Usability Testing Method in Augmented Reality Application

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***Abstract*— Evaluation on system or software is important thing to do, when developing a software or system. This step will ensures yours developed system or software has high quality in functionality or non-functionality needs. Several methods can be used to evaluate the Augmented Reality application: subjective measurement using human perception or objective measure from observation, or evaluation by expert through cognitive walkthrough, heuristic evaluation, lab observation, and questionnaire. An evaluation is more valid if evaluation was done in multiple methods in order to confirm the result of evaluation.**

Keywords: Subjective measurement, objective measurement, expert evaluation

I. INTRODUCTION

Software metrics plays a key role in good software engineering, measurement is used to assess situation, track progress, and evaluate effectiveness, quality of product and more. Some software builders measure characteristic attribute from the application to get value sense if the requirements are consistent and complete, design in high quality, and code ready to release.

Accordingly to Fenton[1], measuring the software is the process of assigning some number of attributes or symbol of entities in real world, and to compare clearly against defined rules. An entity in context software is an object or a progress event in application development process. Attribute is feature or properties of an entity, such as the cost of maintenance or developing software, size of software, time to build, and quality of software.

A software can be measured from quality dimension point of view. When talking about quality, according to Robert Glass [2] user satisfaction is if product comply with user need, good quality, and delivery with budget and schedule.

Evaluation of a software quality is also a process of software metrics, some sequential activities in this processes give the results on value of software or system for the user.

II. LITERATURE REVIEW

Augmented Reality scientists and software creators have to resolve numerous technological thinking to make usable Augmented Reality software, such as developing tracking and output windows, also input/output devices. Since augmented Reality becomes more mature and more augmented software are builts, evaluating AR software from end user become important [3].

A. User and System evaluation in Augmented Reality(AR) System

When developing an AR System, focus on user-driven design is a significant thing, because in real world application software developer must adapt user-centered design method and assess the system with genuine user, because it's an important step to bring the AR technology into people everyday life[3], why?, because when they satisfied with your application or system they will used it.

When evaluating an AR application, different steps of AR system development need different evaluation strategies, before system tested by the user, developer must evaluate the system performance such as how many time systems can recognize the marker, or natural marker, how accurate the system display pair matches marker with AR 2D/3D model, how precise when overlay the marker with the models, user usability and many more.

Many aspects can be evaluated, for usability Augmented Reality application, for example interaction techniques, in regards to user efficiency and accuracy. Detail evaluation aspect is explained by Mauve [4] in following figure

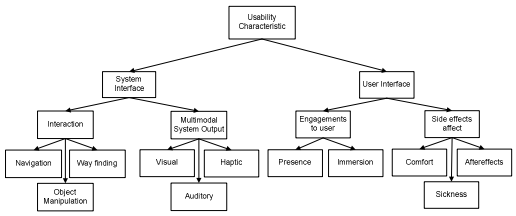

Fig. 1. Usability conducted by MAUVE

According to Stanley Dicks, evaluating the software is suggested to be conducted before the prototype has been finished (when application is developed as prototype), because if application is complete then a usability test will not become relevant , instead a verification examination should be conducted [5].

B. Evaluation types and methods typically use in Augmented Reality User Evaluation

Paper from Swan and Gabbard [6], Dunser and Billinghurst [7] stated that Augmented Reality user evaluations can be categorized into following types :

1. Human perception and cognitive aspect experiment.
2. User task performance examination experiments.
3. Collaboration between users examination experiment.
4. System design evaluation and system usability,.

The method that are used to measure according to Dunser and Billinghurst [3]:

1. **Objectives measurements methods**: result from a repeatable and reliable task of quantitative observations. This method measures: accuracy (average of error), object or user position, time (task completion times), scores from test, and etc.
2. **Subjective measurements methods:** the result based on personal subjective judgement from user, and use questionnaires: grading, rating, or depth judgement.
3. **Qualitative analysis methods:** not concentrated with putting result in statistics number, but qualitative answers, data gathered from structured observation (direct observations, video analysis), and structured, or unstructured interviews.
4. **Expert Usability evaluation techniques method:** not user based evaluation methods like a cognitive walkthroughs or heuristic evaluations by an experts.
5. **Informal testing methods:** user observations (informal) or from feedback during demonstration, get limited finding fact but very common doing in Augmented Reality contexts.

