

Comparative Analysis of Software Quality Models for the Evaluation of Virtual Reality Contents

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Abstract

As with many software products, the surge in virtual reality (VR) market has been continually and explosively growing as digitization is at its full scale. In this regard, quality models would be essentially important in evaluating the quality of VR contents in various applications to meet user demands and requirements. Quality evaluation may also guarantee safety and comfortability with VR components and user interfaces which are designed for VR based cognition training systems. This paper deals with the comparative analysis of software quality models which can be adapted for the evaluation of VR contents designed for diagnosing cognitive impairments with the elderly. Software quality models will be analyzed attempting to address quality issues for VR contents and its environment in order to guarantee effective diagnosis and increase its usability and accessibility.

Keyword : Virtual reality contents, software quality model, quality evaluation, VR-based cognitive training and program

1. Introduction

Korea has reached the aging society in year 2000 according to Statistics Korea [1][2]. That is, the elderly population accounted to 7.2 percent of the total population and continuously increases as it reached 14.42 percent in year 2018 [3]. It is also predicted that the elderly population will reach 24.3 percent in 2030 and 40.1 percent by the year 2060. The Korean government has been planning and providing more programs for the elderly as recent studies indicate that more than 70% of the elderly were not engaged in leisurely activities and most of them were anxious, bored, not too healthy. In addition to cognitive impairments, a Korean aged 65 or older had an average of 3.34 chronic diseases such as cancer, diabetes, asthma, arthritis, osteoporosis, Alzheimer's disease, and dementia [4].

The government believe that the elderly must be supported to become more productive and active

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members of the society, thus, significant programs to improve the elderly well-being has been planned and implemented. One significant program designed for the elderly was to implement cognitive training programs aiming to improve the cognition skills and functions of the elderly and persons with cognitive impairments. Cognition training has been significant in enhancing the individual's cognition process in order to naturally interact with its environment [5].

The emergence of virtual reality (VR) technology enabled an effective utilization of immersive virtual environments providing a realistic simulation on the tasks within the cognitive training and programs [6][7]. It allows for an immersive performance of an individuals sensory perceptions such as hearing, touch, smell, vision, taste, and kinematics [8]. The adaptation of VR-based technologies in cognitive training and programs increasingly becomes popular and widely accepted [9][10][11].

However, just like other software systems and applications, the quality of VR-based cognitive training and programs is of paramount importance for its effectiveness and usability. Moreover, one of the most critical outcome for a quality software system and application is user satisfaction. Unevaluated VR systems can lead to numerous problems such as perceptual issues, user adaptation issues, and human factors. The quality of VR systems must be thoroughly evaluated as problems in such systems can occur at all levels, from hardware, to low-level software, to content creation engines.

This paper deals with the comparative analysis of software quality models for the evaluation of VR-based cognitive training and programs. The set of software product quality international standards will be reviewed and analyzed which has been the basis for the formulation of most software quality evaluation models. Several quality evaluation models which were based on the international standards will also be identified and the results of its comparative analysis will become the basis for introducing new concepts and methods for the evaluation VR-based cognitive training and programs to provide greater user satisfaction.

The rest of this paper is organized as follows: Section 2 provides an overview of the international standards of software quality evaluation; the comparative analysis of software quality evaluation models is outlined in Section 3; the discussion on the results is outlined in Section 4; and the concluding remarks and future research directions were presented in Section 5.

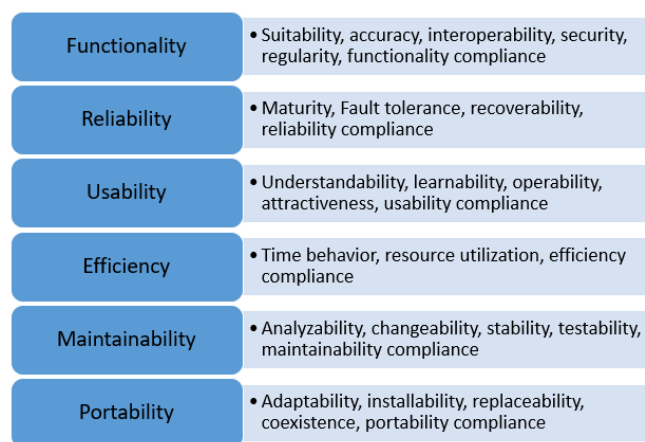
2. The International Standards on Software Quality Evaluation

The international standards on software quality evaluation provides a general framework in order for organizations to define a quality model for their software systems or applications. These standards will

be serving as the basis for designing certain quality models for specific software system such as the VR-based cognitive training and programs. Such that, the target values for the software quality metrics can be specified in evaluating the level of software quality attributes.

