3D Architectural Heritage Platform

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ABSTRACT
In recent years, efforts to digitalize cultural heritage have increased with the developing technology. With the development of three-dimensional (3D) imaging technologies and communication opportunities, the transfer of tangible cultural heritage to the digital environment has accelerated. Many academic and industrial studies have been conducted and methods have been developed in the fields of creating and displaying 3D models of cultural heritage artifacts.
For digitally transferred data to be shared online with other users, there is a need for systematic storage of information, images, and 3D models of cultural heritage. These storage systems help protect our cultural heritage. In addition, it can provide benefits in areas such as restoration work. Storing cultural heritage digitally makes us need a cultural heritage database.
In this project, information and 3D models of the architectural heritage are recorded. Users can view architectural heritage models stereo enabled 3D environments, interact with them and get information about artifacts with this platform.
Before the architectural heritage data is added to the system, its compatibility with architecture, virtual reality (VR) and augmented reality (AR) is checked by authorized users. It is then added to the system with the approval of authorized users. In addition, these models are displayed in VR.

As a result, a system has been created that can be used by researchers from different disciplines, thus enabling academic collaborations to be established. This platform contributes to the registration, promotion and protection of architectural heritage.

KEYWORDS
Architectural Heritage, Digital Cultural Heritage, 3D Modeling, 3D Model Database, Virtual Reality

INTRODUCTION

Cultural heritage is the reflection and expression of people's values, beliefs, knowledge, and traditions from past to present (Selanik & Kurtdede, 2013). Historical and cultural artifacts transferred from the past to the present provide information about ancient life, language, religion, literature, tradition, and architecture (Yastıklı et al., 2022). Establishing a connection between the past and the present creates a foundation for the culture and the world in which one lives. While providing a solid reference in the creation of the future, it also enriches human lives in a spiritual sense.

Cultural heritage, in its meaning, is the values that remind societies and members of these societies of a common past, provide the continuity of the experiences and traditions that people have accumulated throughout history, and guide future formations (Kuşcuoğlu & Taş, 2017; Yastıklı et al., 2022).

Today, with the developing technology, it has become possible to transfer the tangible cultural heritage to the digital environment with the possibilities of modeling, photographic recording, and communication. Many academic and industrial studies are conducted in this field. The use of three-dimensional realistic models in fields such as education, cinema, and games has become widespread, and applications that provide virtual visits to historical and touristic places have begun to emerge (Kersten et al., 2018; Kiourt et al., 2016).

Today, historical artifacts can be transferred to a nearly real-like three-dimensional (3D) environment by modeling software or methods such as photogrammetry and laser scanning. The common 3D model file formats include STL, OBJ, FBX, COLLADA, GLTF and others. The main purpose of a 3D file format is to save information about 3D models as plain text or binary data. They specifically encode the textures, appearance, scenes, and animations of the 3D model. 3D printing, video games, movies, architecture, academia, medicine, engineering, and earth science all use them. While all these developments cause the diversification and spread of 3D environments; it has increased the need for platforms where specialized 3D content such as architectural works are organized (Yiğit & Uysal, 2021).

In recent years, the creation and use of projects and platforms for the sharing and regulation of cultural heritage in the digital environment have accelerated. The ARIADNEplus project (Richards & Niccolucci, 2019), supported by the European Union Horizon 2020, which started in 2019, includes the digital editing and sharing of more than one million archaeological resources, most of which are in Europe. The platform named EUROPEANA (URL-1) also includes the online presentation of the very wide-ranging cultural heritage (such as books, music, and works of art) in Europe. 3D models of works are rarely found on this platform.

In Türkiye, the transfer of cultural heritage to a digital environment has accelerated in recent years. Researchers and other users can view cultural heritage information online and in three dimensions with these studies. In a study by Arca et al. (2018); works of 3D models of cultural heritage in the historical city of Safranbolu were created and the works in the database were shared on the web (Arca et al., 2018). In a study by Altuntaş et al. (2019); three-dimensional models of Sultan Selim Mosque and Yusuf Ağa Library in Konya were created (Altuntaş et al., 2019). Another study, the Adalar Architectural Heritage Database (URL-2), shares information about the architectural artifacts found in Istanbul islands over the internet. 3D models are not included in this project.

PURPOSE

The main purpose of the platform created with this project is to store and record artifacts related to architectural heritage. Thanks to this platform, access to three-dimensional models of architectural heritage artifacts and necessary information such as the coordinates and details of these models on the map will be provided.

A database has been created on the platform, where 3D models of architectural heritage data, photographs, and information about the data will be found. A web interface has been created where users can upload 3D models of architectural heritage data, view existing 3D models interactively and approve the information about this data by authorized users. The web interface is user-friendly and provides quick responses. It is aimed to ensure that these 3D models are efficiently pulled from the created database and viewed with virtual reality glasses.

