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Measuring VR QA Success with Key Performance Indicators (KPIs)

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Abstract:
VR, an industry that has grown rapidly in recent years, has many applications in different sectors, and to address these complex applications, proper QA is necessary for appropriate usability. However, it is challenging to determine the level of success of VR QA since it is a new concept that presents some challenges. This paper seeks to discuss the impact of KPIs in evaluating the success of VR QA. It includes technical efficiency, usefulness, features, and usage rates of the learning system's KPIs. The article also describes ways the VR QA can be assessed, including Automation Testing tools, End-user feedback, and Machine learning. Also, industry standards and future outlooks in the VR QA area are discussed in the context of today, and the idea of improvement and evolution of methods of measuring VR effectiveness is emphasized. For this reason, implementing these KPIs and measurement methods will enhance developers' ability to ensure that the provision of VR applications meets the users, stakeholders, and industry standards' expectations.

Keywords: Quality Assurance, Key Performance Indicators, VR Testing, User Experience, Performance Metrics.

1. Introduction

Virtual Reality (VR) is today considered as one of the mainstream technologies that have found a place in many fields of application such as entertainment field, gaming field, health care field, education field, training field, and many more. The advancements of VR technology have increased in the sense that with the high expectations from the clients and consumers, it becomes vital to sync with them in terms of quality and explore new horizons. However, it is much harder when it comes to VR application quality assurance testing as the main criteria go far beyond the underlying software quality and concern spatial perception in a virtual environment.

QA is an important step in creating VR applications because it helps to pick out problems, prevent failures in applications, and provide a smooth and entertaining experience for the end consumer. In this regard, KPIs are used to successfully monitor the performance of VR QA. KPIs allow one to monitor and compare different facets of VR concerning frame rate, latency, user interaction, and immersion. When setting KPIs, the VR developers will be well-placed to develop better applications for customers that are engaging, valuable, and produced with high reliability.

This article is devoted to detailing the use of KPIs in VR QA and presenting means of determining the success of VR applications. It will also discuss ways to assess the effectiveness of VR QA methods such as automated testing and user feedback, as well as other tools and techniques adopted by the leading organizations. Hence, knowing effective KPIs is crucial to sustaining and developing VR technology.

2. Overview of virtual reality (VR) quality assurance (QA)

VR has brought significant changes in the business world, encompassing games, healthcare, education, and training applications. Nevertheless, organizations must incorporate rigorous QA procedures to achieve the highest level of VR quality. This is the fact that VR QA is all about checking whether VR apps are running smoothly and providing accurate and immersive experiences and stability across different hardware platforms.

Thus, it can be stated that there are several specific challenges when it comes to VR QA as opposed to traditional software QA. As discussed, the nature of VR applications means that in addition to metrics related to performance, the assessments of users, comfort, sickness, etc, are also important. Therefore, quality assurance in VR applications has to deal with the object's appearance, sound, and interactivity [1] [11] Thus, VR QA is primarily focused on the absence of any technical problems, a seamless and engaging experience for the end-users, and unified compatibility with various VR platforms [1]

One of the three major areas of VR QA evaluation is based on the technical aspect. The frames per second, the resolution level, and the rendering choice define how comfortable a user can be playing. Lack of smooth appearance, with a low frame rate or rendering, may lead to discomfort, for example, motion sickness, and thus performance evaluation is an integral aspect that makes VR QA a requirement. There is a trend today for ML models for predicting quality in at least XR services, including VR services, to replace the standard approach and offer the value estimate much more accurately [4] They are able to provide an idea of problems that may arise as far as video rendering or 3D scanning that is imperative to ensure the VR experience remains figment free.

