Novel Virtual Reality Solutions for Captivating Virtual Underwater Tours Targeting the Cultural and Tourism Industries

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Abstract: The underwater environment beyond its natural unique beauties has a great scientific interest as it pertains all fields of marine research; despite this, it has not been adequately exploited for cultural and tourism purposes. Virtual and augmented reality technologies have advanced considerably in re-producing and re-presenting unreachable large-scale environments. To this end, this work presents an *integrated interactive framework for exploring the underwater world* such as submerged cities, shipwrecks, sunken harbors, diving and marine parks, either in situ via *augmented reality*, or remotely via *virtual reality*. Firstly, the designed solution exploits high-resolution visual and range data acquired with state-of-the-art technologies (swath mapping systems, underwater vehicles, unmanned aerial vehicles) and processed through novel approaches to create a synthetic topographic relief basemap and to analyze its geomorphology, as well as the anthropogenic interventions. Secondly, this framework allows to write narrative scenarios and produce interactive VR experiences, through a set of custom tools for multimedia content management. The developed framework, named VIRTUALDIVER, will enable domain experts to design immersive xReality experiences and users to experience environments that are typically accessed only by underwater vehicles in cost-intensive, scientific missions. This will promote the underwater cultural heritage, and natural environment through the development of innovative research, teaching, tourism and creative products.

1 INTRODUCTION

The Greek seabed is rich in biodiversity and has intense geomorphological structures, while numerous shipwrecks exist there as well as immersed infrastructure and ancient harbours, which, despite of their huge touristic interest and being the subject of specialized scientific research, have not yet been highlighted. Although there have been attempts to promote submarine areas in the past, most of them are audiovisual productions such as documentaries, which are usually implemented by foreign corporations (for example, the underwater village of Pavlopetri in Laconia, the shipwreck of Antikythera etc.) (Mahon et al., 2011; Christopoulou et al., 2012).

The use of new research knowledge and innovative technologies to promote the Greek seabed, as well as the free access to scientific data and the transfer of scientific knowledge to the general public, is now possible and can lead to the development of new tourism products, services and activities, which can later attract tourists of general and / or special interest. At the same time, the introduction of virtual and augmented reality technologies into the particularly interesting and hardly accessible underwater environment is a challenge for the niche market and creates new investment opportunities.

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VIRTUALDIVER aims at designing and developing a complex Digital Platform -initially- for the promotion of the underwater wealth of Greece using new technologies (Fig. 1). This product will be a tool for supporting businesses and professionals operating in the field of Culture and Tourism, enhancing special aspects of tourism such as cruises, diving, scientific and other. The platform will use digital bathymetric data, data from Remotely Operated Vehicles (ROVs), as well as topographic terrestrial photogrammetry data from unmanned helicopters (drones) to synthesize 3D digital images of specific areas of tourist interest in high resolution. We will write narrative scenarios and produce interactive experiences. The platform will be able to assimilate real (or virtual) environments with the help of different media such as tablets or virtual reality glasses, as well as more specialized peripherals.

The Santorini volcanic complex was chosen for demonstrating the VIRTUALDIVER platform, as it is one of the most visited destinations in Europe, while it is a unique “open geological museum” with the largest caldera in the world. The Minoan eruption that took place in 1615 BC is the largest of the last 10,000 years and is among the most famous eruptions across the world (Freidrich et al., 2006). The caldera has always concealed the legend of the "Lost Atlantis" and gives birth to new volcanic eruptions (Nomikou et al., 2014). The Kolumbo submarine volcano, 7 km NE of Santorini is the most active in the entire Mediterranean Sea today (Nomikou et al., 2012).

This work has the following scope:

- The development of an innovative product for the provision of specialized services in tourism, with emphasis on marine, diving and cruise tourism.
- The combination of research results of underwater surveys along with terrestrial data and their exploitation in the creative – cultural industry.
- The creation of a complex Digital Platform for the realization of Virtual Experiences and the narration of various narrative scenarios.
- The development of a Mapping Methodology and 3D Visualization of the underwater area, emphasizing on the interpretation of the geological / geomorphological structures of the Greek seabed and its spatial connection to the coastal surface for the needs of Virtual and Augmented Experience.

2 METHODOLOGY

Within the framework of this project, Geomorphology, Photogrammetry, Computer Vision and Human-Computer Interaction will be combined.

