Article

System Architecture Design of a Multimedia Platform to Increase Awareness of Cultural Heritage: A Case Study of Sustainable Cultural Heritage

Benshuo Wang [1], Li Dai [2] and Bojing Liao [3,*]

1   Real Estate and Urban Development Unit, Built Environment Department, Eindhoven University of Technology, 5612 AE Eindhoven, The Netherlands
2   Information System Group, Built Environment Department, Eindhoven University of Technology, 5612 AE Eindhoven, The Netherlands
3   Institute of Creativity and Innovation, Xiamen University, Xiamen 361005, China
*   Correspondence: lbj@xmu.edu.cn

Abstract: Cultural heritage (CH) plays a vital role in passing history to the present and also the future, which means it is important to build an efficient and friendly way to broadcast and inherit these past civilizations. Information communication technology (ICT) is one of the popular methods that can attract people's attention on understanding history or joining in heritage preservation. To achieve that, governments have built a large numbers of official ICT platforms. However, most of them neglected people's preferences on the retrieval of cultural heritage information. In terms of user experiences, the previous platforms are less than satisfactory in increasing the awareness of the cultural heritage. Thanks to the new technology, 3D models and virtual reality (VR) bring spring life to cultural heritage. This paper developed a new multimedia platform based on people's preferences to overcome these disadvantages. UML-based web engineering (UWE) is applied to present the web application's architecture, the database structure, and the platform's interface. To demonstrate the multimedia platform, Strijp-S, an industry cultural heritage site in the city of Eindhoven (the Netherlands), has been used as a case area. This proposed platform provides a new idea on system architecture design of the multimedia platform and may strengthen the public's knowledge of cultural heritage, and thereby increase the awareness of cultural heritage to keep it sustainable.

Keywords: cultural heritage; multimedia platform; UML; database structure; sustainability

1. Introduction

There exist many different media resources to describe and record cultural heritage artefacts, but most of the resources are traditional and vague (i.e., posters on the cultural heritage field) or lack effective processes of digitalization (i.e., oral information) [1–3]. Limited information on a cultural heritage object makes it hard for people to comprehend the heritage on-site and understand its value, and this holds even more for people who cannot visit the cultural heritage site [4,5]. Therefore, there is a need for the public for facilities to access and better understand the tangible and intangible aspects of cultural heritage. Information communication technology (ICT) offers wide accessibility, and it not only allows the user to acquire information about each object as a single, isolated element, but also to view it as part of a broader context, which can help him or her to better understand the whole history of the cultural heritage [6,7].

Media are the carriers to broadcast cultural heritage to the public. In the past century, it was not easy for the public to directly access information on cultural heritage [8,9]. Usually, people acquire information from others, such as via oral stories, resulting in limited understanding of heritage. Today, ICT is used for the development of websites for cultural heritage, often for touristic purposes [1,10,11]. These websites provide enough

information to attract tourists to cultural heritage sites. However, these platforms are not usually developed by taking into account people's preferences regarding the provided information and media to deliver information for each type of cultural heritage. Therefore, these platforms might not be the most optimal for their users.

In recent years, cultural heritage institutions have explored the opportunity to use ICT to enhance the visitor experience, considering the need for information and suitable media for information delivery prior to, during, and after the visiting experience [12,13]. When tailored to the user's needs, ICT platforms can increase awareness of the site, thus supporting citizens and decision-makers to plan activities to protect the cultural heritage [14]. Some studies have focused on the relationship between cultural heritage and ICT design, especially to increase people's awareness of cultural heritage [15–18]. For example, a platform, called PLUGGY, a pluggable social platform for heritage awareness and participation, intends to attract citizens to learn about cultural heritage [19]. Other studies have emphasized the use of ICT in relation to cultural heritage for different purposes. For example, ICT platforms can teach students history and educate them on the preservation of cultural heritage [7,20]. Also, specific ICT applications such as AR/VR applications used in museums can entertain and inspire children, while supporting their learning during recreational time [21].

Although ICT platforms do support users in acquiring information about cultural heritage more easily, they still have shortcomings. First, some platforms use only a single medium, such as Mobile Vaani (MV), which uses single voice media to broadcast cultural heritage to the public [22]. This type of platform can help users to focus on the cultural heritage content through one medium without much effort, but due to the lack of visuals, it cannot support visitors in comprehensively understanding all aspects of a cultural heritage. To gather more information, users have to use other platforms to access more media [23]. Second, the existing single or multimedia platforms do not test people's preferences for the content and media type before the development phase, resulting in unattractive and unsustainable platforms [24]. Third, most of the existing platforms were developed by official authorities. These platforms do not necessarily provide the type of information preferred by users. For example, these platforms show the differences between the past and the present, but ignore more detailed changes about the cultural heritage, such as the process during the changes [25]. Lastly, existing platforms typically cannot be edited by the users; users cannot share their stories or experiences of cultural heritage with other users [26]. Therefore, this research aims to create a new multimedia platform as a prototype to address the above problems.

To increase people's awareness of a cultural heritage by promoting an efficient ICT platform, this study proposes a newly developed multimedia platform. The new platform's design is based on our previous study [24]. The results of that study indicated that users prefer to acquire more information through multiple media types. In addition, users prefer to use more vivid media and advanced technologies to access information and are interested in using the platform's functionalities to understand cultural heritage. The new multimedia platform takes Strijp-S as the cultural heritage site. Strijp-S is an industrial Philips factory located in the Netherlands. The platform uses traditional media, such as 2D maps, text, photos, and videos, as well as media based on advanced technologies, such as 3D models and virtual reality (VR) to display Strijp-S. The platform includes specific buildings, public spaces, and the landscape as tangible cultural heritage elements, and persons, events, and local lifestyle as intangible cultural heritage components. Moreover, it adds a timeline and uploading-experience functions. In this study, the UML-based web engineering (UWE) is used to describe the web application's architecture, the database structure, and the platform's interface.

Based on the literature review above, the main problem is that the existing media platforms do not achieve the expected effectiveness for many reasons, especially because these platforms were not created based on user preferences. Therefore, the main objective of this research is to build a new multimedia platform based on results of user preferences

to media types and cultural heritage content to increase user awareness of cultural heritage and prevent the loss of cultural heritage.

The current research is structured as follows: Section 2 gives a brief introduction of the case area applied in this study—Strijp-S; Section 3 describes the interface of the new multimedia platform; Section 4 explains the architecture of the platform; Section 5 illustrates the different layers in more detail; Section 6 describes a small-scale sample test; and the conclusions are given in Section 7.

2. Case Study: Strijp-S, Eindhoven

Strijp-S is a neighborhood in the district Strijp of Eindhoven, the Netherlands, and the former industrial campus of Philips electronics company. The buildings in the area were built and served with industrial purposes (i.e., factories and offices) to the company Philips. In 1916, Anton Philips built the first glass factory in Strijp-S to produce light bulbs. At Strijp-S, Philips invented and produced many electronic devices, such as radios, CDs, and televisions. The majority of the employees were from the city of Eindhoven. The innovative and productive culture of Eindhoven stemmed from the Philips campus in the Strijp-S area. In the 1990s, the Philips company moved out of Eindhoven, and in 2000 deliberations and plannings about the repurposing of Strijp-S started. In 2002, the land was sold to Park Strijp Beheer B.V., which is a public–private partnership between the city of Eindhoven and VolkerWessels, a Dutch contractor. Today, thousands of new citizens and small high-tech companies occupy the renovated industrial buildings and use the repurposed spaces after the departure of Philips from the area. As a result, Strijp-S is gradually developing towards the new center of Eindhoven [27–30].

