# A Cloud Architecture for Processing and Visualization of Geo-located 3D Digital Cultural Heritage Models

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Keywords: Web-GIS, Geo-located 3D Cultural Heritage Models, 3D Visualization, Web Repositories for 3D Models, Cultural Heritage.

Abstract: The increasing affordability of surveying methods such as laser scanning and photogrammetry has aroused broad and current interest in 3D modelling among cultural heritage preservation specialists. This generated, in recent years, many digital cultural heritage preservation projects across the globe that aimed at documenting cultural heritage sites and objects in a 3D form. Once 3D cultural heritage models have been created, the next step is generally to assure their long-term digital storage, dissemination, and visualization. To this end, this article presents a new cloud architecture for processing and visualization of geo-located 3D cultural heritage models over the web, which has been accomplished by integrating maps, 3D cultural heritage models, and the geospatial data associated with the location of 3D cultural heritage models. The cloud architecture is based on Amazon Web Services, while the core framework for handling the content is managed by free and open-source, database-driven, easy-to-implement KeystoneJS Content Management System. All other frameworks used in the architecture such as for web mapping, 3D visualization, etc. are also based on free and open-source paradigm, which allows flexibility on extensions and re-use. The proposed architecture has been validated through a use-case applied to Australian 3D cultural heritage models.



## 1 INTRODUCTION

In recent years, 3D modelling has become a widespread tool among CH preservation specialists. One of the reasons for this is the increasing affordability of surveying methods such as laser scanning and photogrammetry, which can efficiently and accurately survey tiny cultural heritage (CH) objects as well as complex CH sites (Remondino, 2011). This generated, in recent years, many digital CH preservation projects across the globe to document CH objects and sites in a 3D form (D'Andrea, Niccolucci, Bassett, & Fernie, 2012). The resulting 3D CH models are often employed not only for preservation purposes but also for other purposes such as 3D Geographic Information Systems (GIS), augmented reality, and virtual reality among others (Campanaro, Landeschi, Dell'unto, & Leander Touati, 2016). Furthermore, there are cloud computing-based web repositories, web-GIS platforms, and archives are emerging for long-term storage, visualization, and analysis of 3D digital CH models. Cloud computing offers many benefits over traditional approaches (e.g. on-premise infrastructure) such as scalability, flexibility, and potential to reduce IT (information technologies) costs among others. Scalability of the cloud computing refers to the ability of the system in which every application or infrastructure can be scaled up and scaled down based on the workload (Falatah & Batarfi, 2014; Lee & Kim, 2010; Singh & Malhotra, 2012). While flexibility in cloud computing allows employees to be more flexible in terms of accessing files through web browsers, collaboration, access from different devices and location among others (Bharadwaj & Lal, 2012; Sultan, 2014). Finally, IT costs can be reduced through a reduction in spending on hardware, software, infrastructure, and IT staff among others (Chandra & Borah, 2012; De Assunção, Di Costanzo, & Buyya, 2009).

Despite the fact that there are some web platforms and archives for 3D content such as OMEKA, 3D-COFORM, Sketchfab, TurboSquid, 3D CH models are still problematic to find, use and re-use. A recent

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Nishanbaev, I.
A Cloud Architecture for Processing and Visualization of Geo-located 3D Digital Cultural Heritage Models.
DOI: 10.5220/0009341500510061
In *Proceedings of the 6th International Conference on Geographical Information Systems Theory, Applications and Management (GISTAM 2020)*, pages 51-61
ISBN: 978-989-758-425-1

survey of Champion and Rahaman (Champion & Rahaman, 2019), who surveyed 14 proceedings of leading digital heritage events and conferences, revealed that out of 1483 examined conference articles only 17.9% or 264 articles incorporated 3D models or images of 3D models. Even more dramatic is only 9 articles had accessible 3D content. Furthermore, in most cases, 3D digital CH models incorporate geospatial information relating to the location of the CH site and object.

To this end, this article presents a new cloud-based architecture for integrating maps, 3D digital CH models and geospatial data such as geolocation. The cloud architecture is based on Amazon Web Services (AWS), while the core framework for handling the content is managed by free and open-source, database-driven, easy-to-implement KeystoneJS Content Management System (CMS). All other frameworks used in the architecture such as for web mapping, 3D visualization, etc. are also based on free and open-source paradigm, which allows flexibility on extensions and re-use. The proposed architecture has been validated through a use-case applied to Australian 3D CH models. This architecture can be used, or extended for use, in a wide range of domains including GIS.