ORIGINALITY

There is a need for systematic storage of information, images, and 3D models of cultural heritage in order to share digitally transferred data with other users online. In general, there are websites such as Sketchfab and Turbosquid where 3D models are stored and offered to other users for free or for some fees. These applications contain 3D models of architectural artifacts, but do not retain information specific to architectural heritage. The proposed system, supported by virtual reality, creates a digital infrastructure that offers unique value for architectural heritage.

Generally;

- An infrastructure has been created where explanations, photographs, 3D models and other documents related to the architectural heritage will be used in a beneficial way.
- A web project is developed that allows researchers and other users to access information in the database, enter data, view and position three-dimensional models interactively.
- Three-dimensional model of architectural heritage data is displayed in virtual reality environments.
- Architectural heritage data, which has been partially destroyed or lost by natural or artificial means, is displayed in a virtual reality environment after being uploaded to the system based on data from past photographs, drawings, or other documents

METHOD

This platform, created for architectural heritage, consists of database, web, and virtual reality parts (Fig. 1).

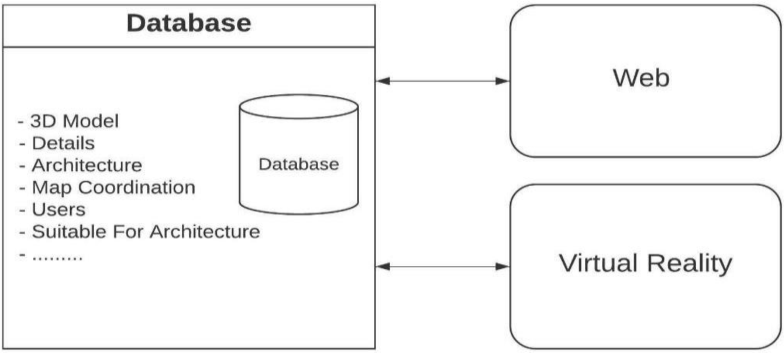

Figure 1. *Project Workspace Overview.*

DATABASE

A database (Raut, 2017) is a means of storing information such that data can be stored and retrieved from it as needed. From its inception in the 1960s until now, different types have emerged, each using its own representation of data and technology to drive transactions. First, relational databases, then object-oriented and recently NoSQL databases have been used (Raut, 2017).

The architectural heritage database (AHD) is one of the main parts of the system. The database provides storage of architectural heritage related data for record keeping. PostgreSQL, which is a relational database, was used for the AHD.

E.F Codd invented the relational database in 1970 (Li, 2018). A relational database is a collection of data items organized in formally defined tables, in which data can be accessed or reassembled in many different ways (Jatana et al., 2012). Relational databases are databases that allow us to identify and access data in relation to other data. In a relational database, data is usually kept in tables. Tables consist of rows and columns. This table/row/column structure allows relationships to be easily defined. Each row contains a unique data sample for the corresponding data category.

When creating a relational database, the domain of possible values, along with constraints, is applied to the data. It is the relationship between tables that makes it a 'relation' table (Jatana et al., 2012).

Relational database management systems (RDBMS) are software that performs the tasks of creating, updating, and managing a relational database (Verber, 2022). Most RDBMS use SQL (Structured Query Language) for accessing and interacting with databases (Verber, 2022).

Relational Databases are based on ACID model (i.e. Atomicity, Consistency, Isolation and Durability (Liu et al., 2016)). The ACID model of database design is an important concept of database theory. The ACID establishes the requirements for atomicity, consistency, isolation, and durability for a database management system. Any relational database that does not accomplish one of these four objectives is not dependable. The ACID provides consistency and usability as powerful features that make relational databases popular (Kunda & Phiri, 2017). Each of the four ACID attributes follows well-defined standards:

- Atomicity: In the shortest terms, atomicity states that database changes should follow the all-or-nothing rule. Either all operations must be successful, or even if one fails, they must all be canceled.
- Consistency: Consistency states that only valid data will be written to the database. If a transaction results in the production of invalid data, the database retrieves the data back to the most recent current state. A transaction can only update the database from one current state to another current state
- Isolation: Isolation requires that multiple transactions occurring at the same time do not impact each other's execution. Multiple simultaneous transactions are guaranteed to be independent via isolation (Kunda & Phiri, 2017).
- Durability: Durability is the storage of the data of the transactions completed by committing in a stable, durable, and continuity-guaranteed environment (such as a hard disk) in unexpected situations such as hardware failure, the transaction log, and received backups are also important in the name of adherence to the principle.

