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Supporting Online and On-Site Digital Diverse Travels

Giorgos Mathioudakis [1], Iosif Klironomos [1], Nikolaos Partarakis [1,*], Eleni Papadaki [1], Nikos Anifantis [1], Margherita Antona [1] and Constantine Stephanidis [1,2]

[1] Foundation for Research and Technology Hellas, Institute of Computer Science, GR-700 13 Heraklion, Crete, Greece; gmathiou@ics.forth.gr (G.M.); iosif@ics.forth.gr (I.K.); elpap@ics.forth.gr (E.P.); anifantis@ics.forth.gr (N.A.); antona@ics.forth.gr (M.A.); cs@ics.forth.gr (C.S.)
[2] Department of Computer Science, University of Crete, GR-700 13 Heraklion, Crete, Greece
* Correspondence: partarak@ics.forth.gr; Tel.: +30-281-039-1754

Abstract: Cultural-heritage research has created a vast amount of information regarding heritage objects and sites. At the same time, recent efforts on the digitization of cultural heritage have provided novel means of documenting tangible cultural resources including digital images, videos, audio testimonies, and 3D reconstructions. Furthermore, ethnographic research is nowadays combined with advanced capturing technologies such as motion capture to record the intangible dimensions of heritage as these are manifested through human expression in dance, heritage crafts, etc. This amount of information is now available and should be used to create novel forms of experiential access to cultural heritage powered by the web and mobile technologies mixed with novel interaction paradigms such as virtual and augmented reality. In this article, a platform is presented that facilitates a cloud-based web application to support location-based narratives on cultural-heritage resources provided through map-based or story-based representation approaches. At the same time, the platform through the power of modern mobile devices can provide these experiences on the move using location-based and image recognition-based augmented reality to facilitate multiple usage contexts. The platform was implemented to support the goal of the project CuRe, in the context of the "Greece-Germany" bilateral collaboration action.

Keywords: cultural heritage; intangible cultural heritage; web-based narratives; web-based storytelling; augmented reality; location based mixed reality

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1. Introduction

Heritage can be thought of as a collection of essential elements, entrusted to succeeding generations for remembrance and preservation. The collection and care of heritage objects and sites is a universal practice of persons, families, and social groups to support their collective memories and values. The expression of values and memories through material heritage implements a reference to the social and historic context, in which these objects and sites were developed.

In the same context, heritage, in some cases, can be also perceived as the interaction between cultures in historic periods that resulted in the exchange of cultural elements, traditions, and values. From a socio-historic point of view, this formulates a time–space continuum that can be accessed historically and geographically [1]. The approach presented in this article addresses both map-based representations of important historical periods and narrative-based representations that can be accessed through the web from home and on-site.

To do so, an online platform is presented as a result of the project, "Cultures and Remembrances: Virtual time travels to the encounters of people from the 13th to 20th centuries. The Cretan experience" (CuRe). The project was implemented in the context of the "Greece-Germany" bilateral collaboration action and co-funded by the European Regional Development Fund with national funding from the Greek Ministry of Development and the German Ministry of Education and Research.

In this context, this research work aimed to support the collection of pieces of information relevant to the collective memory of mankind, to represent them in the platform, and to present them as map-based and story-based narratives. Furthermore, this work aimed to link these narratives to material remains, such as buildings and, more generally, objects of cultural heritage and places of memory, which will be recorded digitally (primarily as photographs, videos, maps, graphical representations, and texts). These will be made available both online and through an application for mobile devices that together will support a location-based mixed-reality (MR) experience by fusing augmented reality (AR) with mobile information to allow users to gain instant access to information on their smartphone or tablet, relevant to the buildings, places, and sites of memory—where they are located. Finally, to ensure the reusability of knowledge and assets, this work builds on top of a cloud-based repository.

2. Related Work

2.1. Narratives

The definition of a narrative is an important part of Information and Communications Technologies (ICT) research efforts on narrative representation and presentation as it defines the scope and objectives of such work and sets up technical challenges. Since ancient times, people have tried to understand and formalize the elements of storytelling. Aristotelian formalist definitions say there is a story in the world (the Fabula) and a person who witnessed it [2]. Then, this person narrates this story using some medium, and so the narration is created. It can be a piece of text, a movie, a poem, etc. The narrative is the sum of these two things, the real story and the narration, including their relationship (plot, subject, or reference function, which are all variations of the same concept).

According to the Oxford English Dictionary, a narrative is defined as "an account of a series of events, facts, etc., given in order and with the establishing of connections between them" [3]. As a result, in this definition, central is the notion of a chain of causally related events. According to [4], stories built on top of this construct usually evolve in time and space and have well-defined boundaries. Furthermore, usually, they have a beginning, an introduction to the situation, a series of events often involving tension or conflict, and a resolution [4,5]. Finally, stories may also present a sequence of facts and observations linked together by a unifying theme or argument.

Text-Based and Visual Narratives

In this context, writers have developed typologies of dramatic situations and identified plotlines common to many narratives [6,7]. The same stands for artists where the term "visual narrative" can be used to define stories told to the eyes of the viewers. Artists, designers, and psychologists have explored ways in which visual media can be organized to engender a narrative experience and have developed techniques for directing a viewer's attention within a visual plane [4]. An important technique that has been studied by psychologists is the usage of outliers as color, size, and orientation to preferentially attract one's attention [8,9]. Visual techniques can further establish the order in which the eye visits elements in the scene controlled through composition, contrast, and grouping, such as gestalt grouping [10], via features such as spatial proximity, containment, or connection.

2.2. The Advent of Web-Based Digital Narratives and New Forms of Visualization

Hypertext and the evolution of the worldwide web made it possible for storytellers to support new forms of narratives. The main challenge of this new era was the potential for reader immersion and reader control of the narrative as implied through the usage of the web [11]. Immersion can be defined as the feeling of being there during events, while control is the ability of the user to decide upon the course of the story. Studies of readers [12] have often found them sometimes disaffected by stories over which they have no control, as they can have the feeling that a more satisfying story ending may have been available to them if they had controlled the story differently. The digital narrative, therefore, offers the potential for immersion and control but does not guarantee reader satisfaction and must be carefully deployed [13].

Web-based multimedia visual experiences are a relatively new, visual storytelling genre. Multimedia visual experiences use hyperlinking to activate an immersive array of images, graphics, audio, and video that accompany a central textual narrative, a strategy first employed in the map-heavy visual story “Snow Fall: The Avalanche at Tunnel Creek” [14]. Accordingly, the genre sometimes is described as “snow falling” by data journalists [15].

Such experiences mashup well with other genres and can include web maps at the start or end to support drill-down or martini-glass narrative structures [16]. In this form of narrative, the audience interactively controls the pacing through scrolling. The multimedia content can include the designer’s voice and can embody the situated perspectives of the people in the visual story. They also develop a deep sense of place through the rich integration of images, maps, videos, and sounds [17]. However, multimedia visual experiences can lose the succinct, partial quality that makes them relatable and memorable, potentially leading to a higher attrition or “bounce” rate before completing the narrative than other genres. For spatial narratives, the maps are included only to support the narrative rather than as a centerpiece for the narrative. Finally, multimedia visual experiences draw from a rich set of quantitative and qualitative primary information that the designers need to collect and thus may not be available for all visual stories.

Modern approaches to the representation and presentation of narratives for cultural heritage extend the socio-historic representation with intangible information such as the movement of the practitioner in heritage crafts and the usage of tools and machines [18,19].

2.3. AR and VR Narratives

Today, AR can be considered as a new medium for storytelling as it can gracefully blend digital content with reality [20]. This convention can be used by authors to create meaningful experiences for the user [21]. To this end, AR naturally borrows elements from films, such as situated characters and props, however, the control of the camera and attention is not up to the director but the user-spectator. This limitation can be bypassed through staging techniques similar to the ones of visual narratives that use lighting and motion to draw attention to parts of the narrative.

Since sometimes the user is an active character in the AR story-world, a convention on the level of the plot is also required, and, in this case, AR can benefit from the idea of plot cul-de-sacs of interactive narratives, where the plot does not advance until a user-driven event or choice occurs [21–23].

In the same context, recently, several technologies for VR-based virtual museums have immerged, including hybrid web-based 3D virtual experiences that are related to this research work. An example is the Invisible Museum platform that supports web-based collaborative virtual-museum authoring and multiple presentation modalities including web, AR, and VR [24].