Until today, a typical barrier to the adoption of Extended Reality (xR) technologies in mass applications is the prohibitive cost of content creation and specialized hardware, as well as the simulator sickness, which is due to the lack of visual preciseness of the virtual environment and the insufficient computing capabilities of portable devices that cause image and conception incongruity. In VIRTUALDIVER, we will deal with specific conditions in relation to the current level of innovation due to the underwater environment, and we will exploit the latest advances in commercial h/w for Virtual Reality (VR) and Augmented Reality (AR). The proposed approach also addresses typical issues in xR experiences via a multimodal approach in the creation of visually pleasant and precise 3D content of the coastal and underwater spaces, which is based on the accurate 3D reconstruction of details and high-resolution texture, the manipulation of artificial 3D models, as well as panoramic videos and images.

2.1 VIRTUALDIVER Framework

VIRTUALDIVER platform is a unified design solution for developing interactive experiences for the cultural and tourism sector. The platform integrates cutting edge VR and AR technologies combined with a designer-friendly multimedia management workflow methodology as a toolkit for building and visualising interactive narratives.

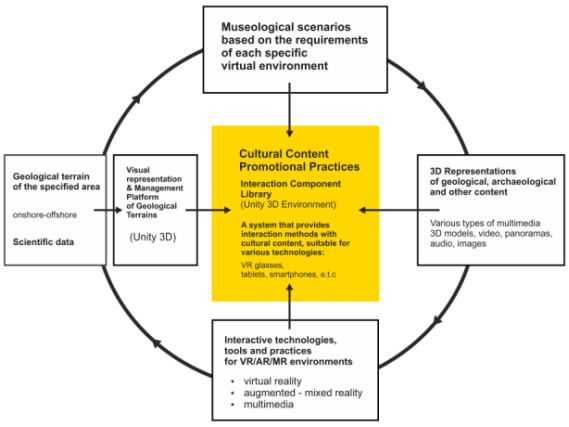

Figure 1: The overall structure of the developed VIRTUALDIVER framework.

As a specialized product, VIRTUALDIVER will aim to support and boost specific forms of tourism such as: cruise tourism, diving, science tourism and more.

The development of the platform is based on the collaboration of scientists from different scientific and engineering fields with the ultimate goal of creating interactive experiences through an interdisciplinary and transdisciplinary design process.

The design team of the VIRTUALDIVER platform consists of a core of researchers from the following scientific fields:

- Scientific disciplines that study geology, oceanography and remote sensing.
- Humanities with an emphasis on culture (museology, archaeology, history, etc.)
- Scientific/ artistic disciplines that study design, filming, script writing, sound and visual arts on a theoretical and practical level.
- Scientific disciplines that study geomatics, information and communication technologies.
- Other scientific fields that can make a useful contribution, depending on the use case scenario.

VIRTUALDIVER platform will be available as a provided service from the project's consortium. The project's goal is to shape a new unique tourism product internationally, promoting the enormous onshore and offshore cultural reserve of Greece. In addition, it will raise the value of the platform's clients (municipalities, ministries, cultural institutions, etc.) and bring increased revenue to the region of application.

2.2 Multimodal Mapping for VR

More specifically, capturing of real-world scenes in 3D models for the visualization in VR is based on a multimodal Mapping Methodology: *i)* a methodology and the system of acquiring heterogeneous-bathymetric, visual and multi-spectral data; *ii)* an innovative Structure-from-Motion approaches that compensate the refraction in underwater image creation for 3D reconstruction of small details and adopting incremental approaches to deal with a large number of images; *iii)* a combination of image processing techniques to restore the warm colours of underwater scenes that suffer from light absorption in water; *iv)* co-registration algorithms to combine heterogeneous data for the creation of novel texture for the reconstructed 3D models and photomosaics; *iv)* classification of multispectral data using deep learning algorithms for recognizing geological materials and create new synthetic texture for seabed models.

In particular, the data acquisition is based on high-resolution bathymetric systems (multibeam systems) for the larger part of the seafloor, and to RemotelyOperated underwater Vehicles (ROV) and Unmanned Aerial Vehicles (UAV) for the acquisition of the more detailed visual and multispectral data. These latter can accurately capture the volcanic geomorphology and the steep internal slopes of Santorini's caldera, as well cultural heritage details The 3D Virtual Representations (single elevation model, 3D detailed photo-textured models and geological maps) will be of high-resolution, but simplified geometric structure in order to constitute the detailed background of the Interactive Platform for the implementation of Virtual Experiences (Fig.1).