Since VR QA involves usability assessment, the latter involves factors that cannot be easily quantified. Human factors, including convenience, active participation, and other related factors that make usage of VR applications in the intended areas highly desirable, are most important. For example, motion sickness, which is an amplified effect of asynchronously frame synchronization or delayed input response, is one of the most crucial factors in the dimension of user satisfaction in VRs [7] Usually, UX assessment in VR is conducted relatively qualitatively, with subjects being asked questions regarding the visual aesthetics, comfort, and the ease with which they could interact with the environment [8]

Another factor of the VR quality assurance is consistent sensory authenticity evaluation—graphics, sound, and haptic feel matching as well [20][15] This is where the difficulty of this assessment is based on determining the extent or the level at which the virtual reality environments replicate actual interaction such as hand gestures or environmental sounds. This sensory quality assessment involves the use of paired-comparison tests in which the users compare the VR experience with reality or with other implementations of VR [3] [17]

3. Role of key performance indicators (KPTs) in VR QA

KPIs are invaluable in the context of QA for VR applications as they provide quantitative means to assess the quality of the created traversable and immersive environments. Since the areas of VR systems are

intertwined with technical and software issues and since the factors that influence user experience significantly include user input, interaction, and the simulations and sensations presented, KPIs give a more quantitative method for assessing quality. In other words, they are helpful not only for controlling the efficiency of the VR systems used in teaching but also for verifying that they meet the necessary quality standards from the users' perspective [4] [9]

In the domain of VR QA, there are halo-metrics such as frame rate consistency, latency, and resolution that help to determine user quality. One aspect is frame rate where low or inconsistent frame rates are detrimental to the user's experience and may cause motion sickness [7] [9] Latency, is a performance that refers to the amount of time that elapses between an action taken by the user and the response of the VR system, equally affects user satisfaction. High latency is always a problem in interactions since it leads to delays and loss of immersion while interacting with either or both parties involved [3]. These technical KPIs are generally measured during the testing phase to control the application usage in terms of performance problems that can be solved in time.

The overall goal of video games is to assess the UX KPIs because they are another significant aspect of VR QA. The following KPIs are concerned with determining the user's comfort while interacting with the VR application and its usability and satisfaction levels. Motion sickness and comfort: Two unavoidable indicators of UX since any errors in design or technology are likely to cause discomfort to the user [9] To capture these aspects, aspects like client reviews, group discussions, and usability studies usually are used by developers [10] Further, there are more quantitative measurements that include eye activity, biometrics in the form of measurements to determine arousal and preferences of the users to the VR environment [19]

In addition to the technological and user experience-oriented measures, sensory-performance indicators have become an emerging issue in VR QA. Sensory immersion, which implies the reproduction of real sensory stimuli in the VR environment, includes the evaluation of video quality alongside auditory and tactile feedback. Some examples of KPIs that may be used in sensory performance are vision acuity, three-dimensional audio, and the dexterity of haptic feedback display [9] [7] This paper identifies sensory Key Performance Indicators, sound, and touch as significant factors that improve the sense of presence and immersion in Virtual Reality through the better rendering of the sounds occurring in the VE and haptic sensations encountered by the user and this is very important in areas such as healthcare, learning and games.

One of the most essential aspects of the use of KPIs for VR QA is the utilization of ML and AI to automate testing and performance measurement. The use of AI solutions in testing allows for analysing a large number of collected pieces of data and accurately predicting possible difficulties, which further enhances the work of QA[9] [1]. For example, it is possible to use ML models for estimating Key Quality Indicators (KQIs) of 360-degree videos or any other type of XR services when it predicts how well the user will interact with immersive environments based on previous data [10] [11] [16]

4. Understanding VR quality assurance (QA)

QA is an important step that takes place before the release of applications based on a VR environment to the end-users of the applications. Because VR environments are composed of interface and content and the user's interaction with the application depends on both the physical and virtual gear and software, QA

remains an integral part of honing these applications. Hence, they offer an optimal experience [1] [19]. Nonetheless, VR QA is unlike the usual software QA since the approaches used in this domain aim to consider the performance indicators, users' experience, and sensory responses to provide a high-quality result.