2.4. Location-Based Narratives

As reviewed by [25], location-based narratives often employ geo-sensing technology together with multimedia content and possibly richer AR-based experiences to provide information based on the location of the user. As a result, the user’s location affects the control of the narrative plot allowing a freer exploration.

The M-views system created at the MIT Media Lab allows readers to experience a cinematic narrative embedded in the MIT campus. Users are encouraged to walk around the campus and view video clips that are triggered by their physical location [26]. In the same context, “Murder on Beacon Hill” takes users on a murder-mystery tour of downtown Boston, though the clips are not automatically triggered by the system but the user [27].

The GEIST system is another similar project, which integrated AR to provide information regarding the history of 17th century Heidelberg, Germany, using mini-stories spread throughout the modern city [28]. A more loose example is the Hop story, which allows the characters in the story to act in their timeline and move to different locations throughout the building during the user's exploration of it [29], adding a layer of time and evolution over time on top of the main storyline.

3. Approach and Contribution

Several research efforts to date have addressed the domain of narratives. However, there is no reusable straightforward solution to support location-based narratives that can be accessed through a multitude of devices and in multiple contexts, employing state-of-the-art web and mobile technologies delivered online and on-site, thus combining the intense on-site experience with richer and more complete information provided through the web channel. To this end, this research work is approaching this challenge through an online system supported by a cloud-based knowledge repository that can act as a distribution point for the feature-rich web, mobile, and AR-powered location-based narratives.

The advanced concepts introduced by this work can be summarized as follows:

- facilitating access to, reusing, and exploiting digital cultural resources both offline and online, in the museum and on the go;
- producing new ways of approaching and understanding history and culture by providing novel forms of information retrieval such as storytelling and narrative visualization;
- demonstrating the use of AR applications to allow visitors/tourists to extract the story through interacting with actual historical artifacts—either located within the museum or located as architectural elements in open spaces;
- extending the interaction with digital exhibits in several directions and enhancing mainstream museum visits;
- offering personalization in several directions: (a) adaptation of histories and narratives to users, (b) personalization of the way the stories are structured and presented, and (c) adaptation of the interaction metaphors and user interfaces to meet individual user needs and contexts of use.

4. System Design

4.1. User Requirements Specification

User requirements specification refers to discovering the requirements of a system from users, customers, and other stakeholders. It is the most critical phase in requirements engineering, and its success is based on identifying the relevant stakeholders and studying their needs. During the requirements elicitation, technical (analysts) and business (stakeholders) groups collaborate towards solving specific business problems. The insufficient-requirements engineering process is an important factor that can lead to the failure of an IT project.

Several techniques are available for requirements elicitation, categorized under four groups [30]: (i) conversational, (ii) observational, (iii) analytic, and (iv) synthetic. It is up to the analyst to select one or more techniques of the aforementioned groups according to the application domain.

Brainstorming is a group-oriented requirements-elicitation method. It is defined as a group of individuals from different backgrounds, usually 5 to 12, developing ideas concerning a problem, for a period of a few minutes to an hour, under the leadership of a facilitator. The facilitator states briefly the problem. The group then generates ideas, following some rules: (i) criticism of an idea is prohibited, (ii) its modification or combination with another idea is encouraged, (iii) quantity of ideas is desired, and (iv) unusual, remote, or wild ideas are welcomed. An unworkable idea expressed by one participant may be the starting point for another idea. The unconventional ideas, of course, are useful because they open new directions of exploration [31]. Brainstorming is not a method for solving problems but a technique for stimulating ideas that will lead to solutions.

In the context of CuRe, a brainstorming session (conversational method) took place at the premises of ICS-FORTH. More than 10 researchers and research assistants, including user experience (UX) experts, software engineers, historians, and social scientists participated in defining the requirements of the system.

4.2. Use Cases and Application Scenarios

The design process of interactive and information-oriented systems, such as the one developed in the context of CuRe, is challenging since the target is to provide solutions considering the end-user aspects. A way to address this demanding task is the creation of use cases, which are indicative solutions and representations of the contract between the stakeholders and the system's behavior. The use cases act as an assistive tool to the developers since they help them understand and create computational systems and platforms as artifacts of human activity, as tools to use in one's work, or as media for interacting with other people [32].

Use cases aim at presenting, in a detailed, clear, and easy-to-understand way, the functional requirements of the system. The related use-case descriptions are given in a non-technical manner, in a way that will support the developers to translate the end-users potential actions into technical features of the system. In that manner, the use cases can also be considered as being a description of a system's behavior, written from the point of view of a user who is using the system to accomplish a task. Accordingly, the use cases can support teams in understanding the value that the system provides to its stakeholders [33]. Use cases always describe who is doing what and when and also what is expected from the system to respond to each request. Thus, use cases comprise a powerful tool to capture functional requirements for software systems and to evaluate them [34]. Use cases describe the interactions of the users with the system and not how the system operates internally (considered as a black box). This methodology has been proved to be useful for constructing and communicating behavioral requirements.

Use cases can be expressed in many ways; they can be presented as simple scenarios, like narrative stories [35], or they can consist of several different parts that decompose the scenarios with detailed templates [36]. In all cases, the use cases should be well-written and easy to read by the designers. Each should include simple action steps, according to which an actor achieves a result or passes information to another actor. This simple and descriptive way of presenting the use cases makes them easy to be understood and followed by the designer. Despite their concreteness, use cases should also provide the designer with some flexibility. Since the requirements can be adjusted at a later stage of the system development, use cases should be updated accordingly.

The use cases proposed for the CuRe system consist of several related scenarios and corresponding episodes. The scenarios are related to the context of the use of the end-users, while the episodes consist of a sequence of steps to achieve a goal. This hierarchical relationship is used to sufficiently model and correlate the corresponding user requirements. The proposed episodes contain sequences of steps describing how the actions and interactions unfold.

One important benefit of the episodes-driven analysis, in general, is that it helps in managing complexity since it focuses on one specific usage aspect at a time. Episodes start from the very simple view that a system is built first and foremost for its users. Thus, episodes allow capturing the user's need by focusing on a task that the user needs to do. Starting by naming the episodes, value is created since this list of titles-context is the list of goals that announces what the system will do. Additionally, episodes help in defining the right functionalities of the system, meaning they ensure that the correct system is developed by capturing the requirements from the user's point of view. Moreover, they help in finding all the exceptions and alternatives, since the main success scenario is a sequence of simple steps, going through each step and checking what else the user could do or what in the system can go wrong.

CuRe deploys two main use cases, one focused on the end-users and a second focused on the content creators and system administrators. The two use cases (UC1 and UC2) are described in the following sections.

4.2.1. UC1: Content Exploring

The main target of the CuRe platform is to host pieces of historical information and present them as narratives to the users, via a dedicated website and a mobile application. Accordingly, UC1 (Figure 1) describes the functionality associated with the role of the user as a content consumer. Further, UC1 is decomposed into three scenarios that categorize the functionality according to the context of use, and specifically (i) being at home, (ii) visiting a museum, and (iii) being on the move. For each scenario, one or more episodes have been defined to describe the functionality in the form of short user stories.

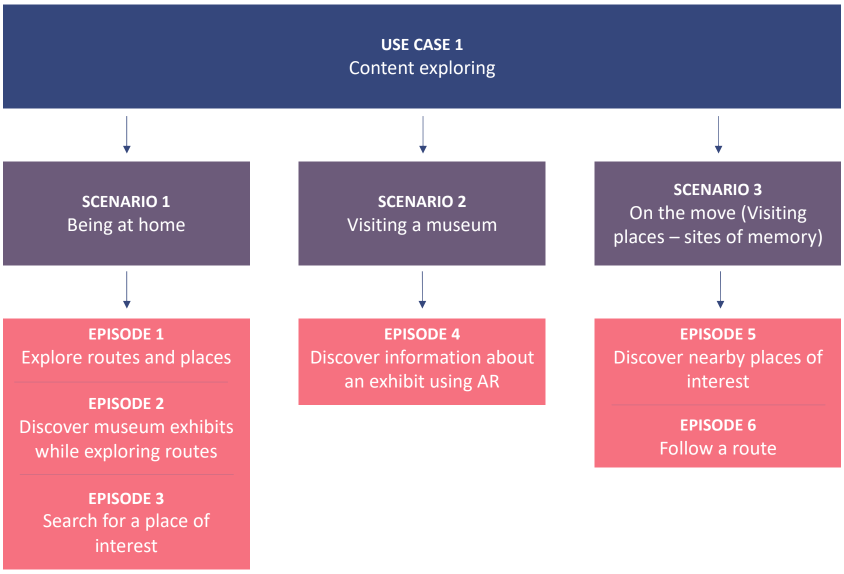


Figure 1. Use case 1—content exploring.