The contributions of this article to the CH and GIS domains are as follows:

- A new AWS-based cloud architecture to integrate maps, 3D CH models and geospatial data such as geolocation. All employed frameworks in the architecture are free and open-source, and completely extendable and reusable. The proposed architecture can also be used in any other cloud platform, which supports Node.js environment.
- Since content management including uploading and editing text data, 3D CH models, and geo-location within the architecture is based on a database-driven, easy-to-implement KeystoneJS CMS, it can help CH and GIS professionals with limited technical knowledge to implement the architecture. Furthermore, many time-consuming web developments such as admin user interface, session management among others are handled by the KeystoneJS CMS.
- CH organizations and institutions such as museums, galleries, and archives can implement this architecture to present available CH objects and assets in a 3D digital form on the web. This can, in turn, help to promote national and international tourism.
- GIS and CH professionals can extend this architecture according to their needs. For instance, raster and vector data can be integrated with the free and open-source framework of GeoServer, which supports geospatial data in many formats and standards.
- Finally, the article extends the existing body of knowledge and expertise in implementing a cloud-based architecture for processing and visualization of geo-located 3D digital models.

## 2 RELATED WORK

Europeana is a CH platform and aggregator with more than 30 million digitized objects from more than 2300 European CH institutions and organizations, while Europeana cloud is one of the largest projects regarding cloud-based infrastructures for CH research and data. Europeana Cloud is an initiative by Europeana Foundation to provide shared cloud infrastructure for aggregating and exchanging CH data among European institutions and organizations. To this end, it offers many services such as unique identifiers to each CH records, storage and access for heterogeneous CH data including metadata, annotation services to add additional data to CH records, tracking of changes made to CH records, flexible, scalable and customizable CH data processing capabilities among others. Europeana cloud, in terms of technical architecture, has been implemented on a hybrid cloud architecture by combining public cloud and private cloud architectures. This allows taking all the advantages offered by these two cloud architectures. For instance, public cloud offers flexibility for scaling up and down the hardware capabilities based on the workload, while the private cloud offers more resistance to failures and less dependency on third-party cloud providers to name a few (Benardou, Dallas, & Dunning, 2014; Kats et al., 2014).

The SACHER (Sacher-Project) (The Smart Architecture for Cultural Heritage in Emilia Romagna) is a project financed by Regione Emilia-Romagna within the European Regional Development Fund. It has developed a cloud-based, open-source and federated platform to manage various aspects of tangible CH such as 3D life cycle management for CH, the multi-dimensional search engine to find CH data from heterogeneous sources among others. The platform offers services both to CH professionals and the public. The cloud platform used in the project is IaaS (Infrastructure-as-a-service) OpenStack, which is often used to build private and public clouds. Regarding the server-side web technology, the project uses the Django web framework, which is written in Python programming language. Swift Object Storage was employed as a storage container for 3D models, while 3D Heritage Online Presenter (3DHOP) was chosen as a visualization framework for 3D models. The multi-dimensional search engine in the platform is based on a NoSQL database of MongoDB. The platform also incorporates a Google map through which CH places can be searched by name, address and building type (Apollonio et al., 2017; Bertacchi et al., 2018).

CNR ITAB (Institute for technologies applied to cultural heritage), while collaborating with ARIADNE (Ariadne-Infrastructure-Project) and E-RIHS (E-RIHS-Project) infrastructure projects, developed a cloud-based modular architecture to enable archeologists to build and visualize 3D landscapes. This architecture was built on a cloud platform of ownCloud (ownCloud), which comes in three versions namely ownCloud Community, ownCloud Online, and ownCloud Enterprise. In all versions, it provides a free desktop client and iOS and Android app to upload and manage the data. The developed cloud architecture offers several services such as terrain service and gallery service. The former leverages on WebGL based Virtual Planet Builder (Virtual-Planet-Builder) tool to load, process and visualize GIS elevation data such as Digital Elevation Models (DEM). The latter service allows users to create, delete, and update projects within the system. It displays all created terrain databases, status, and if available, a short description for each entry among others (Fanini, Pescarin, & Palombini, 2019).

Furthermore, there are some other smaller-scale projects in this regard such as a collaborative project by the National Library of Scotland, Edinburgh Parallel Computing Centre, the National Galleries of Scotland and the Digital Preservation of Coalition. The name of the project is Cloudy Culture, which aimed to investigate the potential of EUDAT (EUDAT) cloud services in CH conservation, particularly to improve preservation and accessibility of European CH data hosted in the National Library of Scotland, and the National Galleries of Scotland. These two CH institutions collect and host an extremely large amount of digital CH data such as maps, books, articles, images among others, which require safe digital preservation (EUDAT).

Another relating project is by Pisu and Casu (2013), which proposed a cloud-based web-GIS framework for documentation and dissemination of architectural heritage. The web-GIS framework resulted in a multi-scale and multi-layer information system applied to Sardinian late gothic architecture.

