A Flexible Framework for Web-based Virtual Reality Presentation of Cultural Heritage

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Abstract. The Virtual Reality (VR) experiences are great for an engaging presentation creating wide public awareness of cultural heritage, especially if the experience is built on a web-based technology. One of the still posing challenges is that once an application has been developed, for example for a virtual museum or a virtual tour, it usually remains fixed to an embedded in the application model. Adding new functionalities or interaction paradigms needs additional development and new deployment. In this paper, we propose a framework, which achieves the decoupling of an experience from the used models and interaction paradigms through scene and input templates and configuration files. This allows an easy way for generation of a variety of experiences even by people with no or limited programming skills.

INTRODUCTION AND STATE OF THE ART

According to [5] the application of Virtual Reality for reconstruction and immersive presentation of archaeological and historical sites and other cultural heritage becomes a well-established trend. In context of the cultural heritage, Virtual Reality is used in various scenarios including exploration, reconstruction, exhibition enhancement, immersive experiencing, etc. In its different deployment versions such as Augmented Reality, Mixed Reality, Substitution Reality, Virtual Reality is not limited only to a single artefact, but consists of many virtual objects arranged in a common scene and are accessible by the user through specific interaction paradigms using multiple sensorial channels. According to [6] Virtual Reality provides user-centred presentation making cultural heritage digitally accessible, especially when physical access is constrained due to diverse reasons. This is of great significance nowadays. The coronavirus public health emergency in the last months all over the world has triggered deep, and possibly lasting, changes in many activities, where a large number of people congregate in limited space. We expect that the traditional way of presentation of the cultural heritage shall also be affected by serious disruptions and this is likely to accelerate a radical transformation of the traditional models, e.g. the physical attendance will more often be replaced by immersive presence in virtual museums and environments leading to VR convergence.

The use of Virtual Reality in relation to cultural heritage dates back decades. [6] provides a detailed survey of the essential aspects and the current state-of-the-art in VR technologies in cultural heritage perspective and describes research performed to develop applications and systems along with a summary of the applied technologies and application areas.

Recently one of the most promising ways for deployment of the VR is offering Virtual Reality directly to the browser, also known as Web Virtual Reality, as explained in [2]. It is already known it is limited in relation to the quality of the offered user experience; however, the new technological developments in the area have changed the situation significantly. Web Virtual Reality in its advanced version enables and simplifies access, multi sharing and handling of the complex virtual environments and provides immersive experience using affordable interface devices. Important technical aspects and application in different domains of Web Virtual Reality are described in [2], [1], [7].

According to [12] the greatest accessibility to the cultural and historical heritage data and models can be achieved through their publishing on the web. While standards applied in the past for 3D visualizations in web browsers (such as VRML and X3D) required use of a browser plug-in or java applet, the modern browsers support WebGL programming interface, which allows hardware-supported visualization as part of an HTML 5 page [13], [14]. In order to reduce data transfer and to improve the response of the web application, [14] offers several levels of detail regarding the elements that make up the virtual environment. This approach was extended in [15], but with more emphasise on the simplification of the models created with 3D reconstruction techniques.

For more specific cases, which are not covered by the available web standards and programming interfaces, it is still necessary to develop browser add-ons. For example, [8] presents an extensive development of the OSG4WEB browser add-on, based on the OpenSG library, including space partitioning using a tree structure, level of detail and other methods to optimize the visualization process. The new methods and algorithms in the libraries with web application enable achievement of these functionalities with javascript code without the need to develop browser add-ons. An example for this is the WINCKELMANN300 project for VR presentation of the Capitoline Museum in Rome [9].

For several years now, it is possible to publish web pages with the possibility for immersive presentation of Virtual Reality environments through HMDs. Until now, the WebVR programming interface has been widely used for this purpose, however now it is considered obsolete [16]. Its replacement is WebXR [11], which in addition to Virtual Reality supports Augmented Reality as well.