There is a huge amount of data nowadays. While the need for a data storage technology that works more effectively on the cluster in dealing with this data is increasing day by day, the NoSQL concept has been put forward as a solution to this need (Davoudian et al., 2018). NoSQL databases store data in a non-tabular way, unlike a relational database (Davoudian et al., 2018).

The CAP theorem is included in NoSQL databases (Li, 2018). The CAP theorem:

- Consistency: Consistency means that the nodes will have the same copies of a replicated data item visible for various transactions. All nodes in the distributed system must have the same data.
- Availability: Availability is the situation in which every request made to the system can receive a response, regardless of whether it is successful or not, even if it does not have the most up-to-date data.
- Partition Tolerance: Even if some of the existing nodes become inaccessible due to a network or other reason, the system can continue to work.

CAP theorem (Fig. 2) states that at most two out of the three properties (Consistency, Availability, and Partition tolerance) can be achieved simultaneously in distributed environments.

Strong consistency ensures that data appears consistently after transactions are performed. According to NoSQL, Relational Databases offer stronger consistency with solid schema (Sing, 2016).

NoSQL has tried to achieve higher performance and accessibility by compromising the strong and instantaneous data consistency of RDBMS. Relational database also has strong security mechanisms used to protect data (Abourezq & Idrissi, 2016).

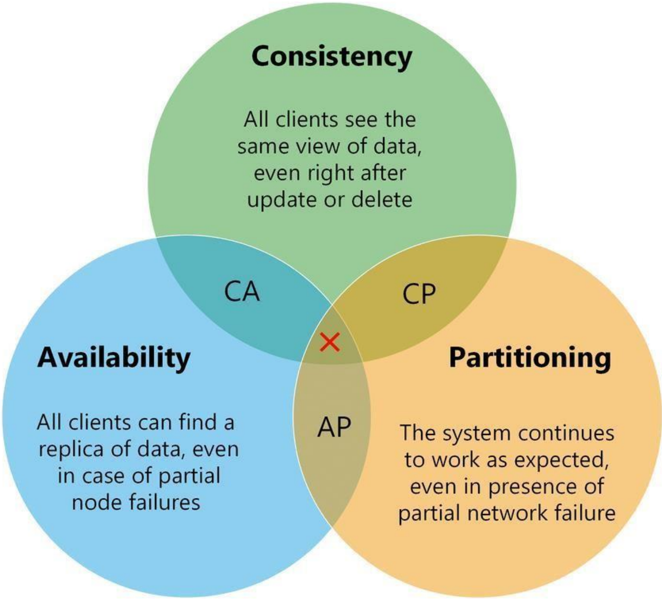

Figure 2. *CAP Theorem (URL-3).*

Every user should see a consistent version of the data. This includes changes made by the user himself and changes made by other users. Accordingly, even when the user himself or another user performs the operation at the same time, he will need consistent architectural heritage data. For this reason, the relational database was preferred in the project as data consistency and security are more important than NoSQL. At the same time, the Relational database was used in the project for reasons such as supporting acid property and supporting operations (complex operations as well as joins) as mentioned before.

An entity-relationship model of the database created to keep information about architectural heritage efficiently, in which the relationships between the data are indicated (Fig. 3).

Model Suitable table keeps information such as the compatibility of architectural heritage data with architecture, augmented reality and virtual reality. If a data is not suitable for any of these, it will not be added to the system since authorized persons will not approve them. When authorized persons reject the data due to any nonconformity, the disclosure information is also kept in this table.

