Novel Museum Digitalization Framework: The Use Case of Athens Museum of Paleontology and Geology

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***Abstract*—Influenced by the growth in demand for online services in various sectors, including cultural heritage, this paper introduces a novel approach for creating virtual tours for the Paleontology and Geology Museum of the University of Athens. The proposed system, v-Palm, encompasses a range of features that aid in creating engaging and immersive tours for online visitors, including a chatbot mechanism that offers seamless interaction with the visitor by providing relevant information and recommendations. Carefully designed educational games and programs can be developed that accompany the digitized museum's content and increase the user engagement. Focusing on the architectural components of the solution, the content management system, the front-end user interface and the content creation mechanism are presented. Challenges and next steps are also discussed, highlighting future open research and development areas.**

***Index Terms*—virtual museum, online tour, conversational agent, educational game, personalised recommendations**

I. Introduction

Lately, the implementation of virtual museums is proven to be a growing area of research interest with the COVID-19 pandemic further accelerating this trend. A virtual museum tour is an engaging alternative to a physical visit, allowing users to access museums' collections regardless of their location. Moreover, recent advances in Information and Communication Technologies (ICT) have made possible high quality 3D scanning of exhibits and spaces (e.g., museums, monuments) that captures their texture in detail. Additionally, higher bandwidth networks have enabled the seamless navigation of users in feature-rich 360 virtual cultural spaces, through which they have access to the textual descriptions of the exhibits but also to a variety of multimedia resources, such as videos and 360 high resolution scans of exhibits. Users have also access to educational games that facilitate interactive learning.

This paper proposes a multi-disciplinary approach of a virtual-tour framework for the Paleontology and Geology Museum of the National and Kapodistrian University of Athens, combining knowledge and expertise of paleontologists and software engineering researchers. This framework enables an immersive virtual tour by combining the digitalization of the museum's collection (i.e., photographs of exhibits, 3D scanning, text scanning, etc.), with the creation of educational games and programs based on this content. In addition, a conversational agent is developed that assists visitors in their tour by informing them about the available features of the virtual museum, directing them to the content of their choice (e.g., games, programs, specific exhibits), and providing personalized recommendations to them.

The remainder of this work is structured as follows. Section II presents the related work on the areas of digitalization of cultural heritage spaces and gamification approaches. Section III provides an overview of the proposed framework. Section IV presents the overall architecture of the system and details its individual components, while Section V discusses how the framework enhances an online visitor's experience, introduces areas for future work and concludes the article.

II. Related Work

A. Virtual tours in Cultural Heritage

Due to the rapid advancement of the technology, and the changes caused by the COVID-19 pandemic, museums have shifted their interest towards the digitalization of their content, the enrichment of the visitor's tour with digital services or even the complete virtualization of the museum visit. Such initiatives are adopted by many popular museums (e.g., the British Museum in London, the Museum of Modern and Contemporary Art in Seoul, the Van Gogh Museum in Amsterdam, etc.) [1] and mainly aim to inform, educate and entertain

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the visitor, and ultimately encourage them to visit the actual museum.

The idea of digitalizing collections and exhibits has engaged researchers for many years. As early as 1947, the "museum of the imagination" [2] was envisioned and defined as "a collection of digitally recorded images, sound files, text and other relevant data of historical, scientific or cultural interest". The researchers in [3] describe the creation of a virtual tour of the Tampines Chinese temple in Singapore. Data concerning the site was collected using a camera with 360-degree recording capability as well as by taking 2D high-resolution photographs, while data regarding the temple's information was obtained through interviews with experts. The platform of the virtual tour allows visitors movement within the temple and when visitors click on appropriate points, further information is provided to them. In [4], the CTDGP system (Cultural Tourism Digital Guiding Platform) is proposed to overcome time and space limitations for visiting places of interest. This platform contains three-dimensional representations of relevant sites where users can navigate using avatars. It is developed through the Unity platform [5], with graphics that resemble a video game. The platform contains tools for guided tours and incorporates gamification techniques. A virtual tour of London's heritage sites is the subject of the study presented in [6]. The aim of the application is to expose language learners to the culture of England. Using the capabilities provided by Google Street View and the Blue Mars Lite platform, users can visit predefined locations of interest in London by 'walking' through the application's interface and having native English speakers as guides.