III. METHODOLOGY

The methodology that is used in this literature review is an induction method in which the researcher collected and observes the journals, and conducts the examination on that paper, about evaluation methods performed in each review journal, after that categorizing and analysis that paper, and did small experiment and make conclusion, and also suggests what method should be used in evaluating an application in the term of quality of a software in the aspect of usability and functionality.

IV. DISCUSION

Based on evaluations type and method that can be used in AR user evaluations by Dunser and Billinghurst, the following evaluatin can be categorized as follow [3]:

1. **Type: (1) user perceptions; method: (1) an objective measurements**: paper Gabbard et al[8], research on how user read some text in outdoor Augmented Reality settings; They established several hypotheses and tested, such sighted text displayed on a patterned brick wall or background, user perform slower when accomplish the task, Gabbard et al tested 24 users using Augmented Reality application to recognize a couple of letter in a ransomed position, independent variables observed: background pattern/texture, color of text, style of drawing, and algorithm of drawing, dependent variables observed are time to response and number of error when read, as result user made error with brick background, and no effect of text color.
2. **Type: (1) user perception, the method: (2) an subjective measurement**: Knörlein et all. [9] assed effect of delay time when visualization the object and the haptic delay on perception of difficulty when using Augmented Reality application, 14 participants were asked to wrap a virtual spring in Visio-haptic setting to choose which one they supposed as stiffer. Similar method to evaluate was done by Pribeanu et al [10] their questionaries' measured user three points of quality: (1) Ergonomic Quality(EQ), how easy to understand , learn and remember the application. (2) Learning Quality (LQ), measures perceived efficiency (PEF). Faster and better understanding on outcome of using a Augmented Reality technology [11], [12], also perceived usefulness: universal outcomes such as enhancement of knowledge, usefulness for testing the knowledge and support for learning process [13]. Hedonic quality (HQ) are cognitive engagement refers to the state of total attention when attention is focused on the interaction side when using the Augmented Reality application [14]. Hedonic quality is relevant, because Augmented Reality environments able to mediate immersive user experiences [15], [16]. In perceived pleasures refers to a pleasurable experience

with the application of augmented reality [17]. Pribeanu et al, set learning scenario on chemistry lesson using AR application. After using the application students get 1-5(strongly disagree-strongly agree) scale Likert questions about student perceived to application, data was examined for existence univariate and multivariate outlier which might attenuate the result. Poushneh and Vasques[18] in their work measured the **pragmatic quality (PQ)** aspect**:** utility and usability, a**esthetic quality (AQ)** aspect**:** pleasurable experiences (Physio-pleasure, Socio-pleasure, Psycho-pleasure), and **hedonic Quality (HQ):** emotional experience, playfulness, enjoyment social experiences, novelty and challenge, self-expression, fulfilment requirements for symbolic meanings of objects on augmented reality application. At Poushneh and Vasques[18] research, the respondent or participant randomly assigned to three kind of treatments. Two Augmented Reality treatments, Augmented Reality using Ray-Ban sunglasses and augmented reality virtual model were examined to online shopping, and last treatment is traditional online shopping. The respondent answering someone to seven scale Likert question about perceived quality. At the end of research, it can be that concluded Augmented Reality enriches User Experience online shopping users to better perform in their tasks and increase in value the functionality of the product. It was also conclude that the Augmented Reality is more entertaining, enjoyable and allows potential buyers to have infinite interaction with virtual information of product, give higher user satisfaction when using that application and increase user willingness to buy. Augmented Reality proven enhanced hedonic quality value. Chin-Hung Teng et al [19] did same method when evaluating the Augmented Reality application. The research measured **System usability** aspect: (1) **Learning efficiency:** Learning efficiency could be defined as the speed by novices knowledge or skills are acquired and become fluent like experts [20], levels of proficiency, with which students could successfully perform their tasks during a period of time; (2) **Flow experience:** concentration, goal clarity, autonomy (sense of control), immersion; (3) **Usage perception:** helpfulness, ease of use, enjoyment, efficiency, and preference. In this work the student as object of research treated using AR application to do some exercise openGL basic function like: creating, translating, rotating, and scaling primitive objects. After treatment student answered some 1-5 scale Likert questions about flow experience, usage perception, and system usability. AR-enhanced version enhanced system usability, more proficient and successfully completing exercise, more engaged in learning task than the ordinary version within the given time. Usage perception result, AR-enhanced version offered students an interesting, useful, and easy-to-use way to learn programming for 3D applications. In the research done by Dai-In Han, et al [21] , measured **product features:** content, presentation, functionality, interaction [22], **product character:** pragmatic attributes (manipulation), hedonic attributes (stimulation, identification, evocation), **Consequences:** appeal, pleasure, satisfaction [23]. Dai-In Han, et al [21] asked 49 participants, from British. They were asked some questions concerning on product character. As the outcomes of the focus groups demonstrated that some of the product features noted in the literature were still significant for the development of mobile AR applications. The results showed that tourists were still considering map-based applications for urban heritage tourism settings as one of the most crucial features of a mobile AR application [21].

