize virtual experiences with AR or cases applied under professional supervision as in hospitals were excluded.

RESULTS

Records used for our study were collected from publication year 2011 to 2021. The Figure 3 shows the number of publications selected over the year of publication considered for systematic literature review and Figure 4 presents the distribution of articles by publication type. The percentage values (%) indicate the distribution of all related articles per publication category. 42 papers were dated between 2011 and 2015 and 28 papers were dated between 2016 and 2021. The study thoroughly reviewed 70 papers from various types of publication among which 42 papers were published in journal and 20 were international conference proceeding papers as shown in the Table 2. Most of the papers (40) were on guidelines for developing AR applications followed by the papers on theoretical frameworks and process of design and usability evaluation, as shown in Table 3 also reveals that research interest in process of design and usability evaluation had increased over years. This is significant especially when considering the elderly people and their caretakers, which consist of people having versatile skills and abilities.

CLASSIFICATION SCHEMES FOR ASSISTING OLDER PEOPLE USING AR TECHNOLOGY

To improve the focus on the latent potential of AR for improving the lives of elderly population, such articles have been issued in which the underlying theme conflate AR application and the issues faced by an ageing population. It is seen that there are very few studies that investigate both the mentioned

Figure 3. Number of publications selected over publication years (2011-2021)

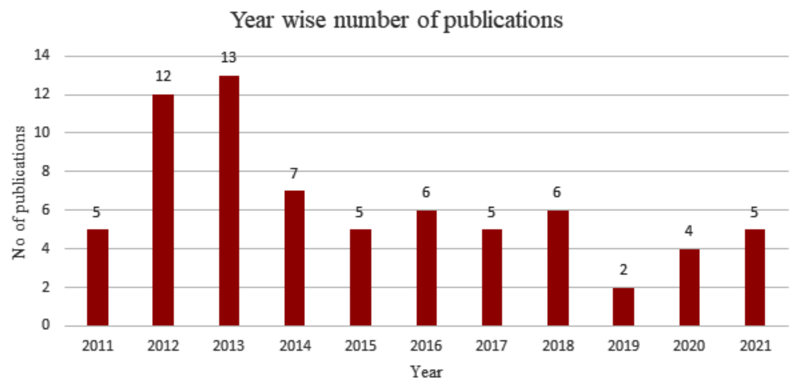


Figure 4. Distribution of articles by publication type.

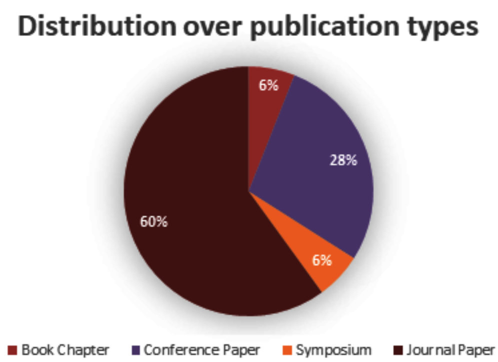


Table 2. Distribution over publication types

Publication type	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
Book Chapter	1	1					1	1				4
Conference Paper	1	3	3	2	2	2	2	2	1		2	20
Symposium	2				2							4
Journal Paper	1	8	10	5	1	4	1	3	1	4	3	42
Total	5	12	13	7	5	6	5	6	2	4		70

Table 3. Distribution over research focus

Research focus	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
Theoretical frameworks	1	2	3	1	1	1	1	2	1	1	1	15
Guidelines for developing AR applications	2	8	10	5	4	4	1	2	1	1	2	40
Process of design and usability evaluation	2	2	-	1	-	1	3	2	-	2	2	15
Total	5	12	13	7	5	6	5	6	2	4	5	70

domains. In the present instance, the method for literature review includes a selection of keywords, filtering, and the process of classification.

The primary domains of classification in AR application for a geriatric population are – (1) transportation, (2) ageing-in-place, (3) entertainment, and (4) training as shown in Table 4 This classification is done based on human factor books for ageing population (Craig, 2013; Czaja,1990; Fisk et al., 2009). This section also includes the exposition of various kinds of AR application for the elderly people, and the findings arrived at in each article.

