

# Dissemination of Environmental Soundscape and Musical Heritage Through 3D Virtual Telepresence

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**Abstract** This paper presents the design and implementation of a 3D environment telepresence visualization interface, aiming at the remote experience and dissemination of musical cultural heritage and environmental soundscapes to the public, utilizing the latest technology available. The architecture of the application is consisting of a server database containing the scientific data collected, and client applications that allow multiple users to enter the 3D environment and interact simultaneously. Based on Unreal 4 graphic engine and developed for a wide variety of platforms, devices and operating systems (i.e. Linux, Macintosh, Windows or Android), these client applications can be ported to PC, tablets, mobile phones and ultimately to any web browser supporting HTML5. To accommodate the dynamic nature of a musical and soundscape heritage archive, expansions will be publicly available through regular updates and client patches. The main research challenges in the domain of cultural heritage informatics are novel data capture in many formats under a variety of conditions and provision of semantically-based representation, search and editing information technologies to support processing, management and dissemination of cultural content and environments. There is a number of parameters that can affect cultural content digitization process: accuracy, volumes of data, variety of capture conditions, material types, environmental challenges. The technical side of exploitation includes the music production of selected samples out of the recorded material and a modern environment for management and dissemination of all the collected material from Audio-Visual

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Ecology and Ionian Music Archive (IMA) projects (#D10, D12/MIS35600—EU funded), using the 3D virtual technology.

**Keywords** Musical heritage · Digitization · Multimedia databases · 3D virtual environment · Unreal 4 · Environmental soundscapes

## 1 Introduction

Two of the main research challenges in the domain of cultural heritage informatics are novel data capture in many formats under a variety of conditions and provision of semantically-based representation, search and editing information technologies to support processing, management and dissemination of cultural content (Arnold 2008; Conti et al. 2006; Cutrí et al. 2008) and environments (Arnold and Geser 2007; Gagliardi and Schettini 2008). There is a number of parameters that can affect cultural content digitization process: accuracy, volumes of data, variety of capture conditions, material types, environmental challenges (White et al. 2004). As far as management and dissemination technologies (Koukopoulos and Styliaras 2010, 2013) are concerned, we should take into account the representation of cultural content (Halkiopoulou and Boutsinas 2012) preserving specific people's temperament in different environments.

European Union sponsored many projects last decade that promote the online accessibility of cultural content (Hankinson et al. 2009) as a key dimension of the information society (Heliades 2016). The Ionian Music Archive (IMA) is an EU funded project (Koukopoulos et al. 2016) under completion that runs at the Section of Applied Technology of the Department of Sound and Musical Instruments Technology that belongs to the Technological Institution of Ionian Islands since early 2012 under project number #D10/MIS35600. The project involves the preservation of a huge amount of musical wealth which is under extinction as well as the provision of a central point of reference for the Ionian musical culture. Joint partners in this attempt include colleagues from the University of Athens, the University of Patras and the Ionian University and at this phase, the islands of Kefalonia, Zakynthos (Zante) and Lefkada (Lefkas) are considered within project scope (see Fig. 1).

There are two main courses of action, one is the preservation and the other is exploitation. The preservation work package includes all the actions that stem from the necessity of not losing all those local music patterns and sounds that our ancestors have brought through time and they are not held in any savable form. Actions of this kind, mainly include sound recordings, digitization of archival material which is also in danger of loss (e.g. music scores, tapes, vinyl disks etc.) and reconstruction of under-extinction musical instruments, such as the Kefalonian “skortsampouno” (local type of bagpipe). In terms of exploitation, typical actions of work include an ethno-musicological framework on which all findings in all areas/islands are placed, as well as an accompanying educational course for local schools. The technical side of exploitation includes the music production of selected samples out of the recorded

**Fig. 1** The Ionian Islands on the map



material and a modern environment for management and dissemination of all the collected material over the web.

## 2 Literature Review

Achieving efficient management and dissemination for Musical Cultural Heritage an advanced information system is designed and implemented which is based on a multilayered architecture.

