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ANALYSIS OF OPTIMIZATION METHODS OF WEB RELATIONSHIPS WITH AUGMENTED REALITY

Annotation. Topicality. With the development of mobile and wireless technologies, AR has received a new post for integration into the full life, in particular with the help of WebAR. The technology is rapidly being introduced into other fields such as commerce, medicine and education. However, other technical challenges include standards for 3D technologies in web applications, which limit the quality and performance of AR applications. Optimizing these applications is an important aspect to improve the user experience and expand the application of AR in various industries. **The purpose** of this work is the analysis of optimization methods of web applications with augmented reality. **The object** of research is web applications with augmented reality. **The subject** of the study is methods of optimizing web applications with augmented reality. **The results**. The work analyzes methods of optimizing web applications with augmented reality. **Conclusion**. An analysis of the optimization methods of web applications with augmented reality was carried out.

Keywords: web, augmented reality, optimization.

Introduction

Augmented reality (AR) is a technology that provides enhanced perception of the physical world, giving users the opportunity to visualize, hear and interact with reality through superimposed multimedia content, which is characterized by a high level of interactivity and information saturation.

Since its inception in the 1950s, augmented reality has seen significant development in fields such as medicine, engineering, education, and more. At first, for its implementation in the real world, you used bulky and heavy equipment. Since 1997, AR has become a recognized research field covering various aspects: tracking, interaction, display, visualization, calibration and registration. The emergence of smartphones has opened up new opportunities for the development of the augmented reality application market.

The period of research devoted to the impact of mobile and wireless technologies on the development of augmented reality has begun. After 2010, researchers focused on the technical challenges and opportunities of AR application development, which further contributed to its integration into everyday life, particularly through browser-based AR applications (WebAR) for smartphones. Modern smartphones, equipped with cameras and such sensors as GPS, accelerometers and gyroscopes, are able to fully reveal the potential of augmented reality [1, 2].

Today, augmented reality is being actively implemented in various spheres of human life, in particular, in trade. However, at the initial stages of its development in this field there were certain difficulties due to investors' doubts about the maturity of the technology. At that time, games were the main driver of AR use. Currently, business models have evolved, and many companies are realizing the importance of investing in WebAR to expand their brand. As more and more brands integrate into e-commerce, competition in this market is intensifying. In order to stand out, businesses must implement innovative solutions to improve the user experience. AR allows consumers to preview a product, which solves the problem of choosing a design, color or size. Technology not only attracts customers, but also increases their satisfaction and positively affects long-term purchase intentions. Today, many commercial sites support AR for selling clothes, furniture and cosmetics. For example, L'Oréal recently launched a website with AR to help customers choose cosmetics more easily online.

Over time, AR is increasingly used in the medical field, where it is useful for both doctors and patients. The technology is used during complex operations, allowing doctors to work with greater precision.

AR also improves education and training by integrating digital content into the real world. Students can use their smartphones or tablets to access AR content that provides interactive learning, exploring complex concepts, or performing virtual experiments.

In addition to commerce, medicine and education, WebAR is actively used in areas such as tourism, hospitality and entertainment. It is expected that the implementation of AR will continue to positively affect the markets of commerce, healthcare and real estate in the coming years. The growing number of studies in this area indicates that in the future sites with integrated AR technologies will be able to significantly improve user interaction with digital environments, providing everyday augmented reality [3, 4].

Based on the above, it can be concluded that the use of augmented reality in web applications has become popular in the modern context. However, the lack of web standards for the use of 3D technologies negatively affects the spread of WebAR applications, which leads to the creation of poorly optimized software solutions. This leads to a deterioration of interaction with the user and a limitation of the performance of the application - a decrease in the frequency of frames, an increase in the delay or an inefficient use of the device's resources, which affects the responsiveness and smoothness of the AR interaction.

So, based on the above, the research and optimization of currently common WebAR applications are relevant today, and the analysis of their optimization methods is expedient.

The purpose of this work is to analyze methods of optimization of web applications with augmented reality.

Main part

Optimizing 3D models plays a key role in reducing resource consumption and ensuring fast and smooth operation in WebAR environments, effectively minimizing latency and reducing content loading time. Excessively large or complex 3D models can slow down the operation of the site and reduce its sensitivity, which negatively affects the interaction with the user and can lead to the outflow of the audience. In turn, the application of optimization methods helps to improve the operation of the application and create a more comfortable user experience.

Significant delays in the visualization of the thickest model occur due to the use of a one-time mechanism for loading and rendering model data, which is based on the synchronous mode of data exchange. In synchronous mode, the client is forced to wait for the complete transfer of the entire model before it is loaded and displayed in the web application. In addition, low bandwidth or instability of the mobile wireless network causes additional delays in loading models. Combined with the site's limited computing resources, this can cause the page to look like it's frozen in the browser. The solution to this problem is the use of WebAR application optimization methods.

The asynchronous and decentralized method of transferring 3D models eliminates the network congestion that occurs during a one-time download. Asynchrony consists in the transfer of data in parts. For example, the process of data transfer of a three-dimensional model occurs gradually: first, the basic mesh of the model is transferred, and during its rendering on the client side of the web application, a file with refined data is simultaneously received. With the receipt of these data, the model is gradually detailed until complete restoration (Fig. 1). Decentralization, in turn, involves the use of several data sources for 3D models, which allows to evenly distribute the load and increase the transmission efficiency [5].