A. *Definition of QA in VR Applications*

QA of VR can be defined as the assessment and control of VR product quality according to the set standards. This entails technical tests such as functional tests, where the actual deployment is conducted to ensure everything works as expected, and other tests like usability tests for the application's user interface and object validation to check the immersive features [12] [17] There are some fundamental metrics like frame rate, frame rate variability, latency, accuracy, as well as user comfort [12] [18] This is because VR application incorporates interaction, visualization, and haptic feedback into real-time; therefore, QA also has features such as motion sickness, graphical output, and compatibility in any accessible devices [19] [20]

B. *Challenges in Ensuring VR Quality*

Maintaining quality with VR applications is quite complex because of how different aspects of the environment, namely the hardware, the software, and the user, all interact. Some key challenges include:

1). Hardware constraints: VR mostly depends on hardware such as HMDs, sensors, and motion controllers. There are "technical flaws that can be described as low refresh rates, low tracking precision, and hardware overheating [10] [18]. This poses a number of problems related to User Experience (UX) that would not be so critical in a common 2D application comfort and engagement in a 3D space. Other issues include motion sickness, where getting motion sickness while in the VR is quite a big deal, and navigation, where any user gets easily fatigued while in the virtual environment. The role of the human factor is critical, as ergonomics and interaction, in this case, can be inconvenient and cause negativity among gamers [19] [8] [20]

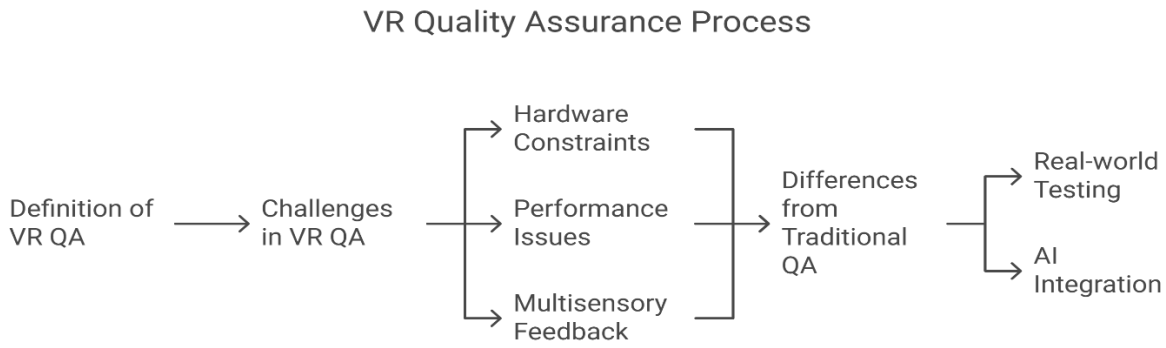
2). Performance and Latency Problems: Real-time efficiency is one of the most important VR features, so performance is critical. Failure to lower latencies results in motion-to-photon delays that would cause motion sickness and discomfort to the users, as noted by [19] [16] Maintaining frame rates above 90 FPS for a good experience is crucial, though that is challenging for both the hardware and software [18] [17]. Multiple elements can be tested in VR applications, mainly since those applications frequently feature complex 3D environments with dynamic features. However, the subjects and objectives of testing in local and global development environments cannot be tested with all possibilities and scenarios, so automated testing approaches are relatively less effective than traditional software QA [9] [17].

3). Multisensory feedback evaluation: The VR system differs from other software and hardware systems where users can only engage most of their sensory organs to receive inputs through a computer only by vision and sound or touch. These elements should also be accurate and synchronized to ensure realism and immersiveness for the target audience [14] [13]. As will be seen in the case of the Zoomorphic treatise,

achieving synchronization between the audio, movements, and visuals can be very complicated, especially with an extensive VR system.

C. Differences between Traditional Software QA and VR QA

In general, the principles of VR QA differ significantly from the traditional software QA principles in the following ways:



Traditional software quality assurance generally focuses on automated testing scripts and scripted test cases; on the other hand, VR-based testing needs real-world testing, given the complexity of the VR applications [12] [18]. Moreover, only a specific setup of the VR QA involves dynamic, motion tracking, spatial audio, and haptic feedback testing [12] [20]

Since VR involves complex experiences and heavily involves using one's senses, an effective outcome and comfortable user experience for all clients require that the testing strategies employed by QA professionals be enjoyable. AI and machine learning for performance evaluation can now be incorporated into VR QA, and this advances the evaluation of quality problems more efficiently [10] [1]

As a practice, VR Quality Assurance presents a number of disparities from the run-of-the-mill QA-Testing, keeping in mind the end goal, the advancements in technology, essential usability, and the general sensory evaluations. Organizing and developing better approaches and leveraging the assistance from AI tools enable delivering high quality VR experiences as the technology progresses. By appreciating such differences and challenges, the fields where virtual reality is applied guarantee maintaining the highest quality or interaction in its applications.