B. Gamification and Educational Games

Gamification and educational games' development strategies are powerful tools that can significantly enhance the user and especially children and student engagement and motivation, providing opportunities for active learning and problem-solving [7], [8]. They create an interactive and immersive learning environment that can transform educational experience. When integrating game mechanics and game development into educational programs, it's crucial to ensure they align with specific learning objectives, while at the same time complementing traditional learning methods [9]. A variety of game mechanics should be used to cater to different learning styles and preferences, providing alternatives for point-based rewards, cooperative games or simulations [10]. Several frameworks have been developed to guide the design and implementation of gamification in educational settings. These include the Octalysis Framework [11], [12], which focuses on eight core drives of motivation, the MDA framework [13], which breaks down games into mechanics, dynamics, and aesthetics, the Self-Determination Theory [14], [15], which focuses on intrinsic and extrinsic motivation, and Kevin Werbach's Gamification Framework [16], providing a step-by-step guide to implementing gamification. Each of these frameworks offers a unique perspective on how to incorporate game-like elements into non-game environments, providing valuable guidance for educators. In the context of the virtual Paleontology and Geology Museum, the ARCS model is particularly relevant. This framework, developed by John Keller, addresses four key elements of motivation: attention, relevance, confidence, and satisfaction [17].

C. Conversational Agents

Conversational agents have proven to be mechanisms that enable the seamless interaction between users and a system. Among the many capabilities of such systems are their ability to offer support, provide information regarding the system and useful recommendations. Such agents have already been employed in cultural heritage applications. In [18] a conversational agent in the form of a Facebook-persona was created aiming to provide better understanding of the works collected by Mario Praz. Simple dialogues guide the users in exploring more content. In practice though, this agent executes simple scenarios based on certain pre-defined keywords.

The researchers in [19] develop a conversational agent that was deployed and evaluated at the museum "Casa Muresenilor" in Brasov, Romania. This agent operates as a Virtual Reality (VR) guide and is displayed as an avatar in a monitor equipped with microphone and speakers. The tools that are used in this work are similar to the tools we use in the proposed v-Palm solution. Specifically, the system employs Google's Speech-to-text in order to get vocal input from visitors of the museum and then performs Natural Language Processing (NLP) with Rasa software. After matching the user's input to specific intents, it generates a response that the avatar expresses by employing text-to-speech techniques. The system was evaluated through questionnaires that were answered by visitors, gaining mostly favorable reviews.

In [20] a chatbot is described that operates in a smart device and carried by a visitor in the Pompeii archaeological park. The overall system consists of a semantic analyzer that detects keywords in the user's text determining the relevant topics, a workflow manager that takes as inputs the topics and performs intent classification and a context aware module that uses a knowledge base as well as external services (e.g., Wikipedia) to acquire the appropriate information. A simple questionnaire was given to users to evaluate the performance of the chatbot, with the vast majority of answers being positive.

III. Digitalization Framework Overview

The proposed solution consists of multiple components that when combined, offer to the visitors of the museum an immersive experience. At first, the content of the museum is digitalized. The exhibits are scanned and photographed using 3D scanning techniques and the museum spaces are captured with special 360 capturing equipment. Scientific texts for the exhibits are written in digital format and audio-visual material for the museum exhibits is collected. The educational games and the educational programs are also digitalized and all the above digital information is integrated into the unified v-Palm platform as shown in Fig. 1 that provides a high-level representation of the v-Palm platform.

The unified v-Palm platform provides several functionalities not only for the visitors of the museum but also for the administrators of the platform. Overall, it provides online visitors with engaging virtual tours, educational programs and interactive games with the assistance of a conversational agent. The 360 virtual tours enable the users of the v-palm platform to roam virtually in the museum, learn about the included collections, view specific exhibits and their 3D captures, play games and interact with the virtual agent. The platform also supports educational games, carefully designed by experts in the Paleontology field and educational programs that simulate a museum guided tour. The conversational agent is accessible through the 360 museum tours and aims to improve users Quality of Experience by giving them easy access to available platform services and offering personalized recommendations. The CMS is the Content Management System where all the digitized information is stored and acts as the backbone of the platform. The system administrators access the CMS to enter new information or modify existing one. The games and the 360 virtual tours are designed by using the Content Creation Mechanism, while the educational programs are created via a secondary creation mechanism that uses a secondary CMS. The latter is targeted to storing content that represent an overall educational programme.