Aiming to a both photorealistic and accurate digital representation of the Santorini's terrain in a VR environment, our team have developed a robust and fast workflow to capture, integrate and combine geospatial data of different modalities. The proposed methodology initially considers the needs of the user and the essential characteristics of the desired geospatial background, the 3D models on it and the other required figurative products. Existing geospatial data were also exploited. In particular, bathymetric data (Nomikou et al., 2014; 2016; Hooft et al., 2017) and imagery from ROV missions (Carey et al., 2013; Camilli et al., 2015), both provided by previous works of the team, and open source data as well (EMODnet data) were used for the off shore 3D model. Regarding the on shore, SRTM, satellite imagery from the WorldView4 and LIDAR data describing Kameni Island were combined (Nomikou et al., 2014). The mentioned dataset was exploited in order to create a truly detailed and of high accuracy 3D model of Santorini Island which later was processed in Unity3D (Fig. 2).

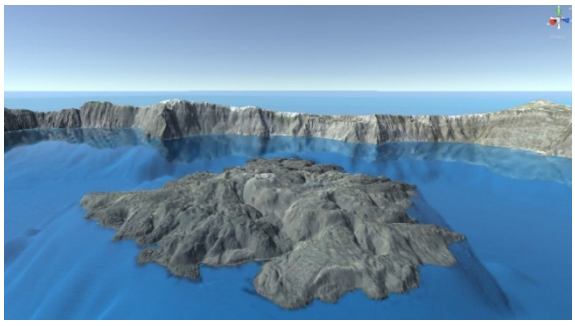

Figure 2: WorldView4 imagery of Santorini volcano combined with surface data.

Innovative methods were developed for drone imagery collection and processing was applied and ROV missions with top-notch camera equipment are on-going. This will lead to a more accurate 3D reconstruction of high interest scenes. In addition to this, GNSS measurements provide the necessary georeference of the 3D models and later will assist the matching between the Points of Interest in real world and the VR environment. Finally, panoramic images and videos add a rather realistic point of view for the User into the VR environment.

The methodology developed by our team consists of three main steps. Initially, bathymetric and SRTM data were scaled down to meet the smallest resolution of our dataset (LIDAR). Afterwards, the elevation data were combined based on the slope of the relief which also considers a buffer area aiming to a smoother terrain. Although this minimizes the spikes and the steep effects on the terrain, it can lead to ambiguities, so particular attention is required. Finally, the surface data and the WorldView4 imagery are combined applying the well-known nearest neighbour matching technique leading to the final terrain background (Fig. 3).

Subsequently, images captured by drone and ROVs using open-source 3D reconstruction software (Colmap, Meshroom), combined with custom algorithms, were processed. The result is exceptional and gives a detailed representation of parts of the island's points of interest (Figs 4 and 5). Panoramic views and videos complete the visual representation of the Santorini Island.

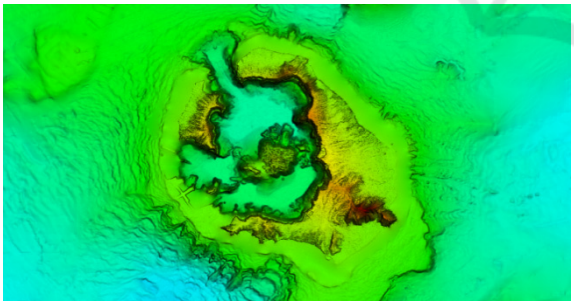

Figure 3: Combined of bathymetric, LIDAR and SRTM data of Santorini volcano.

In VIRTUALDIVER, the platform is being developed on the Unity 3D technology, one of the most widespread platforms for designing, development, and implementation of interactive 3D environments, and will consist of two interconnected systems:

(i) management of 3D terrains and their relevant metadata

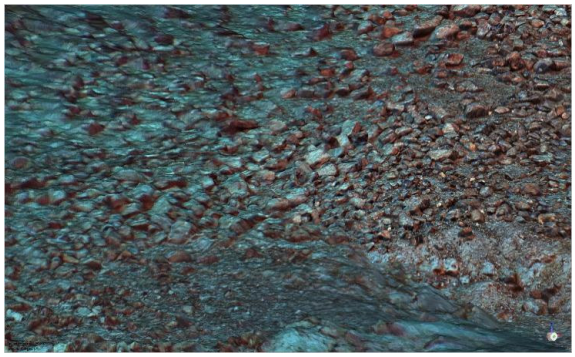

Figure 4: 3D reconstruction of ROV images from Santorini's seafloor.

