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Full-fledged Virtual Exploration of Sacred Spaces

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Abstract

Virtual Reality (VR) revolutionised the way the users can perceive virtual or distant spaces and interact with them. The users wearing VR headsets have the impression as if they would look around at the real place of the sights. The technology is widely used in entertainment and training. Our goal was to examine how the VR technology can be applied to present sacral spaces. We assembled the virtual reality model of a Bulgarian Orthodox church in a cost-effective manner from high-resolution spherical panorama pictures. A complex VR exploration platform was created by integrating our VR presentation tool with the digital repository of Bulgarian icons and iconographic objects. Due to the integration, additional information can be displayed on specific frescoes of the church in the VR space. We offer a full-fledged virtual exploration of sacred spaces where the experience of moving around the virtual space and exploring the details of the church can be combined with transferring lexical knowledge about the church and its selected objects. The first versions of our virtual walks were available on the Web only. Due to the multiplatform development methodology applied, virtual walks can be demonstrated on VR as well.

Keywords:

Virtual Reality, Sacred Spaces, Complex VR Exploration Platform, Virtual Encyclopedia of Bulgarian Iconography, BIDL.

CCS Concepts

*• **Applied computing** → Arts and humanities; **Human-centered computing** → Human computer interaction (HCI) → Interaction paradigms → Virtual reality; • **Information systems** → Information systems applications → Digital libraries and archives;*

1. Introduction

Virtual Reality (VR) provides a more immersive experience to the users than any other digital platform. The users perceive in a VR environment as if they were present in the simulated fictional or real location and they can even interact with it. VR gained popularity in entertainment, games, tourism and proved to be useful in training some skills as well. In recent years, VR technology is spreading in cultural heritage preservation and presentation as well.

Our motivation was to preserve and present the values of churches in an innovative and immersive way. By applying new technologies based on digital content, significant value-added services can be created in the field of cultural and religious tourism. We strive to preserve local traditions and culture, sustain vibrant communities, and promote tourism. Architecture, particularly the unique values of built heritage, plays a key role in strengthening cultural identity. It enriches the shared experience of culture, alongside the works of applied and fine arts. Although the best way to experience the atmosphere of sacred spaces is through personal visits, long distances often make such journeys costly and time-consuming.

We propose taking virtual walks in VR spaces to gain a full-fledged virtual exploration of sacred spaces. It is a challenging task to show the beauty of a church. The VR technology may provide the impression of its users as if they would walk around in the space of the church presented. This special experience gives a taste of the mood and atmosphere of the sacred place. Modern technology can present every little detail and raise awareness of the valuable religious heritage sites. It helps people to experience the spirit of distant places and may arouse interest in them to travel there. Digital technology makes our sacred heritage interesting, exciting and attractive for young people as well, encouraging them to enter sacred spaces of history and learn about them [BNV*23].

We decided to use virtual walks for full-fledged exploration of sacred spaces because they can be used to interactively explore existing or virtual spaces from a remote location. Virtual walks are suitable to present complex spaces consisting of several rooms and/or outdoor locations (e.g. a building and its surrounding yard). The benefit of a virtual walk is that users can freely explore a remote place without disturbing the visitors of the sacred location. The users cannot just simply look around at one place, but they can move from one location to another to explore the whole site and discover connections between the places. Hotspots can be assigned to selected areas of the virtual walk to support the transfer of additional lexical knowledge.

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The main limitation of the VR is approach that users require costly VR headsets for the VR content. Furthermore, the content development is also an expensive process. We reduce the cost of model building by providing a methodology using panorama pictures. The target user group includes the younger generation open to new technologies. Virtual exploration offers a glimpse into the atmosphere of the sacred site, providing an opportunity for those unable to travel and sparking the interest of tourists or pilgrims who wish to visit. A multi-stage research and development process resulted in creating the VR-based virtual walk. About ten years ago, the eLearning Department of SZTAKI elaborated a methodology for creating panorama pictures and implemented its own panorama viewer for their presentation on multiple platforms (Web, mobile, and VR) [NMK*16]. The technology was applied to Bulgarian cultural heritage sites in a cooperation with the Institute of Mathematics and Informatics, Bulgarian Academy of Sciences [LP-MP*17]. Hotspots are assigned to selected areas of the virtual walk to provide additional knowledge (e.g., title, author, period, characters, description, photo etc.) on the specific frescoes of the site.