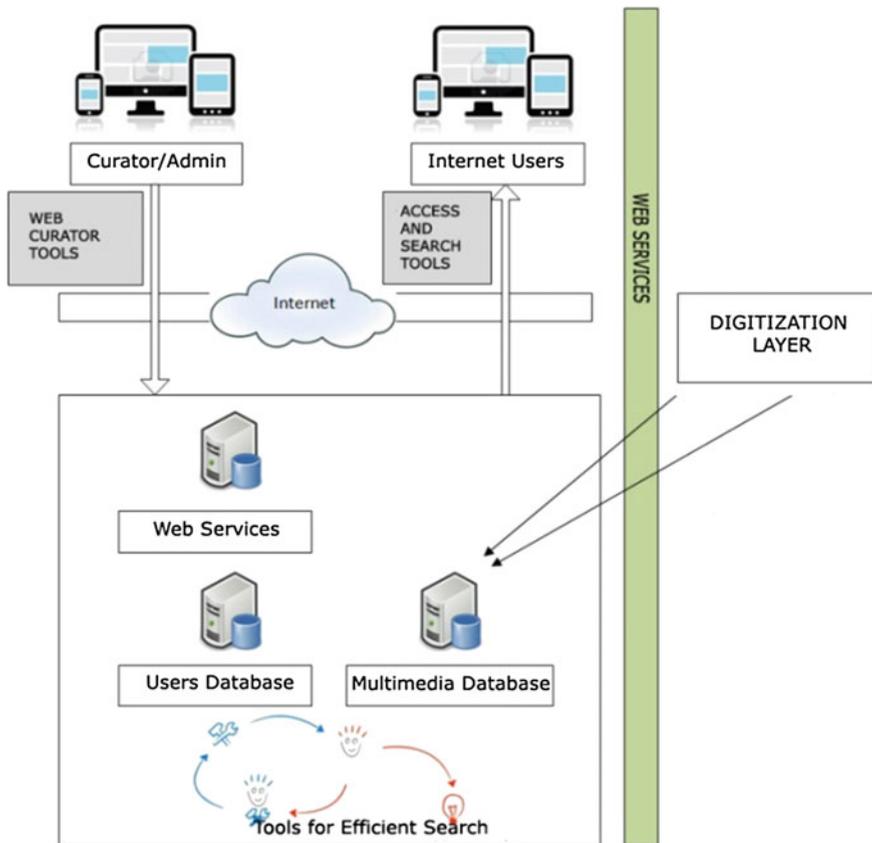
The architecture is modular and consists of mainly two layers:

- The digitization layer in which the digitization methodology and activities are taken place. The layer provides hardware and software tools as well as services for digitization.
- The information system's layer which includes all the necessary databases, web services and tools for efficient multimedia management and dissemination as well as users and systems administration.

The multilayered architecture is illustrated in Fig. 2.

The main entities in the information systems layer are:

- Multimedia database: the multimedia database is responsible for storing and preserving of musical cultural heritage documents and further presented in the next section.



**Fig. 2** General multilayered architecture

- Users database: preserves and manages the user and user groups profiles in terms of access and security features. Each user group has discrete security parameters.
- Web services server: the servers provides the necessary tools and services to the curators, administrators and the internet user. The tools enable the target groups to efficiently access, manage and search the multimedia database.

The user's target groups defined are:

1. The curators group: A group of users with different access levels responsible for inserting, editing and deleting items from the multimedia database. Curators are responsible for providing raw material (archives, location details, description, etc.) or annotating raw material. Also, curators can create musical documents (projects), view, classify and comment them. Furthermore, they can manage and disseminate musical documents (archive directors and music teachers).

2. The administrators group: A group of users with access and manage privileges for the web portal's pages and services.
3. The internet user with access to the search tools and overall information about the musical cultural heritage.

The architecture, the design and implementation principles for the information system are:

1. The entities and relations of the multimedia database are fully taken under consideration for the implementation of the information system.
2. Application of standards and best practices in cultural digitization, management and dissemination for added value.
3. Best practices on long-term digital preservation.
4. Usability and quality criteria for web tools and portals.

