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User Experience Metric for Augmented Reality Application: A Review

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Abstract

Augmented Reality Technology is developing rapidly and has been widely used in the field of education. Due to the ease of developing AR by non-professionals, User Experience (UX) is often not considered in the application. Currently, there are no standard measurements of UX for AR applications especially in Education. The authors reviewed previous research to obtain UX references and the existing measurement standards. From the results of the review, the metrics were analyzed based on the characteristics of AR, especially in the field of education. The metrics will be recommended for the UX measurement of an AR application. The available standard metrics can be used to determine the UX quality of an AR application and contribute to the improvement of UX in AR applications, especially in the field of Education.

Keywords: question answering system; arithmetic word problem, intelligent humanoid robot, natural language processing

1. Introduction

Augmented Reality technology has been widely used in industry and academia. Augmented Reality (AR) technology was firstly used in the aerospace industry as a training tool [1]. However, currently AR technology has been widely used for education as Martin et al mentioned in their research on Augmented Reality as a new trend [2,3]. At the beginning, learning by using AR faces many obstacles because many individuals do not know how to use the technology, as indicated by the research of Sumadio and Rambli that the user acceptance is still low due to lack of interactions and the unfamiliarity of AR users [4]. Wu et al. said that the multiple technology embedded in Augmented Reality Technology can produce overload information for students and the multiple tasks used in Augmented Reality

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Applications [5]. It is a challenge to improve the use of Augmented Reality technology in education related to the user experience. As the AR technology is getting better, it improves the effectiveness of learners in learning, for example in learning materials about electromagnet [6]. User experience is one of the important aspects to consider when designing a Mobile Augmented Reality service in online shopping contexts [7]. So, it is very important for applications to have a good user experience.

User Experience is often equated with Usability. However, according to Justin Misfud, User Experience (UX) is different from Usability, because it has a different objective. Yet, there is a connection between usability and user experience. Usability is part of one Metric measurement while User Experience is one of the components of satisfaction after using an application [8]. In order to measure user experience, the concept of User Experience needs to be understood.

According to ISO 9241-210, User Experience refers to "a person's perceptions and responses that result from the use and / or anticipated use of a product, system or service" [9]. User Experience is not an artifact but closely related to interactions with a product, service, system, or an object [10]. User Experience consists of three characteristics, which are the user involved, the interaction between the user and the product or anything that interacts with the user, and user experience that can be observed and measured.[11]

Vermeeren et al. has surveyed methods for evaluating user experience. The surveys identified 96 methods for evaluating user experience for web-based and mobile products; each method has different advantages and disadvantages [12]. However, there is no standard for evaluating the user experience of each method. Therefore, it is necessary to do further research on the standard size or metric for measuring the user experience of an application. The ease of developing an application using AR technology, especially by non-professional developers, results in applications that have inadequate/low user experience, which affects the quality of the developed applications. The AR technology used in education is still new. So, there is a need for high level engagement to facilitate the adaptation of the users to use the AR application [13]. To achieve a high engagement, the user experience needs to be improved.

Previous research has not discussed the measurement or evaluation of user experience in applications that use AR. The research generally discusses the user experience in general and user experience of web applications. This paper proposes a UX Metric for measuring the user experience of an Augmented Reality Application. The proposed metric will be obtained by identifiying and reviewing papers related to user experience metric and Augmented Reality. Previous measurements are adopted and a standard metric for measuring user experience in Augmented Reality applications used in the field of education is proposed.

2. Methodology

The review starts from (1) planning, (2) searching by criteria, (3) analyzing the research results/findings, (4) writing the results and discussions of the literature review, and (5) proposing the UX metric for Augmented Reality Application.

In the planning phase, the database which will be used as the resource for searching papers is defined. The journals used include *Interacting with Computers, Educational Research Review, Software Quality Journal, User Modeling and User Adapted Interaction, Computer and Educations* and many more. Mostly, the reviewed papers were obtained from Elsevier, ACM, and IEEE publishers.

In the searching phase, the topics included in this aspect are User Experience topics, UX on Mobile Application, Mobile Augmented Reality (MAR), Smart Learning, and Augmented Reality Use in Education. From the papers that have been collected, categorization was done based on the topic.