4.2.2. UC2: System Administration

The CuRe platform aims to provide rich content to users in the form of narratives. To keep the community active, the content of the platform needs to be constantly updated and enhanced. To this end, the system needs to support the role of the user as a content creator and administrator. Accordingly, UC2 (Figure 2) includes the content creation and editing functionality along with system-administration features that will be implemented.

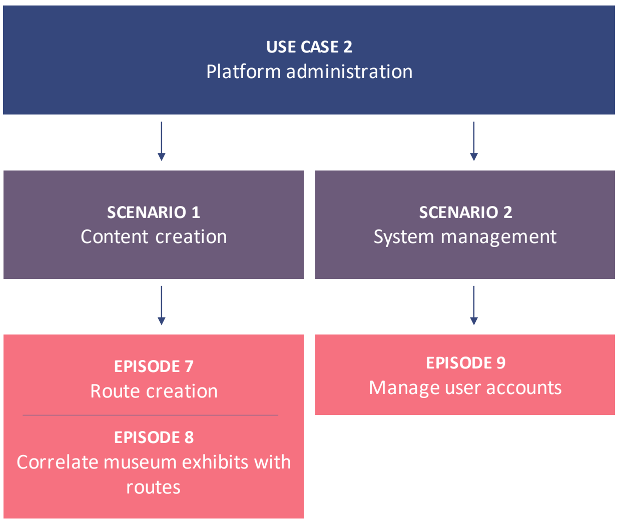


Figure 2. Use case 2—platform administration.

4.3. UI Design

Based on the findings of the brainstorming session and the specification of use cases and application scenarios, several high-fidelity design prototypes were implemented by user interface (UI) designers in collaboration with user experience (UX) experts. Prototyping helps stakeholders develop a concrete sense regarding the application that is not yet implemented. Through the visualization of the application, stakeholders can determine the requirements and workflow of the system. Further, prototyping reduces cost and time because errors are detected in the early stages providing high levels of user satisfaction at the end.

4.3.1. Design Method

Iterative design is a method for developing user interfaces (UIs) by iteratively refining them, based on evaluation results [37]. Various evaluation methodologies can be used between the iterations, as suited according to the prototype status. Iterative design is important to achieve high-quality user interfaces, as even the best usability experts cannot design perfect UIs from the start [38].

Although several stages may be involved in the process (e.g., ideation and empathizing), as dictated by recent design approaches such as design thinking [39], the essence of iterative design lies in the design refinements that stem from the evaluation results. Therefore, iterative design can be represented as a cycle with three main components: design (also encompassing phases of problem definition, ideation, empathizing, and requirements specification), prototype, and evaluation (see Figure 3). Prototypes may vary from low-fidelity to high-fidelity or even fully interactive prototypes of the system under development.

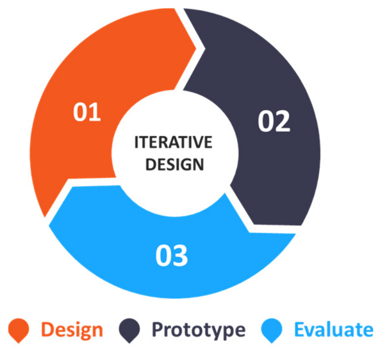
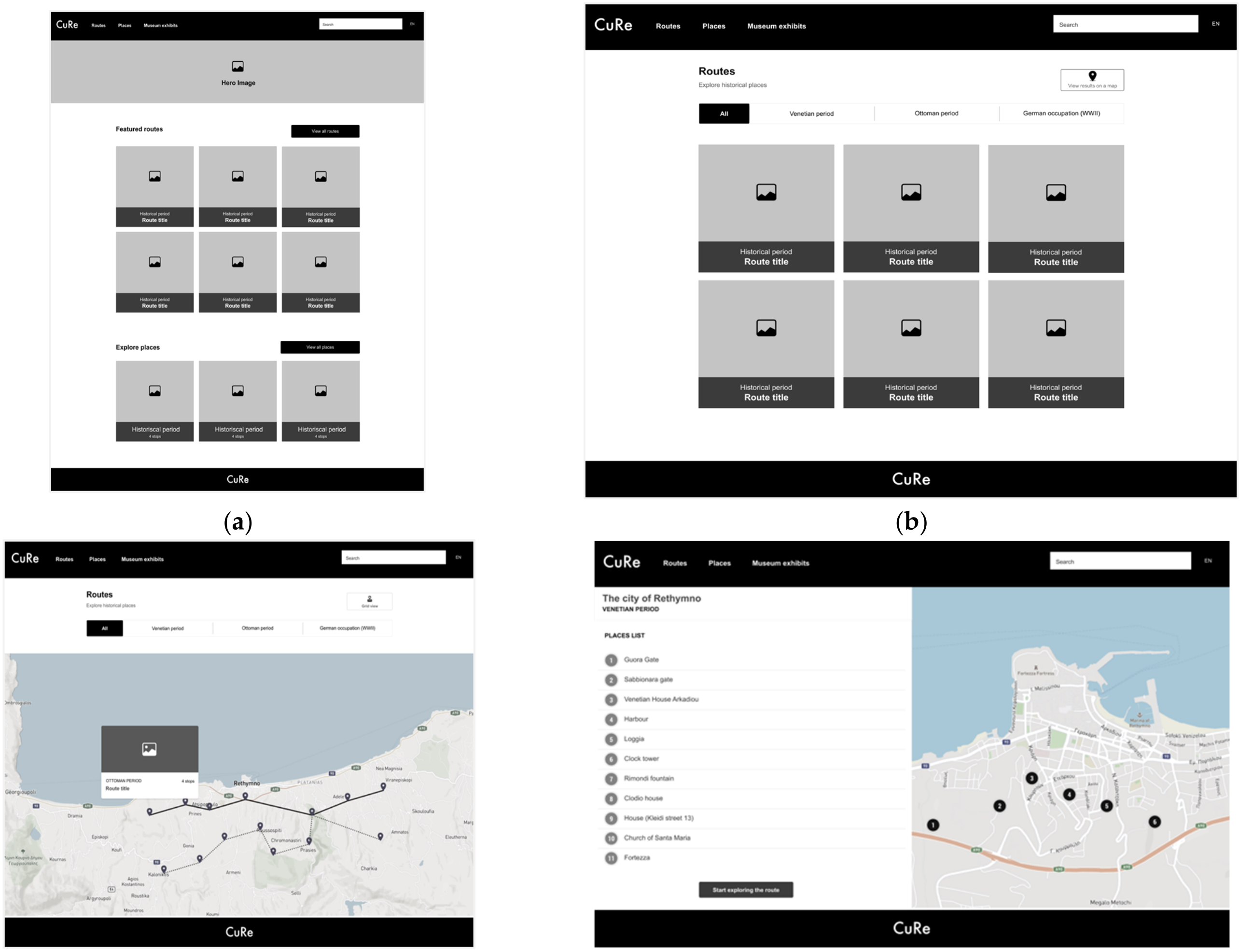


Figure 3. Iterative design process.

In brief, the benefits of the iterative design are that it involves user testing, thus providing valuable user feedback, and that it can identify problems early in the development life cycle, therefore improving usability. All the above benefits of iterative design constitute an efficient and cost-effective process for the development of UIs ensuring a high-quality user experience.

4.3.2. Prototypes for the Web

The outcome of the design phase is a set of low-fidelity prototypes summarized in the following figures. Figure 4 presents the alternative browsing modes supported by the system. More specifically, a narrative presented through a geographic route can be accessed in a multitude of ways including linear (from point to point), summative (summary of main locations), and freely allowing the user to explore the narrative by accessing places of interest in random order.



(**a**) (**b**) (**c**) (**d**)

Figure 4. UI designs: (**a**) home page of the CuRe web platform, (**b**) routes list, (**c**) routes list—map representation, (**d**) route presentation—places included.

