Large-Scale 3D Web Environment for Visualization and Marketing of Household Appliances

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Abstract. Manufacturers are continually looking for new methods to present their products to a broader range of customers in order to increase the selling numbers and brand recognition. Furthermore, with the quickly developing e-commerce market, there is a strong need for efficient and user-friendly methods of online product visualization for both wholesale and retail customers. In this paper, we describe and evaluate a method of products visualization using 3D web technologies. The visualization encompasses a large virtual showroom with a number of high-detail product models. In the showroom, customers can see an entire collection of products and can inspect particular products. The visualization has been designed to reflect as much as possible the real experience, including high detail architecture and furniture, photographs, videos, and music. The virtual environment has been prepared using AutoCAD, SketchUp, 3ds Max and Unity, and exported to WebGL. In the paper, we describe the design of the environment and evaluate its performance on different hardware and software platforms.

Keywords: 3D Web · Marketing · Visualization · WebGL · Unity

1 Introduction

Marketing is one of the critical activities that manufacturers need to perform to boost their selling numbers and gain more recognition among customers. However, recent studies concerning human perception show that most recipients developed resistance towards traditional visual media, which are the primary sources of information these days [10]. As a result, there is a need to find new innovative ways to influence customers. This need can be fulfilled by 3D web visualization. Constant progress in 3D web technology offers new possibilities of transferring various physical spaces into virtual spaces accessible online to a wide range of recipients. By using the 3D web, potential customers may be able to

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experience a virtual reality space being a digital counterpart to a real exhibition, possibly located in a distant place. This way of presenting goods may positively influence the customer's decision process and create proper expectations on the later experience in reality [13].

Another important use of 3D visualization of product exposition spaces is to perform merchandising studies. Such studies verify how different product arrangements in the modeled physical space influence customers' perception of the products. It can increase a store's selling numbers by influencing the customers or promoting a particular product or a group of products. Currently, such merchandising research is typically performed with the use of physical mock-ups of real stores [3]. However, the use of virtual spaces has significant advantages comparing to traditional physical spaces. It allows fast, easy, and well-controlled rearrangement of products. Moreover, there is no need to possess physical versions of all different kinds of products, which may quickly become unusable because of their expiration date.

Building realistic 3D virtual stores is a significant step in the process of moving daily shopping to the virtual world. This process already began with creating the first online stores and is still gaining importance in the modern economy—shopping is one of the most popular online activities worldwide. In 2016, retail e-commerce sales worldwide amounted to 1.86 trillion US dollars, and e-retail revenues are projected to grow to 4.48 trillion US dollars in 2021 [25]. Today, commonly used 2D shopping websites have their natural limitations; for example, lack of interaction with products, limited perception of the products' sizes and properties, and lack of social interaction between people, which can be a significant aspect of shopping for some groups of customers. The use of 3D avatars to navigate and communicate in a virtual environment introduces a social aspect into this activity, which is not achievable in traditional forms of e-commerce. These aspects can have a significant impact on the popularity of new forms of shopping [16].

To reach an average customer, a widely accessible visualization is required. It should be possible to reach the visualization using typical customers' equipment without installing additional software. The best platform for this kind of visualization is the web. In this paper, we present and evaluate a 3D web application that enables users to experience a virtual showroom of Amica S.A., which is a leading kitchen appliances manufacturer in Poland. To make the visualization as user-friendly as possible, and also to maximize the marketing impact, the application covers the whole physical showroom, which is used by Amica S.A. to expose their series of products, mainly for wholesale marketing.

The remainder of this paper is structured as follows. First, in Sect. 2, an overview of the state of the art is provided. Next, in Sect. 3, we present the 3D web application developed for Amica S.A. Then, in Sect. 4, we provide an evaluation of the application that measures its performance in various hardware and software environments. In the last section, we conclude the paper and indicate directions for future works.

2 Related Works

2.1 Designing 3D Virtual Environments

Geometry and appearance of real objects can be acquired using automatic and semi-automatic 3D scanning. There are several methods of achieving this goal. For example, static 3D objects can be precisely digitized using active scanners based on laser ToF measurement, triangulation, and structured light. There are also less precise, but more affordable methods—software tools enabling reconstruction of 3D objects from a series of images, such as Autodesk 123D and 3DSOM. 3D scanning can be combined with other content creation methods, allowing designers to influence the digitization process and the created content.