In the analysis phase, papers suitable with the purpose were further analyzed to obtaine what kind of UX metric that is already used in previous research. Papers that did not match with our criteria were removed. The review of the existing measurements is further explained in Section 3.

In the writing phase, the types of measurement used in the previous research were discussed. From the existing user experience measurement method, an analysis was done on what metrics is used and whether it can be used in other applications, especially those using Augmented Reality technology. Papers are retrieved from 2010-2017

consisting of 43 papers. However, after further analysis, only 16 papers are directly related to the measurement of User Experience (UX).

The results of the papers reviewed were then analyzed to generate the characteristics of AR applications especially in the field of education. Further, a standard metric was determined for AR applications in the field of Education.

3. Review of existing User Experience Measurement

This section discusses some user experience measurements that have been used in several platform applications such as web application, mobile application, Augmented Reality Application, and other specific applications.

3.1 User experience Measurement on Web application

The results of a review of studies from 2001-2008 related to user experience and usability in website applications conducted by Arslan and Assad Riaz indicate that the measurement of user experience is generally done in the implementation and testing phase. The methods for UX evaluation include storytelling and narration, emotion-based evaluation approach; however, they did not describe in detail how the UX metrics were used [14].

The measurement of user experience metric for website application used Heart Framework based on user center metric. The Heart Framework measures the level of user experience on the web on a large scale. This framework consists of the purpose of the product or feature to be measured, the signal which is an indicator of the success of user experience, and metrics to measure the indicator that has been determined [15]. According to Rodden et al., User Center Metric is a happiness metric which is a measure of satisfaction, an Engagement metric to measure how long a user uses a particular application or product, Adoption and Retention Metrics to measure how many new users keep using the app or product in certain periods, as well as Task Success Metrics to measure how effective, efficient and error rates users perform. Each of these metrics is made more detailed based on goal, signal and unit measurement[15] .

User experience becomes one of the key drivers in evaluating the quality of a website. Philip et al, mentioned that Actual User Experience is actually a level where users can achieve usability, safety, and satisfaction in a certain usage context. Usability affects the level of user experience in using a website application. The level of satisfaction in use and safety is an attribute used to measure the level of user experience in a website application. Safety is a measure of user experience because it relates to the emotional level of users who need similarity and trust when using a website application [16].

The development of web services increases along with the increase of user activity online. This needs to be supported by a good user experience in order to provide benefits to users. Väänänen-Vainio-Mattila and Wäljas use pragmatic aspects related to the functional needs of web services and hedonic aspects such as the emotional and psychological needs of users as aspects used for measuring user experience from web service[17,18] .

User experience becomes one measure in developing a good website based on recommender system. Fu et al recommended a good user experience; the system can give control to users in choosing the rating, choosing which features are important for the users and give the users the opportunity to personalize the recommender system used [19,20]. The level of knowledge possessed by the users as well as the size, quality and diversity of the recommendations affect the user experience [21].

3.2 User Experience measurement on Mobile Applications

The user experience evaluated from a mobile application does not start from when the user uses the application, but from the moment when the user downloads and installs the application. Awareness about user experience also needs to start from the developers who design the user interface because this affects the user experience when the application is used [22].

The quality of experience that users feel is influenced by Mobile Content which - of course - is related to the quality of the content provided by the content provider and the quality of service from mobile communication [23,24]. Internet service provided can be used to calculate user experience experienced by users [25].
UX Curve is used to measure UX over a long period of time through the ease to use, attractiveness, utility, and duration of use. This method describes the UX level of mobile users over a period of time and makes it easier to analyze through a graph that shows the level of each measured metric [25].

A framework is proposed by Tan, Rönkkö, and Gencel for usability and UX measurements in the mobile industry using several attributes such as efficiency, effectiveness, satisfaction, productivity, learn ability, safety, accessibility, generalizability and understandability. This framework is developed based on Goal-Question Metric (GQM) approach [26].