The next stage was the creation of Web-based virtual walks and the implementation of a walk editor and presentation tool to explore complex spaces on the Web. The Church of Nativity in Arbanasi belongs to the first places where this methodology was applied [MSS*22]. Compared to panorama pictures, the users cannot just simply look around at one place in a virtual walk, but they can move from one location to another to explore the whole site and discover connections between them.

To provide a more immersive experience to the users, we decided to implement the virtual walk on VR platform as well (Figure 1). Since the VR platform applies a totally different development and running environment than the Web-based platform, the virtual walk presentation had to be reimplemented from scratch. The VR development uses the panorama pictures and the walk data created in the former stages. Due to the proposed development methodology, our virtual walks are available on multiple platforms (Web and VR).

The virtual walk in Arbanasi is integrated with the Virtual Encyclopedia of Bulgarian Iconography (BIDL) which is the richest online knowledge source of the Bulgarian icons. The integration is performed through the BIDL API interface which is used to get information on specific frescoes. Due to the integration, the users can get up-to-date, detailed lexical information on specific parts of the church. Our proposed system combines the experience of moving around the virtual space and exploring the details of the church with transferring lexical knowledge about the church and its selected spots.

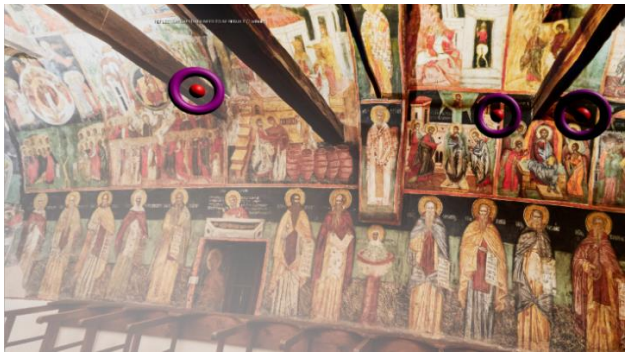

Figure 1: *A view from the virtual walk in the Church of Nativity in Arbanasi on VR platform.*

1.1 Related Work

This section provides an overview of using VR technology for the preservation and presentation of cultural and sacred spaces based on literature. Examples of good and best practices for VR cultural spaces are presented.

The focus of the research is to provide a full-fledged exploration of cultural art spaces with the help of VR technology. The review of the literature on the problem shows that in the last two decades' technological development has led to the possibility of using different types of digital applications (virtual reality, augmented reality, mixed reality, serious games, etc.) oriented to presentation, storage, recovery and reconstruction of artefacts from the cultural past using three-dimensional content [PF21] [BBB24]. Virtual reality [SC18] through an artificially generated three-dimensional image based on photographic images and/or terrestrial laser scanning and digital photogrammetry, imitates the surrounding cultural reality, which makes the technology attractive for use in many institutions, particularly museums, especially due to the impact on the experiences and feelings of visitors/users [CLPO19] [AHH21]. The use of VR in the field of cultural heritage leads to the enhancement of cultural tangible and intangible heritage, as well as to the strengthening of the visitors' immersion in it [SRH*20] [DCG*22]. At the same time, VR environments can create additional perspectives and support the perception and interpretations of cultural heritage [YKJ*17] [MMC18] [SB22] [LSG*23] as well as can be used to extend and improve academic research on cultural heritage [YJL23] [IFA24].

The potential threats and actual incidents regarding the violation of integrity and destruction of heritage objects as a result of their ageing or malicious actions, increasingly raise the question concerning the use of VR for the presentation, preservation and research of spiritual cultural heritage sites such as churches, cathedrals, monasteries, and other similar Christian buildings [SD16] [Bli19] [dLu20] [All22]. In this area, high-quality digitization and maintenance of digital cultural heritage assets are also keys with a view to accessing, managing and exploring them through new technologies [MMM*22]. The full-fledged exploration of sacred virtual reality spaces is important and necessary both for the pilgrim and visitor-tourist, as well as to support different types of explorers and researchers of these places. The integration of virtual reality technologies with available databases regarding such types of places enables a more complete and comprehensive immersion, exploration and investigation.