Both existing and non-existing objects can be modeled with the use of visual 3D content design environments. Software packages that enable modeling or sculpting 3D content include Blender, 3ds Max, Modo, Maya, ZBrush, and 3D-Coat. Professional environments like these offer advanced modeling capabilities of various content elements, but their complexity requires high expertise. Narrowing the application domain and the set of available operations enables the development of tools that are easier to use by domain experts. Examples of such environments include AutoCAD Civil 3D, Sweet Home 3D, and Ghost Productions. These tools enable relatively quick and efficient modeling without requiring users' extensive experience in 3D content creation. It is achieved, however, at the cost of reduced generality of the content creation process.

The high structural complexity of 3D content, combined with the requirement of adjusting specific content parameters, implicates the development of content models—well-defined structures, which describe the content organization and parameterization [30]. Based on such models, the final form of 3D content can be generated by content generation software—either fully automatically or semi-automatically in an interactive process. Content models offer data structures that are better organized and easier to maintain than typical 3D content representations. They also permit automatic verification of data consistency and elimination of redundancy. Content patterns provide an additional conceptual layer on top of content models, defining roles of specific elements in the model [20,22].

Instead of fixed content models, rules of content composition can be used. Such rules describe how different types of content elements should be combined to form the final 3D model. Rules permit flexible composition of content from predefined building blocks—components [5,28–30]. Components may represent geometrical objects, sounds, interaction elements, scenarios, and others. Content creation based on the configuration of predefined components constrains possible forms of the final created content. However, in many application domains, this approach is sufficient, while the process is much more straightforward and more efficient than creating content from scratch.

To further simplify content modeling, separation of concerns between different categories of users is required. Different users may have different expertise and may be equipped with different modeling tools. A non-expert designer may use ready-to-use components and assemble them into virtual scenes. Composing a scene in such a way is relatively simple, but the process is constrained. New content creation capabilities can be introduced by programmers or 3D designers, who can add new components and new ways of combining them.

Another aspect that can simplify the process of 3D content creation is the use of semantic web techniques [1,24,27,35]. These techniques enable the use of high-level domain-specific concepts in the content creation process instead of low-level concepts specific to 3D graphics. Content creation may be also supported by knowledge inference. The use of semantic modeling enables the creation of content that is platform-independent. Several approaches have been proposed to enable 3D content modeling with the use of semantic web techniques [4,6,9,14,32,33].

The availability of easy-to-use and efficient content creation methods, in particular based on the semantic web techniques, enables social 3D content creation [31]. In this approach, content can be collaboratively created by users who both produce and consume the content (prosumers). 3D content sharing portals, such as Unity Asset Store, Highend3D, Turbosquid, 3D ContentCentral, and many others (e.g., CG People Network, Creative Crash, 3d Export, Evermotion, The 3D Studio and 3D Ocean) allow access to vast libraries of 3D content. However, the available content largely differs in style and quality, and is not suitable for applications requiring detailed models of specific products.

2.2 Interaction in 3D Virtual Environments

Choosing proper user interaction methods within a virtual environment is essential to offer a user-friendly 3D experience. The methods should be easy to use and intuitive to new users. This is not an easy task, because such users have often problems even with simple navigation in 3D environments. This section describes different approaches to the interaction of users in 3D/VR environments.

The first approach is based on classic input devices, such as a mouse and a keyboard. The possibility of translating 2D mouse movements to a 3D space [19] and the high degree of technological adoption make this approach preferred by many users in 3D environments. However, due to natural limitations of these devices (low number of degrees of freedom and the requirement to use key combinations), such navigation and interaction can often be non-intuitive and complicated, especially in VR environments.

The next approach consists in the use of specific equipment, such as gaming input devices (joysticks and pads) or dedicated VR devices (tracked controllers and haptic arms) for interaction with a virtual environment. The key advantage of this solution is user's comfort and efficient and accurate control of virtual elements in adequately configured environments [8,12]. However, low availability of such devices, quickly changing standards and—in some cases—high cost of specific equipment, results in limited use of this approach. In the case of more specialized devices, adapting them to environments other than those for which they were initially designed is difficult. Nevertheless, the approach based on specialized devices is often the basis for further research [2,26].