3. **Type: (2) User performance; method: (1) objective measurement:** Dunser [24] in his research, evaluated spatial ability that can be improved by training with Augmented Reality-based geometry education application. This application allows learner to collaboratively construct a geometry problem in 3D spaces. Two hundreds fifteen high school students, divided into four groups: Augmented Reality based Training, Traditional Computer Based (TCB) Training, a control group with geometry classes and a control group non geometry classes. Student in geometry classes must finished six training geometry tasks. Result from this research concluded that Augmented Reality implementation gave significant and specific effects, but with not strong evidence about of the effectiveness of Augmented Reality application based training. Similar method was used when evaluating this method by Gun A Lee et al [25], Gun A Lee et all at research using Preliminary Online Survey**:** to gather information about aspect easiness, usefulness, enjoyable, usability and overall satisfaction, for: AR View application, AR Map View application, List View application.
4. **Type: (3) an user collaboration method: (1) an objective measurement and subjective measurement:** research by Billinghurst et. al. [26], assessed in what way that different user interfaces support task collaboration, compared head to head task collaboration with Augmented Reality task collaboration, and task collaboration using projection display, they attracted to know how user task collaboration variances among two these setting. Fourteen participant pairs were given two tasks to resolve an inner-city logic puzzle and task to place 9 object/building to complete ten tasks in seventh minute. When doing this research billinghurst used

video to capture the behaviour of participants and analysed or observed various communication methods measurement, counting number of gesture, mean number of words in one phrase when they communicated , and number turn in conversation, completion time and data result collected from questionnaire. They found the fact that performance with Augmented Reality support collaboration became slower compared to head to head and projection condition and user did different gesture behaviour, pattern of speech between the conditions.

5. **Type: (2) an user interaction and collaboration; method (3) a qualitative analysis and subjective measures:** research by Morrison and friend [27] conducted a qualitative research to analyse user performance and complement with survey or opinion poll data. They also studied the user interactions and collaborations of GPS or a location-based Augmented Reality mobile-game. Twenty-six participants as part of research were divided in pair or team of three person, used an Augmented Reality mobile game user interface, equipped with a paper-based map. There were also eleven participants used two dimension mobile application map to solve several problems with some clues. During the game, researcher followed the participants and took notes, video, and photographed the participants, and will be used as qualitative analysis later. In addition, data also completed with questionnaire from interviews. Result showed that participants who are using two dimension mobile application maps completed game faster than those who are using Augmented Reality based map, and exposed less focus on user interface itself.
6. **Type: (4) a system usability and system design evaluation; method: a qualitative analysis:** research was done by Nilsson and Johansson [28] to investigate the participant experience of instruction that were given by Augmented Reality application in medical atmosphere. This research showed 2 qualitative research to explore user acceptance and user experience of instructional based Augmented Reality application. Twenty participants were divided into eight persons on first step study and twelve persons on second step study. The Augmented Reality system used head mounted display, marker tracking, microphone and speech recognition feature for simple command input use speech and keyboard. The respondents accept Augmented Reality based directions as the way to prepare and activate medical or tools gear for operation process, after that they had to assembly a medical equipment from direction they heard before. Observation and questionnaire, showed the facts that using Augmented Reality-based instruction get positive response, and any instruction can be received from experience teacher, suggest the Augmented Reality system, develop more interactively. During experiment Augmented Reality system also showed problem of ergonomics issues and distraction because visibility of marker.
7. **Type: (4), a system design, system usability evaluation; method: (4) usability evaluation methods, and or quantitative analysis and others methods.** Research conducted by Hix et al.[29] offer a good sample method of in what way Augmented Reality system can be assessed or evaluated with a completed set of usability evaluations methods, which are discourse a model for a cost efficiency and effeteness usability evaluation and development, established practical of evaluation technique by define interface design and usability evaluation for an open-air Augmented Reality Application. Joao Paulo Lima [30] measure the aaccurate placement of 3D object, on 3D key points, calculate average re projection error., and time to placement of 3D object. They used two method: single reconstruction and multiple reconstruction: Scenario 1: track the rotating model from fixed position, visualized, and identify 3D challenge point and overlay the car model with 3D. Scenario 2: tracking different part of real Volkswagen Golf (engine with limited tracking area, interior from driven seat and no reference point, trunk with variable of light, fender with low detail). They measure the accuracy between reference point (marker), with 3D coordinate, quality (jittering, sensitivity) when illuminate in extreme conditions, and number occasionally error when scenes have low detail. Jianren Wang et al [31] measured the tracking result, with or without using prioritization method and static transformation error compensation in multiple camera mobile device. As result an effective and simple multi-camera collaborative tracking approach which proposed that can overcome occlusion problem in augmented reality applications and reduce uncomfortable experience for the user caused by the temporary unavailability of tracking units [31]. Yi Cao et al [32] research measure Number of image matches between image in dataset and image in data references, image dataset is given little distortion to test whether the tried algorithm still delivers results with high accuracy. Yi Cao et all extracted each image in dataset: extract the featured, and select specific number features as proposed features and perform k-dimensional (KD) to produce training structure to obtains the references feature search spaces, the augmented reality application perform the nearest neighbour search using KNN (k=1) and conducted verification using geometry verification (RANSAC) to ensure positive matching. Using the number of positive matching as precision calculation. S. Ye, C. Liu [33] research measure the number of match point references