3. Interface of the Multimedia Platform

The multimedia platform of Strijp-S (https://strijp-chaware.tue.nl/index.php accessed on 1 September 2020) developed during this research uses the 2D map of the area as the entrance because a map can support access to a range of information sources [31]. On entry, the user can first create a basic understanding of the layout of this area. With the navigation bar on the left, users can choose which tangible cultural heritage object (buildings, public spaces, and the landscape) they would like to learn more about (see Figure 1). When they choose a category, such as the buildings, the related pins representing the POIs will show on the 2D map (see Figure 2). The users can then select the POIs of their interest.
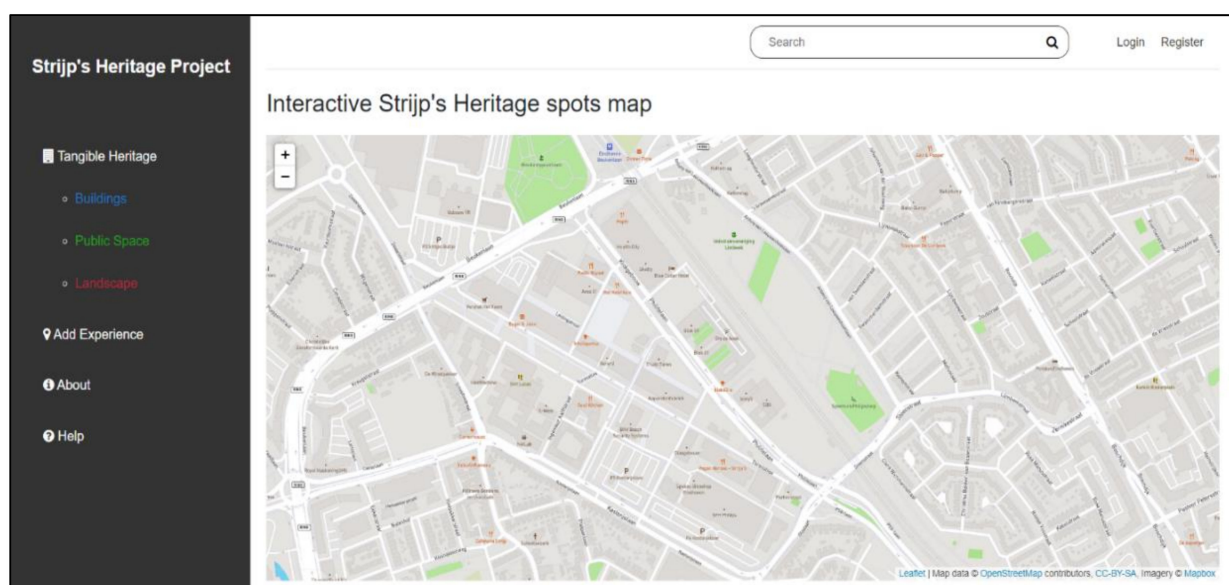

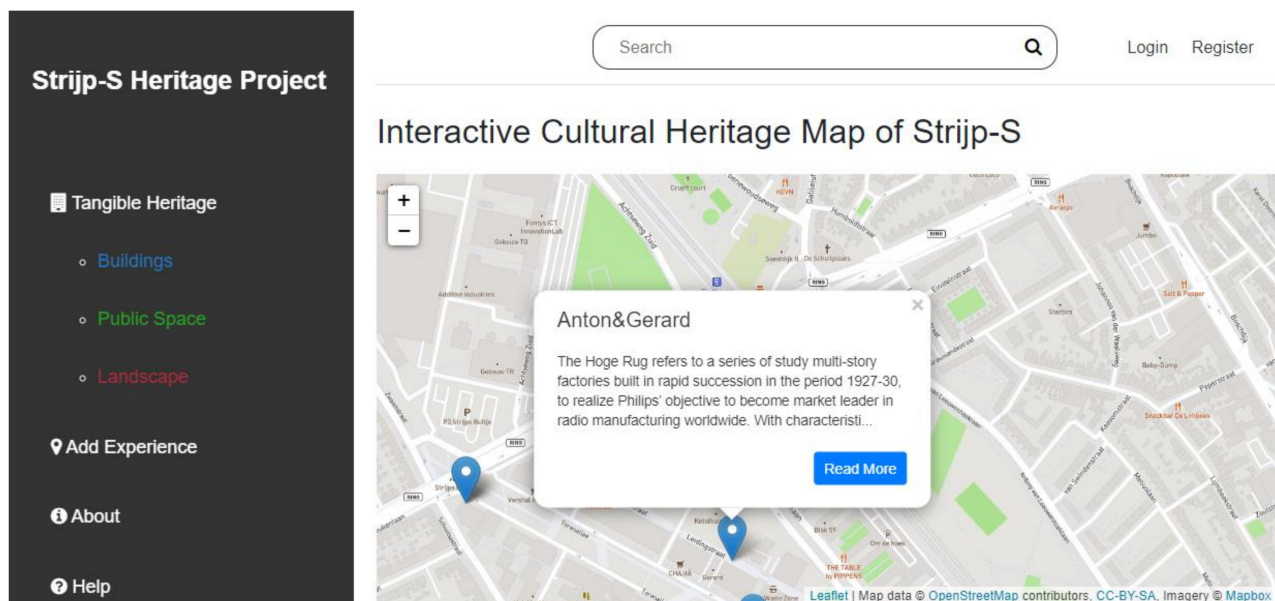**Figure 1.** Multimedia platform entry page.

Figure 2. Cultural heritage objects retrieved from a database.