## **2.1 Database Architecture**

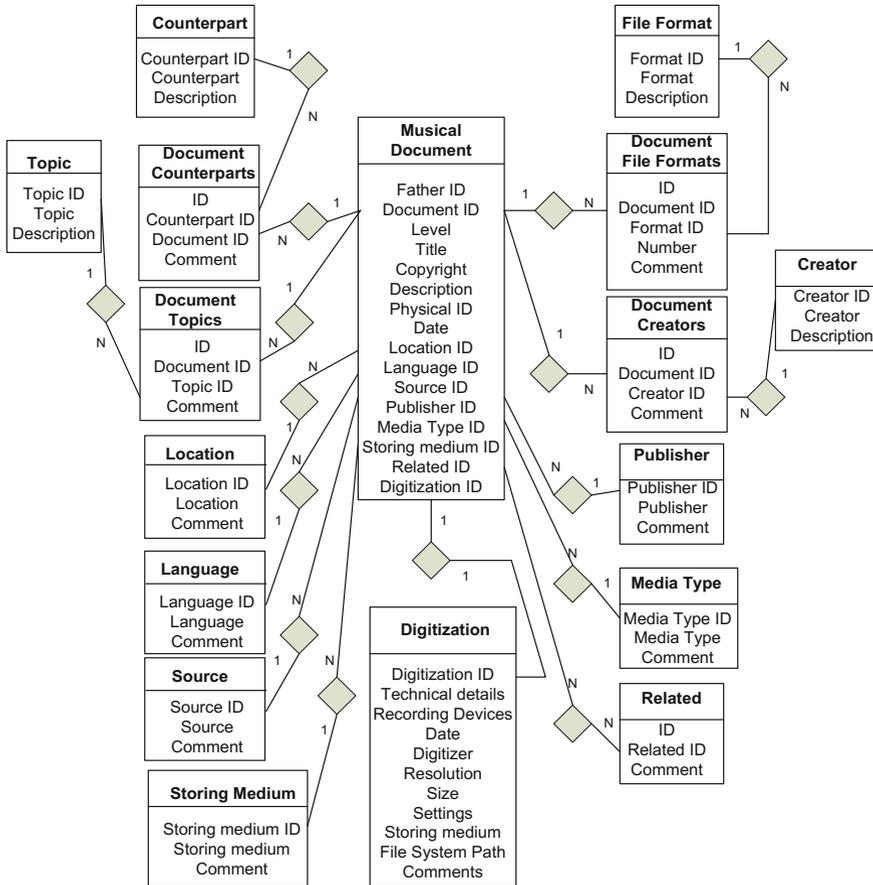
In Fig. 3, we illustrate the architecture of multimedia database that stores musical heritage documents. The basic database entity is musical document. A musical document may have many creators and counterparts and one publisher. Also, it may consist of various file formats, while it contains information of a specific media type. A musical document has been digitized in a specific way, in one location and in one language and it is stored physically in a specific storing medium. Moreover, it may refer to many topics, it has one source and it can be related with many other documents.

## **2.2 Operations**

*Inserting*: it allows authorized users to insert data to multimedia database. The curators can insert primitive material or projects to multimedia database.

*Deleting*: it allows authorized users to delete data from the database. The curators can delete primitive material and projects from the database. Searching: it allows users, depending on their attributes to search for an object (primitive material or project) in the database. This operation is available to all categories of users, but internet users can search only for projects, while curators can search both for primitive material and projects.

*Viewing/listening*: it allows users, depending on their attributes to access, view and/or listen to certain objects in the database. This operation is available to all users



**Fig. 3** Multimedia database architecture

(Tsolis et al. 2007), but internet users can view only projects, while curators can view both projects and primitive material. *Editing*: it allows authorized users to modify existing projects or primitive material. This operation is available only to curators. Editing has the following levels: (i) As is: use of a primitive multimedia file as it is. (ii) Segmenting: use of a specific part of a primitive file. (iii) Processing: use of a primitive multimedia file after it is processed. Annotating: it allows users to annotate primitive material or projects (only curators).

The application architecture is based upon Unreal Engine 4, one of the leading technologies for 3D graphic and gaming engines available in the market. Users connect remotely to a server, using a local client on various platforms (Windows, Linux, iOS, Android on PC, mobiles or tablets) to create an account and gain access to the multimedia database. When connected, multiple users simultaneously or privately, are able to visit virtual environments associated with the sounds and

multimedia files available. Navigation through the virtual environment is possible through various interaction methods including hand or head gestures, gaming control (joystick/gamepad), keyboard, mouse or touch-screen. 3D graphical interaction menus that will be visible to the user, inside the virtual world allow users to choose between different virtual environments, select specific sounds to listen to and navigate through the sceneries.