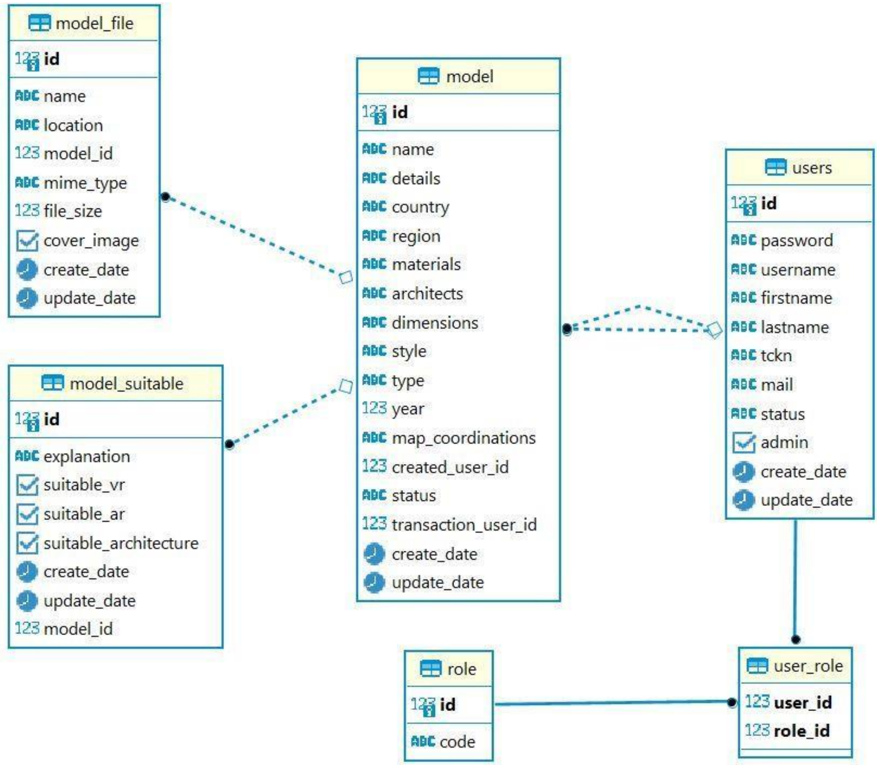

Figure 3. *An entity-relationship (ER) model in which the relationships between the data of the created database are shown.*

In the model table, information about the architectural heritage data are kept. This information includes features such as model name, details, year, architects, coordinates and physical condition.

Artifacts in the architectural heritage data are divided into five classes according to their current physical condition, and this information is stored in the model table (Grilli et al., 2018) (Fig. 4):

1. Completely lost: Artifacts that have not survived physically; as it can be learned through information such as tablets and drawings found in archaeological sites, artifacts that have been destroyed in the recent past due to reasons such as war and natural disasters are also in this class. It may be possible to obtain information about the works from architectural plans, visuals, explanations and descriptions in written texts (Fig. 4A).
2. Ruins: These structures are mostly found in archaeological sites and unearthed through excavations. Although most of it is gone; It is possible to reach useful information about the structure of the work, the materials used and the architectural methods (Fig 4B).
3. Remains: Most of the works in this class have survived and information about the missing parts can be obtained from different sources such as written texts, drawings and plans (Fig. 4C).
4. Artifacts that have survived to the present day in their original form: Artifacts that have survived to the present day, except minor restorations, which did not need any intervention, fall into this category (Fig. 4D).
5. Remaining to the present day by changing in the historical process: Artifacts that have been transformed or reconstructed for reasons such as destruction, political changes, and technological developments throughout history fall into this category. The historical transformation of such works should also be recorded (Fig. 4E).

Figure 4. *Examples of architectural heritage belonging to different classes according to their Physical Condition.*

Files of architectural heritage data are kept in the Model File table. Information about the 3D files, texture files and photographs of the data are kept in this table. Amazon Simple Storage Service (Amazon S3) is used to store the files of the data. This service is preferred because it is an object storage service that offers scalability, data availability, security and performance. User information is kept in the users' table. In the role table, there are authorizations such as adding a model and approving the model. The information about which role the users have, is also kept in the database.

WEB

A web project has been developed for the effective use of architectural heritage data. With this project, users will be able to add architectural heritage data, view 3D models interactively, and view details of architectural heritage data (Fig. 5, Fig. 6).

Figure 5. *An example image from the web project.*

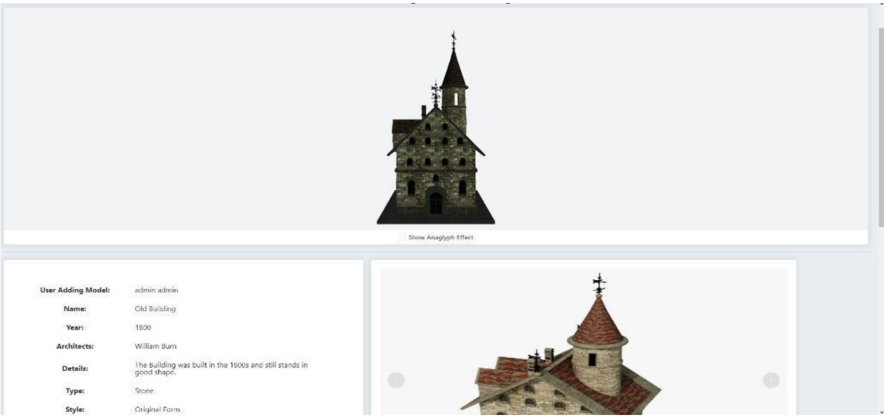

Figure 6. *An example image from the web project.*

In the web project Spring Boot is used for the server and Vue.js is used for the frontend. Spring boot interacts with the database on request. Vue Client sends HTTP Requests and receives HTTP Responses using axios and displays data about components. In addition, the Vue Router is used to navigate the pages. The architecture created for the web project is shown (Fig. 7).