After clicking on a POI, the information index will appear, which lists all related items about this cultural heritage object (see Figure 3). For example, if the user clicks on the "Anton & Gerard" building POI, the building details, related event information, person information, and local lifestyle information are listed. The user can then select any of them to retrieve more information. The stored information about a cultural heritage object includes the following media: text, photos, videos, 3D models (optional), and VR media (optional).
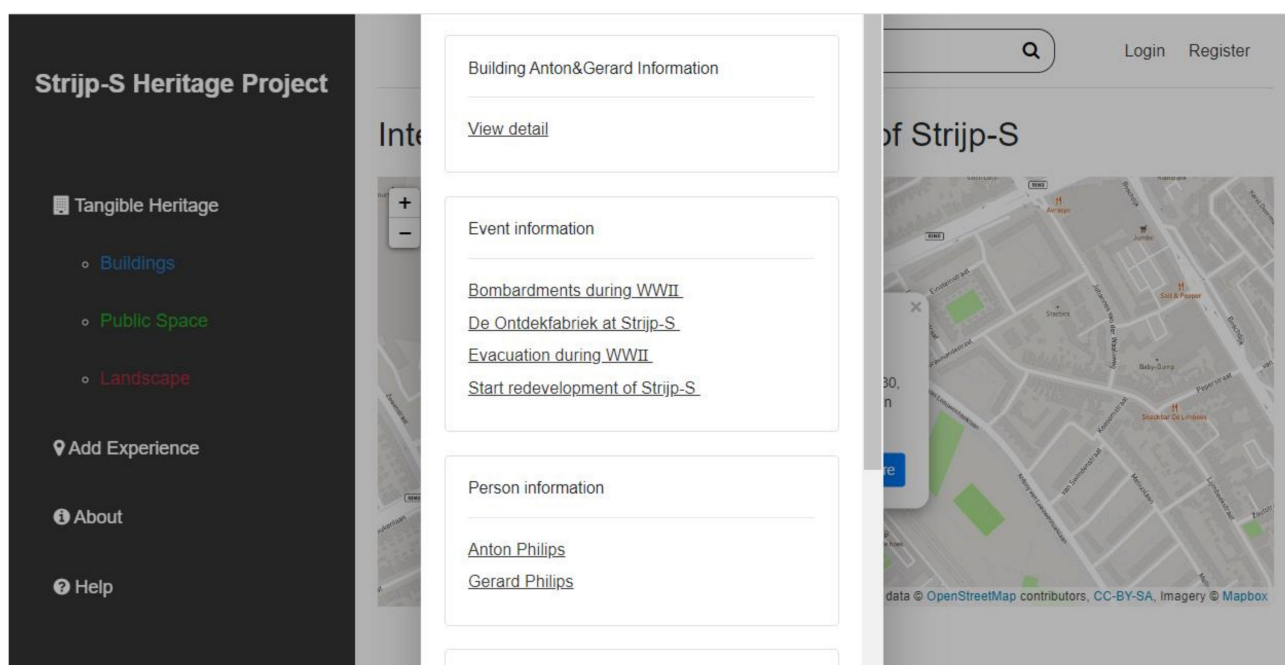

Figure 3. Information List for selected CH object.

Consider the "Anton and Gerard" item as an example. After clicking view detail, the available information about the "Anton and Gerard" object is presented (see Figures 4–6). Similarly, after clicking event information, person information, or lifestyle information about the object, the related intangible cultural heritage information is presented.
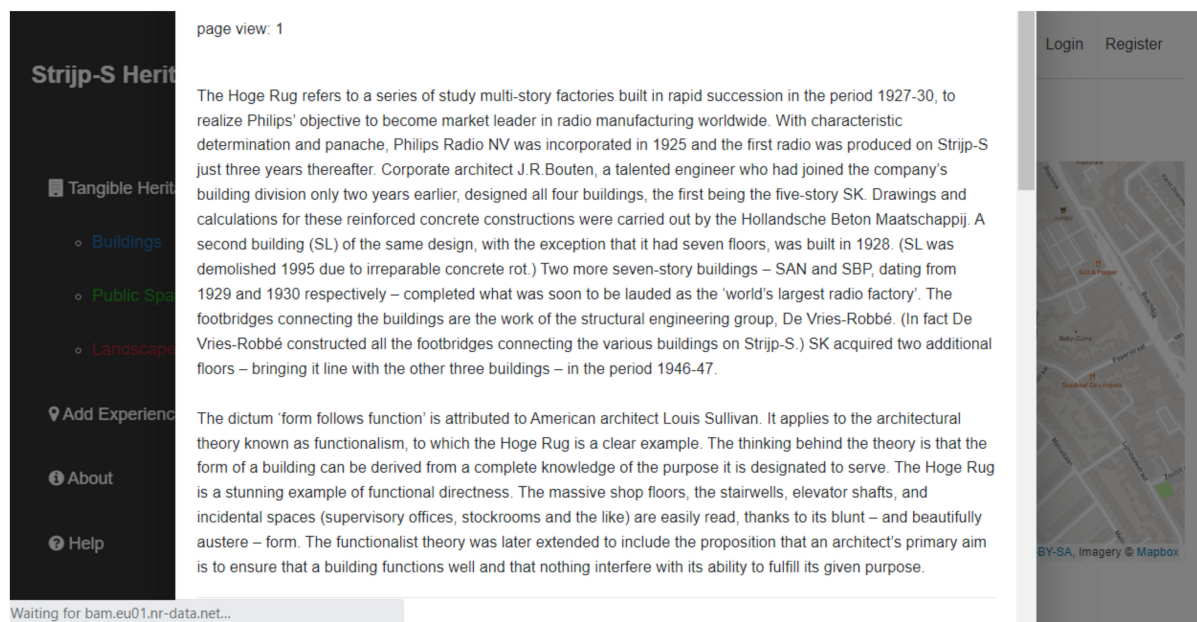
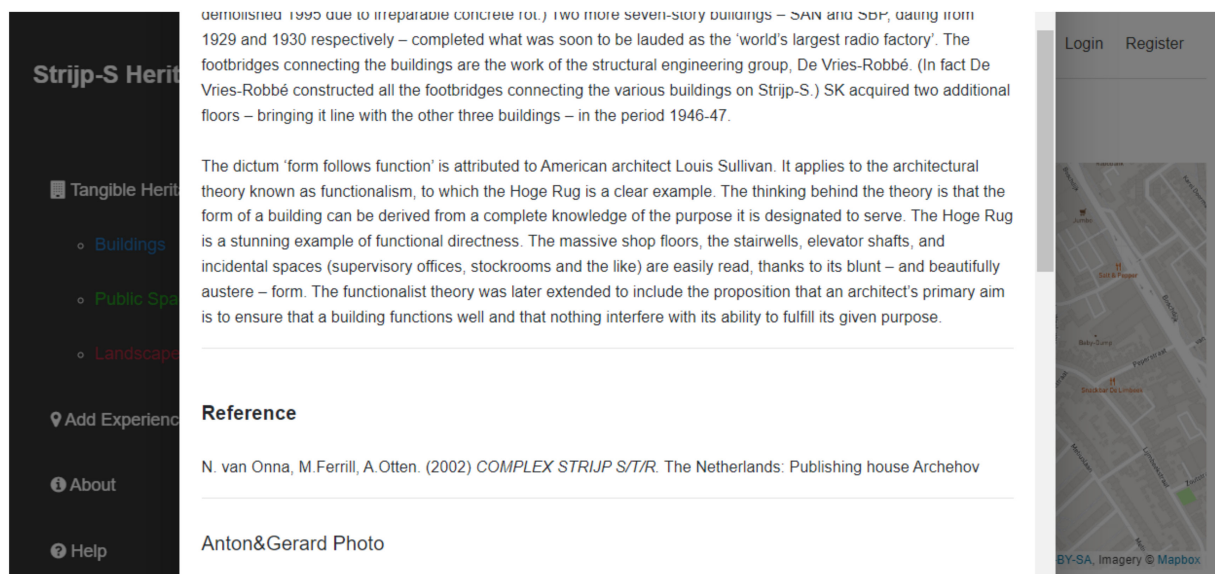**Figure 4.** View detail on building. Anton and Gerard, page 1.