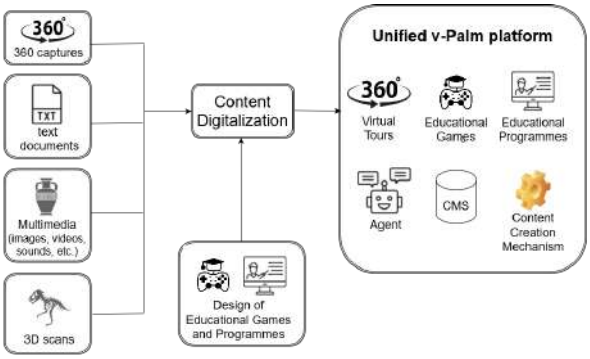

Fig. 1. High-level Overview of the v-Palm Platform.

IV. System Architecture & Description

Fig. 2 presents the employed system architecture highlighting the basic components that will be described in the next subsections, namely the Content Management System (CMS), the Conversational Agent, the Content Creation Mechanism and the development of the Front-End that provides access to all the features of the developed framework. As already mentioned, the Educational Programs use a secondary CMS and are developed via a separate Content Creation Mechanism. However, considering that the latter subsystems are similar to the primary ones, they are shortly analysed.

A. Content Management System

The Content Management System (CMS) is a comprehensive platform that manages various aspects of the virtual museum's digital content. It has been developed with the programming language C# and the Microsoft's .NET Framework

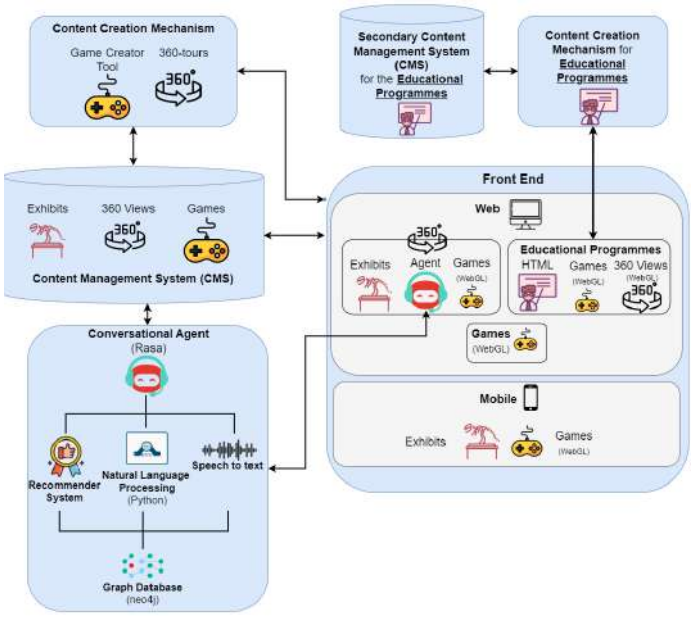

Fig. 2. Architecture scheme of v-Palm Platform.

which supports the creation and execution of web applications and services. Only people who manage the digital scientific content of the museum have access to the CMS. The CMS comprises several subsystems, each dedicated to a specific type of content: exhibits, 360-degree tours, educational games and educational programs. Following, a detailed presentation of the major subsystems is provided.

Exhibit registration subsystem: This subsystem is responsible for registering the museum's exhibits. The primary table in the database schema for this subsystem is the "Exhibition Item" table, which contains the title and metadata for each exhibit. This table is linked to the "Exhibition Item Asset" table, which houses the files associated with each exhibit. The "AssetTypes" table lists the types of files supported by the system. Each exhibit is associated with one or more categories and tags that are stored in separate tables and linked to the exhibits via mapping tables.

360-degree tour repository: This repository stores 360-degree captures and multimedia content for creating immersive tours within the museum. Each tour, stored in the "route360" table, includes a title, description, associated files, and a JSON file that outlines the tour's composition, including exhibits and games. The "Content Creation Mechanism" generates this JSON file. The "route360Versions" table maintains different versions of each tour, providing a flexible approach to managing the 360-degree tours.

Game content registration subsystem: This subsystem registers the content of the games that are incorporated into the 360-degree presentations or the educational programs application. The "Minigame" table serves as the central table for all games, containing basic elements such as the title, introductory text, and feedback text. The different types of games are stored in a separate table, and all multimedia materials for the games

are registered in the ”MinigameAsset” table.