The prototypes created aim to present how the fundamental entities of the platform shall be visualized for the users. In particular, four entities are identified and described briefly below:

- Location: A specific location/place that has a name and is identified by geographic coordinates (latitude, longitude).
- Historical period: A period when a set of related events took place (e.g., World War II).
- Places of memory: A place, which is related to a geographic location (as described above), where a series of events took place under a specific historical period.
- Route: An ordered list of places of memory that define a linear way of exploring a broader part of history for a specific period.
- Museum exhibit: An object of history, which is showcased in a museum.

The home page (Figure 4a) aims to present at a glance all the main entities of the web platform. In specific, links to entity-specific pages (routes, places, and museum exhibits) are presented in the main-menu area. Additionally, the homepage includes an expanded section featuring routes to promote hand-picked content from the administrators. Finally, the home page includes direct links to pages that feature places belonging to a specific historical period.

All routes can be explored on the corresponding page (Figure 4b) accessed by the main menu. This page includes the list of available routes and can be filtered accordingly to present the only routes of specific historical periods. The user can also view the available routes on a map representation (Figure 4c). Upon selection of a specific route, the user can view more details and all the places of interest included in this route, both as a list and on a map (Figure 4d).

Users can initiate browsing a route through reading the details of a specific place and can then jump to the next one (Figure 5) using a free-path narration form. At all times a map presents the specific location of the place. Another approach to access a narrative, routed to web-based narrative techniques, uses an approach that targets readers that are familiar with multimodal documents comprised by a rich set of text, graphics, and map-based visualizations, as shown in (Figure 6a). Using the integrated text-to-speech mechanism, the viewer can also listen to the story-based narrative, as in an audiobook. In both cases, the system is designed to support a wide variety of multimodal information including video and audio testimonies to offer a rich set of information elements for each information point (Figure 6b).

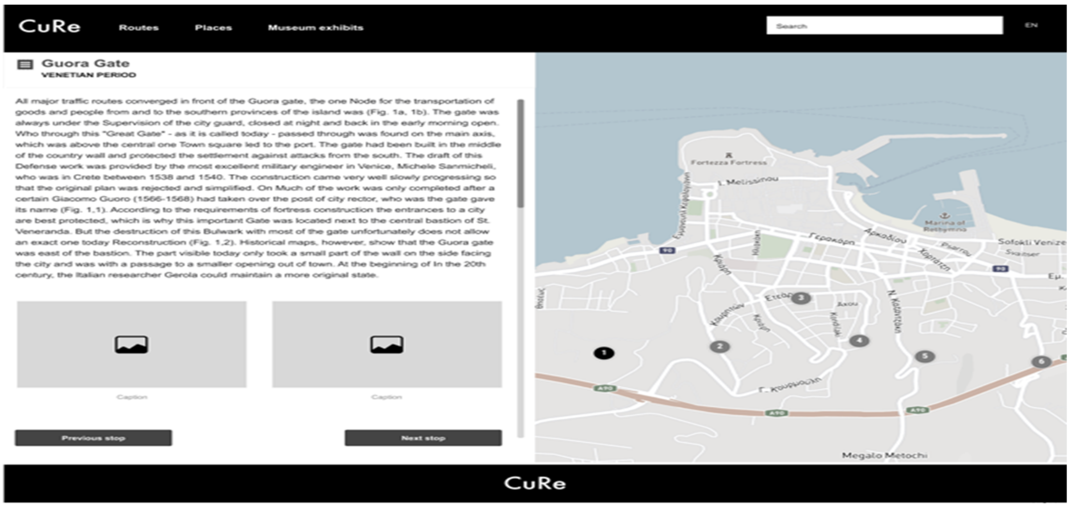
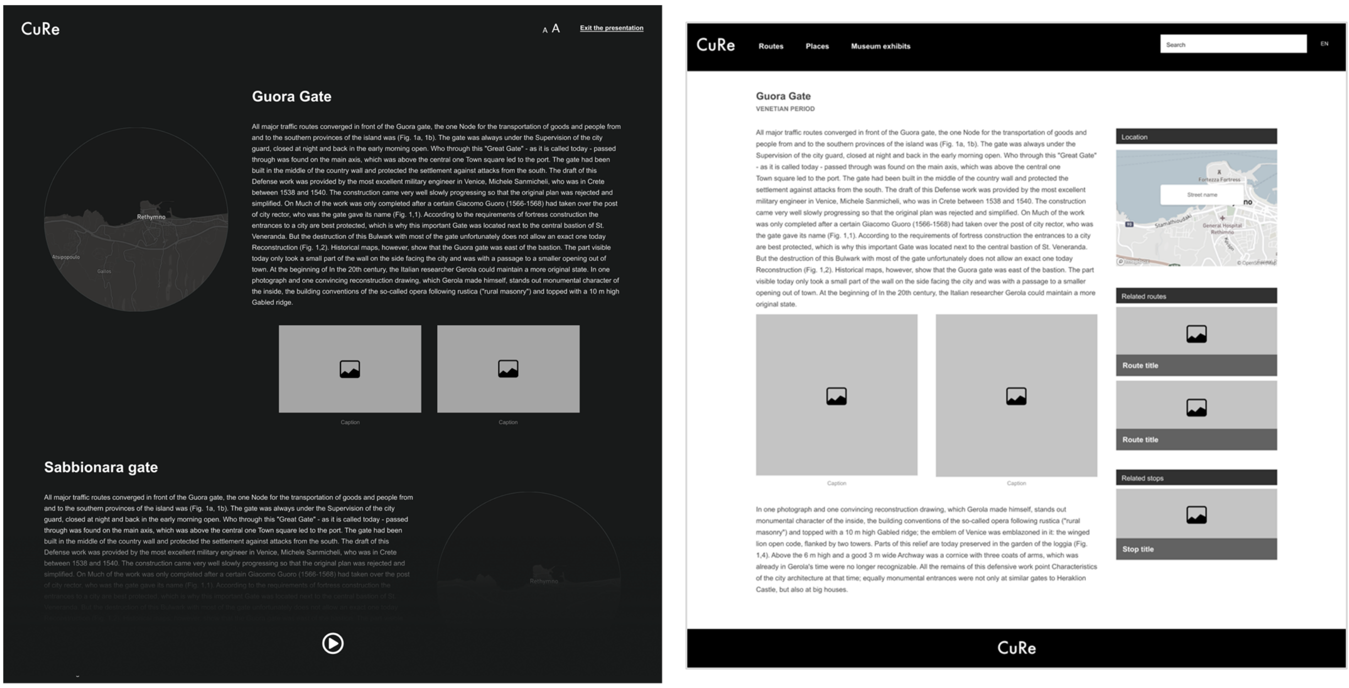


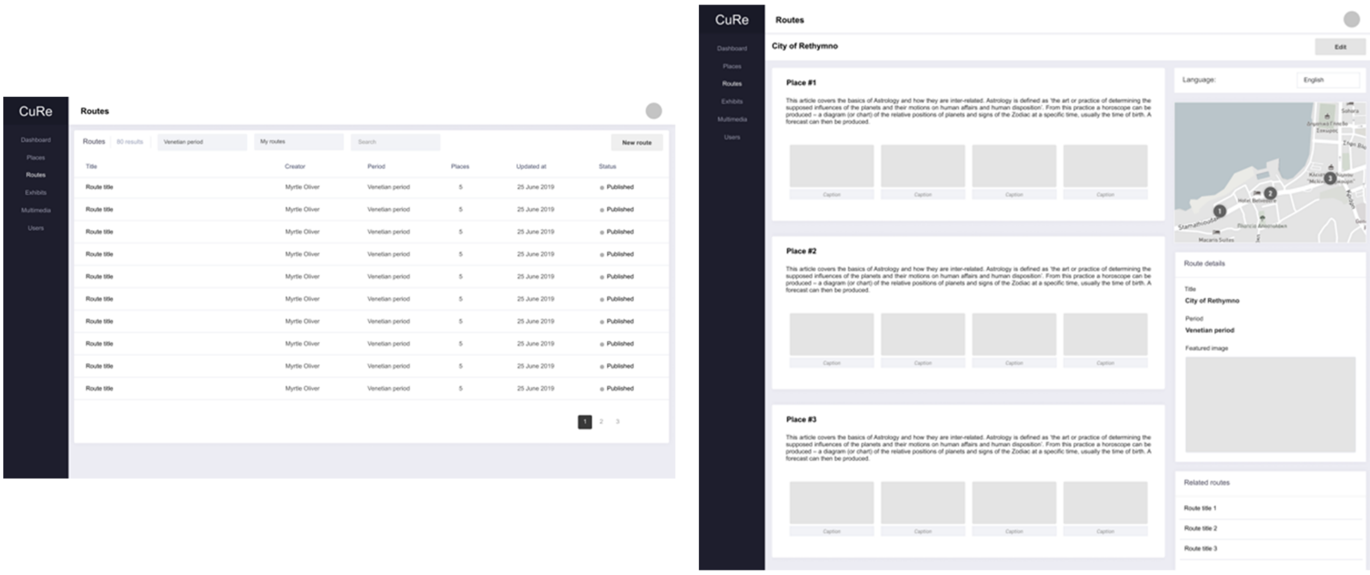
Figure 5. Route—linear browsing.