2.1 The ISO/IEC 9126 International Standard

The ISO/IEC 9126-1 is a generic software quality model that can be customized to specifically evaluate the quality of VR-based cognitive training and programs. This standard generally aims to address the well known human biases that skeptically prevent the efficient delivery and perception of software systems and applications [12][13]. It is divided into four parts: the quality model, internal metrics, external metrics, and the quality in use metrics [13].



[Fig. 1] Software Quality Criteria based on ISO/IEC 9126

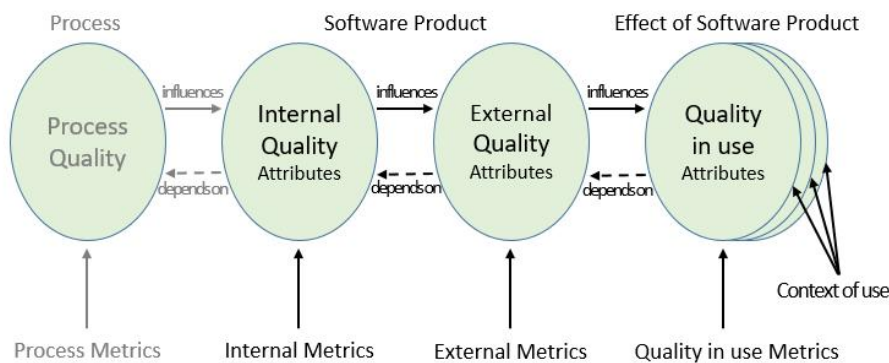
The first part which is the quality model is defined by ISO/IEC 9126-1 and is comprised of 6 characteristics as described in [Fig. 1]. The 6 main quality characteristics of a software product includes:

- *Functionality* which is defined as the set of attributes pertaining to the set of software functions and their specified properties. The software functions performs to the satisfaction of the specified requirements.
- *Reliability* is defined as a set of attributes that signifies the software's capability to maintain its level of performance under stated conditions for a stated period of time.
- *Usability* is defined as a set of attributes pertaining to how users utilize the software based on its purpose.
- *Efficiency* is defined as a set of attributes that signifies the level of performance of the software

based on the utilized amount of resources within certain conditions.

- *Maintainability* is defined as a set of attributes that bear on the effort needed to make specified modifications.
- *Portability* is defined as a set of attributes characterizing the software's ability to adapt into another environment when transferred.

Each software quality criteria (e.g., functionality) is divided into subcharacteristics (e.g., suitability, accuracy, etc.) which are individually measured through a set of metrics defined by the standard. Then, each subcharacteristic (e.g., suitability) is further divided into attributes which are used in verifying or measuring the subcharacteristic but were not defined by the standard as they vary depending on a software system or application.



[Fig. 2] Software Quality Lifecycle on ISO/IEC 9126

The internal metrics are defined as the attributes that can be verified or measured without software execution, while external metrics are defined as those attributes that can be measured while evaluating a running software. The quality in use metrics refers to the software product's effectiveness, productivity, safety, and satisfaction which are used in evaluating the final software system utilized in real conditions. The software quality lifecycle is depicted in [Fig. 2] indicating the relationship where the internal quality attributes determines the external quality attributes and the external quality attributes determine the quality in use attributes.

2.2 The ISO/IEC 25010 International Standard

The ISO/IEC 9126 was replaced by ISO/IEC 25010:2011 Systems and software engineering - Systems

and software Quality Requirements and Evaluation (SQuaRE) - System and software quality models on March 1, 2011 which is a more extensive series of standards [14][15]. This standard has 8 software quality main characteristics and 31 subcharacteristics as identified in [Fig. 3].