Transportation, in this context, encompasses any mean of conveyance. It can be inclusive of walking, using public transport, or self-driving (Fisk et al., 2009). Four studies are relevant in the application of AR in supporting elder drivers on dual parameters of navigation as well as perception of hazard. One of the most pioneer research works has been that of Kim and Dey which have been cited by 62 other studies (Kim, & Dey, 2009). It expounded the development of a prototype which uses AR navigation display system. This display system is to be incorporated within the vehicle windshield for elderly drivers. The results obtained exhibited the efficacy of the entire system. The findings showed that compared to regular navigation display, the AR navigation system has successfully reduced errors and incidences of distraction. The name of the following street and direction can be seen through the navigation display system installed in front of a car.

In rest of the research studies, various developments of AR indicators are explained that generate virtual content for the use of elderly drivers (Schall et al., 2012; Gasper, & Kim, 2013; Rusch et al., 2014). The work by Schall et al. (2012) about the virtual content on broken yellow lines which takes the form of elongated rhombus. It decreases the risk of potential accident due to cognitive impairments. In another research, the AR system merged the time-to-collision display of the lead vehicle for elderly drivers for further safety improvement (Fu, Gasper, & Kim, 2013). In the work of Rusch et al. (2014) an AR cue system is created in which potential roadside hazards are converted into virtual no-turn-left sign. It enables the elderly drivers in estimating the gap in case of left-turns. All these research study included passive feedback of users (Kim, & Dey, 2009; Schall et al., 2012; Fu, Gasper, & Kim, 2013; Rusch et al., 2014). The findings, more or less, harp on the same theme of

Table 4. The classification of using AR technology for older people

Domain	Literature	AR application
Transportation	(Kim, & Dey, 2009), (Schall et al., 2012), (Fu, Gasper, & Kim, 2013), (Rusch et al., 2014)	AR navigation system; AR cues; AR indicator
Ageing-in-place	(Wood, & Mccrindle, 2012), (Lera et al., 2014), (Quintana, & Favela, 2013), (Mirelman et al., 2013), (Hyry et al., 2017), (Metso et al., 2009)	Spoken reminder; AR pillbox; AR discovery and information system
Training	(Yoo, Chung, & Lee, 2013),(Schega, Hamacher & Wagenaar, 2011),(McCallum & Boletsis, 2013)	Augmented treadmill; AR-based gait training program; movement guide
Entertainment	(Lin, Fei, & Chan, 2013), (Kurz et al., 2014), (Yamamoto et al., 2015)	3D Angry Birds-like game; AR table card game Augmented radio
Others	(Malik et al., 2013), (Bernardoni et al., 2019), (Metso et al., 2009), (Panchiwala, & Shah 2020)	Augmented haptic, smart environment

reduction of distractions and navigations errors, improvement of safety of elderly drivers by enhancing hazard detection. There is, however, certain inherent challenge of retaining focus on transportation domain. Such simulator of AR requires support of both software and hardware. Another issue in this regard is the manner of recruitment of elderly drivers.

The concept of ageing-in-place is focused on making regular lives of elderly people easier where they can retain a degree of independence and autonomy in the environment of their home itself (Fisk et al., 2009). Four research papers deal with AR reminder application for home tasks and the various issues faced by elderly people in that regard (Mirelman et al., 2013; Lera et al., 2014; Wood, & Mccrindle, 2012; Quintana, & Favela, 2013). It was found in Lawson et al. that AR reminder having the voice component is most effective, especially when the user is engaged in some other activity (Mirelman et al., 2013). In another study, pillbox system is developed, which was involved in the augmentation of virtual graphics. It is based on the image captured with the help of a robotic camera (Lera et al., 2014). For elderly people suffering from memory loss, 3D content proved to be effective. For instance, the AR system of reminder can successfully detect the QR code of a kettle. After that, it displays the contextual menu of a drink (Wood, & Mccrindle, 2012). The study conducted by Quintana and Favela put forward such AR system that can assist Alzheimer's disease patient as well as their caregiver. The function of the system is to enable such patient in recognising the tags in real physical environment through a mobile phone. The device sends feedback through text, audio, vibration or images. When compared, audio notifications show a higher efficacy than vibration notifications. The common findings from this research are that AR systems can be effectively harnessed in ensuring that elderly people and Alzheimer's patients can live with independence in their homes, and do not need to move into an elderly care facility.