Figure 5. View detail on building. Anton and Gerard, page 2.

In sum, the developed multimedia platform includes a variety of media, such as 3D models, virtual reality (VR) models, and the functionality of timeline. These functions and media can be found in the "view details" of the tangible cultural heritage information index. In the 3D models (see Figure 7), users can rotate and zoom in/out on the model to see the whole layout or part of the tangible cultural heritage. The VR view (see Figure 7) is supported by Google Panorama VR, with which the users can view the 360° panorama environment to watch the real-time tangible cultural heritage and its surrounding environments. For the timeline function (see Figure 7), users can use the middle button to drag left or right to show the past and the current pictures of the tangible cultural heritage. In this way, they can compare the obvious changes of a heritage object between two different years.
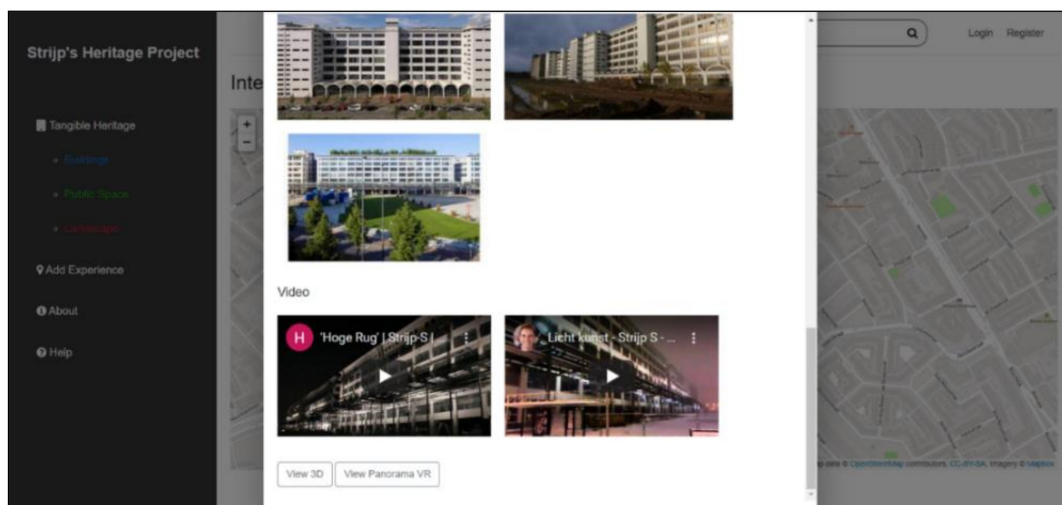
Figure 6. View detail on building. Anton and Gerard, page 3.
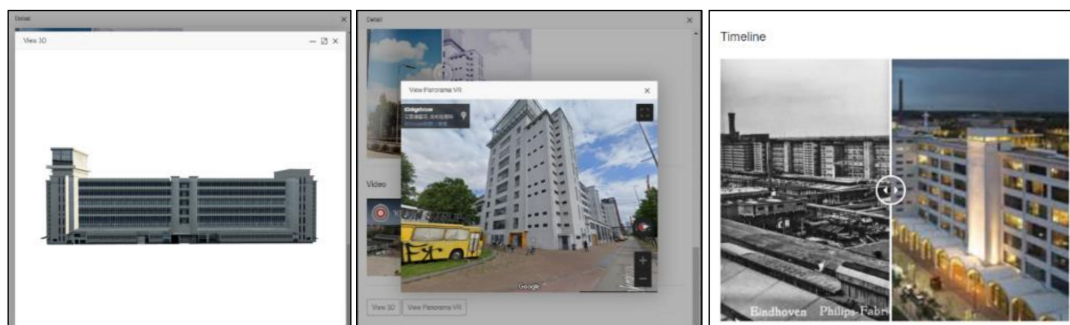
Figure 7. Functions of 3D model, VR, and timeline.

In addition to multimedia, users can create their own account and upload their personal experience with a cultural heritage object to the platform. For that, users first need to select an existing cultural heritage object on the map, then describe their experience and upload relevant text, photos, and videos (see Figure 8).
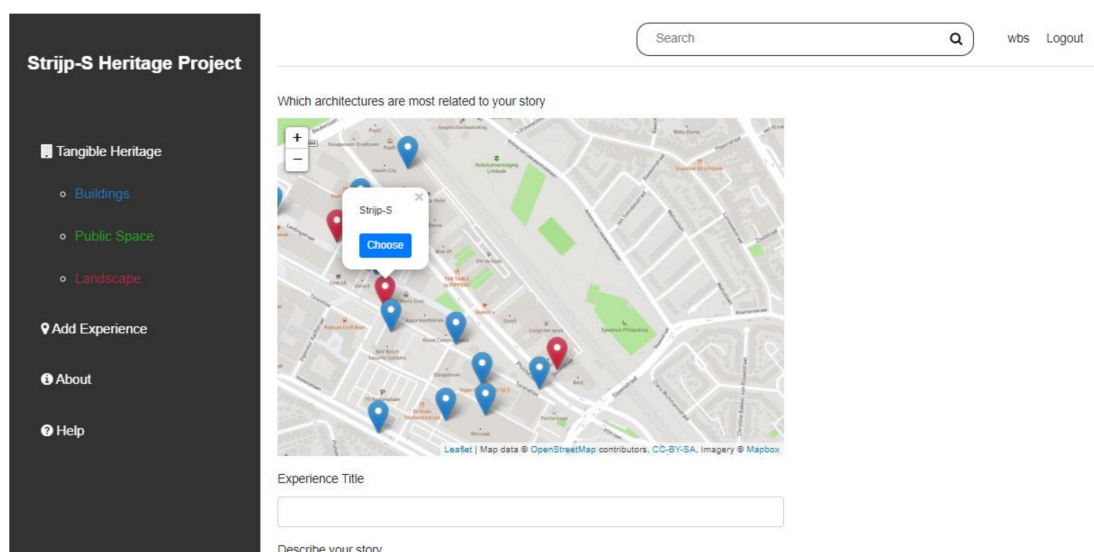

Figure 8. Adding personal experience to the platform.

4. Multimedia Platform Structure

We use unified modelling language (UML)-based web engineering (UWE) to explain the system architecture. UML-based web engineering (UWE) was designed as a common language to define a metamodel-based web mapping methods in addition to existing software engineering methods [32,33]. The tool was developed by Baumeister et al. at the end of the 1990s [34]. The UWE methods have recently been adapted to new web systems, such as transaction-based, personalized, context-dependent, and asynchronous applications [35]. UWE incorporates various software engineering techniques, such as aspect-oriented modelling and new model transformation languages to improve design quality [35]. In this project, UML diagrams are used to represent UWE models of the multimedia platform prototype. UML has been practiced successfully in the modelling of large and complex systems. The UML is used to explain the design of software projects or systems by means of graphical notations [33].