Fig. 1. The process of grid refinement has several stages

The use of model compression technology reduces the file size of 3D models, which increases their efficiency for storage and transmission through a web browser. Libraries such as Zstd and Oodle aim for fast decompression, but do not account for redundancy in vertex data, which can lead to low compression ratios. The Draco algorithm uses quantization and delta coding to reduce the accuracy of vertex attributes, although it does not prioritize texture quality. To optimize results, it may be useful to combine Draco with other texture compression methods, such as KTX2. The Corto library supports streaming, providing fast mesh topology reconstruction during decoding.

The method of data reduction of component similarity in the model increases the efficiency of the process of transfer and loading of models by reducing the amount of data that needs to be transferred. The method is based on the identification of similar parts of models that are the same or similar in the model and the elimination of redundant information. Similar components in the model are defined and represented by a single set of data. Instead of transferring multiple versions of the same geometry or texture, the data is compressed to avoid duplication.

The level of detail (LOD) method optimizes the use of computing resources, such as memory and processor, by dynamically adapting the model. This approach reduces the number of displayed details taking into account the distance, position and orientation of the user (Fig. 2).

Fig. 2. Reducing object detail using LOD

This allows you to reduce the load on the system without a significant loss of visualization quality. Algorithms such as meshoptimizer focus on mesh optimization to improve performance, while multi-resolution methods offer efficient data compression and minimize CPU and GPU load. Hardware acceleration of tessellation and continuous LOD open perspectives for stable frame rates in high-quality AR applications.

With the development of machine learning technologies and neural networks, an updated method for implementing data storage and transmission of 3D models is proposed. The method is a Bayesian learning algorithm for reducing the complexity of coding using the multidimensional Ga-us distribution and the method of maximizing the expected value for subsets without affecting the visual quality of the model [6].

Recently, an HTTP-adaptive streaming system for augmented reality was presented, which aims to provide high-quality streaming services with minimal delay in the conditions of variable wireless networks. The system uses progressive mesh technologies together with a metafile structure to optimize visualization and data transfer planning, taking into account the current network load. Unlike systems that depend on the viewing angle, this system adapts to network conditions and the scale of AR overlays on the screen, which ensures the optimization of transmitted fragments to improve the perception of visual content by the user [7].

In terms of rendering performance, there is no universally lightweight format for 3D files. The USDZ format, developed by Apple and Pixar, is compact and integrates augmented reality features into 3D content, but it is designed for iOS and has limited creation tools. This creates a compatibility problem between the use of cross-platform SDKs and the specific capabilities of each platform. The glTF format, as well as its glb binary, provides efficient loading of 3D scenes in the browser, but different glTF renderers may produce different visual results. To optimize this process, frameworks such as gltfpack with meshoptimizer, which applies various optimization steps, and the Gltf pipeline from CesiumJS with support for Draco compression [8] can be used.

One of the ways to overcome the shortage of computing resources of mobile devices over the last decade has become mobile cloud computing, which allows users to upload intensive computing tasks to cloud servers deployed on remote cloud platforms for processing.

Additional aspects of optimizing web applications with elements of augmented reality are the on-demand downloading of resources, in particular animations and the implementation of model caching mechanisms in web applications [9].

Conclusions

Modern society actively uses web applications for a wide range of tasks, including buying and selling goods, receiving online services and searching for information. The global implementation of the 5G network creates the basis for the large-scale application of WebAR technology in various industries. Optimizing such applications becomes critical to ensure a quality user experience, especially when interacting with websites, where visualization and interactivity are key aspects. Further improvement of WebAR technologies will facilitate more effective integration with digital platforms and increase user satisfaction.

As a result, an analysis of methods of optimization of web applications with augmented reality was carried out. Optimization methods of 3D models, such as asynchronous loading, level of detail (LOD), and data compression, allow you to reduce delays and reduce the load on computing resources. A combination of compression methods (for example, Draco for geometry and KTX2 for textures) improves data transfer efficiency and reduces download times. Decentralization of data allows you to avoid network overload by evenly distributing the load between several sources.

A combination of different optimization methods can significantly increase the efficiency of processes in WebAR applications. For example, combining LOD for dynamic adaptation of the model with the Draco compression algorithm allows you to reduce the size of files and optimize the use of resources. Another option is asynchronous non-loading of models with gradual detailing in combination with KTX2 texture compression, which reduces network load and speeds up loading. Also, the distribution of the load between several sources of data transmission in combination with cloud computing allows you to transfer computing tasks to remote servers, reducing the load on local devices.

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Аналіз методів оптимізації вебзастосунків з доповненою реальністю

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Анотація. Актуальність. З розвитком мобільних і бездротових технологій, AR отримала новий поштовх для інтеграції у повсякденне життя, зокрема завдяки WebAR. Технологія швидко впроваджується у різні сфери, такі як торгівля, медицина та освіта. Однак існують технічні виклики, зокрема відсутність стандартів для 3D-технологій у вебзастосунках, що обмежує якість і продуктивність додатків AR. Оптимізація цих додатків є важливим аспектом для покращення користувацького досвіду і розширення застосування AR у різних галузях. **Метою даної роботи** є аналіз методів оптимізації вебзастосунків з доповненою реальністю. **Об'єктом дослідження** є вебзастосунки з доповненою реальністю. **Предметом дослідження** є методи оптимізації вебдрfcnjceyків з доповненою реальністю. **Результати**. У роботі проаналізовано методи оптимізації вебдодатків з доповненою реальністю. **Висновок**. Проведено аналіз методів оптимізації вебзастосунків з доповненою реальністю.

Ключові слова: веб, доповнена реальність, оптимізація.