Another quickly developing approach for interaction in 3D environments is the analysis of natural human behavior. It includes techniques such as motion capture (e.g., with marker tracking or directly like in case of the Microsoft Kinect sensor system [23]), gesture recognition [15], eye tracking [21], and verbal/vocal input [36]. These techniques focus on providing intuitive, natural interfaces, which are user friendly even for non-experienced users. However, this kind of interaction is not suitable for web environments.

The context-based approach is an interaction technique popular in computer games, in particular in simulations (e.g., "The Sims" and "SimCity" series by Maxis) and in adventure games. This approach is not based on specific input devices, but focuses on the use of available devices to interact with the use of a contextual interface. The set of operations available in the interface depends on the current state of the environment and its objects (e.g., time, position, current object state). The context-based approach is also often used in modern VR environments [11]. However, users may find this approach uncomfortable due to the mismatch between classic UI elements (buttons, menus, charts) and the 3D virtual environment. Also, this technique is not convenient for entering data (such as text or numbers). This is an important limitation, especially when the interface is used for modification of content.

Another way to enable users' interaction within VR environments is to use devices with their own CPUs and screens for controlling the environment. Mobile devices, such as smartphones and tablets, are often used for this purpose due to their widespread availability and advanced user-interface features, including high-resolution touch screen displays and various types of built-in sensors, such as gyroscope and accelerometer. In this approach, a user has a specific predefined interface located on the client device to control the environment. This interface can be generated with the use of specialized software (e.g., PC Remote application by Monect [17]), or it can be dedicated to a specific environment and released in the form of an independent application. However, developing dedicated client applications is a time-consuming and costly activity, and the applicability of such an interaction interface is often limited to a single VR environment, making it unsuitable for the web.

3 Showroom 3D Web Application

The possibility to visualize 3D products over the web has a great value for marketing and presentation of a company's offer. Users are able to access the visualization of products directly from a web browser. There is no need for any extra devices like HMD or other specific VR hardware. Such a presentation can provide the capabilities of navigating, rotating, moving, and zooming depending on the user's needs. Moreover, there can be the possibilities to interact with the environment and the products themselves, including such operations as opening, closing, removing particular elements, and switching on/off a product. This kind of interaction is crucial for convincing visualization and proper demonstration of product's features and functionality [7,34].

In this section, we describe a 3D web application that has been implemented for visualization of products of Amica S.A. – a leading Polish manufacturer of kitchen appliances. To make the visualization as user-friendly as possible, and also to maximize the marketing impact, the application provides digital reconstruction of the whole real physical showroom, which is used by Amica S.A. to expose their series of products, mainly for wholesale marketing. The showroom space also contains other elements, such as screens with slide-shows and movies describing the company, a collection of historical products, and an entire cooking area. The physical showroom serves also as a place for business meetings.

3.1 Architectural Design

A virtual showroom, like any other space, requires a certain representation of real architectural objects. The representation depends on the technology in which the space is to be presented and whether the space is a visualization of a real place or just a sample generated environment. A model designed for a 3D presentation on a computer can be a very detailed reconstruction of the reality. However, not every platform allows for such a level of detail, mainly due to technical limitations. An example of such a platform is the web. Due to the limited capabilities of popular web browsers and typical consumer hardware, the level of details must be strictly controlled. The goal is to provide the highest user experience possible, while limiting the size of the visualization—both in terms of the number of polygons and the size of textures. These features greatly impact the loading time and the performance of a 3D visualization. In some cases, loading a large model may not be possible at all.

Regardless of the technology in which a given architectural space is presented, selected architectural design patterns should be used. For example, when designing computer games, urban design principles should be taken into account when creating urban spaces. The urban structure of buildings in such a case should draw from the basic methods of urban shaping in order to increase the realism and immersion. In turn, in architectural interiors, these rules are less formalized at the stage of spatial visualization and are based mostly on common sense, e.g., objects should not be placed in places that disturb the navigation or obstruct the view. When building a virtual representation of an architectural space, apart from the design patterns, it is important to maintain its correct structure. Such structure divides the space into separate areas, which can be then filled with furniture, equipment, and minor design elements.