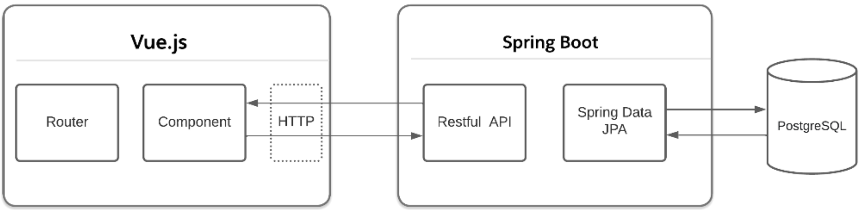

Figure 7. *Architecture Designed of Web Project.*

Frontend

Frontend allows users to have a nice experience while interacting with the interface. It is important to optimize front-end performance when building applications, as it plays an important role in web applications (Sianandar & Manuaba, 2022).

Vue.js is a progressive framework for building user interfaces. Unlike other monolithic frameworks, Vue.js was designed from the ground up to be progressively acceptable. It is not only easy to use, but also easy to integrate with third-party libraries or existing projects. According to the design idea of MVVM (model-view-view model), Vue.js realizes two-way binding of data and view, reducing the connection degree of each part, and more flexible to use. Vue.js is widely used in developing web-based applications (Kyriakidis et al., 2016; Zhang et al., 2021; Sianandar & Manuaba, 2022).

The Vue.js framework can be directly integrated into the Spring Boot framework, and the Spring Boot framework can help complete autoconfiguration (Zhang et al., 2021). A schematic diagram of the MVVM mode of the Vue.js framework (Fig. 8). The Vue.js framework was chosen because of its ease of use, progressive framework, and easy integration with third-party libraries.

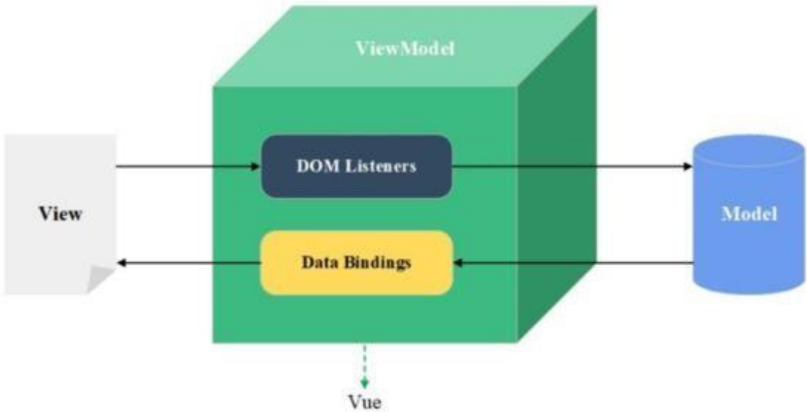

Figure 8. *Schematic diagram of MVVM mode of Vue.js framework (Zhang et al., 2021).*

The web application provides data viewing and user interaction, and also enables artifacts to be displayed in 3D and positioned on the map.

The 3D models taken from the database are displayed in 3D on the browser with WebGL, the version of OpenGL that works in internet browsers. At the same time, the Three.js library is used to display models in 3D. Three.js is a 3D JavaScript library that enables developers to create 3D experiences for the web. With the Three.js library, they are able to use features such as zoom in, zoom out, rotating on models. It is also provided to display 3D models as anaglyphs.

Three.js is used in the web application because the Three.js library provides loaders for various 3D file formats and supports the anaglyph feature.

Google Maps was used to position the 3D Models on the map. Google Maps was chosen because it offers a robust set of APIs for creating and interacting with maps, visualizing location data, and searching via autocomplete. While adding architectural heritage data in the web application, it can be positioned by moving the marker on the map or by entering the longitude and latitude information.

What is Anaglyph?

The most widely used and affordable 3D visualization technique is anaglyph. For this reason, it has started to be used in many 3D applications. Anaglyph 3D is a stereoscopic 3D effect achieved by coding the image of each eye using filters in colors, typically red and cyan. Two separate filtered color images, one for each eye, are included in anaglyph 3D images. Each of the two pictures reaches the targeted eye when seen through "color-coded" "anaglyph glasses," creating an integrated stereoscopic image. The visual cortex of the brain combines this with the perception of a three-dimensional scene or composition (Dhaou et al., 2019).

Server

The Spring Boot framework is the basic component that is responsible for collecting, storing data from the data collection layer. In addition, The Spring Boot framework receives and processes data requests from the display interface layer, as well as provides a standard data interface to external programs (Zhang et al., 2021).

The Spring Boot framework is a subproject within Spring project. The Tomcat server is integrated inside the Spring Boot framework, which can run directly without deployment. The Spring Boot framework is easy to configure and is preferred and used because it runs the tomcat server directly (Miao et al., 2020).