Among the many available software tools and extensions that serve to convert models and data into virtual reality, Unreal Engine (https://www.unrealengine.com/en-US) is one of the main visualisation tools and gives wide compatibility with multiple platforms, allowing the use of any simulation. It provides access to a wide range of advanced functionality and tools, including a feature that uses a visual programming language by manipulating graphical elements rather than written syntax (C++) [Ahm13] [AB22] [VSK*23] [aSA24] and provides good tools and opportunities to work on the presented project.

Allal-Chérif carried out case studies in three cathedrals (Notre-Dame de Paris, France; the Cathedral Church of Saint Peter in Exeter, England; and the Catedral de Santa María de la Sede in Seville, Spain) on the benefits of immersive technologies (augmented and virtual reality and artificial intelligence) [All22]. The next paragraphs summarise these case studies.

The Notre-Dame de Paris was completely digitised, and several 3D models were produced. The CNRS (Centre National de

la Recherche Scientifique, French National Center for Scientific Research) is coordinating the restoration of the cathedral after the fire in 2019. Several hundred thousand euros were invested to create the models. The digital models of the cathedral are crucial for its restoration, preservation, and understanding. Furthermore, it was fully modelled in 3D from photos for the needs of a game as well. The company FlyView offers virtual reality tours to the cathedral with 360-degree footage. The 17-minute scenario provides an intense feeling of immersion. A multimedia concert was designed and staged by Jean-Michel Jarre in a digital replica of the cathedral for the New Year's Eve in 2021. VRrOOm company broadcasted the concert live via several social networks which is now available on YouTube and VRChat. It is possible to attend a 360-degree sound and light show with special effects by using a virtual reality headset that brings a model of Notre-Dame to life.

The Saint Peter's Cathedral in Exeter (UK) has a virtual tour by using ultra-high-resolution photographs on the Web. Viewers can zoom in and out, move from one place to the other with the help of an interactive map, and they can access videos assigned to specific elements via integrated links. The cathedral participated in the European Vista-AR project with the aim to improve the visitor experience in heritage institutions. Several activities were implemented based on virtual or augmented reality (VR or AR). For example, some statues are animated, some parts can be viewed in their original colourized version and serious games can be played by using AR technology. VR offers the opportunity to virtually attend a performance of the cathedral choir, to admire the 360° view from the Mountain peak, and to walk at the edge of the tower.

Both the interior and the surroundings of the Cathedral of Saint Mary of the See in Seville can be virtually visited by using Google Street View. However, the quality of the images is poor. The website "Sevilla en 360°" offers a virtual tour of the cathedral on the Web which provides a much better experience. The virtual tour consists of several panoramic images in ultra-high definition. In Seville, the cathedral can be visited and viewed in detail using Oculus VR glasses either in VR or AR. The user can see not only the current cathedral but its location in different historical eras.

1.2. Purpose and Objective of the Article

This paper presents a specific application of VR, a complex exploration platform aiming to provide a full-fledged exploration of sacred spaces of the Church of Nativity in Arbanasi. We introduce the specific features, main components and the functionality of the proposed system. We provide an overview on the development process as well and describe how the placement of the main components in the VR space can be partially automatized by reusing data from Web-based virtual walks. Integration of the Complex VR Exploration Platform with the BIDL collection "Church of the Nativity in Arbanasi" is presented, and the content of the collection is retrieved through the REST API interface of BIDL into the virtual walk at hotspots. Although our work focuses on the virtual walk of one specific church, this methodology can be applied to other sacred spaces as well.

2 Materials and Methods

2.1 Church of Nativity in Arbanasi

The Church of the Nativity is located in the village of Arbanasi, northeast of Veliko Tarnovo, in central northern Bulgaria. Known for its rich history and historical monuments, the settlement is also one of the most picturesque old villages in the country with its unique revival architecture. The seven preserved churches from the 16th-17th centuries impress with their high and massive walls, with their iron and impenetrable oak doors and with the small window openings protected by metal bars, harmoniously building the overall architectural appearance of the settlement together with the fortified houses with extensive courtyards surrounded with high stone fences [Vac06].