# 3 BACKGROUND LITERATURE

## 3.1 Cloud Computing

Cloud computing is the hosting and the delivery of various services over the Internet. It can include tools and resources such as servers, databases, networking, various business applications and software, which can be leased in an on-demand fashion. Cloud computing has been given many definitions, however, many researchers and professionals in this domain have adopted a definition by the National Institute of Standards and Technology of the United States (NIST), which states it as follows:

*'Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.'*

Cloud computing services can be grouped into three categories namely software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS).

SaaS refers to cloud computing that offers on-demand applications over the Internet. An apt example of this category of cloud computing is Salesforce (Salesforce), which offers a wide range of services to business owners (customer relationship management) to better connect with customers, potential customers, and partners.

PaaS refers to cloud computing that offers platform resources such as software development frameworks and tools. An example of this category of cloud computing is Heroku (Heroku). It provides software developers with virtual containers called 'Dynos' that can execute software applications written in various programming languages.

IaaS refers to cloud computing that offers on-demand infrastructural resources over the Internet. Examples of this category of cloud computing include Amazon Elastic Compute Cloud - Amazon EC2 (Amazon-EC2), Google Compute Engine (Google-Compute-Engine) and Digital Ocean (DigitalOcean) among others. This cloud computing type allows launching on-demand virtual machines (VMs), which can then be accessed to perform computing tasks.

Cloud computing also offers several cloud deployment models, which define how cloud services are made available to users. Public cloud, private cloud, hybrid cloud, and community cloud are 4 common deployment models associated with cloud computing.

Public cloud is the type of cloud computing model that supports all users who want to use cloud computing resources such as hardware and software on a subscription basis, in other words, everyone who subscribed can use the services. It is often used for application development and testing, file sharing and other purposes, in which privacy and security of data are not a high priority.

On the other hand, the private cloud is typically used by a single organization. This type of cloud computing deployment can be hosted internally or externally. This type of cloud deployment offers greater control over cloud infrastructure and a higher level of security compared to public cloud deployment.

Hybrid cloud as the name suggests combines the best of the private and the public cloud. Many organizations use this type of cloud deployment as it allows to take advantage of scalability and cost-effectiveness of public cloud as well as to execute and to store mission-critical applications and data in the private cloud.

In the community cloud deployment model, multiple organizations share computing resources. Hence, the hardware and software capabilities of the cloud are managed and secured commonly by all the participating organizations. Since access to the cloud is restricted to the members of the community, many research organizations and universities often deploy this type of cloud model to conduct collaborative research projects (Ali, Khan, & Vasilakos, 2015; Zafar et al., 2017; Zhang, Cheng, & Boutaba, 2010).

### 3.2 Web Content Management Systems, 3D Visualization Frameworks and 3D File Formats

In recent years, the amount of digital content available on the Internet has increased significantly. Many organizations and individuals are, therefore, deploying web content management systems (WCMS) to provision and manage their information on the web. In essence, WCMS is a software application that can help people with limited technical knowledge to create and manage websites, and web content. WCMS often consists of two parts namely front-end and back-end. The former represents the web user-interface that users see when they visit the website. While the latter represents the server-side, in other words how the website works, changes, and updates. This usually involves databases and servers. WCMS may offer organizations and individuals many benefits such as user-friendly customization of the front-end, user-friendly web content management and editing, and easy-to-follow workflows for search engine optimizations (SEO) among others. Furthermore, there are many free and open-source WCMSs available on the Web such as WordPress, Drupal, Joomla, KeystoneJS to name a few (Horsman, 2018; McKeever, 2003).

Currently, all modern browsers such as Google Chrome, Opera, Safari and Firefox support WebGL technology that allows creating and visualization of 3D graphical applications on the Web. This technology enables web users to experience interactive 3D content on webpages without downloading and installing any plug-ins. WebGL was originally developed by Mozilla, however, currently it is maintained by the non-profit organization called Khronos Group. Since WebGL leverages two hardware components of a computer namely central processing unit (CPU) and graphics processing unit, it offers GPU acceleration to execute large-scale 3D web applications. Thus, it provides improved performance and faster running of applications. The part of the technology that runs on CPU is written on JavaScript programming language, while the GPU part is based on OpenGL ES. Despite the fast execution of 3D web applications, WebGL is a low-level 3D graphics application programming interface (API) (WebGL). This means developing 3D web applications using this technology can be time-consuming, and in some instances extremely complicated. For this reason, many WebGL-based JavaScript libraries have been developed to ease and accelerate the development of 3D web applications. Three.js, Babylon.js, sceneJS are among those libraries, which is widely used to develop interactive 3D web applications. These libraries offer many technical features such as effects, lights, various shaders, and virtual reality among others. They run on all web browsers that support previously discussed WebGL technology. CesiumJS is another 3D library used for developing interactive 3d maps. This library is now an open-standard of Open Geospatial Consortium (OGC).