As explained, the multimedia platform prototype described in this study uses a 2D map as the first step to explore and access the information available on the cultural heritage of Strijp-S. All the tangible cultural heritage, buildings, public spaces, and the landscape are shown on the map as a points of interest (POIs). Given that the platform is designed as map-based, the intangible cultural heritage is attached to the related tangible cultural heritage. For example, if users would like to know about an event, they first need to look up the related artefact on the map. Also, users can type keywords in the search bar to look for information that interests them. Finally, the platform allows users to upload their own travel experience to inspire others.

4.1. Multimedia Platform Use Case

Use cases are used to visualize the functionalities that the system provides. The UML elements Actor and UseCase are used to build use case diagrams. A use case diagram illustrates use cases, actors, and associations, showing the actor roles in interaction with the system (see the legend of Figure 9). Actors are used to model the users of the web system. Normally, the system users include anonymous users (called general users), registered users (called registered users), and the system administrator. The general users can view the whole platform and use the functionalities except for "uploading own experience". If general users would like to share their own experience with others, they need to register their own accounts and upload their experiences. Moreover, the UWE divides the use case into three different types: <<Navigation>>, <<Process>>, and <<Personalized>> use cases. The <<Navigation>> use case displays typical user behavior when interacting with a web platform, such as browsing through the content or typing the keywords into the search bar. The <<Process>> use case describes business tasks that end users will perform with the system, such as registering an account. The <<Personalized>> use case implies the personalization of a web system; it means the users can edit the system, such as uploading their own experience.

The use case model of Figure 9 includes the <<Navigation>> (□) use cases of "Search", "Choose one TCH (Tangible Cultural Heritage)", and "View Others' Experiences". In the "Search" use case, users can type keywords in the search bar to search for cultural-heritage-related information of their interest, while in the "Choose one TCH" use case, users can click on one of the POIs (points of interest) of tangible cultural heritage on the map to access information. Users can only access information of intangible cultural heritage through selected tangible heritage.

The platform also allows users to upload their own experience. Therefore, the model includes the "View Others' experiences" use case, at which users can learn about the personal experience of other users related to a cultural heritage object. "Register" is an example of a <<Process>> use case (△), which allows the general users to create their own account. The <<Personalized>> (☆) "Upload own experience" use case is utilized to support users in uploading their personal experience related to a cultural heritage object. Figure 9 presents the multimedia platform restricted to the functional requirements from

the general user and registered user viewpoints. It identifies the main functionalities and associates them with use cases. General users can search for information or choose a tangible cultural heritage (TCH) to retrieve more information and register their own account to become a registered user to upload their own experience and share it with the public.
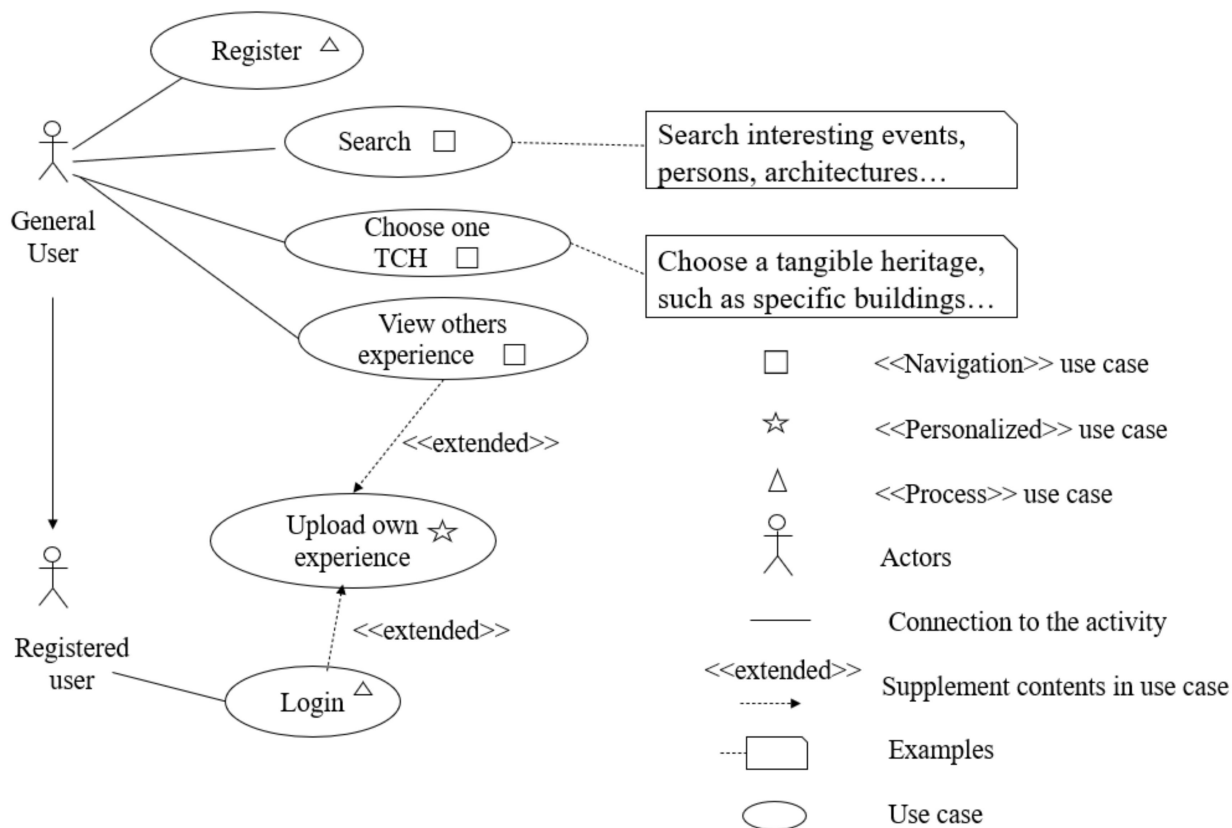

Figure 9. UWE case model for the multimedia platform.

4.2. Multimedia Platform Activity Diagram

The UML activity diagram represents workflows of stepwise activities and actions with support for choice, iteration, and concurrence [35]. It includes activities and control flow elements (see legend of Figure 10). The activities are the actions that users can perform, and control flow elements determine the sequences of the activities. The UWE profile includes a set of stereotypes adding web-specific semantics to UML activity that is depicted by the icon ○ for <<create content>>. Stereotypes of activities are used to distinguish possible user actions in the web environment, browse and search, which comprise changes in at least one database. To this category of stereotypes belong ⟹ represents <<browse>>, ⟨?⟩ represents <<query>>, and ⟺ represents transactional actions (see legend of Figure 10).