The architecture layout that provides access to remote users (Fig. 4), is based on a client-server framework connection over the internet. Offline access is available as

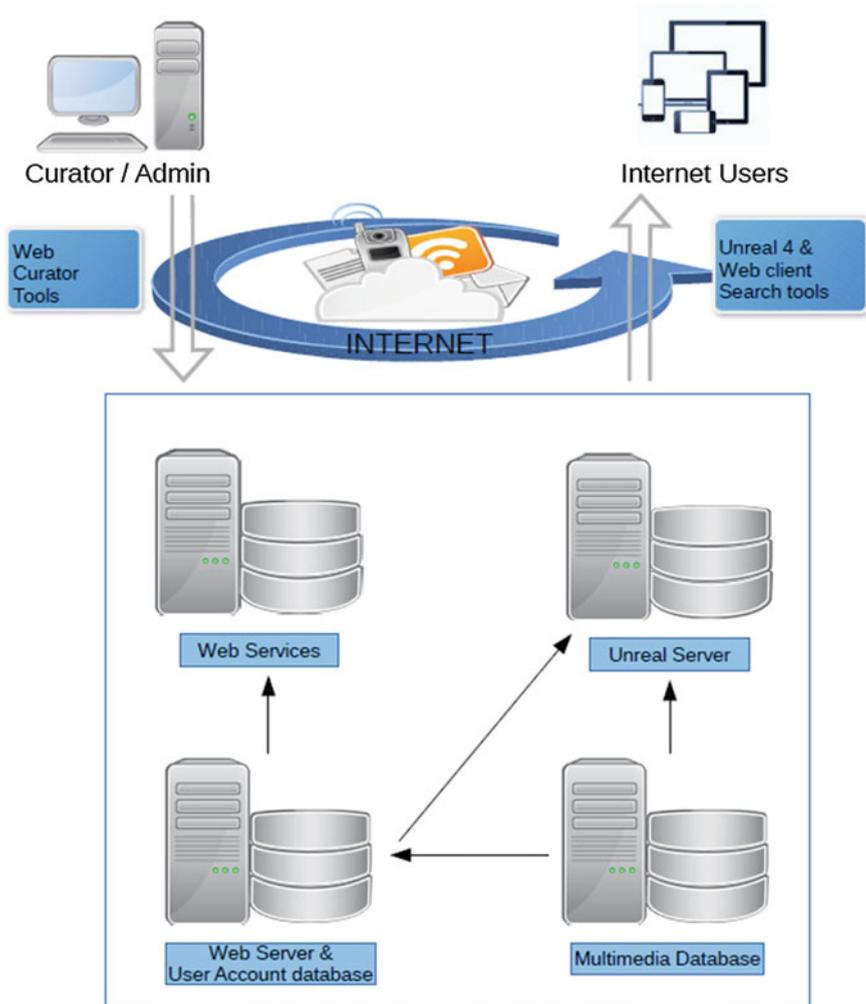


Fig. 4 Architecture layout

well, as a single-player mode, with the user limited to the content that has already been downloaded to the client. The client contains the multimedia files stored in a local database and they will be accessed as soon as the user chooses associated environment through the virtual 3D menus.

For every multimedia sound, a virtual environment scenery is designed using Unreal Engine 4 technology. The technology allows a very realistic representation of items associated with the multimedia files accessed by the users, i.e. a bird on a tree inside a forest, a village chorus with local musical instruments on a social event (weddings, celebrations etc.), sounds of waves on a beach, night sounds on a mountain and many other available in the Musical Cultural Heritage multimedia database.

Unreal Engine 4 multi-player is based around the client-server model. The server is an important part of Unreal Engine 4 multi-player that takes all of the important synchronization decisions, contains all of the authoritative state, handles client connections, travelling to new maps, uploading new game data for new environments and handles the overall game-play flow of starting an event, ending it, etc., while connected clients maintain a close approximation of events that are triggered both by user interaction and server's responses.

## 3 Methodology

### 3.1 *Audio System Overview*

The audio system in Unreal Engine 4 is made up of several components, each working together to produce the audio experience for users. When an audio file is imported into the engine and dropped into a level, several options become available such as the basic Volume or Pitch levels to adjust, as well as more fine-tuning settings such as Sound Attenuation, which defines how a sound is heard based on the distance from its origin. Unreal Engine 4 also allows for building composite sounds in the form of Sound Cues. The Sound Cue Editor which enables combining sounds as well as applying modifiers called Sound Nodes to alter the final output. All the sounds from the Ionian Music Archive database will be imported to the game engine using the content browser

The remote user accesses the game server through a client that includes all or part of the Ionian Music and Sound Archive, included in the downloaded client package distributable. When the user needs access to a new sound library that is not downloaded yet, the client will request access to the multimedia database server and update/patch the new sounds, graphics or interface binary executables.