in frame by frame tracking methods. Video dataset extracted its features by using Makars-displacement, Makars-IOT, TLC and KLT-IOT methods, searched for the smallest average error distance range, tried video consists of four video classes, namely: normal image quality, image with noise, occlusion, and illumination changes.

TABLE I. EVALUATION AND METHODS

Methods	*Authors*	*Year*
• Perceptions • Objective measurements	Gabbard and Swan [8]	2008
• Perception • Subjective measurement	Knörlein et al. [9]	2009
	Pribeanu et al [10]	2016
	Poushneh and Vasques[18]	2016
	Chin-Hung Teng et al [19]	2017
	Dai-In Han, et al [21]	2017
• Performance • Objective measurement	Dunser [24]	2006
	G. A. Lee [25]	2012
• User collaboration • Objective measurement and subjective measurement	Billinghurst et. al. [26]	2002
• User interaction (and collaboration) • Qualitative analysis (and subjective measures)	Morrison et al. [27]	2009
• System usability, system design evaluation • Qualitative analysis	Nilsson and Johansson [28]	2008
• System usability, system design evaluation • Usability evaluation techniques, or quantitative analysus (and or others methods).	Hix et al.[29]	2004
	Jianren Wang et al [31]	2017
	Yi Cao et al [32]	2015
	S. Ye, C. Liu [33]	2017

V. CONCLUSION

The main purpose of software metrics is to perform a measurement of an application, in term of product, process, project and people. To measure the quality aspects of a software we can use the ISO 9126-1 as the standard reference, aspects assessed: functionality, reliability, usability, efficiency, maintainability, and portability[34].

Three methods of evaluating usability are: testing, inspection and inquiry, based on Nielsen J [35], and several other authors of these methods consist of: **(1)Testing Methods** (coaching method, co-discovery learning, performance measure, question asking protocol, remote testing, retrospective testing, shadowing method, teaching method, thinking aloud protocol); **(2) Inspection Methods** (cognitive walkthroughs, feature inspection, heuristic evaluation, pluralistic walkthrough, perspective-based inspection); **(3) Inquiry Methods** (fields observation, focus groups, interviews, logging actual use, proactive field study, questionnaires).

To give stronger conclusion author did small experiment to measure the usability of three Augmented Reality applications, using inquiry method by interviewing 10 respondents with questions about: (1) easiness the application to accomplish the task given, (2) how easy to use the application, (3) application feedback when user did some wrong step, (4) and overall user assessment of the app. Authors also make observations of the number of errors and the time required by each respondent to complete the tasks in the three applications. From the experiment we can see positive correlation between result from interview and observation to time completion and number of error during task, the first application to get the lowest score in the interview, three of the five ranges, also confirmed to have the longest completion time between the two other applications, compared to the application that gets the highest score in the interview is the third application, application confirmed get a fairly good completion time (44 seconds), below the second application whose average completion is 41 seconds but with an average number of errors more. As table below.