Figure 10 illustrates the activity diagram for the use case find-interesting-information in the multimedia platform. Users choose a category of tangible cultural heritage and click a point of interest (POI) on the map. Then, a list is shown with information about the selected cultural heritage, such as detailed information about a building and related intangible cultural heritage information. Users can choose an option from the list to browse the content, including the various media. After viewing the content, they can finish their actions (close the pop-up window or go back to the list/homepage to view other contents). Moreover, users can register or log in to their accounts and upload their personal experiences anytime.
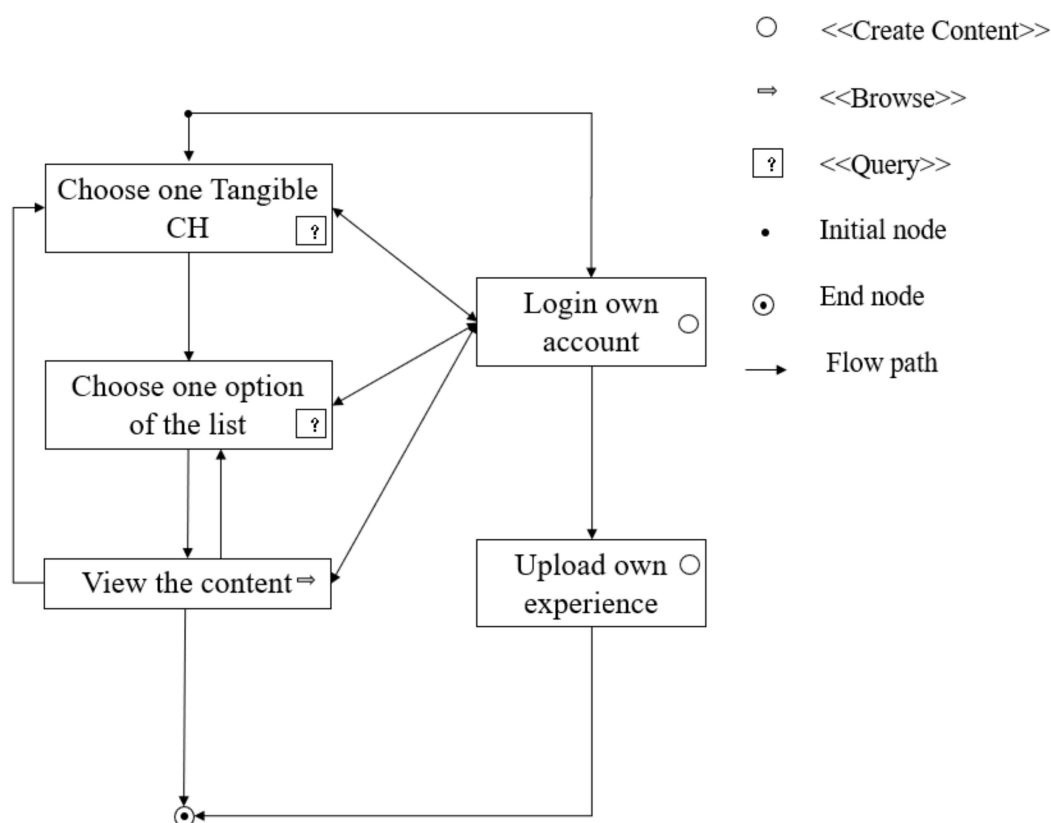
Figure 10. UWE activity diagram detailing the finding-interesting-information use case.

4.3. Multimedia Platform Content

The content model is the basis of a web system. The content model aims to present a visual description of the domain-relevant information for a web platform that mainly contains the web application's content. Moreover, it also includes entities of the domain required for customized web applications, called user models. Both the content model and user model are graphically represented as UML-class diagrams. The content model of the multimedia platform is depicted in Figure 11. While in UML-class model entities represent content and users, UML associations model relationships between content and user properties (see legend of Figure 11).

Cultural heritage is divided into two classes in the multimedia platform: tangible and intangible cultural heritage. The tangible cultural heritage class has three subclasses: buildings, public spaces, and the landscape. The intangible cultural heritage class is also constituted from three different subclasses: significant person, significant event, and lifestyle. All of these contents are displayed through different media, which are subclasses of the media class: map, 3D model, virtual reality (VR), text, photo, and video.

4.4. Multimedia Platform Navigation

Based on the requirement analysis and the content modelling, the navigation structure of the multimedia platform is modelled. Navigation classes (visualized as □) represent navigable nodes, and the navigation links show the direct links between navigation classes. Access primitives are used to reach multiple instances of a navigation class (<<index>> ≡), it includes the index of the tangible cultural heritage of Strijp-S and the index of information of tangible/intangible cultural heritage) or to select items (<<query>> ?). The entry and exit points of the business process are modelled by the process primitive (△) in the navigation model. The process links model the linkage between the navigation classes. Koch and Karus [33] designed the UWE as methodological guidelines for developing an initial outline of the navigation structure of a web application. The naviga-

tion structure of the multimedia platform designed and developed for this study using the UWE method is shown in Figure 12.
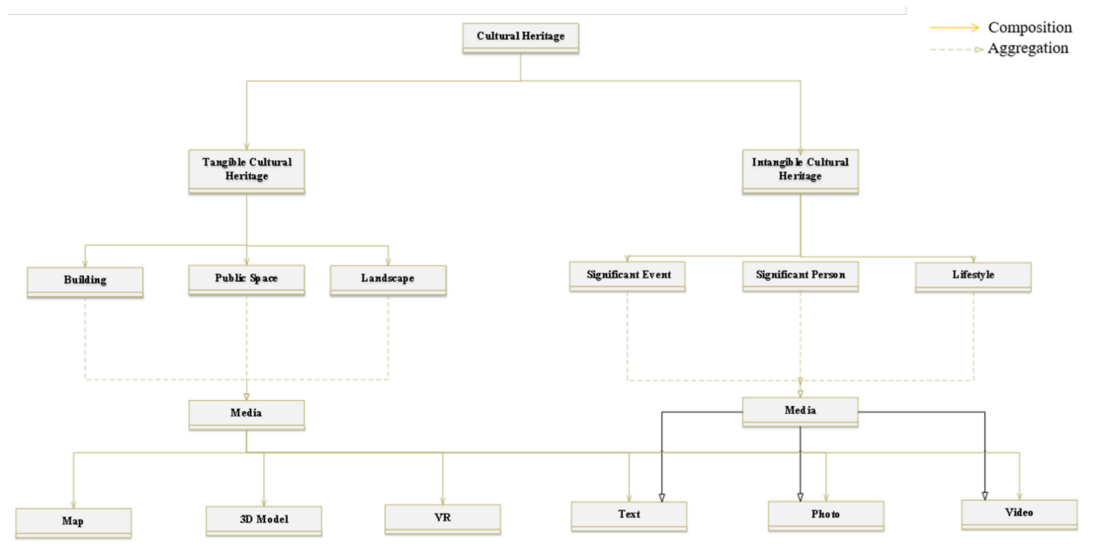