Spring Data JPA is preferred to perform data layers operations. Spring Data is part of the Spring library. Spring Data JPA is not a JPA provider. It is a library that adds an extra layer of abstraction on top of our JPA provider (like Hibernate). Spring Data is an abstraction used to significantly reduce the amount of source code required to implement data access layers.

Restful API is used for data flow between client and server.

REST is a software architectural style that defines the set of rules to be used for creating web services. REST provides communication between client and server, working over HTTP protocol (Fig. 9). It provides communication of the application by carrying XML and JSON data between client and server. Services using REST architecture are called RESTful services (RESTful API).

Rest uses the HTTP protocol to exchange data and files over URL addresses. When a request is made to a URL, a response in URL JSON or XML format is returned, the response is parsed, and the request is completed. REST client-server can communicate easily even if hosted on different servers.

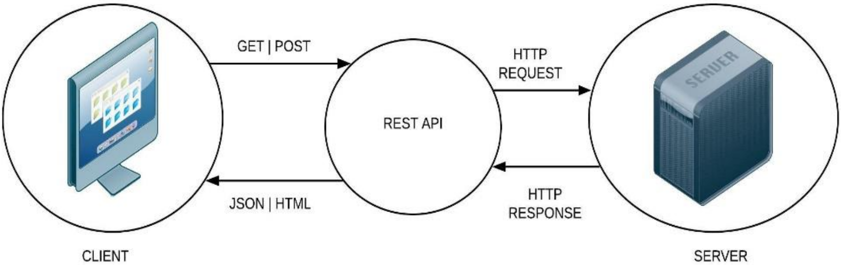

Figure 9. *Rest Software Architecture.*

HTTP requests are:

- GET is used to list and display data.
- POST is a request to add data
- DELETE is used to delete data
- PUT updates data if it exists, adds it if it is not

VIRTUAL REALITY

The purpose of the virtual reality (VR) application is to display the three-dimensional models in the architectural heritage database in the virtual reality environment. The device that will perform the imaging is the Google Cardboard derivative virtual reality devices, which are more convenient for widespread use due to their price. These devices work with the principle of creating a binary (stereo) image on the smartphone screen placed inside (Fig. 10A). By dividing the phone screen in the horizontal position into two halves, the image created for the right eye is shown on the right side, and the image created for the left eye is shown on the left side. The lenses on the screen bring the perceived screen distance to a reasonable level. Head movements are detected with motion sensors on the phone and the user is given the opportunity to look in desired direction (Fig. 10B).

A- Principle Of VR B- VR image example

Figure 10. *VR principle and VR image example (URL-4).*

FLOW OF THE PROJECT PROCESS

Unregistered users must register to access the platform. They can then gain access to the platform. Authorized users can change the roles of existing users or newly registered users. They can give users the authority to "Add Models" and "Confirm Models". Only users with the "Add Model" authorization can add architectural heritage data after entering the required information (Fig. 11).

Before adding the architectural heritage data system on the model add page:

a. 3D model files of architectural heritage data can be viewed interactively (Fig. 12).
b. Photographs of architectural heritage data can be viewed (Fig. 13).
c. By moving the marker on the map or by entering the coordinates, the coordinate where the architectural heritage data is located can be determined (Fig. 14).

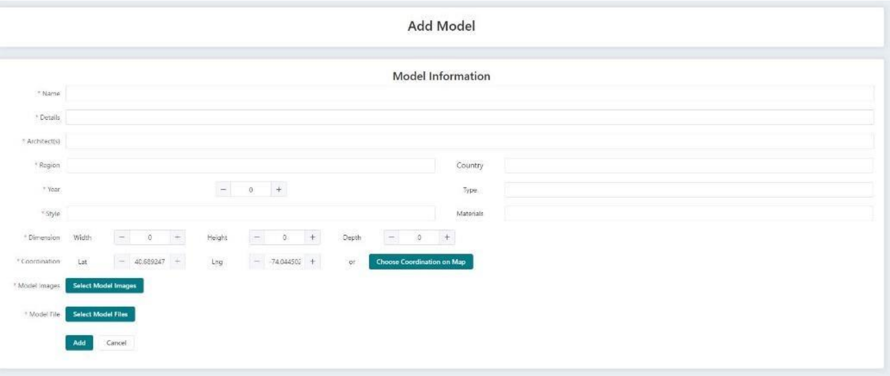

Figure 11. *Model add page, after entering the information here, the model is added.*