Unreal Engine 4 currently supports importing uncompressed 16 bit wave files at any sample rate (see the chart below). For best results, it is recommended that sample rates of 44,100 Hz or 22,050 Hz be used. Importing a sound file into the editor generates a Sound Wave asset that can be dropped directly into a level or can

be used to create a Sound Cue and edited inside the Sound Cue Editor. Unreal Engine 4 also supports multi-channel sounds (e.g. Fig. 5) and uses a special naming convention when importing files for multichannel use.

### 3.2 Sound Cue

Sound Cues are composite sounds that allow to modify the behavior of audio playback, combine audio effects, and apply audio modifiers with Sound Nodes to alter the final output. The Sound Cue Editor is a node-based editor that is used to work with audio. By default, every Sound Cue's Audio Graph Node contains an Output node, which has a speaker icon on it. The Output node's default value for Volume Multiplier is 0.75, and for Pitch Multiplier is 1.00. These values can be modified in the Details panel. The volume and pitch settings are used to manage relative Sound Cue volumes. This affects the output of all audio contained within the Sound Cue. If multiple Sound Waves are used with Mixer or Random Nodes, it is possible to control their volume and pitch independently by adding Modulator nodes.

Every imported audio file is represented in the Sound Cue Editor as a Sound Wave. A Sound Wave asset can be selected in the Content Browser and then added to the Sound Cue by right-clicking anywhere in the Sound Cue Editor and choosing the Sound Wave in the From Selected category on the context menu (Fig. 5).

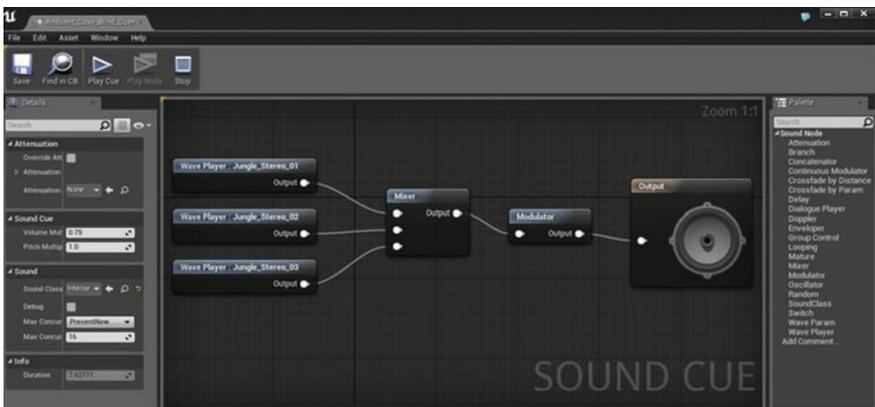


Fig. 5 Sound cue layout

### 3.3 *Audio Node Graph*

The Audio Node Graph is located in the Viewport panel. It displays the audio signal path from left to right, with interconnected nodes representing audio control modules and audio files. The Output node, which has an image of a speaker on it, represents the final output of audio as heard in-game and is always positioned furthest to the right in the signal path. The source audio files (Sound Waves) are always positioned furthest to the left in the signal path. Wires are used to connect the nodes.

To preview playback, play buttons are located in the toolbar at the top of Sound Cue Editor window. The Play Cue button plays the entire Sound Cue, and the Play Node button plays the sound from the selected node. (If multiple nodes are selected, the Play Node button is grayed out and unavailable.) While a Sound Cue is playing, to aid in debugging, the wires of currently active nodes turn red. This makes it easy to follow the Sound Cue's construction in real time.