Regarding the visualization objects and artefacts from the cultural and historical heritage domain the way is well paved: in general case, the 3D models are loaded into a library /environment/-game engine. The most widely used ones are the Unity and Unreal game engines, which include built-in support for various Virtual Reality devices. Examples of this can be obtained in [17] and [18].

However, the task for creation VR experiences by non-professionals or users with limited expertise in programming is not a trivial and easy one. In our survey, we were not able to find any information about frameworks which enable users with no programming skills to design and create VR experiences that can be globally and easily accessible by the public, especially in the domain of cultural heritage. To achieve this, we are following the concept model proposed in our previous work [4] and here we describe the presentation module of our framework aiming to achieve flexibility in the presentation of a variety of VR experiences in an unified way on the web.

CONFIGURABLE EXPERIENCES

Evolution of 3D interactive content for the web

Fig. 1 shows a diagram of the evolution of 3D content for the web. In its early stages providing interactive 3D content on the web was only possible via dedicated browser plugins, like VRML and X3D plugins or the Unity Web Player [8]. This has the benefit of allowing the plugin developer to embed various desired functionalities, including optimizations and performance improvements, but the users must install the plugin separately. With the advent of WebGL after 2006 it became possible to have 3D web applications natively supported by the browser [8]. Traditional scene graph SDKs now supply WebGL-based JavaScript implementations, for example OpenSG as OSG.js [9], allowing for faster development of more advanced 3D web applications. WebGL was the foundation that allowed the initiative of the WebVR API as well as various custom WebAR libraries like AR.js and the one proposed in [10]. Currently the WebVR API has been deprecated and has been succeeded by the WebXR API which aims to provide the basis for both immersive VR as well as AR experiences [11].

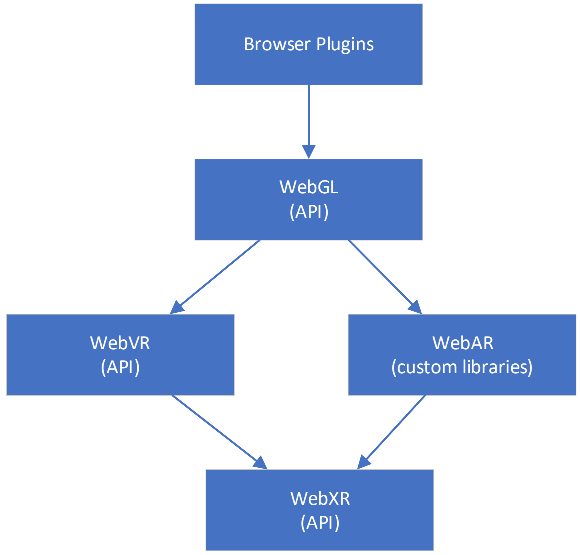


FIGURE 1. The path to WebXR

Foundations

As a basis for our framework A-Frame was chosen. As stated on its web page (https://aframe.io/) A-Frame was specifically designed for developing VR applications for the web and provides a declarative style extensible layer over three.js (https://threejs.org/) with a powerful Entity Component Architecture. While keeping ease of use through declarative HTML, allowing it to be used by non-developers, it also retains the ability to use JavaScript and DOM APIs and provides access to the lower level layers of WebXR and WebGL (see Fig. 2). Thus, a cultural heritage domain expert with no programming knowledge can still understand and eventually edit the contents of a template created in A-Frame while more advanced functionalities and communications can be delivered using the lower level APIs. Similar approaches can be seen for example in [2] and [3], where A-Frame has been combined with D3.js for web immersive data visualisation, and in [1] where A-Frame has been combined with Molly for dynamic generation of virtual scenes based on data retrieved from a database.