3D file formats are used to store information relating to a 3D object such as geometry, appearance, scene, and animation. 3D file formats are divided into two types in terms of licencing, which are proprietary and non-proprietary. Proprietary formats are native file formats from software applications, whereas non-proprietary formats are open-source file formats. gLTF, Collada, 3D Tiles, and OBJ are some of the well-known examples of 3D file formats.

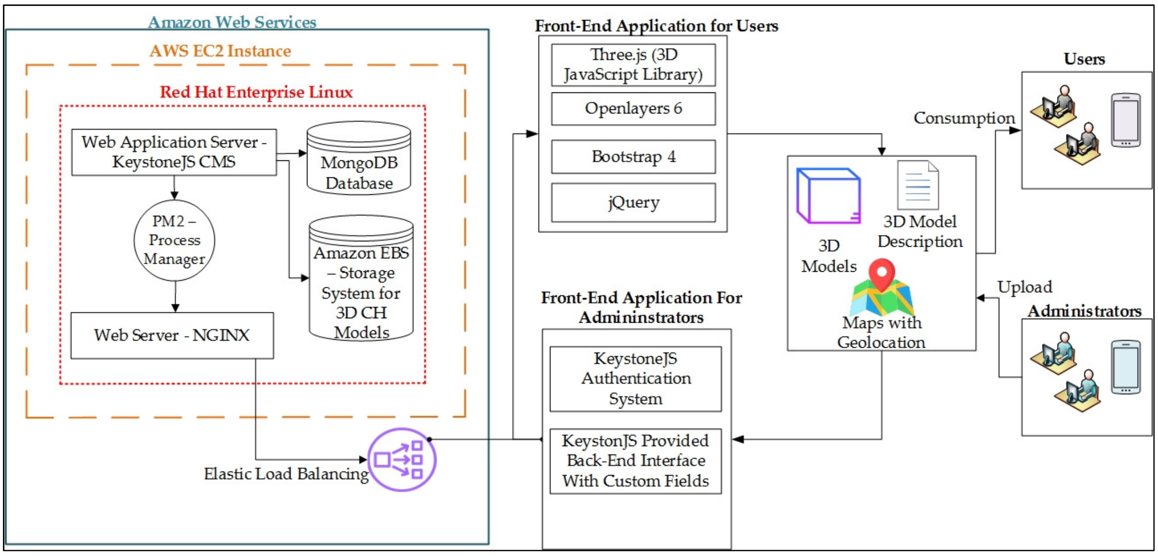


Figure 1: A methodology for the proposed cloud architecture for processing and visualization of 3D digital cultural heritage models.

# 4 METHODOLOGY

To accomplish the proposed cloud architecture, a methodology as shown in Figure 1 has been developed. The web application server KeystoneJS CMS and front-end application in the methodology are based on the previous research work of the author. The methodology presented in the article extends those parts with cloud computing concepts such as Amazon EC2 Instance, Amazon EBS storage for 3D CH models, Elastic Load Balancing, PM2 process manager, the web server of NGINX, cloud installed MongoDB database among others. This extended methodology consists of the followings:

Cloud computing infrastructure from AWS including Amazon Elastic Compute Cloud (AWS EC2), Red Hat Enterprise Linux as an operating system, Web Application Server – Keystone JS CMS, MongoDB database, Amazon Elastic Block Store (Amazon EBS), PM2 - Process Manager, Web Server – NGINX, and Elastic Load Balancing.

Front-end application for administrators which includes the KeystoneJS authentication system and KeystoneJS provided back-end interface with custom fields.

Front-end application for users which includes Three.js – WebGL-based 3D JavaScript library, Openlayers 6 – web mapping library, Bootstrap 4 for the graphical user interface, and jQuery

Datasets including maps, Australian 3D CH models, 3D model descriptions and geospatial data in the form of geolocation such as longitude and latitude.

Finally, users and administrators, who consume the data and manage the data respectively.