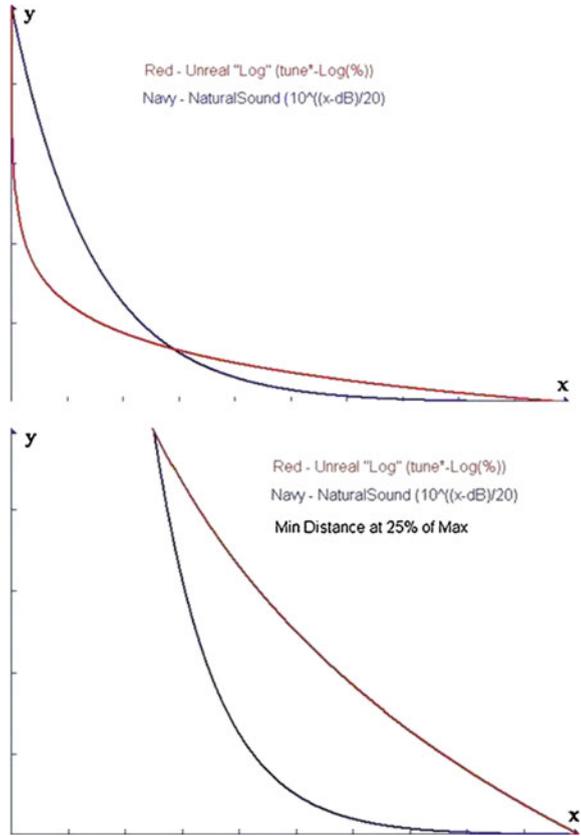
### 3.4 *Sound Attenuation*

Sound Attenuation assets allow the definition of attenuation properties in a reusable manner. Any place to specify one-time use attenuation properties, can be specified instead by the Sound Attenuation asset. This allows adjustment to attenuation properties without having to revisit every sound individually. Sound Attenuation is essentially the ability of a sound to lower in volume as the player moves away from it. It works using two radii: MinRadius and MaxRadius. As a user moves from the sound's origin through the MinRadius, volume of the sound is at 100%. Passing between the MinRadius and the MaxRadius, the volume linearly fades between 100% and silence. The rate at which this fade occurs is based on the DistanceModel property and the Distance Algorithm setting, which provides several types of falloff curves to control the volume in-between the radii. Once outside the MaxRadius, the user is outside the limit of the sound and hear only silence. While the Distance Algorithm can be used to define the falloff, Attenuation Shapes can be used to specify the shape of the Attenuation Volume itself. Sphere, Capsule, Box, or Cone can be used as the Attenuation Shape based on audio preferences and confinements.

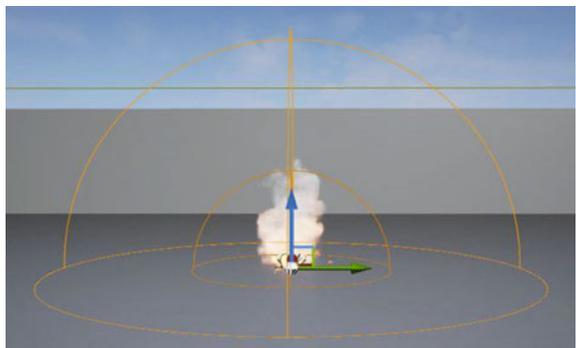
### 3.5 *Attenuation Natural Sound*

The Natural Sound attenuation model is a more 'realistic' falloff model that tries to take into account how sounds are heard in an environment. Among many distance algorithms this is the best use case for natural sounds i.e. fires or other point-interest

**Fig. 6** Attenuation natural sound graph



**Fig. 7** Attenuation sphere control



or high frequency content that the logarithmic attenuation does not feel 'right' for a sound's falloff (Fig. 6).

### 3.6 Attenuation Sphere

Use case: The default volume is good for most usage scenarios, like ambient outside sounds (fires, birds, streams, etc.) (Fig. 7).

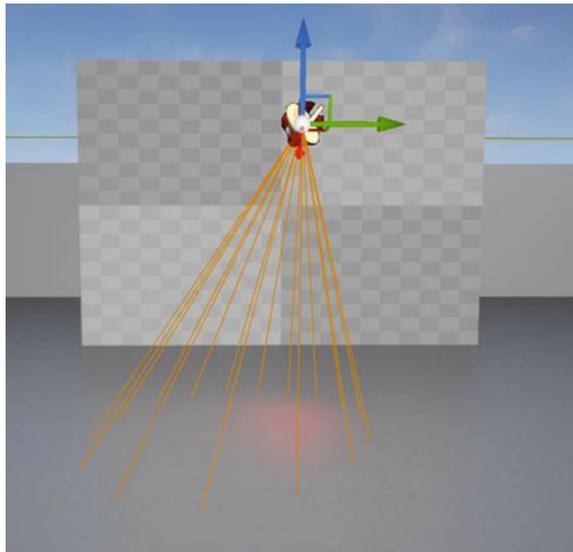
### 3.7 Attenuation Cone

Use case: Good for projecting sound at a player as the sound is at its max when inside the cone in front of the origin, directly behind the origin results in silence (the example above could represent a security camera which tracks the player) (Fig. 8).