TABLE II. QUESTIONARRY AND OBSERVATION RESULT

App #	Interview					Observation	
	Q1	Q2	Q3	Q4	mean	Time avg	Error avg
1	3.29	3.3	2.9	2.57	3	105s	25
2	3.1	4.7	4.7	3.7	4.1	42s	8
3	4	4.6	4.3	3.7	4.3	43s	6

The conclusion if we did right procedure of measurement, two methods or more of measurement will give the same pattern or similar result. This means that the result of one method will support or confirm the result of the other method, if you want a more valid measurement then we have to use more than one measurement method. Author suggested, in the future when performing a usability evaluation of an application or system, the evaluation technique should measure user perception, objective measuring by observation or experiment, and evaluation form expert, we can combine several methods mentioned above.

REFERENCES

[1] N. Fenton and J. Bieman, Software Metrics A Rigorous and Practical Approach, 3rd ed. CRC Press, 2014.

[2] R. L. Glass, "Defining quality intuitively," IEEE Softw., vol. 15, no. 3, pp. 103–104, 107, 1998.

[3] D. Andreas and M. Billinghurst, "Handbook of Augmented Reality," pp. 289–307, 2011.

[4] K. M. Stanney, M. Mollaghasemi, L. Reeves, R. Breaux, and D. A. Graeber, Usability engineering of virtual environments (VEs): Identifying multiple criteria that drive effective VE system design, vol. 58, no. 4. 2003.