## 4.1 Cloud Computing

AWS has been selected as a cloud computing solutions provider as it is dominant and the largest provider in the cloud computing market. Furthermore, it offers a variety of services and virtual machines for various purposes such as from hosting a small website to Big Data analytics. In the architecture, EC2 has been deployed to get the cloud computing capacity and launch the virtual server. As an operating system of the EC2, Red Hat Enterprise Linux has been deployed which is a Linux distribution developed by Red Hat for the commercial market. This operating system was chosen because it is one of the leading Linux kernels with high security, reliability, and good community support. The web application server in this architecture is KeystoneJS CMS, which is based on Express.js framework and Node.js runtime environment. Since KeystoneJS is a database-driven CMS, it comes with a MongoDB database by default. This database has been utilized to store all the data within the architecture except for 3D CH models. The storage of 3D models has been facilitated by Amazon Elastic Block Store (EBS), which is a high-performance storage service to use with Amazon EC2. Another important feature of this storage is the possibility to enable the automated capability to back up the data into Amazon S3. NGINX has been used as a web server in the architecture, whereas PM2 Process Manger used to manage and monitor the web application of KeystoneJS. Finally, Elastic Load Balancing is used to automatically distribute incoming traffic to the web application, which helps to improve the responsiveness of the web application.

### 4.2 Front-end Application for Administrators

Front-end application for administrators has been accomplished with the auto-generated admin user interface by the KeystoneJS. It also handles the authentication system for administrators out of the box. KeystoneJS allows creating as many administrators as needed. However, one limitation of KeystoneJS in this regard is it does not provide a feature to assign roles to the administrators, which can grant or restrict access to certain fields and documents within the admin interface. Text data in the administrator interface is inputted via WYSIWYG (what you see is what you get) editor, while files such as 3D CH models are uploaded via the built-in file upload interface. For the uploaded content, there are three states available namely draft, published, and archived.

### 4.3 Front-end Application for Users

Front-end application for users was achieved using Three.js, Openlayers 6, Bootstrap 4 and jQuery. Three.js is a cross-browser 3D JavaScript library based on previously mentioned WebGL technology, which facilitated 3D visualization in the architecture. It offers numerous features to build simple and complex 3D scenes and worlds. This 3D library has been chosen because of its non-proprietary license, integration with all web browsers that support WebGL, and relatively well-documentation among others. Openlayers 6 is used for web mapping in the architecture, which can visualize maps including geospatial data such as vector data and raster data in different geospatial files from various sources and geospatial web mapping standards of Open Geospatial Consortium (OGC). Since Openlayers is an open-source, mature, web mapping library with a strong community of developers, it has been selected for map and web geospatial data visualization. Bootstrap 4 framework is used as a helper framework for graphical user interface implementation. It is the world's most popular framework for building the front-end development of web applications, which is also known for its responsive and mobile-first concepts. Since Bootstrap focuses on simplifying the development of front-end web applications, it offers several ready-to-use templates and components such as navigation, forms, and typography. Finally, the jQuery framework is a JavaScript library for simplification of HTML DOM manipulation, event handling, and asynchronous calls. As of writing this article, it is employed by 74% of the 10 million most popular websites (W3Techs).

### 4.4 Datasets

As a use case, eleven different 3D digital CH models have been deployed to the architecture. All deployed 3D models are digital replicas of the places located in Australia. As a sample, four of these 3D models are presented in the article namely Time Ball Tower-Williamstown, Cape Liptrap, Magnetic Termite and a part of the Abrolhos Islands. The images of these places are shown in Figure 2.

Figure 2: Sample of the employed 3D digital models in the use case. In a clockwise direction, Time Ball Tower, Williamstown (Image Source: https://bit.ly/2FfKuuT, Copyright by Nick Morieson. CC BY-SA 2.0), Cape Liptrap (Image Source: https://bit.ly/2MTdNrr, Copyright by Jorge Lascar. CC BY 2.0*),* Magnetic Termite (Image Source: https://bit.ly/2ZO5an6, Copyright by Geoff Whalan. CC BY-NC-ND 2.0), Abrolhos Islands (Image source: https://bit.ly/37qOPaG, Copyright by ernie_greatoutdoors. CC BY-SA 2.0).

One of the best choices with regard to 3D file formats is glTF as it significantly minimizes the size and loading times of 3D models in comparison to other 3D file formats. Hence, all 3D models in the use case are encoded in glTF format. Furthermore, the architecture has also been tested with another 3D file format called "OBJ". This format is an open format