5. Discussion

Using KPIs in Virtual Reality (VR) Quality Assurance (QA) has implications and prospects for both benefits and drawbacks. The solution has been made to conform to the evaluation criteria of the VR applications by using the technical, user experience, and sensory performance metrics to evaluate the solution that has been developed [12] When these aspects of the proposed VR system are used as KPIs, developers can improve VR and solve problems like motion sickness and system inefficiencies [2] [12] In addition, the application of AI and ML into QA processes has a possible application of automating performance assessments, thus enhancing the scale and effectiveness of VR testing [18] [8]

Despite these advantages, VR QA faces several challenges, particularly in hardware limitations, usability evaluation, and the complexity of real-time interactions [7]. Compared to the software QA, VR applications need multisensory testing, simulations of real-life situations, and embracing feedback to measure the rates of immersion correctly [8]. Another challenge that has not been solved yet is to achieve a high frame rate and low latency since users may feel uncomfortable in case of performance degradation [6] [9]

Another critical issue is the subjectivity of the users' experience measurements. Hence, although exact indices like latency and resolution can be measured quantitatively, attributes like comfort and interest are non-parametric and difficult to quantify [16] [6]. This can be done through the use of feedback from users, surveys, and the collection of biometric data to overcome this problem, but this creates variability since people have different perceptions and levels of adaptation to VR [2] [7] Secondly, maintaining application compatibility is still a problem since VR applications should run on various devices and equipment [9] [7]

In the foreseeable future, VR QA advancements will likely improve KPIs, AI testing tools, and the evaluation framework. The further evolution of AI applications for predictive analytics in QA can improve automation testing, partially eliminating the necessity for manual testing [9] [2] [6] Furthermore, as a new technology, the adoption of VR in different sectors, such as healthcare and education will likely require specialized KPIs to measure the effectiveness of the applications under different [8] [2]

Thus, KPIs' contribution to the provision of quality VR applications is extremely important, but their execution requires an approach that should include both quantitative and qualitative perspectives. Overcoming these challenges calls for technology advancement and teamwork between companies in developing VR QA's future prospects.

6. Conclusion

Given that Virtual Reality (VR) is the future of technology in social and business domains, Quality Assurance (QA) must be central in facilitating operations and meeting standard and customer expectations. KPIs are an orderly way of measuring VR applications based on technical and user-centered factors, usability, and specificity [9]. Broad factors like frame rate, latency, and immersion can be optimized to increase the quality, immersion as well as smoother feelings to the end users of the VR applications [15] [9]

Nonetheless, some issues are still present when KPIs are applied in VR QA, including the following The reasons are numerous, the most apparent being the presence of real-life hardware constraints, motion sickness, and the challenges of figuring out how to properly test the incorporation of multiple sensory experiences into the virtual reality platform, all of which placed the testing of VR above and beyond traditional software [3] [7]. However, the use of user experience metrics poses challenges to QA since some of the measurements are more opinion-based, and this makes the flow of the quality assurance process hard to govern since the effectiveness combines automated testing, user feedback, and Biometrics data analysis as stated by Smith and Patel (2018). The issue of cross-compatibility adds to the challenge regarding VR QA because the application has to work across multiple platforms and operating systems [5] [8]

In the future, AI integration and the use of ML in VR QA are supposed to bring imperatives of analytics and automation in performance testing [9] [5] With the growing application of VR in education, healthcare, and training, it will be essential to have VR KPIs relevant to each industry to properly

determine the efficiency of the VR application [1] [4] [5] The consistent advances in technology together with standardization of the VR QA procedures will be pivotal in the enhancement of the VR quality, consumers satisfaction and development of various VR applications.

All in all, despite the issues described above regarding VR QA, the use of KPIs, and employing the opportunities of AI solutions, we will reach the qualitative and quantitative growth of VR applications. In order to sustain the development of advanced VR experiences, developers need to pay more attention to some current problems and optimize the QA processes.

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