The use of AR in rehabilitation training is explained in three works. The development of augmented treadmill in proposed in Mirelman et al. (2013). It conducts the study on the potential risk of fall due to motor and cognitive deficits (Yoo, Chung, & Lee, 2013). The findings in Schega et al. (2011) specifically shows that AR based training program for gait training of elderly woman after hip replacement surgery is effective. The training program engages real-time visualisation of certain kinematic variables. This entire process is done through a head-mounted device (McCallum & Boletsis, 2013). Moreover, the study in Yoo et al. (2013) showed how AR could help in increasing muscle, and maintenance of balance with the hap of exercise. External projection equipment uses both reality and virtual component to make movements (Schega et al., 2011). It becomes quite obvious that in this domain, there is an additional need for knowledge about neurology as well as sports science. It will enable to determine the extent of suitability and feasibility in AR-based training regimen.

Furthermore, two research studies have considered the implementation of game design in AR for elderly people. A specific architecture was merged with gesture-based device. The objective is to extend a theoretical justification creation of simulations like 3D Angry Birds game (Lin, Fei, & Chang, 2013). On the other hand, Lin et al. took into consideration the existing gap between digital information product and elderly users. An AR-based table card game was developed that included the combination of conventional cultural assets and advanced digital technology (Kurz et al., 2014). There was no categorisation of the two articles (Malik et al., 2013; Bernardoni et al., 2019), as the objective of these studies was to conduct a literature review than zeroing on the appropriate application for ageing. The opposite spectrum of the utility of AR application is also present. The adverse feedback of AR handheld application for elderly people is mentioned in Kurz et al. (2014). The design issues were reviewed in AR applications such as voice augmentation and transport system (Malik et al., 2013).

DISTRIBUTION OVER DESIGN CHALLENGES OF AR SYSTEMS

Having described the AR system's components, the impetus is on the development of such application which combines all these elements (Bressler, & Bodzin, 2013; Cieutat et al., 2012). However, such design techniques, guidelines, and evaluation methods are sparse in existing research (Huang et al., 2012). For instance, AR designers (Quintana, & Favela, 2013) had a new challenge wherein information had to be associated, organised and presented in a dynamically changing real environment. The objective is, however, to safeguard users from experiencing cognitive overloads due to the massive amount of information. The challenges mentioned in Table 5, motivate and justify the subsequent research with a specific focus upon design principles of AR systems.

Some of existing papers discuss different suggestions for capturing and sharing design or evaluation knowledge for AR in different formats, such as design approach (Lera et al., 2014), design guidelines (Friedman et al., 2000), (Billinghurst et al., 2009; Santos et al., 2015; Chastine et al., 2007; Nilsen, & Trond 2006; Ortman et al., 2012) **,** design patterns (Schmitz , Specht, & lemke, 2012; MacWilliams et al., 2004; Xu, et al., 2011) and usability principles (Kalalahti, & Joanna 2015; Ko et al., 2013).

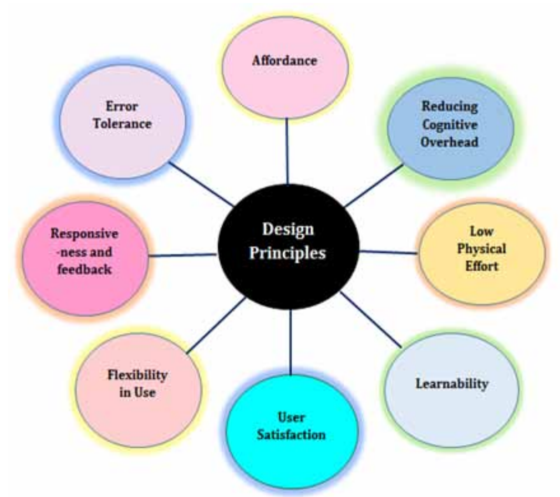
All this research pertains to accumulation of design knowledge. It must be noted in this regard that design principles have a distinct nature from that of other formats. It is due to the fact that principles are usually generative concepts. The objective of all the principles laid down in the paper is not to substitute existing guidelines, but to enrich those. Such design principles can emanate from technology or psychology.