### 3.8 Reverb Effects

Reverb Effects are a definable asset with several properties that can be easily adjusted and applied to any Audio Volume placed in a level. With a Reverb Effect, settings (pictured below) can be adjusted to allow control of elements like the echo density, overall reverb gain, air absorption, to help craft the overall “feel” that the developer is after.

**Fig. 8** Attenuation cone control



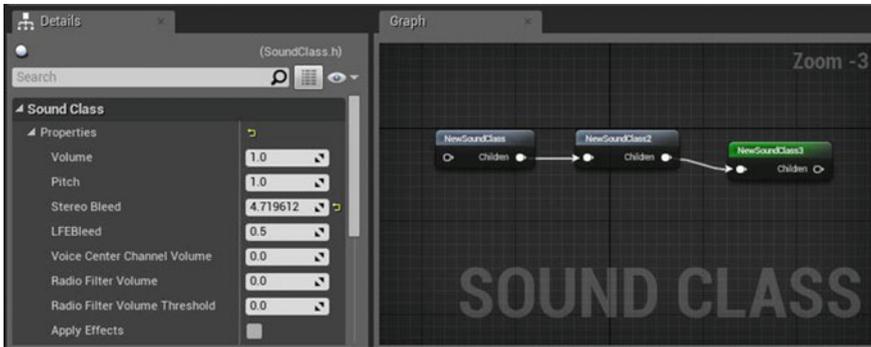


Fig. 9 Sound class control

### 3.9 Sound Class

Sound Classes are a collection of properties that can be applied to a number of Sound assets. The properties inside a Sound Class act as multipliers to the existing values and will be carried out by all Sound assets assigned to the Sound Class.

Hierarchies can be created by adding Child Classes, which will allow to pass down only specified properties from the parent class to children classes. Classes can be connected together inside the Sound Class Editor, which shares a similar node-based interface as seen in the Sound Cue Editor.

Passive Sound Mixes can be added (see the Sound Mix section below) to a Sound Class which will kick in and activate automatically whenever the Sound Class is played (for example, having music automatically lower whenever a dialogue Sound Class is played) (Fig. 9).

### 3.10 Sound Mix

Sound Mixes allow to set the EQ Settings (Equalizer Settings) and modify Volume and Pitch properties of Sound Classes. Multiple Sound Mixes can be active at the same time, all contributing to the overall audio effect. It is possible to Push (Activate) or Pop (Deactivate) Sound Mixes directly inside a Blueprint with the Push Sound Mix Modifier and Pop Sound Mix Modifier nodes or activate them passively whenever a sound with a given Sound Class is playing within a specified threshold. Within the Sound Mix asset itself, which can be opened by Double-Clicking the asset in the Content Browser, several properties exist. EQ Settings for the mix can also be specified to adjust the high, middle, and low frequencies and gains. As the EQ Settings of multiple Sound Mixes cannot be combined, the EQ Priority allows control of which active mix's properties are applied at any given time. Inside the Sound Classes section, it is possible to set

which Sound Classes are to be affected by the mix. For each Sound Class there are Volume or Pitch adjusters, options to set if the mix settings are to be applied to Child Classes, or modify the Voice Center Channel Volume.

The Sound Mix section allows to specify how the Sound Mix properties are applied or removed. Delay indicates how long before the mix properties should begin being applied. Fade in Time and Fade out Time specify how quickly to transition from no effect to the specified properties. Duration allows a pushed Sound Mix to automatically pop itself after the specified duration. A value of  $-1$  indicates to never automatically pop and passively applied Sound Mixes will not automatically pop.