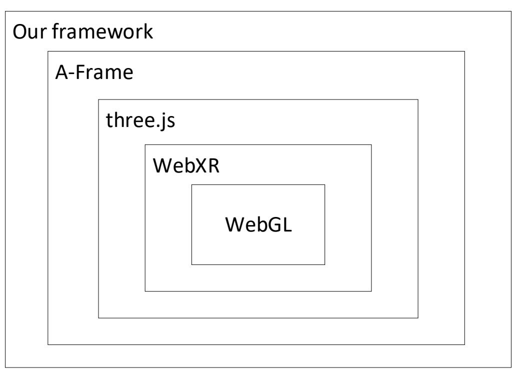


FIGURE 2. Layered model describing the API foundations of our framework

Configuration based flexible presentation

We are taking a different approach than the ones described above. In our case the configuration of the scene is being prepared in a separate scene configuration module which generates a json file containing the configuration to be applied to a specified scene template – see Fig. 3.

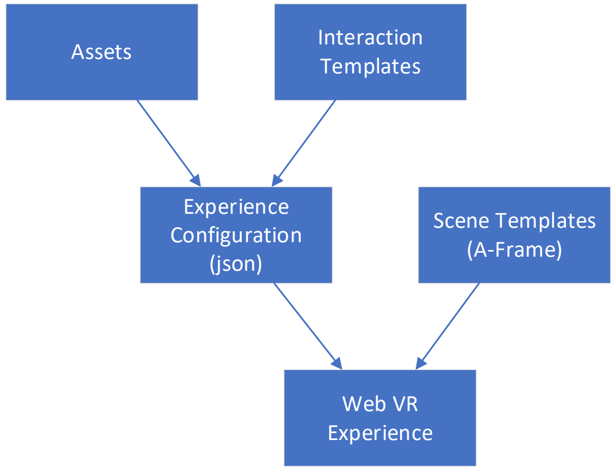


FIGURE 3. Web VR experience preparation using json file containing the experience configuration and an A-Frame scene template

On one side, there is the *scene template*, which can be different depending on the scenario of the experience, for example model exploration, 360 photo/video gallery, virtual museum, etc. This is practically an html web page containing an A-Frame scene. On the other side is the json *experience configuration* supplying information about the contents and settings for the template. For example, the initial position of the user in the virtual scene, the model(s) that are to be loaded and an input template. A sample json configuration is show on Fig. 4.

```
{
    "rig":[-15,14,5],
    "interaction":"travel",
    "models":[
    {
        "file":"./3DModels/rila_monastery/rila_monastery.gltf",
        "position":[0, 0, 0],
        "orientation":[0,0,0],
        "scale":[0.002, 0.002, 0.002]
    }
    ]
}
```