(**a**) (**b**)

Figure 6. (**a**) narration mode; (**b**) detailed view of a place of memory.

Further, a content-management application was designed to facilitate the continuous enrichment of the content. This application includes user interfaces (Figure 7) for listing, viewing, and editing all the entries of data (places, museum exhibits, narratives, and users).



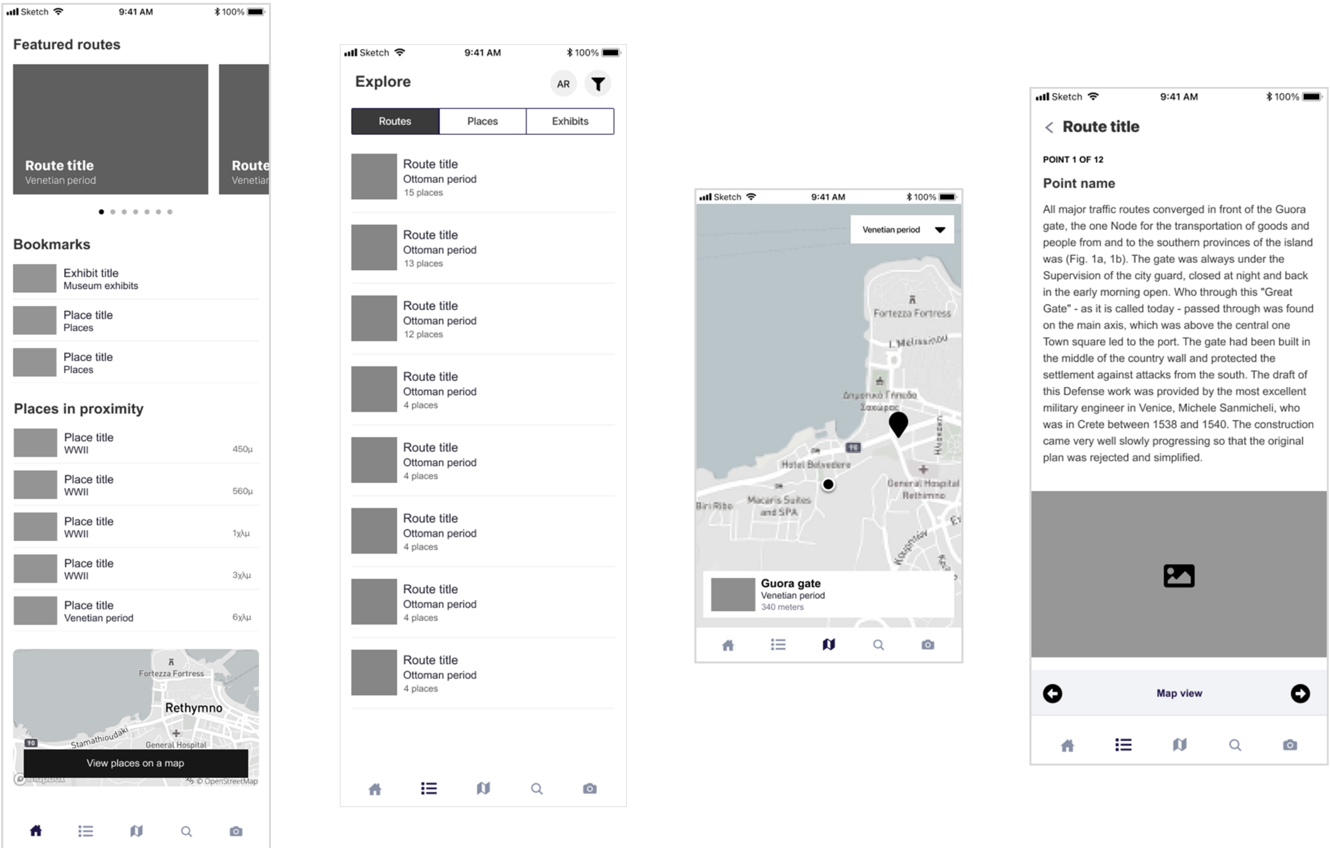
(**a**) (**b**)

Figure 7. (**a**) List of routes and (**b**) route details.

4.3.3. Prototypes for Mobile Devices

Although the web-based system was implemented to support a responsive layout and thus to allow browsing through multiple devices, a complementary mobile app was designed to extend the capabilities of the platform and offer location-based AR experiences for sites and exhibits. The AR presentations are supported by the mobile devices' sensors, such as GPS, accelerometer, gyroscope, etc. When it comes to museum exhibits, object recognition is to be supported through image processing offered by AR-capable mobile devices.

In particular, the prototypes created for the mobile device include a home screen (Figure 8a), where featured routes and nearby places of interest are provided. A browsing screen (Figure 8b) includes lists of all main entities of the system (routes, places, and exhibits) along with search and filtering functionality. Places and routes can also be visualized with the use of a map (Figure 8c) that also includes the location of the user. The user can start following a route using the corresponding route screens (Figure 8d) that support the virtual guidance of the user to the sites of memory.



(a) (b) (c) (d)

Figure 8. UI designs: (**a**) home screen, (**b**) content items browsing, (**c**) map screen, (**d**) route screen.

5. System Architecture

The CuRe system aims to support multimodal location-based narratives implemented as a combination of cloud, web-based technologies and an autonomous mobile app that supports content exploration on the go and that offers AR experiences. The functional architecture of the CuRe system presented in this section (Figure 9) defines the fundamental architectural components, as well as the synergies between them.

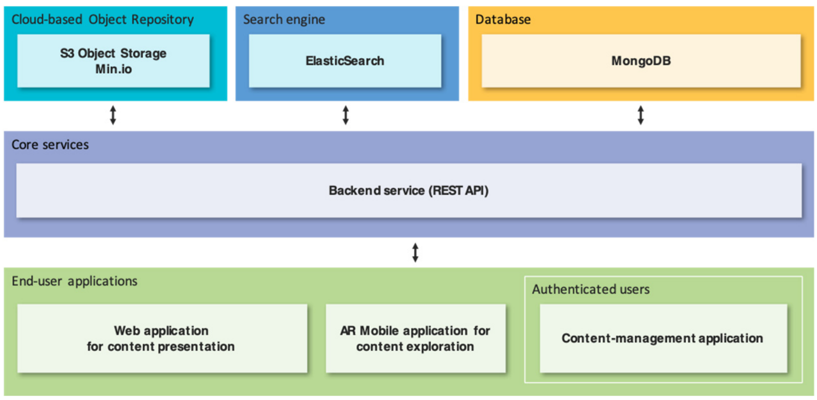
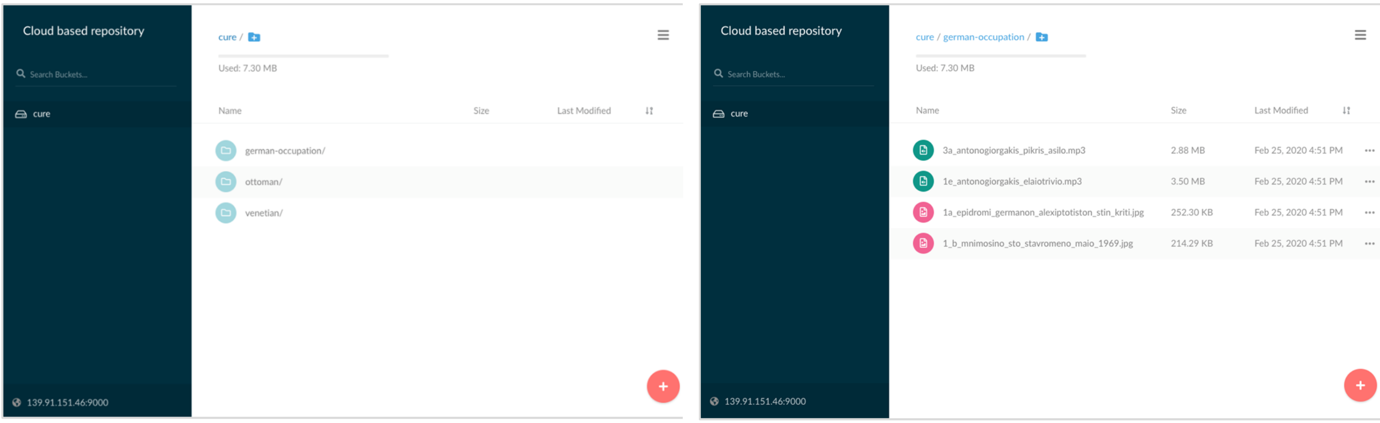


Figure 9. Functional architecture of the CuRe system.