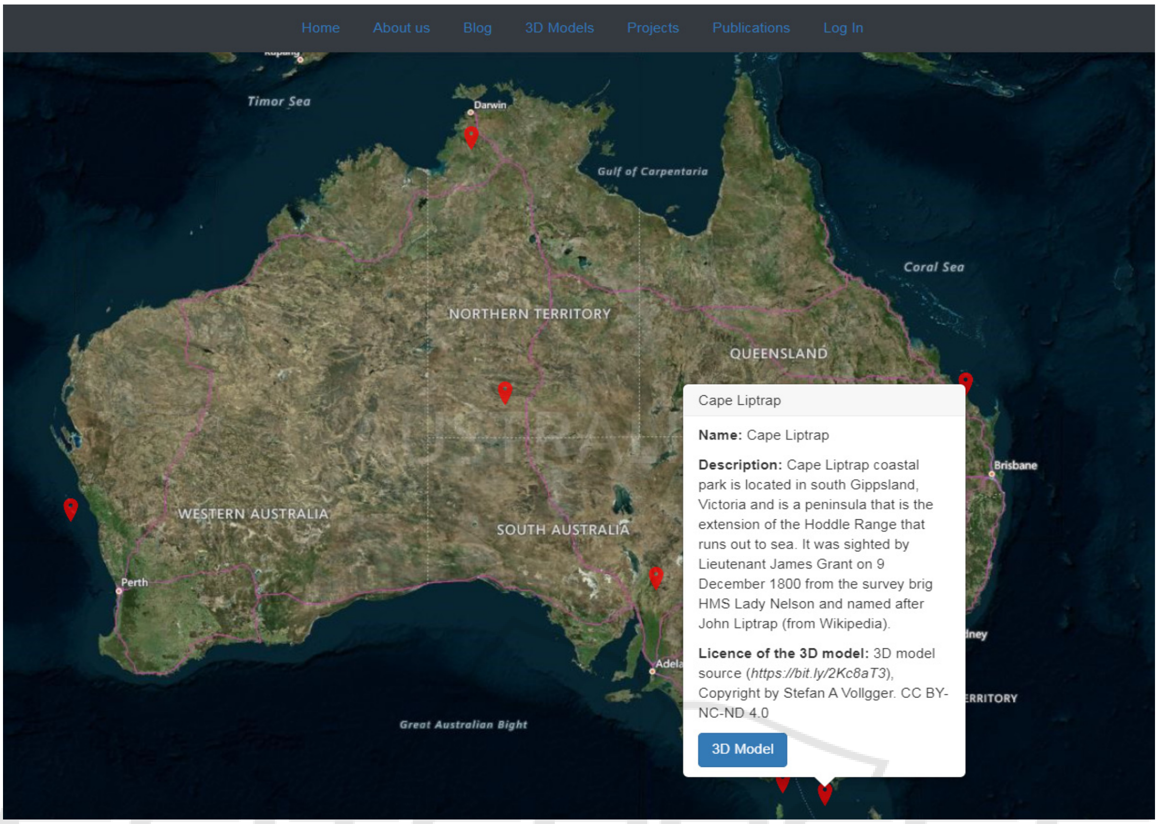


Figure 3: The web interface for users, the map copyright by Microsoft Bing Maps 2019.

by Wavefront technologies, which incorporates three files. The first file is for storing a 3D object-related information such as vertices, faces, and has an extension of ".obj". Whereas, the second file is a material template library with an extension of ".mtl", which stores the appearance of the 3D model. Finally, the last file is for storing associated images with the 3D model, which can include more than a single image file. The file extensions for the images can be in ".jpeg", ".png" among others. The path link for all images is stored in the previously discussed ".mtl" file.

### 4.5 Users and Administrators

Users of this cloud-based architecture platform can view a map, interact with vector data in the form of point features which represent CH places, read descriptions of CH places, and view 3D CH models. Whereas, administrators can create and edit CH places, upload 3D content to the platform, input geospatial data such as geolocation associated with CH places, select and change the state of the content among others.

## 5 RESULTS AND DISCUSSIONS

The cloud architecture integrates web maps, 3D digital CH models and geospatial information associated with the 3D CH models in the form of geolocation, while also offering numerous cloud architecture benefits such as improved application performance, scalability, and enhanced responsiveness.

The overall web interface for users consists of three main components namely base map, clickable red markers which represent CH places with relevant CH information, and viewer for visualization of 3D CH models. This user interface is shown in Figure 3. Once a user clicks on a red marker, the pop-up box appears with the information relating to the CH place such as name, short description, and licence information of the 3D model. To view the 3D model, they should click onto the 3D model button in the pop-up box.