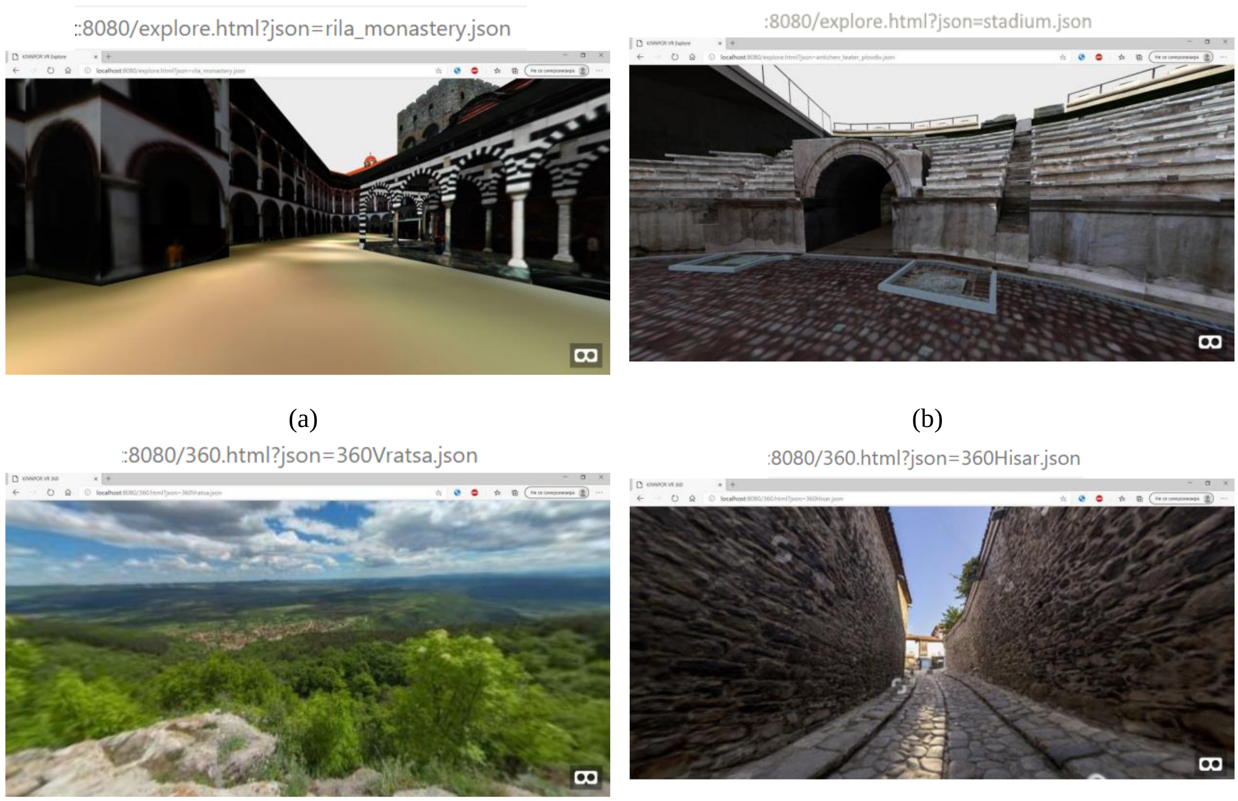
FIGURE 4. A simple sample json file containing a configuration for an exploration experience containing a single model

The input template is another configurable part that allows greater flexibility, it specifies the interaction paradigm to be applied to the user input, e.g. whether the user will be allowed to travel through a larger 3D environment or will simply be able to select / grab a model and look at it.

Show Cases

The proposed framework is being developed for the project “Virtual Plazza for Interactive Presentation of Bulgarian Cultural Heritage Sites”, which is still under development. The idea is to create an interactive map of cultural heritage sites in Bulgaria. For some of them VR experiences will be designed relying on the here presented framework so that a geolocated pin on the map can directly link to a web VR experience.

Fig. 5 shows two different use cases for the content handling by the user of which the proposed framework has been used. Fig. 5 (a) shows an *explore* scene template used with a configuration allowing the user to travel around the Rila monastery, while Fig. 5 (b) shows the same scene template with a configuration allowing the user to travel around the Roman stadium in Plovdiv. Fig. 5 (c) and (d) show the use of a scene template for 360 photo visualisation.



(c) (d)

FIGURE 5. Examples of combinations of different scene templates with different experience settings

CONCLUSION

The here presented framework allows an easy generation of VR experiences for the web. By using initially developed A-Frame scene templates, input templates and available assets a variety of experiences can be created by providing a different configuration file to the same scene template. The framework is being developed for the project "Virtual Plazza for Interactive Presentation of Bulgarian Cultural Heritage Sites", where a link to a web page containing the scene template can be added to a geolocated pin on an interactive map. Thanks to its flexibility and easy configurability of new experiences the framework will allow for continuous extension of the available experiences. (някакъв outlook какво още се планира)

ACKNOWLEDGMENTS

The work was supported by the Bulgarian Ministry of Education and Science under Cultural Heritage, National Memory and Social Development National Research Program approved by DCM No 577 of 17 August 2018.

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