Dialogue Voice and Dialogue Wave

### 3.11 Creating 3D Widgets

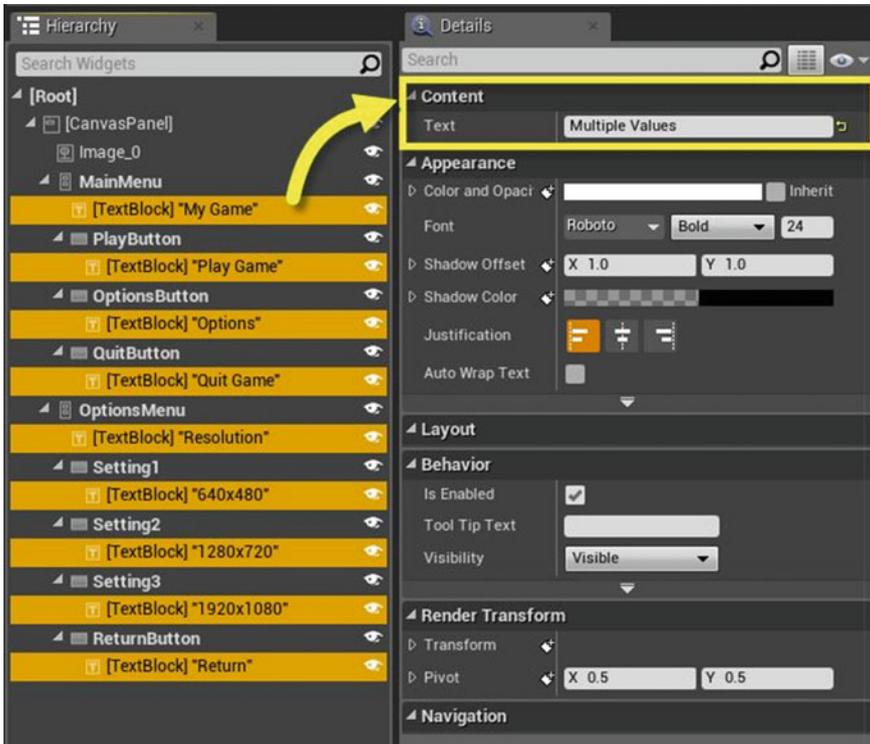
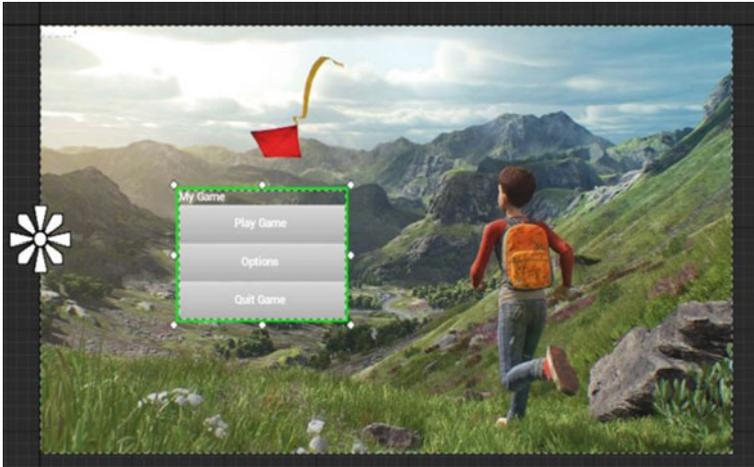


Fig. 10 3D widgets control panel



**Fig. 11** UI screen space

Most UI elements can be rendered in 2D screen space, however there may be instances where it is desirable for an object to appear inside the game world instead overlaid on screen. This could be a computer terminal or key pad that a player must interact with, it could be the display of an enemy or player health bar, or even a menu that will be displayed in the game world in 3D space (Figs. 10 and 11).

## 4 Results

With the use of Unreal 4 it is possible to allow access to the Ionian Music & Sounds Archive to a much broader audience. People from all over the globe and of all ages are able to explore the archive, represented in an immersive audiovisual experience, strongly associated with the environment that each sound originates from. Such access methods, especially when they are used on very common devices like smartphones, tablets or PCs and when they can easily be integrated with social media, will increase popularity, user views and web traffic of the website that is already available.

The suggested user interface, being based on one of the best game engines available, serves both as an educational and entertaining material, raising visiting interest and touristic attraction to audiences that would be otherwise unreachable. By enhancing the game interface using 3D Virtual Reality technology (i.e. Google Cardboard or Oculus Rift) which are fully compatible with Unreal 4, the result can prove an entertaining, immersive and attractive showcase, increasing marketing potential.

## 5 Conclusion

In this paper we describe the design and implementation of a 3D environment telepresence visualization interface, aiming at the remote experience and dissemination of musical cultural heritage and environmental soundscapes to the public, utilizing the latest technology available. The implementation technologies are based on open source software tools (Unreal 4, Mysql, PHP, Java), programming languages and standards which support sustainability of the services on the long term. Local societies and cultural organizations must indulge to this idea and contribute to the subsequent incorporation projects that will maintain this project as an active source in the era of digital tourism.

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