(ii) implementation of narrative scenarios. The goal is the management unit of the 3D terrains to be able to import and manage single seabed and terrestrial topography, while subsequently the interactive platform will be able to provide a series of specially developed tools aiming for a designer's friendly workflow of VR interactive experiences production.

Figure 5: 3D reconstruction of Oia village at the northern part of Santorini volcano.

VIRTUALDIVER aims to: i) provide massive development and dissemination of virtual experiences of coastal and underwater space by creating a composite digital Interaction Platform, ii) differentiate the product in relation to the international standards, and iii) promote the underwater environment and innovative technologies as essentials to map the coastal and, above all, the marine space, enhancing experiences through the geological interpretation of the volcanic relief of Santorini.

3 INTERACTIVE PLATFORM DEVELOPMENT

3.1 Defining Functional and Technical Specifications of the VIRTUALDIVER Platform

The functional requirements of the end users of Virtual Experience have been recorded and analyzed based on international experience, the Companies' experience in related projects, and the Advisory Committee's view. Within this frame, the expectations of the User related to his virtual Tourism-Cultural interests and the forms of interaction that are currently available with Virtual and Enhanced Reality devices have been recorded.

The technical specifications of the Interaction Platform and the Geomorphological Mapping System and 3D Visualization System have been determined. In this delivery, one-to-one operational requirements of the Functional and Technical Specifications of the Platform have been met, as well as the technical requirements for accurate and spatial data analysis, interaction files connecting the work packages, device capabilities, etc.

As far as the VIRTUALDIVER Interaction platform is concerned, it will be developed using the Unity Real-Time Development Platform and will act as an add-on for the platform dedicated for developing interactive experiences. Taking advantage of Unity's capabilities, a series of interaction components will be developed, each with a different approach of handling multimedia content. Depending on the requirements and limitations of the interactive experience that needs to be created, a series of interaction components will be available (Fig. 6).

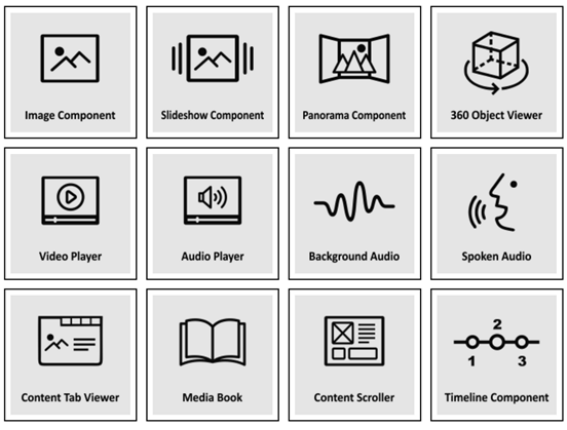

Figure 6: The proposed interaction components of the VIRTUALDIVER framework.

These components will act as tools for the authors (the design team) of the Interaction Platform, that will facilitate the creation of diverse interactive narratives. The key factor of our proposed methodology is the simplification of complex development workflows, without the need of any specialized programming knowledge. Based on a designers' centric workflow approach, our proposed methodology advances the interdisciplinary collaboration among scientists and experts from diverse scientific fields with different backgrounds.

At the current stage of development, the methodology and design principles for the creation of a series of interaction components have been set. Despite that, the requirements of the case study will determine which interaction components will be prioritized for development and implemented for a fully immersive Virtual Reality experience. In future stages of the platform, the implementation of interaction components with similar characteristics in an Augmented Reality environment will be examined.

3.1.1 Planning and Collection of Heterogeneous Data

Planning and collection of heterogeneous seafloor, coastal and onland data (ROV, UAV). The main data is multi-spectral and RGB, and at the same time other receivers for georeferencing and mapping of heterogeneous file data (EMODNET data, Copernicus Marine Services, etc.) have been deployed as well as geological data.

3.1.2 Website

For the dissemination and publicity needs of VIRTUALDIVER, an appropriate Project Website has been created, to promote the activities and outputs of the project (www.virtualdiver.gr) and also all public deliverables. Additionally, website will communicate directly a Twitter, Slideshare and Facebook page, using the "Network Publisher" plugin for WordPress.

3.2 User Interface Design

The interactive components were complimented with a set of UI designs that promote simplicity and ease of use. The goal was to give the design team a familiar User Interface to work with in order to create seamless interactive narratives. The same design principles were applied to all the interactive

components (visual and functional consistency) providing thus a unified experience for the design team (Fig. 7). Concerning the end users' needs and requirements, a set of UI designs was implemented, based on best practices for VR User Interface design combined with academic research from the HCI field specialized in VR application development.