The process of designing and creating architectural spaces can be accomplished in several ways. It is possible to fully prepare a 3D space in a modeling program. However, this approach requires specialized knowledge and skills to use 3D content creation tools efficiently. Users have more freedom in designing, but the process is more time consuming. The second possibility for this type of space is to use ready-made tools that support the creation process. Thanks to such tools, which use either artificial intelligence or assistance functions to support the design process, a designer can prepare a given space in a much easier and faster way. Instead of looking for semantic links or specific design patterns, thanks to the use of this type of tool, a designer automatically gains feedback on possible mistakes or solutions. Most often, these tools have component libraries that additionally facilitate the creation process [18]. It is also possible to use generators of architectural spaces, but currently these tools are still in an early stage of development and do not allow for a great amount of freedom in the design process.

3.2 Amica Showroom Design

In the case of the Amica 3D showroom application, the intention was to reproduce the real environment as accurately as possible. Original construction designs were provided by Amica S.A. in the *.dwg format. To avoid losing information, they were again imported into AutoCAD, where all redundant drawing elements usually found in architectural projects were removed. The drawings prepared in this way were then imported into SketchUp. This program was chosen due to the possibility of representation of the real dimensions with an accuracy of millimeters. At this stage, the general outline of the architectural space was prepared in the form of walls, floors, ceilings, and doors. The prepared model was then exported to the COLLADA format. In parallel, elements of decor were designed in 3ds Max. The difference between 3ds Max and SketchUp is essential. In SketchUp, it is easier to operate on real dimensions, while 3ds Max is much better suited for modeling elements of decor, as it provides a much larger set of tools for creating curves and complex shapes. The elements of the decor prepared in this way were then exported to the *.fbx format. Finally, these models were imported into Unity, where they were placed properly on the scene, and appropriate textures were assigned to them.

3.3 Web Application Design

The Unity environment (v. 2018.3.12f1) was used to program all elements of navigation and user interaction. Many optimizing processes were also carried out to boost the application's performance, so that it can be displayed quickly and smoothly in web browsers. To compile the application, we used Unity WebGL build option, which allows Unity to publish content as a JavaScript program that uses HTML5 technologies and the WebGL rendering API to run 3D content in a web browser. The deployment architecture of the web application is presented in Fig. 1.

In the case of web applications, the client hardware is not known. Users may run such applications on laptops or other computers with limited computing and graphical capabilities. To reduce possible fluctuations in the application's performance, post-processing methods in the form of motion blur and chromatic aberration were used. These effects reduce the impression of a sudden drop in frames per second. The compiled project's size was reduced from 30 GB, which was the size of the original compiled Unity project, to 118 MB in the case of the binary web application.

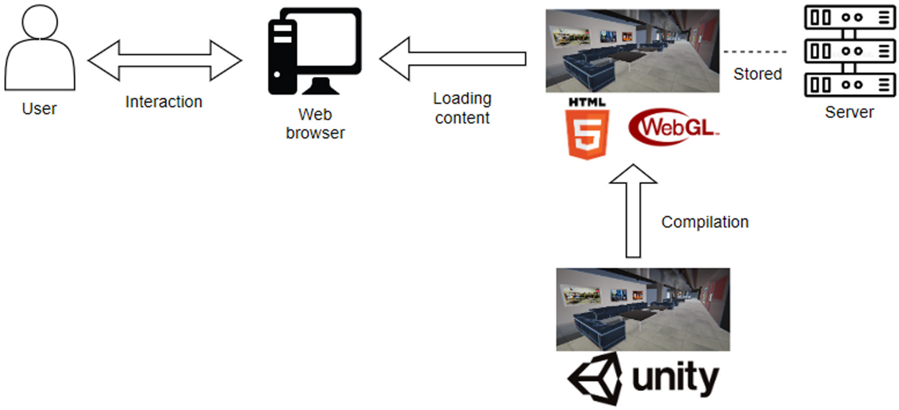

Fig. 1. Deployment architecture of the showroom 3D web application

The optimizations used for the creation of the web version of the application include:

1) striping unused engine code;
2) applying occlusion culling, which disables the rendering of objects not currently visible by the camera;
3) using the Brotli compression format, which significantly reduces the size of the final build;
4) pre-baking collision data into the meshes at the build time;
5) reducing the resolution of all textures and optimizing mesh data;
6) reducing the size of embedded movies.

