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User Experience In Augmented Reality: A Review Of Studies

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ABSTRACT. In recent years, augmented reality (AR) has seen significant advances in interaction, tracking, and rendering. However, with the recent advancements in AR applications, there is still a substantial challenge associated with AR from the User Experience (UX) design perspective. This paper aims to summarise the existing research on AR and UX. The literature review identifies a considerable number of publications for a preliminary assessment using credible online databases and digital libraries, resulting in a taxonomy of current UX research in AR. Also mentioned are the research findings and prospective avenues for future research.

Keywords: Usability, User Experience, Augmented Reality.

Introduction

Augmented Reality (AR) has been a research and scientific literature subject for almost two decades (Chiang et al., 2022). The high number of AR paradigms, proposed solutions, applications, frameworks and services present throughout the field's lifespan depicts the latter's diversity and complexity (Gorman & Gustafsson, 2022). Among some of the depictions of the reality of the digital reality associated with human interaction for information, AR technology is highlighted owing to its physically flexible and significantly more compact form, enabling its usage in various places. It is an emerging technology that enhances a user's perception of the real environment with computer-generated data through a real camera to capture an image, software to recognize and add virtual characteristics, and projection of these components to link physical and virtual aspects (Gong et al., 2022).

AR can effectively deliver information in a "just-in-time" and "just-place" way. Therefore, this technology is broadly used to simplify the user's life by incorporating virtual information into his immediate surroundings and any indirect view of the real-world environment, such as a live-video feed. Whereby improving the user's engagement with and perception of the real environment.

Nonetheless, AR offers an excellent opportunity for enhancing daily life activities (Arena et al., 2022). However, using this technology at the outset may be difficult since many people do not know how to use it, and user adoption still seems to be limited because of the lack of interaction and the inexperience of AR users (Sung et al., 2022). Therefore, this article intends to illustrate and debate aspects of the UX within the AR technology framework for the purpose is to produce usable AR products.

2. What is Augmented Reality?

AR is a real-time direct or indirect view of a physical, real-world environment that has been enhanced/augmented by adding virtual computer-generated information (Vona et al., 2022). It is interactive and registered in 3D and combines real and virtual objects. Paul and Fumio define it as a continuum between actual and virtual worlds, with AR and Augmented Virtuality (AV) in between, with AR being closer to the real world. However, AV resembles a virtual environment more, as depicted in Figure 1 (Milgram & Kishino, 1994).

VR technology, or Virtual Environment as Milgram called it, completely immerses users in a synthetic world without allowing them to see the real world, AR technology enhances the sense of reality by superimposing virtual objects and cues onto the real world in real-time (Milgram & Kishino, 1994). Azuma et al. stated that AR is limited to specific display technology, such as a head-mounted display (HMD), nor the sense of sight. AR can augment all purposes, including smell, touch, and hearing. It can also enhance or replace users' missing intentions through sensory substitution, such as improving the vision of blind or visually impaired users through audio cues or augmenting the hearing of deaf users through visual cues (Azuma et al., 2001). They also explored AR applications that entail the removal of real objects from the environment and the addition of virtual objects (Azuma et al., 2001). Removing an object from the real environment corresponds to covering it with virtual information that fits the background to give the user the sense that the thing is absent. Adding virtual items to the real environment enables the user to perceive information that he/she cannot directly perceive with his senses. By showing digital information through a headset, the data transmitted by the virtual item can assist the user in doing daily duties, such as guiding employees through electrical lines in an aeroplane (Azuma et al., 2001). The uses of this technology include medical visualization, entertainment, advertising, maintenance and repair, annotation, and robot path planning.