3.3. User Experience Measurement on Augmented Reality Application

A review of studies related to UX from 2005 to 2014 focusing on Mobile Augmented Reality (MAR) and UX has been done by Irshad et al. The review resulted in three categories of research: UX as a phenomenon, UX as field of study, and practical application of UX. From these three categories, it is concluded that there are still issues related to UX evaluation on Mobile AR [27].
Dhir and Al-Kahtani use three evaluation methods for evaluating UX on MAR prototypes such as MAR Street and Navigation Apps, the Map Barrier Apps, and the MAR Playfulness app which is an information sharing application with virtual pet. The first UX evaluation method used is the SUXES method which measures the service quality of an application by using user satisfaction level metrics. The second method is AttrakDiff25, UX evaluation method by using Pragmatic Quality criteria that measure the usability level of an application, Hedonic Quality-Stimulation, namely the level of fun that comes from the features provided, Hedonic Quality-Identity which is the level of user fun in recognizing the applications used, and Attractiveness which is the level of users' interest in using the application. The third method is Emocard that measures the emotional relationship of users when interacting with the application [28].

3.4 Other User Experience Measurement

UMUX (Usability Metrics for User Experience) is a measurement of User Experience by conducting subjective assessment on the acceptance of an application based on Usability components such as efficiency, effectiveness, and satisfaction [29]. This metric has been tested on enterprise applications in Intel and audio conferencing applications and can provide measurements of user experience effectively.

User experience in games is evaluated from concept, pre-development, production to implementation and testing with various methods ranging from questionnaires, focus groups, interviews, video coding, quantitative comparison of games' behavior, and heuristic evaluation. However, about the review did not discuss the metrics used in evaluating user experience.

Mandryk et al. used psychophysiological techniques to measure user experience in entertainment technology using metrics measured through the Procomp Infiniti Hardware and Biograph software to obtain galvanic skin response (GSR) data, heartbeat from electrocardiography (EKG), electromyography of the jaw (EMG), as well as respiration amplitude (RespAmp) and respiration rate (RespRate) [30].

4. Discussion

The review focused on the measurement of user experience in web-based applications, particularly the performance and the level of engagement in web applications used as well as the satisfaction obtained when using the application. The level of security affects emotional factors and the level of user trust in the applications used. The web-based system applications require additional measurements of the level of control available to users. The attributes used in measuring usability are widely used for measuring UX on web-based applications. Also, the measurement of UX needs to consider the level of user knowledge because applications with new technology sometimes give inadequate UX to users who have no prior knowledge.

The measurement of UX in mobile apps is determined by the existing content on mobile, mobile communication, and internet service which affect the users' UX. The UX measurement standard in mobile applications is inseparable from the usability attribute that is evaluated simultaneously by implementing the proposed framework by Tan, Rönkkö, and Gencel.

User experiment measurements are viewed from UX Component, measured applications, metrics used for measuring and UX Aspect (See Table 1).

Table 1 Review of User Experiment Measurement

References	UX Component	Application	Metric	UX Aspect
10	Product	Website	Understandbility, Learn -Ability, Efficiency, Effectiveness, Operability, Attractiveness, Usability Compliance	Pragmatic Hedonic
11	Product User	Website	Happiness Engagement Adoption Retention Task Success	Pragmatic Hedonic
12	Product User	Website	Usability Satisfaction in Use Safety	Pragmatic Hedonic
13	Product Service	Website	Usability social presence cross platform interaction	Pragmatic Hedonic
14	Product Service	Website	Usability social presence cross platform interaction	Pragmatic Hedonic
15	Product User System	Recommender System Website	Algorithm Diversity Satisfaction	Pragmatic Hedonic
16	Product User	Recommender System Website	User Control	Pragmatic

17	Product User System	Recommender System Website	Usage Effort Effectiveness Satisfaction Outcome Related Experience	Pragmatic Hedonic
18	Product User System	Mobile	Review Connection	Hedonic
19	User System	Mobile	Content Internet Service	Hedonic
20,21	Product System	Mobile	Service Availability Satisfaction	Hedonic
22	Service	Mobile	Ease to use Attractiveness Utility Long-term Use	Pragmatic Hedonic
23	Product	Mobile	Effectiveness Efficiency Satisfaction Productivity Learnability Safety Accessibility Generalizability Understandability	Pragmatic Hedonic
26	Product User System	Mobile AR	Service Quality Pragmatic Quality Hedonic Quality Stimulation Hedonic Quality Identity Attractiveness Emotion	Pragmatic Hedonic
27	Product User	General	Efficiency Effective Satisfaction	Pragmatic Hedonic
28	User	Entertainment Apps	Psychology Metric	Hedonic

Research on the measurement of UX in MAR still provides opportunities for further discussions as previous research only discussed UX as an indispensable phenomenon in building AR application. Moreover, applications that use AR technology are generally associated with innovation technologies such as mobile devices, wearable computers, and immersion technologies. Because it involves other objects such as wearable, immersion technology, and mobile devices, the measurable UX components do not include the Product Component and User Components as well as Service and Infrastructure Components.