Functional suitability	• Functional Completeness, Functional Correctness, Functional Appropriateness,
Performance Efficiency	• Time Behavior, Resource Utilization, Capacity
Compatibility	• Co-existence, Interoperability
Usability	• Appropriateness Recognizability, Learnability, Operability, User Error Protection, User Interface Aesthetics, Accessibility
Reliability	• Maturity, Availability, Fault Tolerance, Recoverability
Security	• Confidentiality, Integrity, Non-repudiation, Authenticity, Accountability
Maintainability	• Modularity, Reusability, Analyzability, Modifiability, Testability
Portability	• Adaptability, Installability, Replaceability

[Fig. 3] Software Product Quality Characteristics based on ISO/IEC 25010:2011

The ISO/IEC 25010:2011 standard updates the former standard and added security and compatibility as main software quality characteristics. This model can be utilized by the developers and organizations as their basis for specifying and evaluating software systems such as VR-based cognitive training and programs. This quality evaluation standard can be beneficial into the different phases and activities of the development of VR-based cognitive training and programs such as the following:

- VR-based cognition training system requirements identification;
- VR-based cognition training system requirements validation;
- identification of the VR-based cognition training system's design objectives;
- identification of the VR-based cognition training system's testing objectives;
- quality control criteria identification;
- VR-based cognition training system acceptance criteria identification

3. Comparative Analysis of Software Quality Evaluation Models

This section identifies several software quality models that were based or derived from the international standards for evaluating software quality. In addition several open source software evaluation models were also described that can be applicable for evaluating VR-based cognitive training and programs. Then, the comparative analysis of the identified quality models will be discussed.

The Bertoa quality model is based on the then ISO/IEC 9126 international standard which defines a set of quality attributes in the effective evaluation of commercial off-the-shelf (COTS) software components [16]. These COTS components can be adapted by developers and software development companies to build more complicated software systems. The Bertoa quality model for COTS subdivides the subcharacteristics in ISO/IEC 9126 into runtime and life cycle subcharacteristics.

The Component based Quality Model (CBQM) is generally aimed to address the problems on the two inseparable questions that arises in Component-Based Software Development (CBSD) approaches which are based on software components reuse [17]. The reuse can be done through selecting appropriate software system components and assembling them. These questions include issues regarding the measurement of the component's quality, and the measurement of the software system's quality based on the components. Thus, to address these issues, the CBQM framework was developed to define the overall quality of software components and the entire software system itself; the metrics that enables the measurement of size, complexity, reusability, and reliability of each of the software components and the software system as a whole.

The Alvaro software quality model defines a framework for the evaluation and certification of software components to establish their quality [18]. This model also aims to address the problems concerning with software development based on Component-Based Software Engineering (CBSE) which is regarding the quality of the components used in a software system. Generally, the reliability of a component-based software system depends on the reliability of its components. Thus, it is essentially important to efficiently select and evaluate software components before they can be considered for the development of any effective component-based software system.

There are also open source software (OSS) evaluation models that can provide organizations or users with the tools to evaluate and measure the trustworthiness, suitability, and quality of open source softwares. The Capgemini Open Source Maturity Model (C-OSMM) which was developed in 2003 by Capgemini company aiming to assist decision making in the determination of which open source product

is suitable for an organization [19][20]. This model is based on the software product's maturity and keeps away immature software products from organizations. The model utilizes maturity indicators (e.g., usability, interfacing, performance, reliability, etc.) in measuring or evaluating software products.

The Open Business Readiness Rating (Open BRR) framework is developed by Carnegie Mellon West University, Spike Source, Intel and O'Reilly's in 2005 which was influenced by the C-OSMM and ISO/IEC 9126 models [19][20]. The Open BRR also aims to assist the decision making in the evaluation and determination to which open source software product would be most suitable for the needs of an organization. The model includes 4 phases of software assessment:

- *Phase 1: Quick assessment filter.* The components that does not meet the basic criteria were removed and filtered out of the open software selection.
- *Phase 2: Target usage assessment.* The selected components will be assessed using 12 categories (i.e., 1 is the highest, 12 is the lowest) and 7 categories will be selected to allocate a percentage of importance for each component.
- *Phase 3: Data collection & processing.* The measured data used in the corresponding category will be collected and the weighing applied for measurement will be calculated.
- *Phase 4. Data translation.* The BRR score is calculated based on the category ratings and the functional weighting factors.