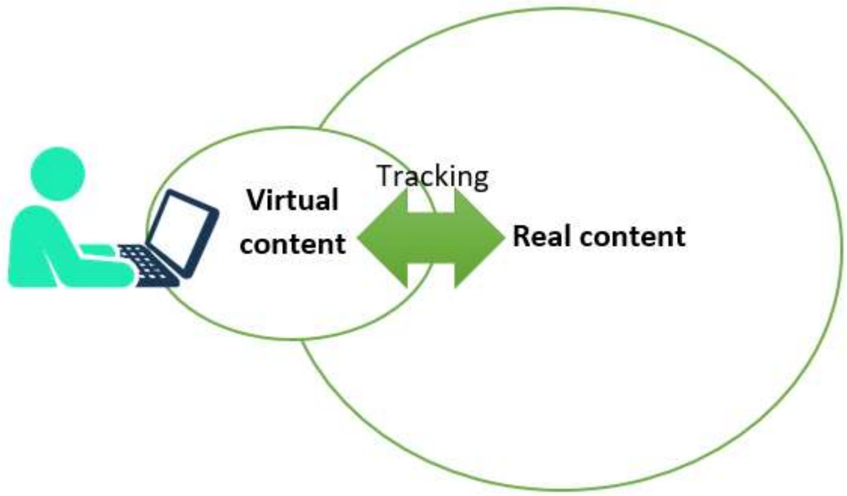

Figure 1 Integrating Virtual Content into the Real Environment

3. What is User Experience?

According to Justin, User Experience (UX) is distinct from Usability since it serves a different purpose (Mifsud, 2011). Nevertheless, there is a link between Usability and UX. Usability is part of one Metric measurement, whereas UX is one of the application's pleasure factors (Quaresma et al., 2022; Salman, Deraman, Jalil, et al., 2017; Salman & Deraman, 2020; Salman, Deraman, et al., 2017a, 2017b). To quantify UX, it is necessary to comprehend the notion of UX. UX is defined by ISO 9241-210 as "a person's perceptions and responses resulting from the usage and anticipated use of a product, system, or service" (ISO). Consequently, UX is not an artifact but is strongly associated with encounters with a product, service, system, or object (Mkpojiogu et al., 2022).

However, UX is a larger entity, encompassing usability and including a system's pragmatic and hedonic aspects (Schankin et al., 2022). For example, regarding AR, many definitions (Templin et al., 2022) often imply the use of 3D graphics superimposed on the user's view of the world, emphasising the visual aspect of AR. However, from a UX point of view, any media visual, sound, haptic, etc. can enhance the user's reality and specific context (Cooper et al., 2021), thus addressing the meanings of locality and intentionality (Ritsos et al., 2011). Additionally, the nature and form of the UX are affected by the number and type of interactions within the synthetic space.

UX comprises three aspects: the user, the interaction between the user and the product or anything that interacts with the user, and observable and quantifiable UX (Schankin et al., 2022). However, there is no standard for assessing the UX of each aspect (Schankin et al., 2022). Therefore, additional research is required to select the standard size or metric for measuring the UX of an application. Furthermore, the simplicity with which an application can be produced employing AR technology, particularly by non-professional developers, results in applications with inadequate/low UXs, negatively affecting the quality of the applications developed.

4. Approach

The methodology of this paper is represented in four steps, as shown below (see figure 2):

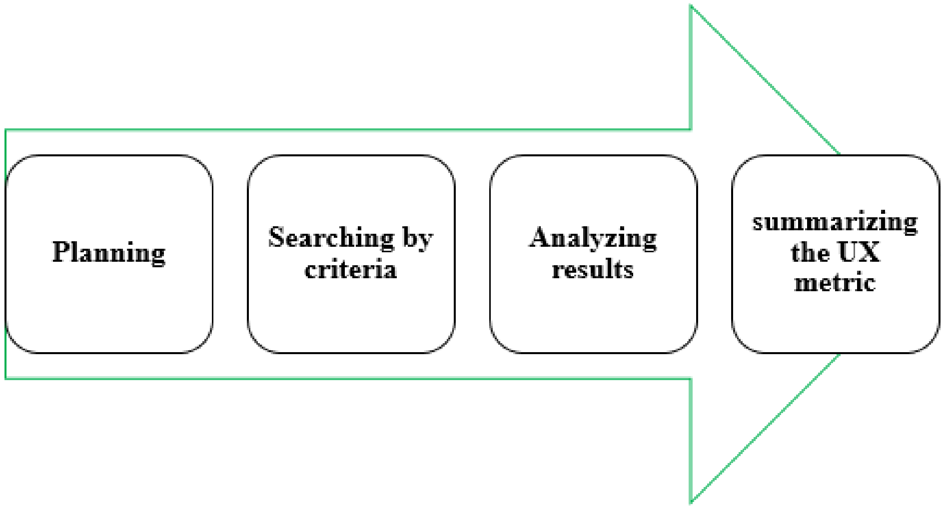

Figure 2 The Phases of the Research Methodology

In the planning phase: the author determines the research scope to include: Elsevier, ACM, IEEE and other credited publishers.

In the searching phase, the research covers two mean areas: UX in different contexts and AR from various aspects. Based on these areas, consider the number of papers collected.

In the analysis phase, the author analyses the collected papers to bring UX metrics from various areas. Articles that did not match the author's goal are removed. The review of the current metrics is elaborated upon in the next section. In the summarizing phase, the author compiles papers on UX measurement-related AV and describes them in table 1. The articles are derived from the period between 2010 to 2022, consisting of 47 articles. However, after precise analysis, the finding revealed that just 12 studies specifically address the measurement of UX in an AR context.

5. Existing User Experience Metrics Assessment

This section highlights UX measurements from several contexts to develop a holistic view of AR applications (see figure 3).