Educational programs: Educational programs are described with a title, a description, and a link to the corresponding content. Each program is associated with specific keywords and exhibits.

The database schema also includes tables to support multilingualism at both the user interface and content levels, catering to future use. This feature ensures that the virtual museum is accessible to a global audience, promoting inclusivity. In summary, the CMS is a robust and flexible system that effectively manages the diverse range of content within the virtual museum. Its structure and functionality ensure that the museum's digital content is organized, accessible, and easy to update, providing a rich and engaging user experience. The CMS is complemented by a secondary CMS that stores and makes available the educational programmes that are developed in the museum. Each educational programme consists of a set of slides that contain information in the form of text, figures and videos and can be offered as a service to the visitors in the museum, focusing on visits from schools in the various educational levels.

B. Conversational Agent

Towards the enhancement of the user's experience, a conversational agent in the form of a chatbot is deployed, aiding the visitor's navigation through the museum, facilitating the exploration of exhibits, games and educational content and providing the user with personalized recommendations concerning the museum's collection [21].

The chatbot operates both in English and Greek and assists in the provision of the virtual museum's services. Namely, it can direct the visitor to the 360 museum tour, aid in the exploration of the museum's collection by suggesting exhibits depending on the user's choices, as well as inform visitors about the available educational games and programs. The users can interact with the conversational agent through a suitable User Interface (UI) either via buttons, where users select one of the options presented in their screen or by typing free text. The conversational agent's functions are further supported by key components of the agent's internal architecture, i.e. a Knowledge Graph (KG), an NLP component and a Recommendation System (RS), which are described in more detail in the following paragraphs.

The KG, which is a structured representation of knowledge in the form of a graph, related to a specific area, stores data relevant to the virtual museum's content and is periodically updated by the CMS. Specifically, this data is provided by the museum's experts and is related to the museum's exhibits and their characteristics, such as the exhibit's name, its thematic category, the type of animal it represents, the location where the exhibit was found, the exhibit's correspondent body part, the habitat where the represented animal lived and the paleontological period in which the exhibit belongs. Moreover, knowledge concerning the educational games and programs is also stored in the KG. The entities mentioned above are represented by nodes, which are linked by edges denoting relationships between them. Once the user requests for an item, the corresponding information is retrieved from the KG in the form of a query and is returned to the user through a suitable answer by the conversational agent's UI. In addition to that, the structure of the KG enables the semantic reasoning between the exhibits, denoting their correlation and boosting the RS component's functionality, by detecting exhibits closely related to the ones previously examined by a user.

The developed NLP component is responsible for understanding the user's intent as expressed via a provided text through the conversational agent's UI, either in English or in Greek, detecting the entities (present in the KG) that they may refer to and assisting in this way in forming meaningful queries to the KG. In order to understand the intents expressed by the visitors (e.g., see an exhibit, play games, have a tour), an intent classifier developed by Rasa software is employed [21]. The model was trained by using as input examples of users messages and noting the intent that these messages correspond to. The intent classifier is able to generalize well in both languages for simple messages. To handle more complex cases, two custom-built NER components (one for each language) were trained in order to detect entities. To handle the sparsity of publicly available data for the case of paleontology, data augmentation techniques were developed in order to generate sufficient data to train the components, in the form of example sentences that could possibly be used by users.

Following the user's exploration of an exhibit, the RS component is employed to provide them with a list of recommended exhibits relevant to their preferences and similar to the exhibits viewed before. To this end, a hybrid recommendations method combining content-based and collaborative filtering mechanisms is developed [21]. The first mechanism's operation leverages knowledge from the KG by discovering a list of the most correlated exhibits to the one currently viewed by the user. The second mechanism, retrieves information about the past museum visitors' activity regarding the examined exhibits and constructs an anonymous profile of the past users. By extracting similarities between the current user's behaviour and the actions of past visitors, the most similar users are selected, enabling the discovery of the most common exhibits viewed by them. By combining the results of the two mechanisms, a list of recommended exhibits is composed, after filtering-out non-explainable recommendations, i.e, exhibits that don't share any common attribute to the current exhibit (e.g., body part, animal type, etc.) and exhibits that the user has already seen in the past. In case only non-explainable recommendations occur, the RS component, by examining the past users' activity, recommends a short list of the most popular exhibits. The final exhibits detected by the RS component, are presented to the user through the agent's UI, accompanied by explanations about their similarity to the currently examined exhibit.