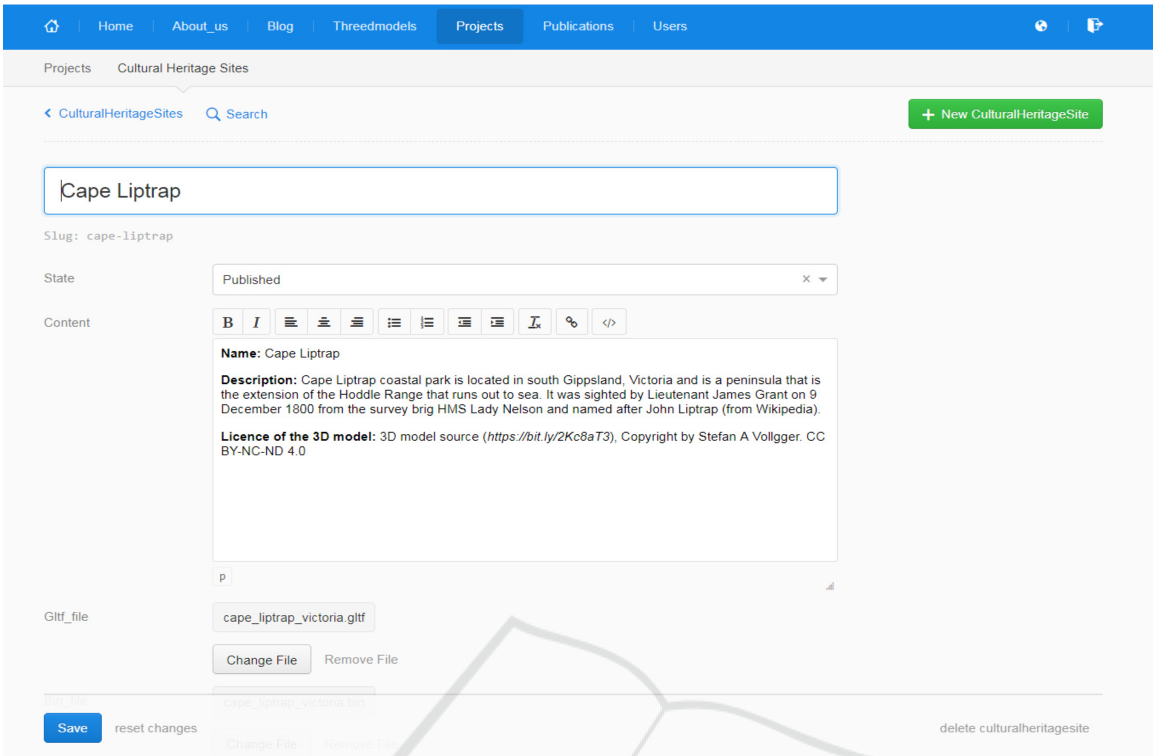


Figure 4: The web interface for administrators, copyright by KeystoneJS, MIT licence 2019.