The earliest started and richly decorated church in the village of Arbanasi is the Nativity Church [Vac08]. In terms of its construction, it has a complex and long history, passing through three construction stages from the second half of the 16th century to the middle of the 17th century. The interior of the temple was completely covered with painting in 6 stages - 1597, 1632, 1638, 1643, 1649, 1681, as a result of which a unique mural ensemble was created with a great thematic breadth and encyclopedicity. The walls and vaults with a total area of over 2,000 square metres are completely covered with frescoes, including hundreds of compositions with characters that exceed 3,5 thousand [Shu59] [Pra81]. The church houses unique images, one of which is the image of the "Wheel of Life", as an example of post-Byzantine art. Apart from being the earliest known representation of the subject in Bulgaria, it stands out for its originality, as human life is represented in 9 stages and it is difficult to find parallels with other similar depictions on the Balkan Peninsula or known from written sources philosophical concepts [Lec17]. Also extremely interesting is a row of images of pagan thinkers and writers, as harbingers of Christ, painted in 1681 in the women's section of the church. Pagan thinkers and writers such as Solon, Pythagoras, Socrates, Homer, Aristotle, Plato, Galen, Plutarch, the ancient prophetess Sibyl, etc. - a total of 12 in number (similar to the number of Christ's disciples) are depicted, all without exception, with golden nimbus around their heads, as worn by all persons revered as saints from the Old and New Testaments [Duy78]. Many images and scenes, as indicated in the church, are unique in their character.

The exceptional historical, cultural and artistic wealth of the temple needs an appropriate digital platform to fully present its exceptional content and to contribute to the manifestation of the cultural contribution of this priceless sacred space of the Bulgarian cultural heritage.

2.2 BIDL

"Virtual Encyclopedia of Bulgarian Iconography" (BIDL) is developed as an infrastructure component of CLaDA-BG, the Bulgarian National Interdisciplinary Research e-Infrastructure for Resources and Technologies in Favor of the Bulgarian Language and Cultural Heritage, Part of the EU Infrastructures CLARIN and DARIAH [LGP*21], and functions on the basis of a complex web-based environment for storing, retrieving and managing data from the humanities and social sciences, called CultIS (https://cultis.math.bas.bg/en) [GLP-M*24]. The CultIS platform is an infrastructure component of the CLaDA-BG, the Bulgarian National Interdisciplinary Research e-Infrastructure for Resources and Technologies in favour of the Bulgarian Language and Cultural Heritage, part of the EU infrastructures CLARIN and DARIAH (2018-2027), whose mission is to create a national technological infrastructure for resources and technologies for linguistic and cultural heritage.

With its rich set of technologies aimed at supporting a wide variety of digital cultural entities, and with its powerful functions and components, CultIS provides interactive virtual representation of objects and collections, standard and complex searching and

grouping in different intersections, comprehensive storage, flexible management and structuring of metadata, data, objects, multi-layer data indexing using dictionaries, etc. CultIS can store and manage various types of digitized copies of cultural heritage objects, including text, graphics, video, audio, 3D formats or other media objects, as well as relevant metadata.

The BIDL digital library, operating based on the CultIS platform, contains hundreds of Bulgarian iconographic artifacts from different authors, periods, iconographic schools, geographical locations, museums, churches, monasteries, etc., and shows the development of Bulgarian icon painting from the 9th to the 19th century.

Bulgarian icon painting is distinguished by technological, thematic and plot diversity, and reflects the high artistic taste, great professionalism, painterly gift and sophisticated sensitivity of Bulgarian artists over the centuries, as the stylistic and graphic development of the icon is not hindered by the established canon. The user can familiarize himself in BIDL with the technology of creating the icons, adaptation to the relevant modern means, materials and technologies, development, modifications and local features [MSS*22]. BIDL also provides opportunities for comparative studies between subjects, details, techniques, etc., to discover icon affiliations to a certain period, painting school or author, as well as to discover influences or copies of respective icons.

Using advanced technological solutions, permanent and dynamic collections of artifacts can be created on individual or cross-platform requests, regarding a specific church, such as the Church of Nativity in Arbanasi.

For description of semantic metadata and indexing of the content of iconographic art, the domain ontology for Eastern Christian iconographic art, developed by the IMI-BAS team, is used [P-DP-MP11]. A key role is assigned to the „Iconographical Object “, which is digitized and described according to a descriptive model by three “thematic entities” (also called levels of knowledge) (Figure 2).