The Unity WebGL support and performance varies among the major desktop web browsers. Unity WebGL content is not fully supported on mobile devices, although in many cases, it works, especially on high-end smartphones and tablets. The problem is that many mobile devices are not powerful enough and do not have enough memory to support Unity WebGL content well. For this reason, the browser shows a warning message when trying to load content on a mobile browser.

Interaction and navigation in 3D applications can be accomplished using traditional computer input devices (i.e., a mouse and a keyboard). Indirect mapping of the movement of a 2D mouse (having 2 or 3 degrees of freedom) to 3D space (requiring 6 degrees of freedom) can be done using additional buttons on the mouse or keyboard. The keyboard allows relatively rich interaction. It is used by most 3D web applications and games where the camera is positioned in the first-person perspective (FPP). A user moves by pressing the WSAD buttons or the arrow buttons on the keyboard and rotates the camera by moving the mouse. Additionally, by holding the Shift key, a user can move faster around the showroom. On mobile devices navigation is accomplished with the use of the touchscreen.

3.4 Functional Design

The showroom 3D web application's primary goal is to allow every customer to get familiar with the products and the brand itself. The virtual showroom is a detailed reconstruction of the real exhibition. The space is filled with kitchen appliances produced by Amica (Fig. 2). Users can freely walk around the space and view products from all directions. The experience resembles walking a real exposition, but customers are able to view the products without leaving their homes. An alternative way of gaining more information about products is by watching short movie clips with the visualization of products' operation. Such movies—embedded in the 3D environment—are an efficient way of presenting features and additional information that are hard to visualize in the form of 3D models.

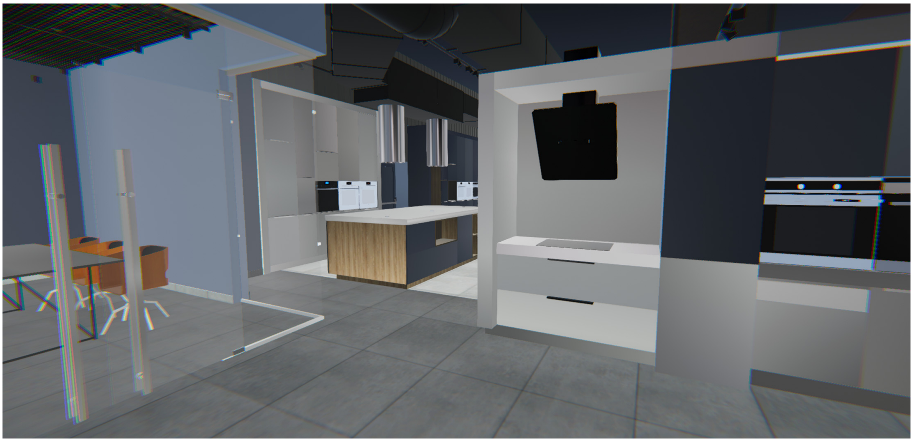

Fig. 2. Area of the showroom with kitchen appliances displayed for view

The visualization of the offered products is not the only purpose of the application. Another critical aspect is the possibility of getting to know the company better. While walking around the showroom, a user can watch and listen to movie clips that explain the production processes. Other movie clips present the history of the company (Fig. 3). There is also an exhibition of historical products together with a high-resolution graphic that shows the most critical events in the company's history (Fig. 4). These elements are a significant part of the Public Relations strategy that builds trust in the brand and can increase sales numbers in the future.

4 Evaluation

The goal of building a web application is to make it accessible to most users on most devices. However, the level of support for WebGL varies among browsers

Fig. 3. Movie presenting history of the company

and operating systems. Therefore we tested the functionality and the performance of the application on all major browsers. In Mozilla Firefox, Google Chrome, MS Edge and Opera web browsers, the application runs without problems. In the case of Apple Safari, at the time of testing, the browser did not support WebGL 2.0, but only the older version of WebGL 1.0, so the application could not run.