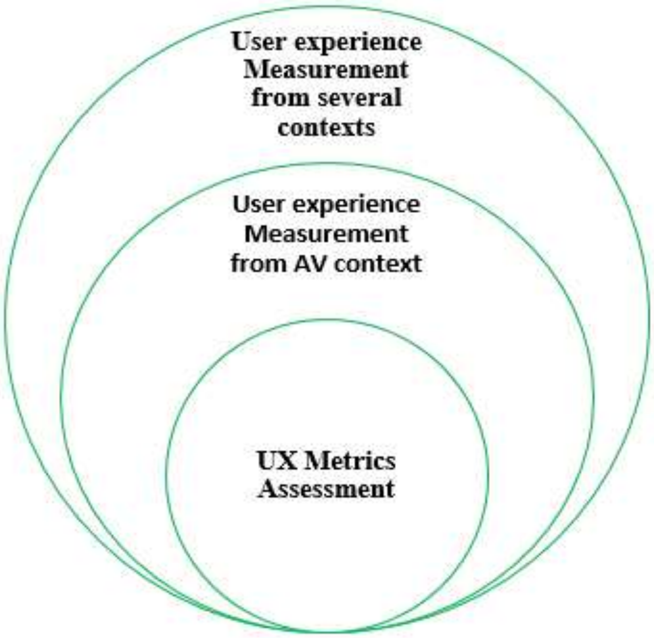

Figure 3 The Literature Review Scope

5.1. User Experience Measurement from Several Contexts

From the period 2010-2022, there are many studies related to UX and usability have been conducted. For example, Scott conducted a quantitative statistical analysis to research a dataset derived from a survey of UX practitioners (Young et al., 2020). Themes extracted from the survey responses revealed a set of factors influencing UX maturity development. He concluded there is a need to offer a library-focused maturity scale with recommended practices for advancing UX maturity in academic libraries (Young et al., 2020). A study by Na and Yi found that UX is the most critical factor in the design of the "Daily Yoga app"; which is required for improvement to achieve an attractive user interface (Yu & Huang, 2020). Based on previous studies, Sungchul and Robert proposed a theory to define better the relationship between increases in sensory-based realism and presence, and thus help VR researchers create more compelling experiences (Jung & Lindeman, 2021). In addition, they suggested that researchers and designers consider preference a critical component for evaluating the impact of VR experiences, especially from a business perspective (Jung & Lindeman, 2021). According to Arslan and Assad, usability and user experience evaluations do not keep up with the development technology, and there is a need to define new measurement methods' applicability during the software development life cycle. Therefore, they conducted informal interviews with software companies to identify the challenges of using current methods (Arslan & Riaz, 2010). Tan et al. present a paradigm for measuring usability and UX in the mobile sector based on various criteria, including accessibility, satisfaction, comprehension, learnability, efficacy, safety, productivity, and generalizability. The framework is constructed using the Goal-Question Metric (GQM) methodology and evaluated using a case study undertaken by usability research, development, and consulting firm for the Swedish mobile industry (Tan et al., 2013). Sari et al. proposed the "UX Curve" method that aims to assist users in retrospectively reporting how and why their experience with a product has changed over time. They evaluated UX using the following metrics: usability, attractiveness, utility, and duration of usage (Kujala et al., 2011). According to Rodden et al., the engagement metric is a happiness meter that counts the time a user spends utilizing a specific service or product. Adoption and retention metrics quantify the number of new users that utilize an application or product throughout specified periods. Task Success Metrics measures user performance in terms of effectiveness, efficiency, and mistake rate. These metrics are specified according to objective, signal, and unit measurement (Rodden et al., 2010). The "real UX," according to Philip et al., is the degree to which users can achieve usability, safety, and satisfaction in a given setting (Lew et al., 2010). Usability influences UX in the context of satisfaction, where satisfaction is a characteristic used to measure UX in software products16. Vaananen and Waljas employ pragmatic aspects of the functional demands of web services and hedonic elements such as users' emotional and psychological needs to measure UX with web services (Väänänen-Vainio-Mattila & Wäljas, 2009). Fu et al. provided guidelines for a positive UX. They concluded that the system could provide users with the option to rate characteristics essential to them, allowing for the customization of the recommended system (Pu et al., 2012). In addition, they revealed several tradeoffs between system elements and individual and situational variables (e.g. the amount of preference feedback users provide is a tradeoff between perceived system usefulness and privacy concerns). Two experiments were done by Mandryk et al. to investigate the effectiveness of physiological measures as evaluators of UX with entertainment technology. They discovered that the body responds physiologically differently when playing against a computer versus a friend. These physiological outcomes are reflected in the participants' subjective reports. In addition, they present instructions for obtaining physiological data for UX analysis based on our empirical research (Mandryk et al., 2006).