There are two representative works directly discussing about the design principles for AR (Dunser et al., 2007; Metso et al., 2009). Motivated from the previous literatures, we have identified certain design principles for designing AR systems are shown in Figure 5.

Table 5. Distribution over design challenges

Design Challenge	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
Affordance			1	1	1	1		1				5
Reducing Cognitive Overhead			1							1	1	3
Low Physical Effort	1	1	1	2	1	2		2		1	2	13
Learnability		1								1		2
User Satisfaction	2	6	4	3	1	1	2	1	1		2	23
Flexibility in Use	1	2	2		1	1	2		1	1	1	12
Responsiveness and Feedback	1	2	3	1	1							8
Error Tolerance			1				1	2				4
Total	5	12	13	7	5	6	5	6	2	4	5	70

Figure 5. Overview of design principles for designing AR systems



FINDINGS AND DISCUSSION OF STUDY

In this section, we look back at the aims of the study and discuss how the lessons we have learned help in addressing the research questions. In order to overcome the challenges, most reported technology challenges that had to be overcome for AR applications to come to mainstream. Among those challenges, the price of manufacturing AR devices and limitations of AR specific and consumer devices led the way.

In all, the literature review did not reveal popular use of AR among people, and one can suggest that virtual reality and AR has not yet become commonplace. It is largely restricted to early adopters, gamers, and technology enthusiasts at large. The major reason is due to the steep price of AR devices. For an average consumer, there is no value to purchase a basic AR device.

Furthermore, to create an immersive experience in virtual and AR, combination of diverse disciplines is required. The capital required for the integration of such disciplines is even higher. As such technologies become more common; recovery of costs is expected to become easier.

One of the major limitations of virtual reality or AR devices is related to its field of view or FOV. Presently, FOV extends to 90 degrees. On the other hand, in normal human vision, there are 120 degrees in vertical and 190 degrees in horizontal. To make such technologies more lucrative, the projected image through AR devices must have a large FOV. As it stands today, with greater FOV, the device also becomes bulky. Hence, the parameters that have to be improved include brightness, weight, FOV, display quality, and latency, apart from advanced user experience. The power consumption issues are also something that have to be taken into consideration. For a true AR experience, there is a need for higher processing power. The devices that are readily available in the market are mostly tethered devices. It means that the headset must necessarily be connected to a console or personal computer. Such arrangement automatically restricts users' movement. For navigating our regular lives, connectivity becomes crucial. With respect to virtual reality and AR, 5G may be able to bring more stability. The potential benefits could be higher accessibility and much better-quality content. The application of AR will become advanced if the required infrastructure is in place. AR devices should be able to run successfully across different ecosystems. Also, it should be easy to wear those devices and have higher processing power.

In all, keeping in mind the chosen focus group of users – elderly people and their caretakers, who often are elderly as well – the limitations and requirements pointed out should be carefully considered. The assistance enabled by AR should be easy and comfortable for its users instead of causing more challenges and technical devices around the elderly. In this respect, the current study revealed valuable new knowledge to be applied by the designers and service providers.

CONCLUSION AND FUTURE WORK

The literature review indicates the basic steps in AR applications. Certain modifications in software engineering become imperative for the improvement of the research tool. It equips the developers in designing better AR applications for elderly people.

The AR framework includes six components – (1) user, (2) interaction, (3) device, (4) real content, (5) virtual content, and (6) tracking.

These six components would help in the innovation and development of actual AR applications. These elements have to be present for the purpose of creating the foundation of any AR applications. The literature review indicates that the domain analysis should provide more focus on training, transportation, entertainment and ageing-in-place. Given that, research in this area has consistently increased since 2012, and there is a scope for greater discourse for the design of AR application for elderly people. More research is required for the shortcomings that became evident in the empirical studies of the research papers.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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