4.1 Design of the Experiment

To check the application's performance, we tested it on three different computers, including two with different graphics cards, four browsers, and three selected spots in the virtual showroom. The following configurations of computers were used for testing:

1) Device I: Intel Core i5-4210H processor, 8 GB RAM, graphics cards: Intel HD Graphics 4600 (Device I*) and NVIDIA GeForce GTX 960M (Device I**)
2) Device II: Intel Core i5-9300H processor, 8 GB RAM, graphics cards: Intel UHD Graphics 630 (Device II*) and NVIDIA RTX 2060 (Device II**)
3) Device III: Intel Core i7-5930K processor, 32 GB RAM, graphics card: NVIDIA RTX 2080

The tests were performed in the following browsers:

1) Opera Browser version: 69.0.3686.95
2) Google Chrome version: 84.0.4147.105
3) Microsoft Edge version: 84.0.522.44
4) Mozilla Firefox version: 78.0.2 (64 bits)

Fig. 4. Historical products area in the showroom

The following spots in the virtual showroom were used as testing areas:

1) Spot I – the lobby area (Fig. 5)
2) Spot II – the comfort area (Fig. 6)
3) Spot III – the display area (Fig. 7)

The key to choosing these spots was the complexity of the 3D models in these areas. Starting with the first area, the complexity of the models increases: spot I has the smallest complexity (59K visible triangles and 95.2K vertices), spot II has the medium complexity (720K visible triangles and 863.7K vertices), and spot III has a very high complexity of the models (3.7M visible triangles and 3.4M vertices). In each experiment in a given spot, the user's viewpoint had the same location and direction in space.

The first goal of the experiment was to measure the performance of the application by checking the average number of frames per second (FPS) for every spot, device, and browser. To check the performance, we used FPS meters that are built into the browsers.

The second goal of the experiment was to check the time it takes to load the application into the browser. We compared the times by using network monitoring tools available in the browsers in the developer mode. We compared the loading times in four different browsers on all test devices. All client devices and the servers were running in the same campus network (1 Gb/s).

4.2 Experiment 1 – Rendering Performance

The results of the first experiment measuring the average number of FPS for every device, spot, and browser are shown in Table 1. Every value in the table represents the average number of FPS in a given spot. Overall, the results are good, indicating that even very complex 3D applications can be effectively used

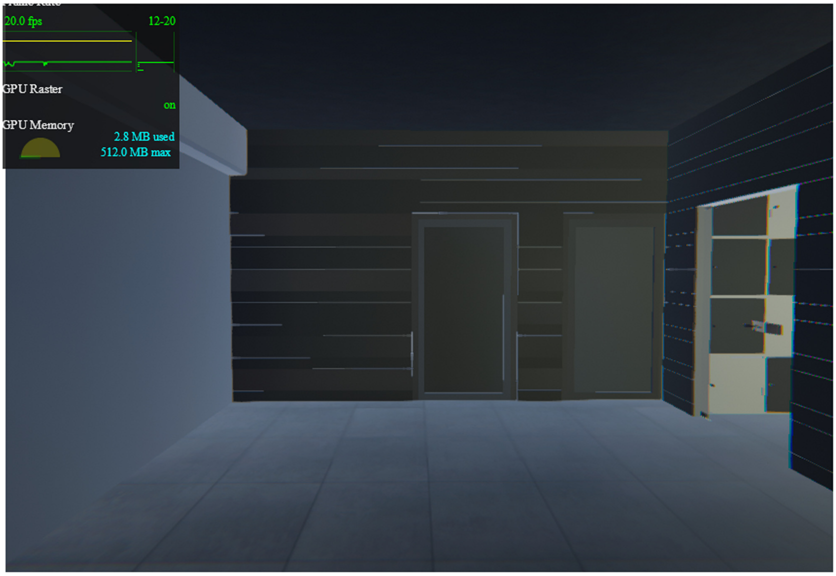

Fig. 5. Spot I – the lobby

in their web versions. The highest scores were about 60 FPS (which is the maximum for the browser). Such scores were achievable in spot I and—in some cases, spot II—but only on devices with more advanced graphics cards. The weakest performance could be noticed in spot III, where some devices could not deal properly with the complexity of models. In Opera, Chrome, and MS Edge, they reach there only about 6 FPS on low-end devices.