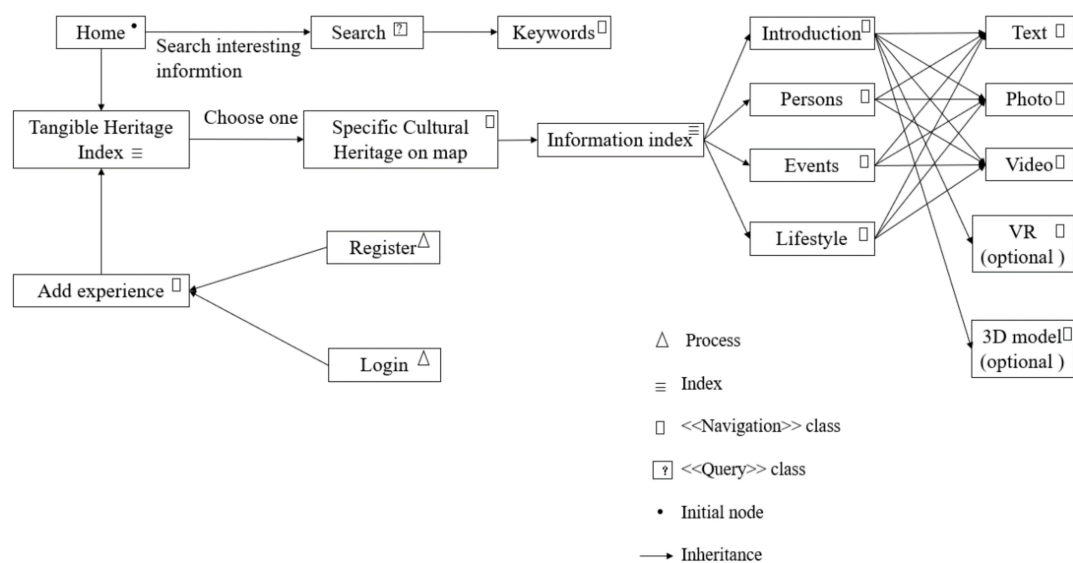**Figure 11.** Case study: Content model.

Figure 12. Navigation from specific cultural heritage.

By means of a query search, the user can search for any interesting information about a specific cultural heritage, using keywords such as the name of a building or event. Moreover, users can go to the platform's main menu (tangible heritage index) and search for specific cultural heritage by choosing an object on the map to open the information index. Then, they can select one of the available information media (e.g., photos) to open the link. The users can acquire information of intangible cultural heritage through accessing the relevant tangible object. The media will be the carrier to display all content. The search function can also be used for directly reaching the information index.

5. Database Structure

5.1. Architecture of Multimedia Platform

In the previous part, the structure of the multimedia platform was described by UWE, and in this section, the system components organization will be explained using the MVC

(model view controller) pattern, which is well-known in software engineering [36]. The MVC is commonly used in developing user interfaces [37].

The model layer can be considered as the first layer of interaction with any database used in multimedia platforms. Meanwhile, the model layer also takes care of tasks such as saving user data. The view layer displays a representation of the modelled data. It is responsible for using the correct media to present user's requested information. The controller layer handles user requests and is responsible for connecting between model and view layers.

The MVC architecture provides easy web application handling [38–41]. The Lavarel framework in PHP language for web development, built upon the MVC architecture, was used to implement the application. Laravel needs a web server running PHP5 or higher [1].

In this research, we designed and deployed a cultural heritage multimedia platform to give users access to a wide range of multimedia content. The platform uses a map-based metaphor to introduce the content delivery process for different kinds of content: text, photo, video, VR, and 3D model. The platform architecture is composed of three main layers with two main layers decomposed into two sublayers (see Figure 6). The layers are explained in more detail in the following.

The **view layer** contains two sublayers: the **map layer** and the **multimedia layer** to display the cultural heritage content. The **map layer** represents the entrance to the platform and shows all the POIs (points of interest) on the map. Users can choose the cultural heritage object of their interest (POI) to retrieve the information. The map is supported by Google maps. The **multimedia layer** contains all media used by the objects to be displayed, such as video, VR, and 3D models. The platform can present all the related media based on the user's request.

The **controller layer** manages data transfer between different media and user requests. It responds to the user's input and performs interactions on the data model objects. The **model layer** consists of a repository for managing the storage of the multimedia content, which is the platform's database. The model layer contains two sublayers: the **heritage categories and the user profiles**. The **heritage categories layer** contains the details of cultural heritage, including tangible and intangible cultural heritage information. The user details, such as their account name, e-mail address, and password, are stored in the **user profiles layer**. The database is supported by MySQL. Please see Figure 13 about the architecture of the multimedia platform.

5.2. Database Design

In the last section, we explained that the viewer layer has two sublayers: the map layer and the multimedia layer to display cultural heritage. All the media content is included in the model layer supported by a MySQL database, 8.0 version [42]. This section will explain how the MySQL database's tables (see Figure 14) are designed to connect to the map layer and the multimedia layer.

In the developed system, the map layer is the entrance to the multimedia platform. Therefore, the database's main table is spot, which represents the map's POIs, which contain all information about a specific tangible cultural heritage (CH) object, such as name and address. To save storage capacity and increase performance [43], the intangible CH objects event, person, lifestyle, and experience are the branches of the main table—spot. They contain similar attributes for every table, such as the title and ID. Because the spot table is essential to the database structure, the ID is the unique (key) attribute for every CH object in the database. It connects all other tables to the spot table. Since the media VR and 3D models are used to display only the tangible cultural heritage, they are included in the spot table. The other media, photo and video, are available to all tangible and intangible CH objects and, therefore, are stored in separate tables. The search function can reach all tables from the main spot table. For example, suppose a user would like to search for interesting information about a specific CH object. In that case, he/she can either choose the object and select from the media list to explore the CH information or type in keywords in

the search bar to retrieve CH information. Both methods can lead to reaching what he/she wants, showing the available media content. The database structure is showed in Figure 14.
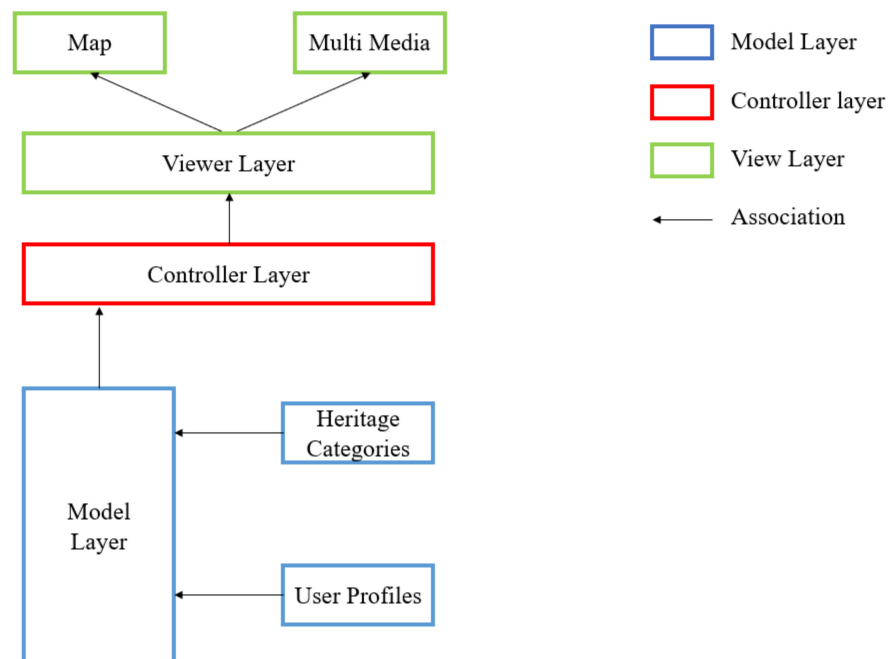