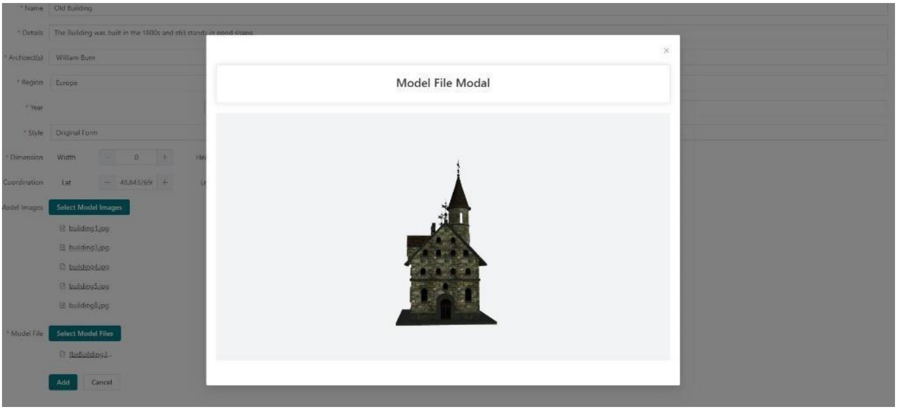

Figure 12. *Model is displayed in 3D on the Add Model Page.*

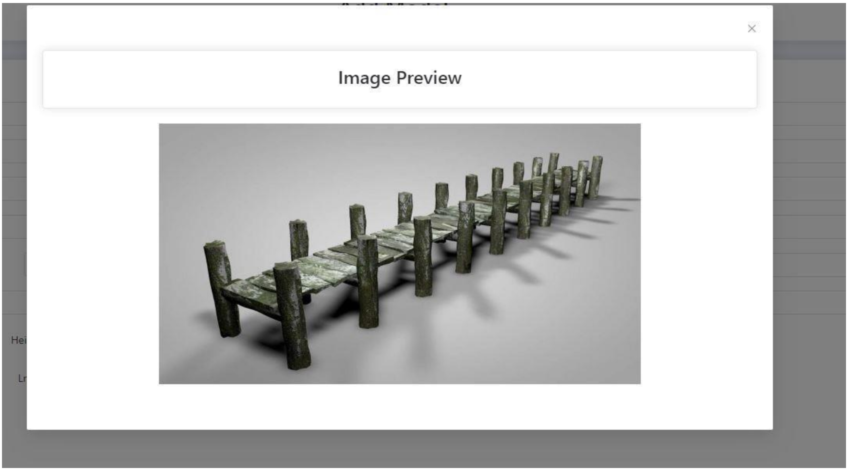

Figure 13. *Photographs of model can be viewed on the Add Model Page.*

The compliance of "architecture, VR, and AR" is checked by users with the "Confirm Model" authorization for newly added architectural heritage data or existing architectural heritage data (Fig. 15). If it provides all these three features, it is approved by authorized persons and added to the system.

If any property is not provided, it rejects the data by adding a comment. After the user corrects the data, it is reviewed again.

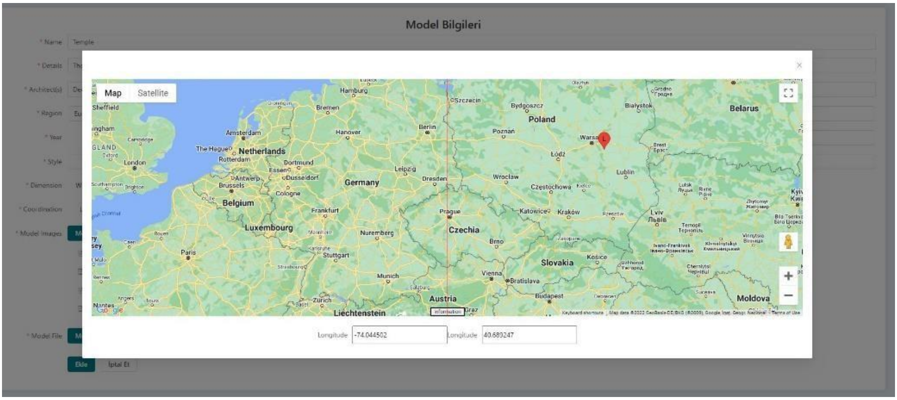

Figure 14. *Map on Add Model Page.*

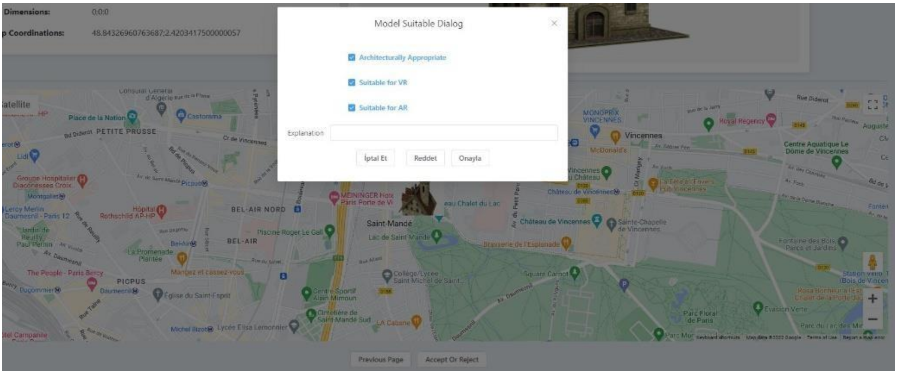

Figure 15. *The compliance of "architecture, VR, and AR" is checked by users with the "Confirm Model" authorization.*