Figure 7: The pop-up interaction component as used by the design team within the Unity Editor environment.

Based on research literature concerning head movement and hand usage in VR (Alger, 2015; Applebee, 2016; Chu, 2014; Oculus, 2015), a set of ergonomic interaction rules was defined, thus making the overall VR experience more comfortable. Based on those design rules, an interactive tool bar was designed and developed that makes it easier and more intuitive for the user to explore interactive multimedia content and navigate between narratives (Fig. 8).

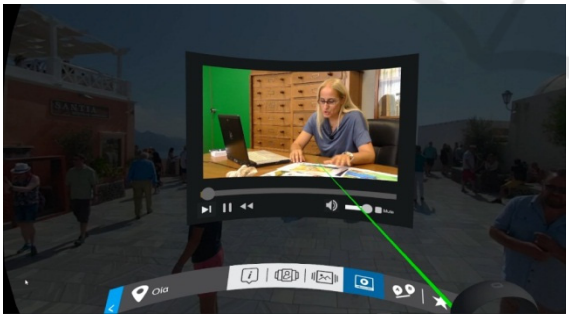

Figure 8: Interacting with multimedia content using the interactive tool bar.

3.2.1 Creation of Geo-Ecotourism Scenarios, Educational Material and Productions and Their Interconnection through the Interactive Platform

Narrative scenarios, multimedia educational material for selected points of interest, and a series of audiovisual products are being created to be used to produce interactive experiences. Each scenario in the VIRTUALDIVER platform consists of a number of points of interest, categorized according to their characteristics such as: tourist interest, geological interest, marine ecosystem, archaeological site, etc. To illustrate each point of interest, the design team will be able to use a range of interaction components for the exploitation of multimedia content, each of which will correspond to a different type of data (e.g. image, audio, video, panoramic images and videos, 3D objects, use of 360 video footage, panoramic and drone photos, 3D animation, interactive maps, interactive timelines, explanatory interactive diagrams, specially designed soundscapes, etc (Fig. 9).

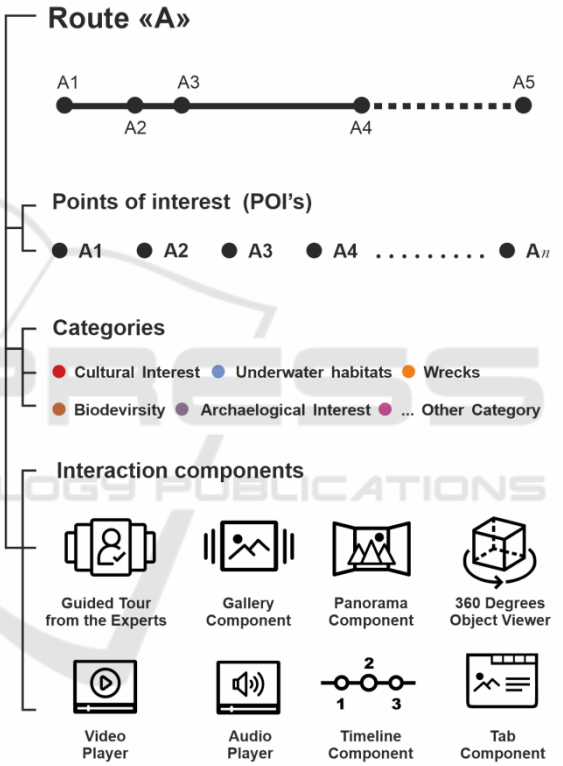

Figure 9: Points of Interest, categories and narrative tools.

4 DISCUSSION AND CONCLUSIONS

VIRTUALDIVER intends to promote technical and financial constraints on the creation of Virtual Experiences in the exciting submarine world, in order to be an attractive entertainment and cultural product that will be deployed by tourism and cultural institutions in Greece. The proposed approach concerns the development of an Interaction

Platform that will simplify the process of implementing the Integrated Virtual Experience - narrative scenarios, audio-visual productions and educational material – on the one hand for non-experts and, on the other hand, the creation of geospatial backgrounds and 3D visual information. The Interaction Platform will be fed by the innovative Mapping System and 3D visualization of submarine areas with an emphasis on the interpretation of geological/geomorphological structures and the spatial connection to the coastal area for the needs of Virtual and Extensive Navigation. The digital platform is based on the unique, complex and extremely interesting volcanic area of Santorini, which is of great value as a tourist product.