[5] R. S. Dicks, “Mis-usability : On the uses and misuses of usability testing,” SIGDOC ’02 Proc. 20th Annu. Int. Conf. Comput. Doc., pp. 26–30, 2002.
[6] J. E. Swan II, J. L. Gabbard, and M. Hall, “Survey of User-Based Experimentation in Augmented Reality,” Proceeding 1st Int. Conf. Virtual Real., pp. 1–9, 2005.
[7] A. Dünser, R. Grasset, and M. Billinghurst, “A survey of evaluation techniques used in augmented reality studies,” ACM SIGGRAPH ASIA 2008 courses, no. September, p. 5, 2008.
[8] J. L. Gabbard and J. E. S. II, “Usability Engineering for Augmented Reality : Employing User-Based Studies to Inform Design,” vol. 14, no. 3, pp. 513–525, 2008.
[9] B. Knörlein, M. Di Luca, and M. Harders, “Influence of visual and haptic delays on stiffness perception in augmented reality,” Sci. Technol. Proc. - IEEE 2009 Int. Symp. Mix. Augment. Reality, ISMAR 2009, pp. 49–52, 2009.
[10] C. Pribeanu, A. Balog, and D. D. Iordache, “Measuring the perceived quality of an AR-based learning application: a multidimensional model,” Interact. Learn. Environ., vol. 4820, no. February, pp. 1–14, 2016.
[11] D. D. Iordache Dr, C. Pribeanu, and A. Balog, “Influence of specific ar capabilities on the learning effectiveness and efficiency,” Stud. Informatics Control, vol. 21, no. 3, pp. 233–240, 2012.
[12] M. N. Redó, A. Q. Torres, R. Quirós, I. N. Redó, J. B. C. Castelló, and E. Camahort, “New Augmented Reality Applications,” Teach. through Multi-User Virtual Environ., pp. 365–386, 2010.
[13] E. Ai-Lim Lee, K. W. Wong, and C. C. Fung, “How does desktop virtual reality enhance learning outcomes? A structural equation modeling approach,” Comput. Educ., vol. 55, no. 4, pp. 1424–1442, 2010.
[14] P. Zhang, N. Li, and H. Sun, “Affective quality and cognitive absorption: Extending technology acceptance research,” Proc. Annu. Hawaii Int. Conf. Syst. Sci., vol. 8, no. C, pp. 1–10, 2006.
[15] M. Dunleavy, C. Dede, and R. Mitchell, “Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning,” J. Sci. Educ. Technol., vol. 18, no. 1, pp. 7–22, 2009.
[16] H. K. Wu, S. W. Y. Lee, H. Y. Chang, and J. C. Liang, “Current status, opportunities and challenges of augmented reality in education,” Comput. Educ., vol. 62, pp. 41–49, 2013.
[17] H. van der Heijden, “User Acceptance of Hedonic Information Systems,” MIS Q., vol. 28, no. 4, pp. 695–704, 2013.
[18] A. Poushneh and A. Z. Vasquez-Parraga, “Discernible impact of augmented reality on retail customer’s experience, satisfaction and willingness to buy,” J. Retail. Consum. Serv., vol. 34, no. September 2016, pp. 229–234, 2017.
[19] C. Teng, J.-Y. Chen, and Z. Chen, “Impact of Augmented Reality on Programming Language Learning,” J. Educ. Comput. Res., p. 73563311770610, 2017.
[20] G. Kolfschoten, S. Lukosch, A. Verbraeck, E. Valentin, and G.-J. de Vreede, “Cognitive Learning Efficiency through the Use of Design Patterns in Teaching,” Comput. Educ., vol. 54, no. 3, pp. 652–660, Apr. 2010.
[21] D. Han, M. C. Dieck, T. Jung, D. Han, M. C. Dieck, and T. Jung, “User experience model for augmented reality applications in urban heritage tourism urban heritage tourism,” J. Herit. Tour., vol. 0, no. 0, pp. 1–16, 2017.
[22] M. Hassenzahl, “The Thing and I: Understanding the Relationship Between User and Product,” in Funology: From Usability to Enjoyment, M. A. Blythe, K. Overbeeke, A. F. Monk, and P. C. Wright, Eds. Dordrecht: Springer Netherlands, 2005, pp. 31–42.
[23] L. Deng, D. E. Turner, R. Gehling, and B. Prince, “User experience , satisfaction , and continual usage intention of IT,” Eur. J. Inf. Syst., vol. 19, no. 1, pp. 60–75, 2010.
[24] A. Dünser, K. Steinbügl, H. Kaufmann, and J. Glück, “Virtual and augmented reality as spatial ability training tools,” Proc. 6th ACM SIGCHI New Zeal. chapter’s Int. Conf. Comput. Interact. Des. centered HCI - CHINZ ’06, pp. 125–132, 2006.
[25] G. A. Lee, A. Dunser, S. Kim, and M. Billinghurst, “CityViewAR: A mobile outdoor AR application for city visualization,” in 11th IEEE International Symposium on Mixed and Augmented Reality 2012 - Arts, Media, and Humanities Papers, ISMAR-AMH 2012, 2012, pp. 57–64.
[26] M. Billinghurst, H. Kato, K. Kiyokawa, D. Belcher, and I. Poupyrev, “Experiments with Face-To-Face Collaborative AR Interfaces,” Virtual Real., vol. 6, no. 3, pp. 107–121, 2002.
[27] A. Morrison et al., “Like Bees Around the Hive : A Comparative Study of a Mobile Augmented Reality Map,” pp. 1889–1898, 2009.
[28] S. Nilsson and B. Johansson, “Acceptance of augmented reality instructions in a real work setting,” Proceeding twenty-sixth Annu. CHI Conf. Ext. Abstr. Hum. factors Comput. Syst. - CHI ’08, p. 2025, 2008.
[29] D. Hix et al., “A Cost-effective Usability Evaluation Progression for Novel Interactive Systems,” 37th Annu. Hawaii Int. Conf. Syst. Sci. 2004. Proc., vol. 0, no. January, pp. 1–10, 2004.
[30] J. Paulo Lima et al., “Markerless tracking system for augmented reality in the automotive industry,” Expert Syst. Appl., vol. 82, pp. 100–114, 2017.
[31] J. Wang, L. Qian, E. Azimi, and P. Kazanzides, “Prioritization and static error compensation for multi-camera collaborative tracking in augmented reality,” in 2017 IEEE Virtual Reality (VR), 2017, pp. 335–336.
[32] Y. Cao, C. Ritz, and R. Raad, “Feature selection for low bit rate mobile augmented reality applications,” Signal Process. Image Commun., vol. 36, pp. 115–126, 2015.
[33] S. Ye, C. Liu, Z. Li, and A. Al-Ahmari, “Iterative Optimization for Frame-by-frame Object Pose Tracking,” J. Vis. Commun. Image Represent., no. January, 2017.
[34] I. S. Organization, “ISO 9126 Software Quality Characteristics :An overview of the ISO 9126-1 software quality model definition, with an explanation of the major characteristics.” 2001.
[35] J. Nielsen, Usability Engineering, First. Morgan Kaufmann, 1993.