5.1. Cloud-Based Object Repository

Cloud storage is intended to act as a single storage infrastructure for multimodal content, while the web platform is the main distribution channel of the stored narratives. As a solution for the cloud-based repository of the CURE system, the MinIO cloud storage server was adopted [40]. MinIO is a high-performance, distributed object storage system. It is software-defined, runs on industry-standard hardware, and is 100% open source under the Apache V2 license. MinIO writes data and metadata together as objects, eliminating the need for a metadata database. It is designed to be minimal and scalable and can store unstructured data such as photos, videos, audio files, etc. MinIO servers can be installed on physical or virtual machines or launched as Docker containers and deployed on container orchestration platforms like Kubernetes, Mesosphere, and Docker Swarm.

Although the multimedia content stored in the object storage is solely accessed via the backend service of the system, a web user interface is supported by the object storage service for administration purposes. The object storage service supports buckets of data that are used to group content. Multiple directories can be created under a bucket for further organization of the content. Figure 10a presents the user interface of the tool, showing the content under the "cure" bucket (default bucket). A directory (Figure 10b) was created for each historical period, and the content was hosted under them. Further categorization can be applied by creating directories per content type, e.g., image, video, audio, 3D models, etc.



(**a**) (**b**)

Figure 10. (**a**) the root directory of the web UI of the cloud-based repository; (**b**) content under a directory.

5.2. Database

To maintain and preserve the system's data and metadata, there is a need for a permanent storage solution that will be responsible for the data storage and retrieval within the system. To this end, a NoSQL database was integrated to handle the collections of data and to provide a fast storage solution with instant access. In contrast to relational databases, NoSQL databases offer a significant performance increase on queries and efficient large-scale data management. In particular, a MongoDB database was integrated into the CuRe system. MongoDB is a popular, well-documented, and scalable database, which is built with a focus on modern technologies and cloud computing. Some of the most significant features of MongoDB include:

- Powerful query language: Rich and expressive query language that supports filtering and sorting by any field. Supports aggregations and other use-cases such as geo-based search, graph search, and text search. Queries are themselves, JSON, and thus are easily composable.
- Rich JSON documents: Data are stored in the form of JSON documents, which is the most natural and productive way to work with data. It supports arrays and nested objects as values and allows for flexible and dynamic schemas.
- Scalability: Supports horizontal scaling through Sharding, distributing data across several machines, and facilitating high-throughput operation with large sets of data.

5.3. Search Engine

To further support content exploration within the CuRe system, a powerful search mechanism is required to enable instant keyword-based text search on the content. Although MongoDB supports searching against the documents stored, a more efficient and scalable solution was integrated to facilitate content search within CuRe.

Elasticsearch is a highly scalable, open-source, full-text search engine that features storing and searching large volumes of data, efficiently in near real-time. It is generally used as the underlying engine powering application with complex search requirements. Elasticsearch is easy-to-use, has a great community that actively supports it, and is compatible with JSON.

5.4. Backend Service (REST API)

The backend service (REST API provider) is the main backbone component of the system. Its main objective is to manage and serve content to the end-user applications and support the synergies between the system components. In specific, the backend service connects to and retrieves data from the database and object storage, performs any data manipulation required, and exposes the content to the end-user applications via a well-defined REST API. The same applies to content production, where the content is transmitted from the content-management application to the backend service, which then performs the data storing to the database and object storage.

Accordingly, the backend service supports (i) content creation, editing, retrieval, and deletion (CRUD operations); (ii) multimedia content uploading and retrieval, such as images, video, and audio; and (iii) interfaces to support keyword-based search on the content, which is provided by the corresponding search engine.

The backend service is implemented as a Node.js [41] service. Unlike most other modern development environments, Node.js processes do not rely on multithreading to support concurrent execution of business logic, but they are based on an event-driven, non-blocking I/O model. Event-driven programming offers a more efficient, scalable alternative to multi-threading since the latter requires a large number of resources to maintain the threads. Moreover, the development of the coordinator will benefit from the support of the Node.js' package ecosystem, npm, which is a vast open-source libraries repository.

5.5. Web Application for Content Presentation

The web application for content presentation has the most significant role in the CuRe system, as it addresses the needs of the end-user for content consumption. The app provides graphical user interfaces to facilitate content exploration, via map-based or story-based representation approaches, by the end-users.

This frontend web application is implemented using Angular [42], an open-source framework, supported by Google and a large community. Frameworks like Angular facilitate the implementation of complex single-page applications (SPA), by providing mechanisms for the management and presentation of data originating from a data provider. Applications implemented in Angular benefit from the high-efficiency and security characteristics that the framework provides out of the box.

5.6. Content-Management Application for Content Producers

The CuRe system is implemented as a dynamic platform where content is constantly enriched, and new narratives are formed. The online content-management application of the CuRe system facilitates user contributions by providing graphical user interfaces targeted to content producers. In particular, authorized content producers can create, update, and delete entries for places, museum exhibits, and narratives. The application supports rich-text editors to enable text formatting and embedded multimedia.

The online content-management application is a frontend application implemented using the Angular framework and is powered by the REST API of the backend service. In contrast to the public web app for content presentation, an authentication mechanism is integrated into the application to provide authorized access only.

5.7. Mobile App

The mobile app supports information browsing through direct facilitation of cloud storage while extending the "on the move" capabilities of the system with geo-localized information provision and AR-based detection of museum exhibits.

The mobile app is implemented using Ionic [43], a development framework that supports cross-platform mobile applications. With Ionic, there is a single code base that is manipulated accordingly to provide native applications for all major mobile platforms.

6. Deployment

The CuRe platform consists of multiple services, such as the cloud-based repository, an HTTP server (used to serve the web applications), a database, etc. The deployment of such a platform is a challenging task as each component may require a specific environment (operating system) or libraries to run. To address these constraints, services need to run in isolation using a specific environment and configuration. To this end, the Docker [44] solution was used. Docker is based on the containerization method of virtualization, according to which a container consists of an entire runtime environment, an application, its dependencies (libraries and executables), and configuration files. Docker is an open-source project providing tools to support developers to create software and share their development environment as well as system administrators to deploy software [45]. Docker meets all the requirements for the deployment of a platform like CuRe, i.e., (i) components' isolation and self-containment, (ii) scalability, (iii) high availability, and (iv) data persistence.

Accordingly, the cloud-based repository was deployed using Docker on VMs of the cloud infrastructure at FORTH. Further, the deployment stack can be migrated with ease to any other enterprise-level infrastructure such as AWS [46], based on business demands.

7. Use Case

7.1. Socio-Historic Context of the Implementation and Objectives

Due to its exposed geographical position in the Mediterranean—a major island a couple of hundred miles offshore from European, Asiatic, and African coasts—Crete has always been and still is at a crossroad of cultures, religions, and modern (nation-centered) ideologies. The story of Crete's unique cultural heritage is a story of sieges, captures, and conquests, but it is also a story of encounters between groups that first met in a frame of hostility and that over time found ways of interaction and coexistence that was not without tensions but was still peaceful. An integral part of the modern cultural evolvement on the island is tourism, both national and international. Groups of people visit Crete, often for a short period, and face a wealth of remains, which are stimulating, but too numerous, disparate, and complex as to put them into a narrative and perceive the relevant cultural messages.