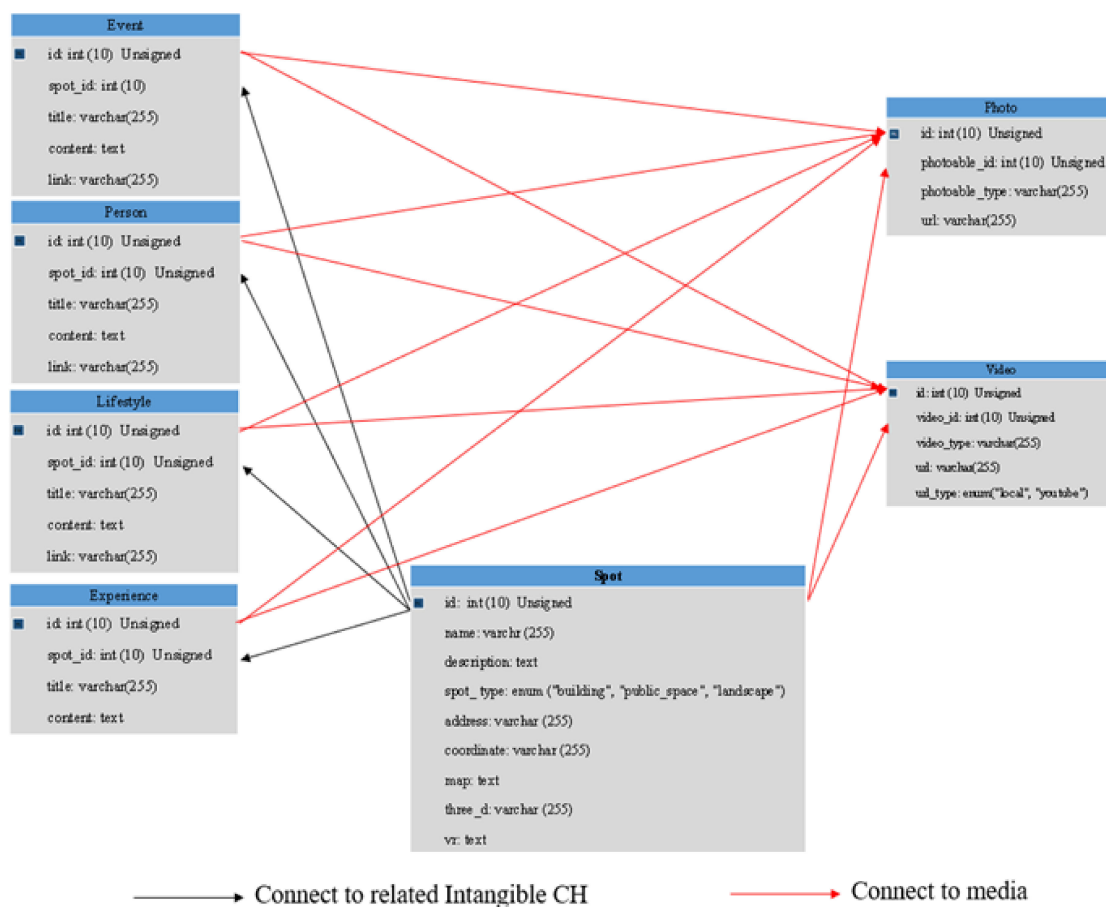**Figure 13.** Architecture of the multimedia platform.

Figure 14. Database structure of the multimedia platform.

Moreover, the platform allows users to upload their own experiences to enrich the database. At first, the user needs to choose a CH object on the 2D map to attach his/her related experience. Then, he/she can upload the related text, photo, and video. Because the 3D model and VR need a specific format, varying formats would cause system disorder. Therefore, the platform was not set up for uploading 3D models and VR function by users. The user experiences are stored in the lifestyle table and are compatible with the selected spot's ID.

6. Test

Before issuing the new multimedia platform to the public, we ran a small-scale sample to test it. The respondents in this test were from multiple nations, which means they have different cultural heritage backgrounds. They were asked to use the platform for at least 5 min and give comments after using it. The results indicated that most respondents admitted that the new platform could help them acquire more information about Strijp-S and increase their awareness of it. For example, the positive comments are "Very nice and helpful, the multi media platform is a great addition.", "You get all the information about the buildings, parks and events. It invites you to come to Eindhoven to see IT naturally", "Very smart way of presenting information, very nice", "It was a great platform, easily to use and search relevant information", "This is very helpful for people want to visit Eindhoven", and "It was cool if you are interested in the Dutch culture, but I think not if you already live in the Netherlands".

However, there were also some disadvantages and useful comments that respondents came up with, such as "The content is okay, but the way the platform is designed, looks a bit old-fashioned", "The 3D didn't work", "Multi media platform can be more interactive. Texts support the information flow, but on some area's the information flow is a huge bundle of text", "First of all, I could't read the whole text, there are definitely a couple of bugs in the system. I could read a part which was interesting, but I might have missed information".

7. Conclusions

This research has described the design of a multimedia web platform prototype using the UWE technique. As presented in this study, a multimedia platform is crucial for creating awareness of cultural heritage before or after visiting a heritage site. It can support creating and strengthening the public's knowledge of cultural heritage in Strijp-S in the city of Eindhoven. This platform aims to overcome the shortcomings described in the related work by using multiple media and tailoring the design to known user preferences.

The main contribution of this research explains the process of the new multimedia platform based on user preferences and proves that it can be helpful in increasing awareness of cultural heritage. Through a small-scale sample test, the results indicate that the multimedia platform can help the users to acquire more information about cultural heritage. A large-scale sample experiment across the whole Netherlands will be conducted in a future study. In that experiment, we will test the relationship between with the awareness of cultural heritage and the new multimedia platform. Also, we will compare the platform with other comprehensive search engines, such as Google, to prove that the new platform can increase awareness of cultural heritage and has higher effectiveness than other existing search engines. Therefore, the dedicated multimedia platform can help users to acquire information more efficiently than other platforms. This result can help the local government or related institutions create a multimedia platform based on the city situation to broadcast local cultural heritage to the public. In this way, the urban cultural heritage can be preserved better.

During the design and development process, several limitations were encountered. The developed multimedia platform includes a range of media but can still be extended with new media such as VR models for use with head-mounted displays and augmented reality [44]. Currently, most content of the Strijp-S site only includes photos/models of the

outside of the CH buildings, given the available information. The multimedia platform can be extended by adding more (visual) information about the inside of the buildings. Moreover, the interface of the platform is not suitable for every user. Designing a user-friendly interface is also the next mission of maintaining the platform. Finally, the platform is only available for (laptop) computers; developing a smartphone app will help to popularize its use, especially on-site during user visits. In addition, the function of "uploading own experience" allows people to upload any information to the database, which could lead to uploading false information. This function needs a filtering mechanism to select the appropriate information for the public, which is to be developed in future work.

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