In Fig. 8, a comparison of rendering speed in different browsers is presented. Based on the experiment, it can be observed that Mozilla Firefox provides the fastest rendering. It clearly stands out from the rest. In our case, it had almost twice the average FPS of the rest of the browsers. Opera, Chrome, and MS Edge did not differ significantly.

The next comparison (Table 2) presents the average number of FPS for every spot grouped by browsers. As can be expected, spots with higher complexity of models have a smaller average number of FPS. The highest differences are noticeable when comparing both spots I and II to spot III and the Firefox browser to the others.

The next figure (Fig. 9) shows the performance comparison between devices. As expected, the choice of the graphics card had a significant impact on the performance. The highest difference is noticeable between the graphics cards from the RTX series and the others, especially when we look at the performance of device II with the two different graphics cards.

Fig. 6. Spot II – the comfort area

Table 1. Performance results (FPS by device and browser)

		Spot I	Spot II	Spot III
Device I*	Opera	20	17	11
	Chrome	15	14	10
	Edge	16	13	11
	Firefox	40	32	13
Device I**	Opera	16	13	6
	Chrome	15	13	6
	Edge	16	13	6
	Firefox	54	45	21
Device II*	Opera	22	15	7
	Chrome	26	16	8
	Edge	20	17	8
	Firefox	57	28	13
Device II**	Opera	34	35	21
	Chrome	34	32	20
	Edge	35	32	22
	Firefox	60	56	30
Device III	Opera	59	32	17
	Chrome	59	34	15
	Edge	59	37	16
	Firefox	59	59	33

4.3 Experiment 2 – Loading Times

The average loading times for different devices and browsers are shown in Fig. 10. It can be noticed that the loading times are high, which is partially due to the large size of the content (118 MB), and partially due to the content processing time in the browser. Nevertheless, they are all below 30 s and in most cases below 20 s, which means that with appropriate warning message users should accept it.

Figure 11 presents average loading times in four different browsers. The most noticeable is the difference between Mozilla Firefox and other browsers. On the Firefox browser, the average loading time is higher in all cases. The differences between Opera, Google Chrome, and MS Edge are not large.

Fig. 7. Spot III – the display area

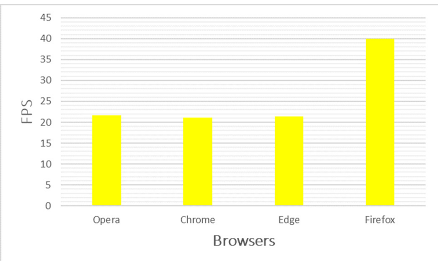

Fig. 8. Comparison of the performance in different browsers

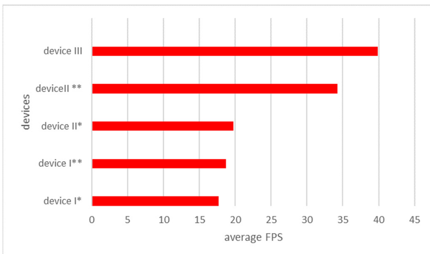

Fig. 9. Comparison of the performance on different devices

Table 2. Performance results (FPS by spot and browser)

	Spot I	Spot II	Spot III	*Average*
Opera	30.2	22.4	12.4	*21.7*
Chrome	29.8	21.8	11.8	*21.1*
Edge	29.2	22.4	12.6	*21.4*
Firefox	54	44	22	*40*
Average	*35.8*	*27.65*	*14.7*	***26.05***