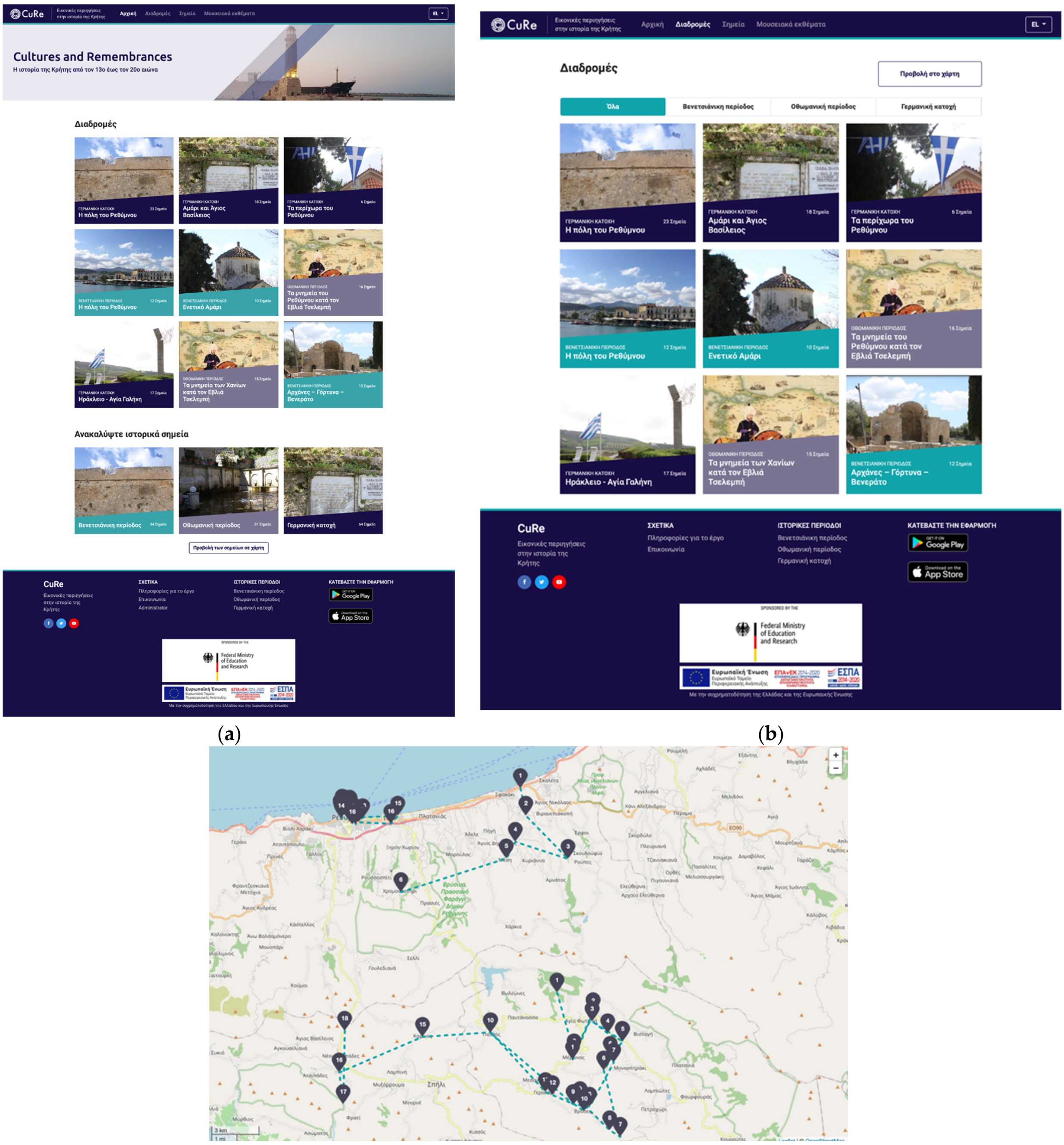
The main periods addressed by the presented use case include:

1. the Venetian presence on Crete, as a paradigm for processes of interconfessional interaction between the orthodox inhabitants and the catholic rulers;
2. the Ottoman period, as a paradigm for processes of interreligious interaction and coexistence between Christian (orthodox) and Muslim Cretans, Jews, and Armenian Christians but also for the damnation of memory after the Muslim Cretans were expelled as a consequence of the Greek–Turkish war and for the restoration of memory, which has taken place recently in public history;
3. the German occupation during WWII as a paradigm of viewing, mapping, and narrating a country and its people in a period of atrocious violence and mass murder. Within the frame of memory, the concept of "linked memory" and multi-lateral culture of remembrance is tested. This also expands to the vivid remembrance of the British support provided to the resistance on the island.

7.2. Sequential Location-Based Narratives

For the CuRe project, a vast amount of information was collected by researchers and configured accordingly into location-based narratives (routes). These narratives guide the visitor to explore personal stories and documents, which are linked to material remains, such as buildings and places of memory.

Starting at the home page (Figure 11a) of the web application, the visitor can view some featured routes, all accompanied with information about the historical period they refer to and the number of locations they include. A full list of the routes is presented on the corresponding routes page. On the routes page, two alternative views, a list (Figure 11b) and a map-based (Figure 11c) view are offered to assist the content-exploration process.

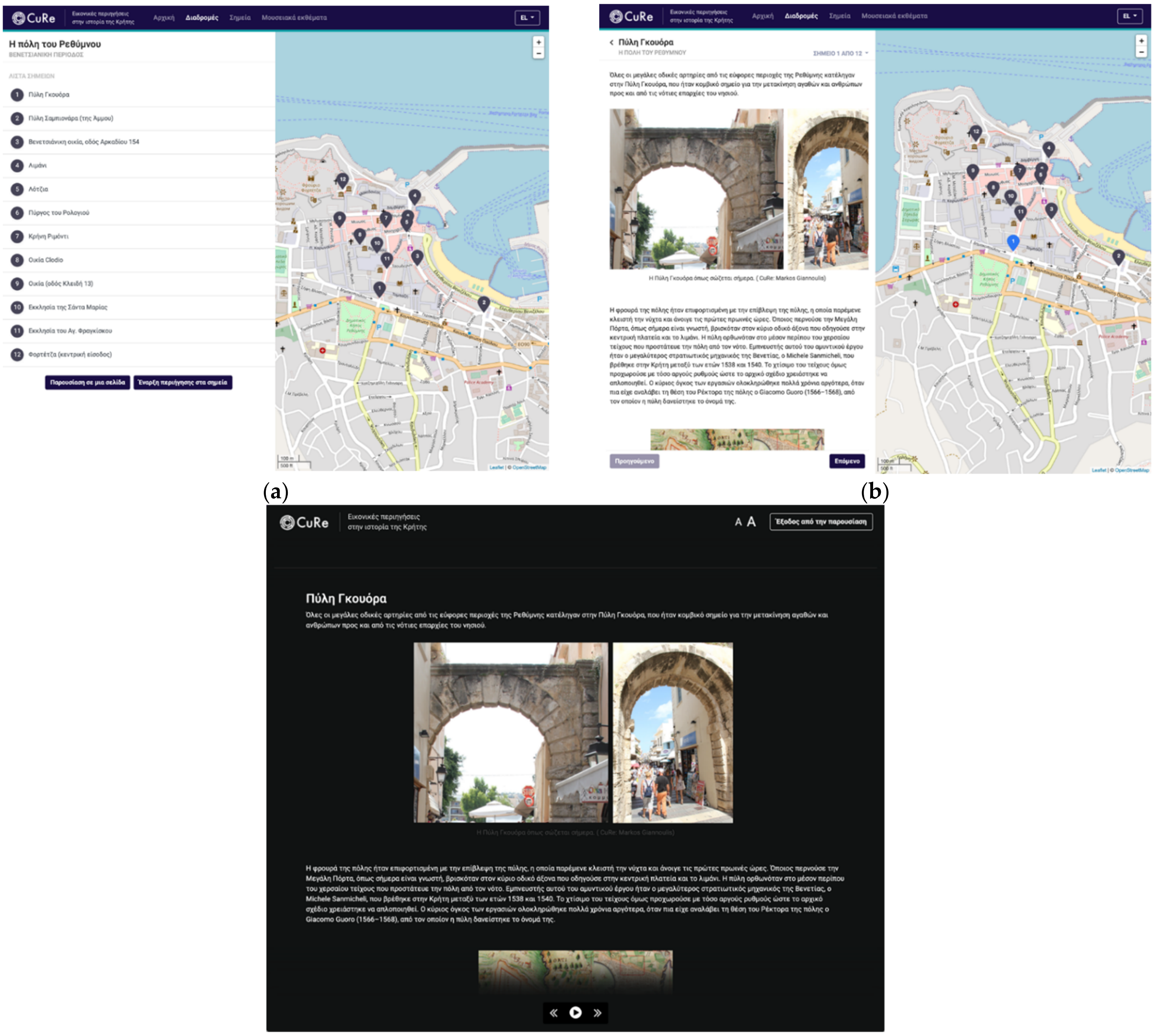


(**a**) (**b**)

(**c**)

Figure 11. (**a**) homepage, (**b**) routes list, (**c**) routes on a map.