C. Content creation mechanism

The Content Creation Mechanism has been developed using the widely used game engine, Unity. Unity offers the ability

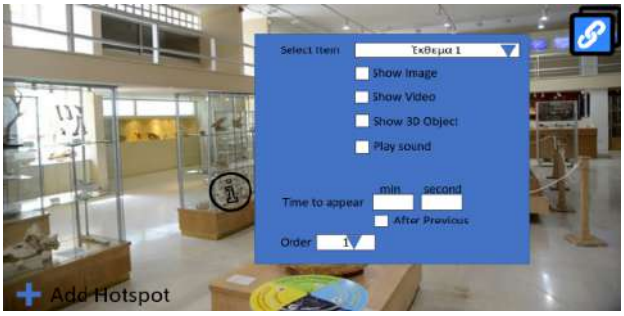

Fig. 3. An indicative CMS screen.

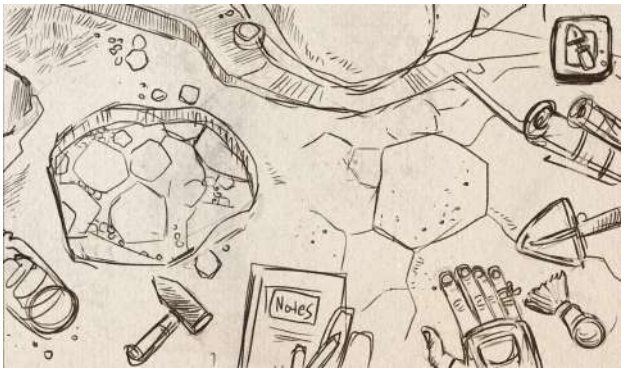

Fig. 4. A drawing of the "Excavation Bone Separation" game.

to create aesthetically pleasing and functional applications that can be executed on various device types. The content creation application is in the form of an executable file for optimal performance, while the outputs (virtual tours and games) are made available via a web browser within the unified user interface. However, some of the games are also available through a mobile application. Users of the Content Creation Mechanism enter the system with the same credentials they have on the CMS to create the 360 virtual tours and the educational games of the platform.

To create a virtual tour, the user must first create the tour in the CMS, as described above and upload the corresponding 360-degree captures that the tour will include. Then, the user can edit the captures and place the desired interaction points on them. An interaction point could be information about an exhibit, a game, or a link to another 360-degree view (Fig. 3). When the user selects the entry of information about an exhibit, a list of exhibits registered in the CMS is presented and the user selects the one to place in the specific location. Afterwards, the user chooses the display mode of that interaction point along with the relevant multimedia material. The transition from one 360-degree capture to another is achieved by linking them through an image file or text that is inserted by the user in the application (e.g., an arrow). In this way, different paths are created that a visitor can follow within the museum. The paths and the content of each capture are saved in the tour's JSON file and stored in the database. In order to include a game at a specific location in a 360-degree capture, the user follows similar steps with the case of exhibits and selects the desired game from a list of games that have already been registered in the CMS.

To create an educational game, the user should first upload all the necessary components of the game such as title, text, images, sounds in the CMS. Then the Unity provides a user-friendly environment for building the game. Various game development mechanisms have been adopted to satisfy the requirements of users of different age. The following types of games are available in the v-Palm platform, aiming to create an engaging, interactive, and educational experience that inspires a deeper interest in paleontology and geology:

- Excavation Bone Separation
- Who Wants to be a Paleontologist?
- Matching Game
- Crossword Puzzle Game
- Find and Connect the Puzzle Pieces

Each game contributes differently to the educational process. For instance, the treasure hunt, "Find and Connect the Puzzle Pieces" encourages users to explore the museum and find specific objects or fossils. The game enhances user engagement, but also promotes exploration and discovery, which are key aspects of the learning process. The available quiz games ("Who Wants to be a Paleontologist", "Crossword Puzzle Game" and "Matching Game") test users' knowledge while motivating them to acquire and apply new knowledge.