The sublevels, with which each of the three main entities is enriched, cover a wide range of characteristics. The general data identifying the main aspects of an Iconographical Object such as Title, Iconographic School, Author, Period, Location, Type, Dimensions, are included in the “Identification” entity. The second entity “Description” covers information concerning the Object Description, Iconographical Scenes and Characters and provides a better understanding of the content and the descriptive details of the theme and forms of representation of the Iconographical Object. In the third entity “Technology”, information concerning Technique description, Base description, Iconographical technique, Base, as well as State, restoration traces and comments is presented. The metadata values of these entities are documented, provided and supported by the scientific diagnosis applied to the iconographical objects and collections. The descriptive model is implemented in a flexible and extensible way, including all types of typical relations for a conventional relational database.

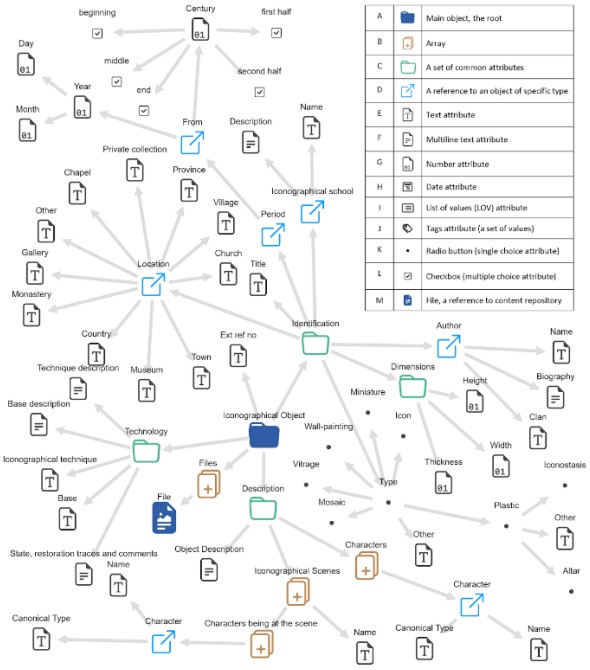

Figure 2. *Descriptive model of the Iconographic Object.*

2.3 Web-based Virtual Walk Editor and Presentation Tool

A virtual walk can be created by assembling several panorama pictures taken on different locations of the same site. High-resolution, 2D or real 3D and 360° spherical panorama pictures are taken of the target indoor or outdoor spaces. Panorama pictures of several rooms or other areas hosting exhibition objects can be assembled into one virtual walk. The first version of our virtual walk ran on PCs through the Web. SZTAKI developed a proprietary methodology to create virtual walks from panorama pictures and implemented a player for presenting the virtual walk.

The virtual walks can be visualised either on 2D (e.g., computer screen) or 3D (anaglyph 3D glasses) display devices. 2D displays are more widespread but the virtual tour is especially spectacular on 3D displays. The movement between the rooms and the interaction within a room is controlled by the input devices (keyboard, mouse) of the computer. The connection of the rooms can be represented by a graph where the nodes correspond to edges and two nodes are connected by an edge if a direct movement is possible between the nodes. A small map facilitates the navigation among the rooms. Hotspots can be assigned to selected areas of the virtual walk to provide additional multimedia content on demand. The content of the hotspots can be defined in HTML format.

The service was applied to various application areas (industry, economy, education, science, tourism, and knowledge dissemination). A virtual walk was created for the Church of Nativity (https://media.gameathand.com/nativity/index.html), among others (Figure 3). It contains panorama pictures both outside and inside of the church.

A JSON file contains the description of a virtual walk, including a graph representing the connectivity of the rooms, indication of the room to start the walk, description of each room, location of hotspots, etc.

Figure 3. *Web-based virtual walk of Church of Nativity in Arbanasi (source: [MSS*22]).*

3 Results and Discussions

3.1 Complex VR Exploration Platform – Specific Feature and Functionality

The VR exploration platform offers the following specific features and functionality:

- **Presentation of sacred spaces (i.e. churches) in an immersive manner.** Our aim is to present sacred spaces to interested people from a distance as if they were there at the site. The user should be able to explore the space by looking around from different locations, have a close look at the walls and objects located in the surrounding space, get additional information interactively on relevant components of the ambience and freely move in the space without any disturbances from the real environment of the user.
- **Presenting complex spaces.** The sacred spaces usually consist of several rooms and their direct neighbourhood also represents a high cultural value. For this reason, we propose modelling the sacred space not as a single space but a complex space consisting of several connected subspaces.
- **Possibility of standalone discovery of the site.** The users can explore the sacred space at their own pace, they can freely move in the VR space, explore details and get lexical information on demand. We exclude solutions where the users can only watch VR content.
- **Proposing a cost-effective solution.** Creating complete 3D models of complex buildings often requires high costs which we would like to avoid.
- **Reusing the Web-based data describing virtual walks.** The predecessor of the proposed system provided the virtual walk functionality on the Web. Although the development and running environment of the Web and VR platforms are significantly different, our aim was to reuse the Web-based walk data on VR to reduce the walk implementation time. We developed a methodology to transform the data files of the virtual walk from Web to VR platform.
- **Integration with a digital library to provide additional information.** The proposed VR application provides additional information by applying hotspots placed in the VR space. The source of the content is a digital library of Bulgarian icons. The integration facilitates the content creation, and the system can provide up-to-date and reliable information to the users.

3.2 The Creation of VR-based Virtual Walk of the Church of Nativity in Arbanasi

3.2.1 Overview. The VR-based virtual walk was created by using the Unreal Engine developed by Epic Games. Unreal projects are generated for each individual virtual walk, with the use of the Unreal Editor as the implementation tool. Some source code was written in C++ but most of the application logic was prepared by using so-called blueprints. Blueprints can be visually created inside of a graph editor named Blueprint Editor without typing code and saved as assets in a content package. C++ code is generated from the Blueprint classes. Blueprint technology can accelerate VR development and engage users with game development even if they are not experts in the traditional programming languages.

The Unreal Engine applies the object-oriented paradigm and invokes the concept of inheritance. The blueprints can be created based on existing parent classes. Due to the inheritance, changing the functionality or properties of the parent class alters all its child classes accordingly. Inheritance is widely used in our development work e.g., in creating spheres, arrows, hotspots, etc.

The Editor Utility Widgets can support the work in the Unreal Editor with scripts which can be used to automate editing the VR applications. They can be used to automate the modification of assets, place game content in the VR space, initiate various actions in the editor or extend the editor with new UI items. Similarly to other objects, they can be created as a blueprint. We applied the editor utility widget to place the walk components in the VR space based on the data of a Web-based virtual walk.

The Web Browser plugin of the Unreal Engine can display HTML files in VR. We used it to show the hotspot contents.

The next subsections introduce the main components of a VR-based walk which should be created during the development process:

3.2.2 Main VR Components Used in the Virtual Walk. Actors represent the objects in Unreal which can be placed in the VR space. They are instances of Blueprint classes. Our virtual walk has three main actors: Hotspot Actor, Move actor and Sphere Actor. Their instances can be placed directly on the VR space.

- **Sphere Actor.** Spheres serve to display rooms in the VR space. A sphere instance is created for each 360° panorama picture of the walk based on the Sphere Actor class. The surface of the spheres is generated from the panorama pictures (Figure 4).

Figure 4. *Spheres representing panorama pictures in the VR space.*

- **Move Actor.** The Move actor is responsible for the movement between the spheres in the virtual space. The users can move from a sphere to one or more neighbouring spheres by teleporting. They can move both forward and backward between the spheres. As many move actor instances are created as the number of different movements between the spheres. They are represented by an arrow in our virtual walk (Figure 5).
- **Hotspot Actor.** The instances of the Hotspot Actor class provide additional information (e.g. texts and images) at a point of the VR space. In our case, a hotspot can present the title, description, photos and any other information on a fresco which can be retrieved from the BIDL. The Hotspot Actor includes a variable to identify the content source. The hotspot contents are in HTML format and can be displayed by using the Web Browser plugin of the Unreal Engine. The hotspots have two types in our walk according to the origin of their content:
  - The content is imported from BIDL through the REST API interface. The hotspot ID stores the identifier of the object in BIDL. The content is generated from the response to an API query. The content can be **generated** in-real time when the user opens the hotspot or when the virtual walk is created. In the first case, the provided content is up-to-date and any change in the BIDL will be displayed on the hotspot as well. Since the content is rarely modified, the second case can be appropriate for our purposes which does not require any API calls during the walk.
  - The content comes from the data of the Web-based virtual walk. Their layout is not designed for the VR platform; therefore, the first option is preferred.