5.2. User Experience Measurement on AR Application

Irshad et al. conducted a literature review covering the UX in the context Mobile Augmented Reality (MAR). The assessment yielded three research categories which are: UX as a phenomena, UX as an academic discipline, and UX's practical application. Based on these three criteria, it can be determined that Mobile AR 27 still has UX evaluation concerns (Irshad & Rambli, 2014).

Vida Davidavičienė et al. employed methods such as expert evaluation, observation and UX questionnaire methods. The study identified the main factors influencing the positive UX which are: the explicit purpose of the application, ease to use and learning, smooth operation, imaginative information presentation, and interactivity (Davidavičienė et al., 2019). Christos et al. analyzed the main aspects affecting the acceptance of AR by firefighters. The research used a technology acceptance model, extended by the external constructs of perceived interactivity and personalization, to consider both the system and individual levels. The authors claim that usability is the strongest predictor of firefighters' behavioural intentions to use the AR system, followed by the ease of use with more minor, meaningful, direct and indirect effects on firefighters' intentions

(Papakostas et al., 2021). Effie and Matthias discussed UX-relevant AR and concluded that the lack of foundation in usability/UX frameworks shows a gap between the HCI and technology-enhanced learning communities. In addition, the lack of creative usability/UX evaluation methodologies for AR and the continued reliance on questionnaires may hinder the development of AR. Moreover, the learner's age does not appear to be a significant factor in determining the perceived usability and UX or the learning effect of AR (Law & Heintz, 2021). Shafqat et al. suggested a UX model for MAR, which includes components and design considerations that can contribute to positive UX. The proposed UX model is used to evaluate and test the validation of the MAR applications regarding UX. The outcomes of this model demonstrate superior result in measure users' satisfaction, and clarity compared to certain criteria appeal (Shafqat & Byun, 2019).

Dhir and Al-Kahtani conducted a study comprising a user experience evaluation of different prototypes using three methods. The main contributions of this study are to solicit expectations when consumers use MAR applications. Second, assess the UX over different prototypes using standard metrics. Third, provide methodological insights on UX evaluation experiments (Dhir & Al-Kahtani, 2013). Table 1 describes the details of measurements derived from different contexts.

Table 1 Review of UX Metrics

no.	Authors	Context	Metrics
1	Tan J, Ronkko K, Gencel C.	Mobile industry	Service Quality, Attractiveness, Hedonic Quality, Stimulation, Pragmatic Quality, Emotion, and Identity
2	Pu P, Chen L, Hu R.	Systems	Content, Internet Service
3	Väänänen-Vainio-Mattila K, Wäljas M.	Web services	Satisfaction, usage Effort, Experience, Effectiveness, and Outcome Related
4	Irshad S, Rambli DR.	Mobile applications	Efficiency, Effective, and Satisfaction
5	ISO 9241-210:2010	Ergonomics of human-system interaction	Efficiency, Operability, Attractiveness, Learnability,

			Effectiveness, Usability Compliance, and Understandbility
6	Albert W, Tullis T.	Software development	Adoption, Retention, Engagement, Task Success, and Happiness
7	Vermeeren AP, Law EL, Roto V, Obrist M, Hoonhout J, Väänänen-Vainio-Mattila K.	Software development	Ease of use, Satisfaction, and Safety
8	Rodden K, Hutchinson H, Fu X.	Web applications	Algorithm Diversity, and Satisfaction
9	Pilomia J.	Mobile application	Utility, Usability, Long-term Use, and Attractiveness
10	Knijnenburg BP, Willemsen MC, Gantner Z, Soncu H, Newell C.	Systems	Service Availability, and Satisfaction
11	Mohseni S.	Mobile application	Efficiency, and Effectiveness Understandability, Accessibility, Generalizability, Productivity, Learnability, Safety, and Satisfaction
12	Arslan M, Riaz Ma. A	Web applications	Interaction, Ease of use, and Social Presence

6. Conclusion and Future Work

AR technology has emerged as a powerful tool to empower users in their daily activities. The UX factors, such as the sense of presence, ergonomics, satisfaction, overall usability, and product identification, are an integral part of AR standardisation. More emphasis has been placed on researching possible UX solutions with AR technology. The author believes solving concerns of the UX evaluation in AR is necessary. This review's primary objective is to provide resources for the AR community by presenting UX-related study metrics. The review will assist promote UX as a measurement and enhance the quality of UX research in AR. Future research must include other publisher databases such as ProQuest, SpringerLink, and ScienceDirect to fully understand UX measures in the context of AR.

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