New existing measurements in AR applications are used for common needs such as seeking information, but not specific measure of MAR in Education. Meanwhile, many educational applications have used AR technology. However, the review has not identified any metric for measuring UX from AR Education application. According to

Wu et al., in developing an AR application for education, it is necessary to consider three approaches: role approach of the user whether as a single player or multiplayer, location approach in terms of how users interact with the physical environment, and the task approach which is how to design learning tasks in the AR application [31]. Understanding the three approaches is required in developing an AR application which influences how UX is evaluated.

In measuring the user experience, the tasks and users need to be understood. Then, several metrics in the measurement can be combined [32]. Based on the results of the review of related research and the analysis of the characteristics of applications with Augmented Reality technology in education that takes into account the role, location and task, the writer proposed a standard metric developed by Tullis and Albert [11] that uses usability metrics to be processed into UX metrics. There are four categories of metrics: performance metrics which are measurements based on user behavior in the tasks given, including errors made during the task; the second metric is issue based metric which is a UX measurement based on issues related to the usability issue that will affect the UX of a single application; the third metric is self-reported metrics related to user perceptions when interacting with applications, such as ease of use, usefulness or awareness of features that exist in the app; the last metric is behavioral and physiological metrics that are metrics related to user behavior and emotions to know the experience felt by the users deeper. The last metric generally uses additional software to measure emotions or gestures of users while interacting with the app.

Table 2 User Experience Measurement for AR Education Application

UX Component	Metric
Product	Performance Metric, Issue Metric
User	Performance Metric, Issue Metric, Behavioral and Physiological Metric
System	Performance Metric, Issue Metric
Service	Performance Metric,

The authors adapted UX metrics used in previous research and the Usability metric to measure UX from educational AR applications (See Table 2). If it is still in the development stage, AR Education application needs an additional Issue Metric to measure how many issues or problems that occur and how many participants who experienced the issue. However, if it is already in the implementation stage, UX Metrics is used in terms of UX aspects, namely pragmatic aspect which consists of performance metrics, and hedonic aspect including Self-Reported Metric and Behavioral and Physiological Metrics. The performance metrics can be made more detailed regarding the sections of metrics such as the number of successful tasks, user learning ability, and the time required to complete a particular task. Self-Reported Metrics relates to the ease of use of the AR application to learn something, including the level of ease of using AR technology that is a new technology. Further, the need for a User Control metric to measure the extent to which the user plays a role in interacting with the application of the AR. To find out if the user experiences difficulties in using AR as a new learning method, measurement of user emotion when using this AR Education application can be added.

The UX Component of AR Education application can be divided into four components: Product, User, System, and Service. In Education, it can measure users' learnability using performance metric such as how long the use can complete the task, how many uncomplete tasks. Also, Issue Metric can measure how many errors that users find when navigating the application. Behavioral and physiological metrics can measure emotions of users when learning from AR applications.

5. Conclusion and Future Work

Good user experience can help users accept applications. Moreover, AR technology is developing and interacting with new equipment. Therefore, UX measurement is not limited to products in the form of applications and users, but also includes Service and Infrastructure available.

Measurement of User experience has a close relationship with Usability measurement. Data obtained from usability can be used as a metric in UX measurements. The results of the review can be adapted/combined to measure the quality of UX of AR applications in the field of education; the measurement should pay attention to Performance metrics, Self-reported metrics and Behavioral and Psychological Metrics. UX aspects measured include Pragmatic Aspect which includes completion of assigned tasks and Hedonic aspect which includes user satisfaction when interacting with the applications.

The authors' suggestions still need to be evaluated by examining the UX in AR educational applications. It is also necessary to determine the appropriate UX evaluation method for evaluating the UX of an AR Education Application.

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