Role-playing games allow users to take on the role of experts, collect and analyze information. They boost users' understanding of the subject as they are actively involved in the learning process. The "Excavation Bone Separation" game is a role-playing game, offered by the v-palm platform and aims to familiarize users with regions of Greece where significant paleontological excavations have been held and provide them with information about the findings in an interactive way. The users choose a thematical area of interest from a presented map and are directed to a screen with a virtual excavation pit or rock. With the help of a brush or a chisel, they reveal buried bones, taking on the role of scientists. Once users retrieve the entire bone, which is a realistic representation of an actual museum exhibit, the bone is transferred to a virtual space of a laboratory in order to be characterised and added as part of an animal skeleton. There, users are also provided with information about the excavation area and the corresponding finding. Afterwards, users are redirected to the virtual excavation site, aiming to collect all the bones of the excavation and assemble the entire skeleton. When their attempt is completed, they are rewarded and redirected to the initial map of the excavation sites options to choose a new area of interest. A drawing, concerning the virtual environment of the game is presented in Fig. 4.

D. Front-end development

The provided services and the produced, by the museum, digital content are easily accessible via a web application

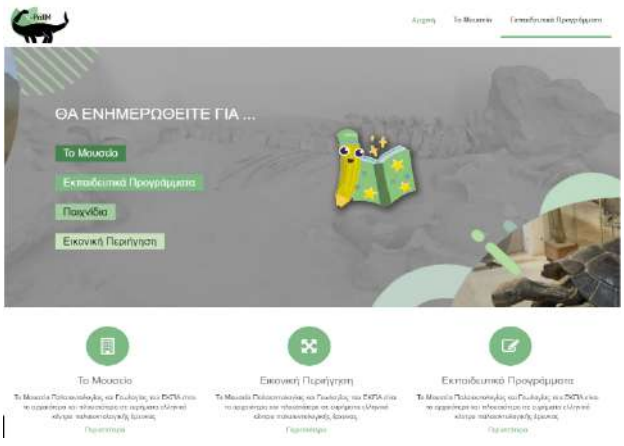

Fig. 5. Front-end Interface.

Fig. 6. An Educational Program.

(Fig. 5). The virtual museum tours with the integrated conversational agent, the educational programs as well as the educational games are all available through the main menu of the application.

Concerning the educational programs, each one of them is accompanied by a brief introduction, a representative image, and the contents of the program itself. By selecting one of the sections of the educational program, the content expands at the page level for that particular section, while the menu remains accessible for transitions between sections (Fig. 6). The content is organized into small units, with "next" and "previous" indicators for navigating from one section to another. Within an educational program, individual virtual tours and selected games can be included. Their addition aids user to explore the museum, better understand the scientific material and enjoy the learning experience.

To facilitate communication among the subsystems, Application Programming Interfaces (APIs) have been implemented, enabling subsystems to interact and exchange relevant information (see Fig. 2). APIs have been developed between the CMS and:

- The 360° Tour Presentation Application: Initially, the API sends a JSON file containing the structure of the chosen tour (360° views, exhibits, and games included in the selected tour) and dispatches the 360° views (files) that are part of the tour. When a user selects an exhibit or initiates a game, the API sends the multimedia files associated with the exhibit or the game.
- The Games: The API sends the relevant data and multimedia files of the game.
- The Mobile Application: The API provides a list of the museum's exhibits. When an exhibit is chosen, the API sends all the accompanying data (text, multimedia and three-dimensional files).
- The Conversational Agent: The API sends information about the exhibits, the 360-degree captures, the 360 virtual tours, the educational games and programs of the platform, so that the conversational agent enhances user's exploration of the museum. Concerning recommendations of exhibits to users, the API also sends information about exhibits viewed by visitors in the past.

V. Conclusions and Future Work

This article presents the overall framework for the virtualization of the Paleontology and Geology Museum of the University of Athens. The framework contains many components that through their interaction provide engaging services to the museum's visitors. The basic components of such an architecture consist of a CMS that supports the whole operation of the system, by storing all the available data, a conversational agent that interacts with the users by providing relevant information and also the content creation mechanism. The platform's front-end and its main functionalities are detailed.

The proposed framework offers a variety of functionalities that enhance the user experience when visiting the virtual museum. Aiming to surpass the traditional tour, this engaging virtual cultural space permits users to acquire knowledge about paleontology and geology effectively through the 360 virtual tour, the interactive educational games, the curated educational programs and the interaction with the conversational agent. We believe that such an encompassing framework marks a step forward for the museum. As part of future work, we plan to implement the speech-to-text module that will increase the ease of use of the system and make the museum's collection accessible to people with disabilities. Moreover, we aim to design special questionnaires to evaluate the overall performance of the proposed system and make adjustments according to the collected feedback.

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