The confirmed architectural heritage data can be viewed by anyone in the system (Fig. 5).

Details of architectural heritage data can be viewed on the detail page as follows:

a. 3D model of architectural heritage data is displayed interactively.
b. The 3D model of architectural heritage data can be displayed as anaglyph (Fig. 16).

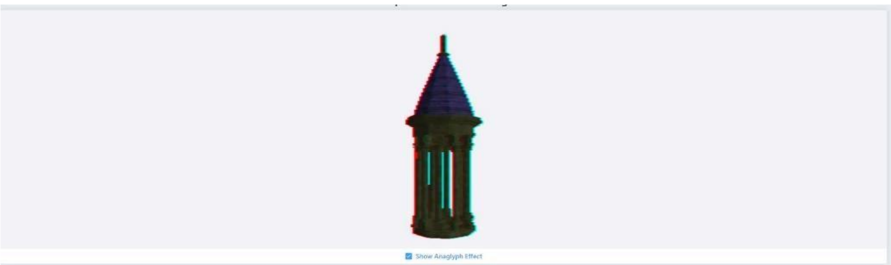

Figure 16. *Example of anaglyph effect of 3D model.*

c. Detailed information and photos of architectural heritage data are displayed (Fig. 17).

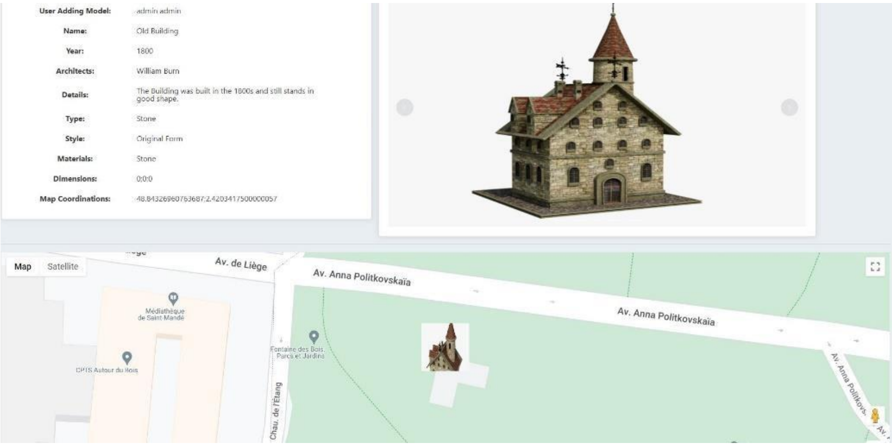

Figure 17. *On detail page, an example image of the data and location information.*

d. The location information of the architectural heritage data is displayed on the map (Fig. 17).

CONCLUSION AND RECOMMENDATIONS

In recent years, developments in digital photogrammetry and computer technology have also significantly affected the spread of cultural heritage on digital platforms. Thanks to this created platform, it is ensured that cultural artifacts are recorded. In addition, 3D models of architectural heritage are displayed interactively with this platform. Since the platform also supports virtual reality, virtual tours can be made around and inside cultural structures.

The 3D architectural heritage platform allows recording the current state of heritage that has been damaged, partially destroyed, or lost by natural or artificial means. It can also be shown by recording the changes that the heritage has undergone over time. The platform enables users to witness history by displaying cultural artifacts in virtual reality environments in three-dimensions. In this way, people can gain social and interactive experiences that combine learning with fun.

Architectural heritage artifacts that have been destroyed or in need of restoration can be restored in a way that protects the cultural heritage by making use of this platform. In addition, through this platform, a system has been created that can be used by people from different disciplines such as computer science, architecture, archeology and urban planning, and that allows various collaborations to be established.

In line with the results of the study, it is recommended to write an augmented reality application using this platform. Thanks to this application, it is possible to display the architectural works in their real location, allowing users to see the past images of the works in the present time period.

As a result, keeping up with the times with the developments in technology, it is possible to protect and sustain the cultural heritage and transfer it to future generations. In the future years, important developments can be seen in many areas such as tourism, with the provision of physical and digital access to cultural heritage.

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