The Navica Open Source Maturity Model (N-OSMM) is developed by Bernard Golden, the Navica's CEO, in 2004 aiming to assist organizations in evaluating open source software products as well as determine whether such software product can realize the requirements and needs of the organizations [19][20]. The evaluation process of N-OSMM consists of 3 phases: assess vital product elements, define a weighting factor for each product element, and calculate the product's overall maturity score.

The Methodology of Qualification and Selection of Open Source Software (QSOS) is developed by Atos origin which is developed primarily to focus on the qualification and selection of free and open source software based on its support and technological surveys [19][20]. The QSOS model evaluation process consists of 4 phases: Definition, Evaluation, Qualification, and Selection.

- *Phase 1: Definition.* This phase covers the definition of the component's characteristics with respect to software families, type of license, and types of communities.
- *Phase 2: Evaluation.* This phase covers the evaluation of the components through the collection of information from the open source communities.
- *Phase 3: Qualification.* This phase covers the identification of filters and constraints for the

selection of OSS components.

- *Phase 4: Selection.* This phase covers the selection of the components based on user requirement.

Software quality evaluation models plays a vital role in the success of software systems as well as its effectivity and suitability for businesses and organizations. The identified software quality models can be the basis for the design of tailored evaluation models which can be designed specifically for a particular software system or software category such as the VR-based cognitive training and program.

4. Discussions

This section provides an analysis of various software quality models that can be applicable for evaluating the suitability and quality of VR-based cognitive training and programs. The quality model can determine the quality characteristics that will be the basis for the evaluation of VR-based cognitive training and programs [21][22]. Quality evaluation is essentially necessary to measure the degree of how satisfactory the software system is to meet the needs of users and organizations.

[Table 1] Phases for the Evaluation Process of VR-based Cognitive Training and Programs

Phases	Description
Definition of Quality Requirements	The quality requirements must be defined. The characteristics and subcharacteristics of quality model must be selected and prioritized based on ISO/IEC 25010:2011. The quality characteristics and subcharacteristics must be arranged based on each component of the VR-based cognitive training and programs
Evaluation Preparation	The metrics for the evaluation must be defined to impose a matrix of measuring the quality of each component and the VR-based cognitive training and program as a whole. Each component can have a different evaluation metric (e.g., hardware, software).
Evaluation	The implementation of the evaluation metrics to evaluate and measure the quality of each component and the VR-based cognitive training and program as a whole.

The emergence of VR technologies in cognitive training and programs has been rapidly evolving and to guarantee the best results in terms of training effectiveness and user satisfaction, quality evaluation must be implemented to its development. The quality model for VR-based cognitive training and programs can be consists of quality requirements definition phase, evaluation preparation phase, and

evaluation phase. This tailored model will be based on the current international standard, ISO/IEC 25010:2011, for quality evaluation of existing software.

This 3 phases of the quality evaluation process as depicted in [Table 1] must be applied on all components of the VR-based cognitive training and programs which includes both hardware and software. Thus, the evaluation also consists of metrics for evaluating and testing the operability, suitability, comfortability, and other quality characteristics of VR hardware components (e.g., head mounted display).

User satisfaction must also take account into the evaluation which refers to the VR-based cognitive training and programs capability to satisfy the user needs and the requirements of organizations.

5. Conclusion

The need for a quality model is essentially important for the suitability, effectivity, and reliability of VR-based cognitive training and programs as well as in user satisfaction. This paper deals with the comparative analysis of software quality models which were patterned from the international standards of software quality evaluation. The international standard for quality evaluation can be tailored to specific software systems where the desired qualities can be designed to best suite the needs of an organization.

The design of the quality evaluation model for VR-based cognitive training and programs can be based on the desired components that the system requires which will be suitable for the needs of the users with cognitive impairments.

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