The contribution of VIRTUALDIVER to the sector of "Tourism, Culture and Creative Industries" is crucial, as it addresses private (or non) operators with an innovative B2B service in order to boost their commercial value through the creation of a unique tourist product - experience of impressive virtual environments. Moreover, it will establish a new approach to promoting the cultural and environmental supplies through enhancing special forms of tourism. Regarding the underwater environment, which is hardly accessible to the average visitor in Greece, VIRTUALDIVER will serve as a mediator for the perception of this particular aspect of the world that surrounds us.

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REFERENCES

Alger, M. (2015) Visual Design Methods for Virtual Reality [online] Available at Internet: http://aperturesciencellc.com/vr/VisualDesignMethodsforVR_MikeAlger.pdf [2019-08-28]

Applebee, A. (2016) Virtual reality: Templates for UI design in VR [online] Available at Internet: https://blog.kickpush.co/beyond-reality-first-steps-into-the-unknown-cbb19f039e51

Camilli R., Nomikou P., Escartín J., Ridao P., Mallios A., Kilias S.P., Argyraki A. and the Caldera Science Team (2015). The Kallisti Limnes, Carbon Dioxide-Accumulating Subsea Pools. *Scientific Reports, 3:2421*.

Carey S., Nomikou P., Croff Bell K., and Ballard D. (2013). Exploration of the Santorini volcanic group, southern Aegean Sea: *Oceanography (Washington, D.C.), v. 26, no. 1, supplement, p. 44–49*.

Christopoulou Al., Gadolou An., Bouyia P. (2012). "The Antikythera Shipwreck. The Technology of the ship, the cargo the Mechanism". *Trans. M.A. Fowler, Athens: National Archaeological Museum*.

Chu, A. (2014). VR design: transitioning from a 2D to a 3D design paradigm. Presented at Samsung Developer Conference, 19 November, 2014. Available at Internet: https://www.youtube.com/watch?v=XjnHr_6WSqo [2019-08-28]

Friedrich WL., Kromer B, Friedrich M, Heinemeier J, Pfeiffer T, Talamo S. (2006). "Santorini eruption radiocarbon dated to 1627-1600 B.C.". *Science. 2006 Apr 28;312 (5773):548*.

Hooft E.E., Nomikou P., Toomey D.R., Lampridou D., Getz C., Christopoulou M-E., O'Hara D., Arnoux G.M., Bodmer M., Gray M., Heath B.A., VanderBeek B.P. (2017). Backarc tectonism, volcanism, and mass wasting shape seafloor morphology in the Santorini-Christiana-Amorgos region of the Hellenic Volcanic Arc. *Tectonophysics 712–713 (2017) 396–414*.

Mahon I., Pizarro O., Johnson-Roberson M., Friedman A., Williams S.B., Henderson J.C. (2011). "Reconstructing Pavlopetri: Mapping the World's Oldest Submerged Town using Stereo-vision". *2011 IEEE International Conference on Robotics and Automation Shanghai International Conference Center*.

Nomikou P., Carey S., Papanikolaou D., Croff Bell K., Sakellariou D., Alexandri M., Bejelou K. (2012). "Submarine Volcanoes of the Kolumbo volcanic zone NE of Santorini Caldera, Greece". *Global and Planetary Change 90-91, 135-151*.

Nomikou, P., Parks M., Papanikolaou D., Pyle D., Mather T., Carey S., Watts A., Paulatto M., Kalnins M., Livanos I., Bejelou K., Simou E., Perros I. (2014). The emergence and growth of a submarine volcano: The Kameni islands, Santorini (Greece). *GeoResJ., Vol.1, 8-18*.

Nomikou P., Druitt T.H., Hubscher C., Mather T.A., Paulatto M., Kalnins L.M., Kelfoun K., Papanikolaou D., Bejelou K., Lampridou D., Pyle D.M., Carey S., Watts A.B., Weib B. & Parks M.M. (2016). "Post-eruptive flooding of Santorini caldera and implications for tsunami generation". *Nature Communications, 7:13332*, DOI: 10.1038/ncomms13332.

Oculus VR (2015) User input and navigation. Oculus best practices. Available at Internet: https://pdfs.semanticscholar.org/0d8b/1d9d32bebdc79143f07ad673d97dac230cfe.pdf [2019-08-28].