Figure 5. *Move and Hotspot Actor instances placed in the VR space in the developer environment. The Move Actor instances are denoted by arrows while the Hotspot Actors are denoted by cubes.*

3.2.3 Creating and Placing the Components of the Virtual Walk. The creation of each component and placing them in the proper place in the VR space is a time-consuming task. This process is accelerated by implementing an Editor Utility Widget. The widget creates the virtual walk from the data file specifying the Web-based virtual walk. The main steps of this process are as follows:

- Reading the JSON file describing the Web-based content.
- Creating spheres representing the rooms. This step includes reading the panorama pictures, rotating all of them into the same direction, creating textures and materials for the spheres from the panorama pictures).
- Setting the start position of the virtual walk.
- Creating hotspots.
- Creating move actors.

3.2.4 Displaying Hotspot Content. A Widget class is created to display the content of the hotspots. As many instances are created as the number of hotspots. Hotspot layout can be edited in Blueprint Designer Mode (Figure 6) while the relevant logic can be defined in Graph Editing Mode of the Unreal Editor. The hierarchy of the interface is preferably represented by a tree which can be freely extended with new items. The items can be modified, and event handlers can be added to them. Currently, the user interface consists of a Canvas Panel and a Web Browser. The Web Browser widget comes from the Web Browser plugin. The Event Graph is displayed when the Graph Editing Mode is selected, and all event handlers can be managed. When a hotspot is selected, the event handler assembles the HTML page which can be opened in the Web Browser.

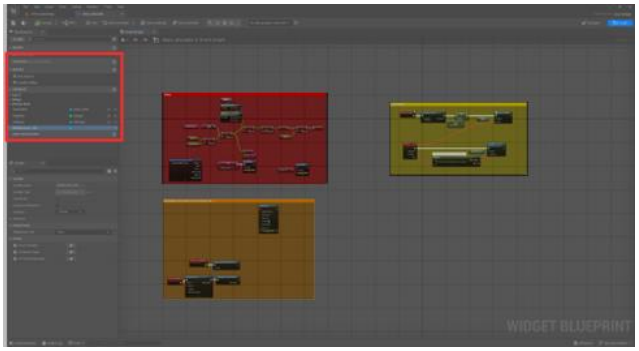

Figure 6. *Blueprint Designer Mode*

3.2.5 VR Pawn. A VR Pawn forms an important part of the VR project which represents the character moving in the VR space. Its Event Graph can be used to manage the events coming from the VR inputs. Input Actions should be created which manage the input events. Input Mapping Context can be used to assign input actions to controller buttons. For example, the widget of the hotspot can be scrolled with the thumbstick of the right controllers in the virtual walk.

3.3 Integration of Complex VR Exploration Platform with the Bulgarian Iconographical Digital Library (BIDL)

BIDL provides a RESTful (representational state transfer) application programming interface (API), which allows easy and lightweight JSON-based (JavaScript Object Notation) communication between BIDL and any other external or internal software platform. RESTful requests are sent using the secured HTTPS protocol and have syntax similar to the MongoDB query syntax. For example, a request for querying all objects located at Arbanasi village would look like this:

```
[
    {
        "match": {
            "_t": "ct:Iconographical.Object"
        }
    },
    {
        "lookup": "identification.location"
    },
    {
        "match": {
            "identification.location.village._v:en": {
                "$eq": "Arbanasi"
            }
        }
    }
]
```

And the response would have the following structure:


```
{
    "data": [
        {
            "_id": "62aa0e9e9daa038508bd7c04",
            "identification#location#village": "Arbanasi",
            "identification#location#church": "The Nativity of Christ",
            "_title": "Tree of Jesse, detail",
            "_thumb": "0d58148e-6666-44c4-b2ec-74dca286ef4b.jpg"
        },{
            "_id": "5f3fd17da07b3b0858774aa8",
            "identification#location#village": "Arbanasi",
            "identification#location#church": "St. Nicholas",
            "_title": "A complex icon with 12 gospel scenes",
            "_thumb": "23.jpg"
        },{/* more data... */}
    ],
    "header": [
        "identification#location#village",
        "identification#location#church",
        "_title",
        "_thumb"
    ],
    "count": 26
}
```


The "_id" attribute can be used to get detailed metadata about a specific object (described by Figure 1), using the same REST API.

Hotspot contents on the collection "Church of the Nativity in Arbanasi" and specific frescoes are retrieved through the REST API interface of BIDL into the virtual walk. We used the VaRest plugin for the Unreal Engine to support REST API queries. The process of calling REST API URL, getting response content as string and decoding the JSON object can be defined in the Blueprint Editor (Figure 7).