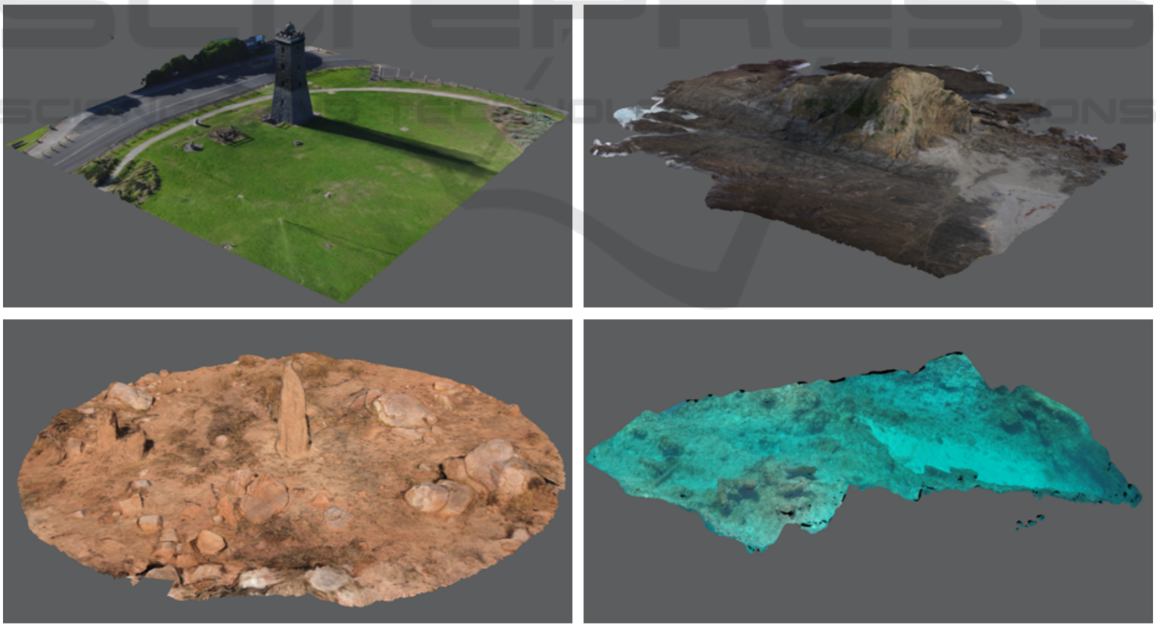

Figure 5: Use case of Australian 3D cultural heritage models. In a clockwise direction, Time Ball Tower, Williamstown (3D Model Source: https://bit.ly/2ZJR3PZ, Copyright by Digital Heritage Australia. CC BY 4.0), Cape Liptrap (3D Model Source: https://bit.ly/2QFMwtI, Copyright by Stefan A Vollgger. CC BY-NC-ND 4.0 ), Magnetic Termite (3D Model Source: https://bit.ly/2syNqjO, Copyright by Rupert Rawnsley. CC BY 4.0), Abrolhos Islands (3D Model Source: https://bit.ly/2syY9e3, Copyright by Maritime Archeological Association of Western Australia. CC BY 4.0).

In KeystoneJS CMS there is no limitation on the number of administrators. Hence, it allows creating as many administrators as needed. A page relating to creating a new CH place and uploading 3D content to the architecture is shown in Figure 4. When creating a new CH place, administrators should input the name of the CH place, description including short information and licence information of the CH place, and 3D digital CH model to upload. 3D digital CH models are automatically uploaded into Amazon EBS storage and path to the 3D content is stored in the MongoDB database.

This path is then used in the front-end application to retrieve the 3D CH model. The administrators can also select the state of the CH place from 3 options namely draft, published, archived. These states can help to manage the process of publication. For instance, they may upload the content but wish to publish it later in time. Finally, for each and every CH place administrators should input geolocation in the form of longitude and latitude. The precise geolocation for the most CH places can be found in the GeoNames platform, which is a geographical database with more than 11 million place names.

### 5.1 Use Case of Australian 3D Digital Cultural Heritage Models

The architecture has been employed in a sample use case to better evaluate its benefits and limitations. As mentioned in the datasets section, eleven different 3D digital CH models have been used in this use case. The visualization of four of these 3D CH models is shown in Figure 5, which is achieved using the Three.js 3D visualization library. The 3D models can be manipulated along the X, Y and Z coordinate axes, and can be zoomed in and out.

### 5.2 Level of Customization for the Front-end 3D Visualization

As mentioned previously, in this architecture 3D visualization is achieved using the Three.js library, which offers plenty of customizations. These customizations include importing and removing complimentary 3D models at run-time, various cameras such as orthographic, perspective and stereo cameras, various audio types such as positional and non-positional, various lights such as point, directional, and spot-lights, and three levels of details (LOD) among others. These customizations can take effect at run-time as Three.js is capable of updating scenes continuously.

### 5.3 Scalability of the Architecture

The proposed architecture is based on AWS, which offers many features for scalability, load balancing, etc. The architecture particularly uses Elastic Load Balancing to automatically distribute incoming traffic. This offers an on-demand scale-up, in other words, the ability to increase the number of EC2 instances running the web application when there is a high load of incoming traffic. Whereas KeystoneJS CMS handles internal tasks within the web application. Since KeystoneJS CMS is based on the Node.js runtime environment, it supports an event-driven system capable of running asynchronous input and output. In other words, it can run several processes separately from the primary application thread. Therefore, this offers numerous benefits such as improved application performance, scalability, and enhanced responsiveness.

## 6 CONCLUSIONS

With the rapid evolution in digitization technology, CH professionals are now equipped with advanced 3D surveying tools and techniques. This allows them to create a realistic 3D digital replica of CH sites and objects of various sizes including tiny artefacts and large-scale CH establishments. Nevertheless, 3D CH models are still difficult to find, use and reuse, especially those which resulted from the individual CH research projects. According to the survey findings of Champion and Rahaman (2019), who looked at 1483 digital heritage articles published in 14 recent proceedings of major CH conferences, from the examined 1483 conference articles, only 9 articles had accessible links to 3D assets.

This article presented a new cloud-based architecture for integrating maps, 3D digital CH models and geospatial data, which can be used for processing, visualization, dissemination and digital preservation of 3D digital models.

All frameworks used in the architecture such as for content management, web mapping, 3D visualization, etc. are based on free and open-source paradigm, which allows flexibility on extensions and re-use. For instance, raster and vector data can be integrated into the architecture by implementing a free and open-source geospatial framework of GeoServer, which allows publishing geospatial data to the web using open standards such as from OGC. Furthermore, among others, on top of this architecture geospatial analyses on the web can be performed using Turf.js, web virtual reality can be implemented using React 360.

The proposed architecture has been validated through a use-case applied to Australian 3D CH models.

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