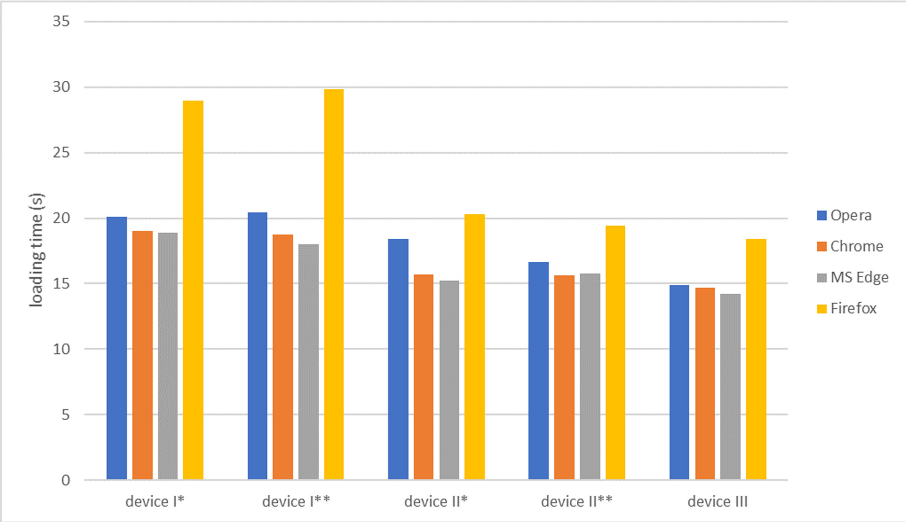

Fig. 10. Comparison of the loading times for different devices and browsers

The last comparison (Fig. 12) presents the average loading time on three different devices. The results indicate that devices with better performance have lower loading times, yet the differences are not significant.

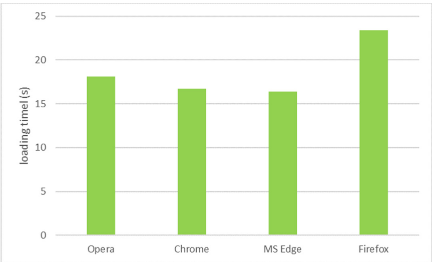

Fig. 11. Comparison of the average loading times in different browsers

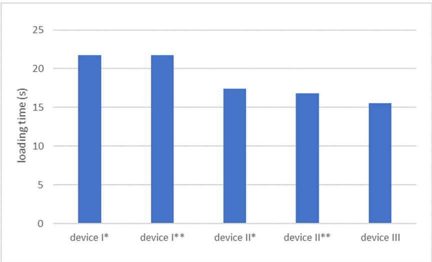

Fig. 12. Comparison of the average loading times on different devices

4.4 Discussion

The results of the first experiment clearly indicate that each of the three elements: the equipment, the browser, and the complexity of models influenced the application's performance. The most important impact had the level of detail in the 3D models. For users with slower devices, it can be a significant obstacle to use the application conveniently. Even devices with much better specifications had a noticeable decrease in performance in places with a high number of triangles in the 3D models. This indicates that during the creation of a virtual space like a showroom, it is essential to find the right balance between models' level of detail and rendering capabilities to enable as many users as possible to use the application efficiently.

The second experiment shows that both the browser and the type of device influence the loading times. In the case of Mozilla Firefox, the loading of the application is longer than in the case of the rest of the browsers (but the rendering performance is the highest). Comparing different devices, it can be observed that better specification of the device can slightly reduce the loading times.

5 Conclusions and Future Works

The use of 3D web applications can have a significant impact on promotion and marketing. It gives manufacturers new possibilities to present their products, and it can be an efficient method for companies to reach large numbers of people with their promotional content. Unlike VR/AR technologies, an application that uses 3D web technologies can be used by customers regardless of the place and the device. However, designing a 3D web application is a complicated process that requires many factors to be taken into account, e.g., proper design of the virtual space, conveniently implemented interaction, complexity of models, and devices used by users, which can influence the performance of the application.

In this paper, we described a 3D web application implemented for promoting kitchen appliances and the Amica brand. The application permits visualization of products and presentation of information about the manufacturer. We have also conducted an evaluation of the application's performance by testing it with different devices and browsers. The evaluation indicates what level of performance is achievable, and how much it depends on the used 3D models, hardware, and software.

Future works encompass further improvement of the performance of the 3D web application by applying other optimization techniques. We also plan on adding new methods of interaction in the application. Currently, the application enables only viewing the products in 3D. Adding interaction capabilities like opening ovens, switching them on/off, and using control panels can greatly increase the customers' immersion level and keep their attention for longer. It would also permit to present more information about the products. Moreover, we plan to test users' perception and interest in the developed application to gain more knowledge about the application's usefulness for marketing purposes.

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