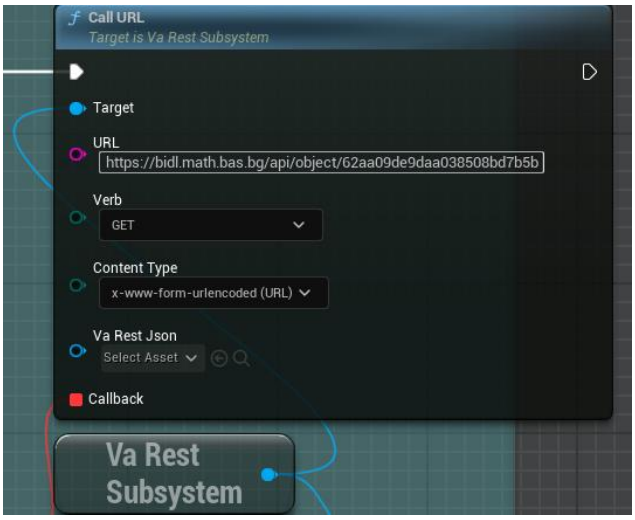

Figure 7. *Get request from BIDL API in Blueprint Editor of Unreal Engine*.

3.4 Technologies Used for Complex VR Exploration Platform Development

The technical background for the VR development comprises the following items:

- VR headset: Meta Quest 3 represents a mixed reality VR headset from Meta. The headset is accompanied by two controllers with wrist straps. The device belongs to the most popular VR headsets due to its fast performance, high resolution, and moderate price. Hundreds of applications are available on the device for gaming, training, and streaming in the VR space.
- Game engine: The VR-based virtual walk was developed on a PC with Windows operating system. The virtual walk is based on the Unreal 5.4 game engine developed by Epic Games for 3D games. Unreal Engine is written in C++ and supports the game creation on a wide range of desktop, mobile, console, and virtual reality platforms. Its source code is freely available for the registered developers via GitHub.
  After a free registration for an Epic Games account, we downloaded the Epic Games Launcher which is widely used to distribute video games. Unreal Engine was installed from the Epic Games Launcher.

VR distribution platform: We applied SteamVR developed by Valve Corporation to test our VR-based virtual walk on the headset. SteamVR is available on Steam and provides an environment to run VR games and other applications. After creating a free account, we installed Steam which belongs to the most popular digital distribution platforms. SteamVR was downloaded from the Steam home page.

To test the virtual walk, the headset and the PC running SteamVR should be connected to the same Wi-Fi network. Then the Steam Link is started on the headset to match the headset with the PC. When the connection is established, the virtual walk can run on the device. During testing, the walk can be controlled with VR controllers and the screen of the PC displays the video stream equal to that in the headset. It is also possible to create a package which can be installed on the VR headset and can be used independently from the PC.

4. Conclusions and Future Works

In this study an application for the complex exploration of cultural and sacred spaces on the VR platform was presented. It was tested for the presentation of the Church of Nativity in Arbanasi (Bulgaria), and we provided an overview on the development process as well. The proposed system combines immersive VR experience with lexical information from a digital library (BIDL).

Due to the proposed walk development methodology, we became able to publish virtual walks on multiple platforms. Thanks to this approach, the walk development is more efficient. At the current stage of the development, we can publish virtual walks on Web and VR platforms. Although the development environments are totally different, the meta data and the multimedia items of the walk can be reused in both platforms which can accelerate the development by discarding some time-consuming development steps.

We are planning to publish our virtual walks on mobile platforms as well. The main aspects and directions of the future work are also related to enhancing functionality (e.g., gamification) of the virtual walk on VR platform and creating VR-based virtual walks for new destinations. We have panorama pictures and Web-based virtual walks on several sites in European countries with sacred, cultural, gastronomical, architectural and scientific significance. Our plan is to apply our methodology to these places as well and create further virtual walks on the VR platform. The full-fledged observation of cultural sacred spaces also requires the creation of proper functionality for personalization in the VR walk. This task is currently under design and implementation and will be based on user activity analytics. A special model for content personalization will be developed.

Our plans include user experience tests and collecting feedback to validate the effectiveness of VR experience in an educational or cultural context.

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