Once selected, a detailed view of the route is presented to the user (Figure 12a), along with the list of the places forming the route. The places are ordered, and the corresponding number on each place indicates the recommended path for the visitor to follow. To support multiple styles of exploration, two alternatives were integrated to facilitate the route presentation. The first of them was used to present the places one by one (Figure 12b). Using this viewing alternative, the visitor has the opportunity to read about the corresponding place of memory and view multimedia items attached while having the map alongside. Thus, there is a direct connection between the actual location on the map and the content displayed to the visitor. The second viewing alternative is used to facilitate route exploration with minimum user interaction. The content for all the places of memory included in the route is displayed on a single page with high contrast (for easier reading), while a text-to-speech mechanism can be used to read aloud the text to the user and scroll the page as the narration progress (Figure 12c).

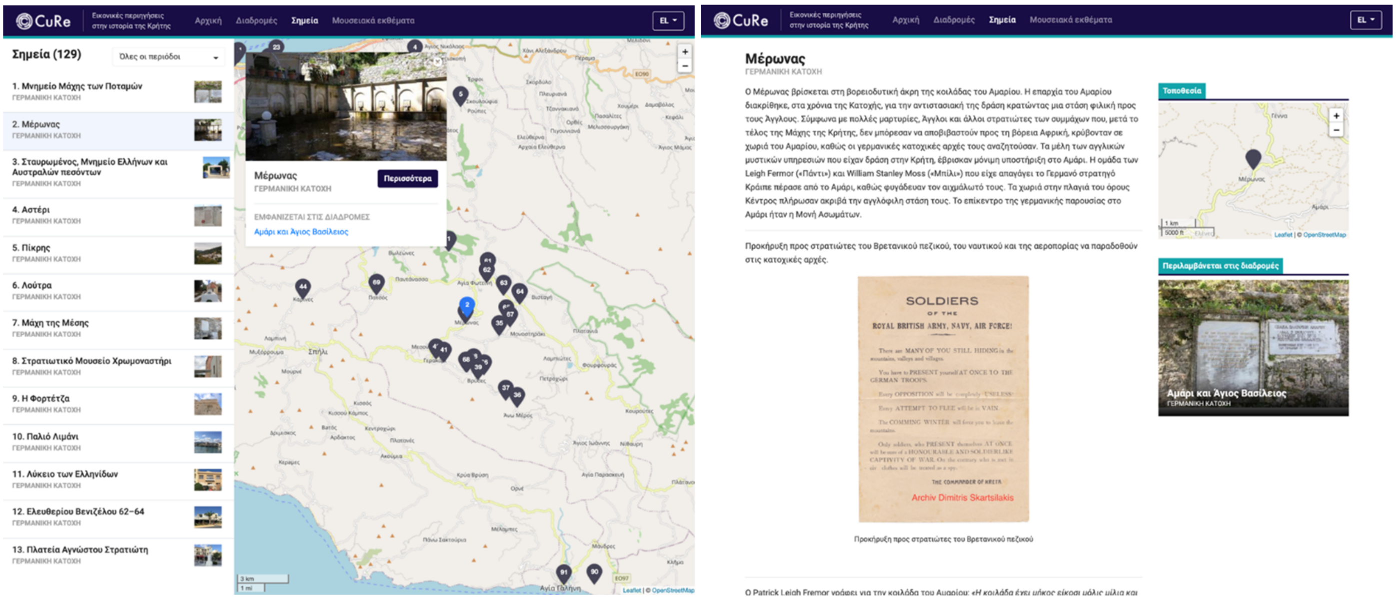


(**a**) (**b**) (**c**)

Figure 12. (**a**) single route view, (**b**) linear exploration of the route, (**c**) narration view of the route.

7.3. Point of Interest-Based Exploration

To support the use-cases defined in Section 4.2, an alternative exploration method is offered to the visitor, focusing on the places of memory themselves rather than the narratives formed (Figure 13a). This alternative facilitates the presentation of all places on a map regardless of the route they belong to. The visitor can select a place either on the map or the list displayed on the left. Further, the places can be filtered by the historical period to which they belong to narrow down the results. The visitor can view more information for the selected place of memory on the corresponding page for the place details (Figure 13b). Alongside the content, a list of related routes is included to support further exploration of content through the routes.



(**a**) (**b**)

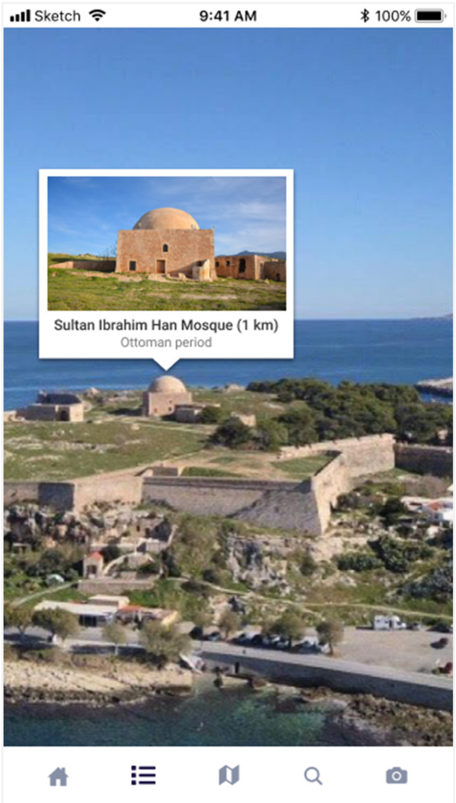
Figure 13. (**a**) summary of points of interest; (**b**) detailed view of a place of interest.

7.4. On-Site Mobile and AR-Based Access

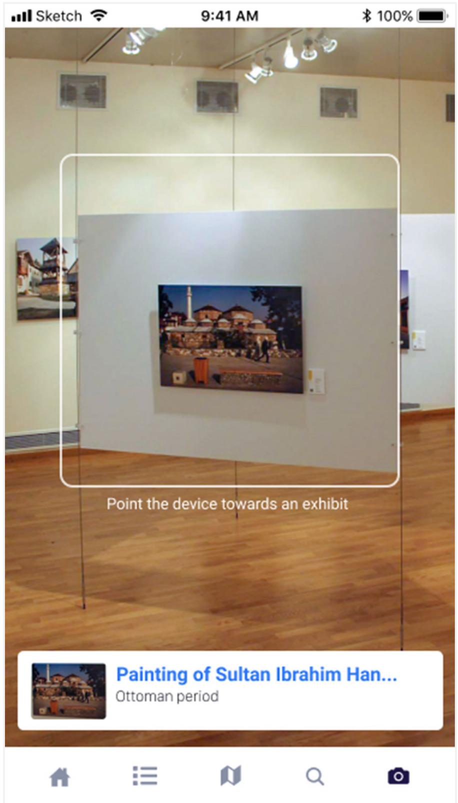
One of the key innovative features of the CuRe system is the ability to view historical sites of memory using augmented reality, transforming the content exploration into an immersive experience. In particular, the mobile application was designed to visualize points of interest in the real world, through the user's camera (Figure 14a). Accordingly, users can utilize this view to explore nearby sites of memory. The device's sensors (GPS, gyroscope, and compass) are used for the points of interest to be visualized. The application exploits the device's location data and the points' coordinates to present them on the screen and will keep updating their placement in real-time as if they were attached to physical locations. The elements closer to the user will be displayed as larger and on top of the projection stack, while the farthest should be positioned on the back, at a smaller size.

7.5. Exhibit Augmentation through Mobile AR

The CuRe mobile application aims to support, among others, the role of the user as a museum visitor. The user needs to be supported to explore more information about a museum exhibit using the mobile app and, further, to discover related places of interest and routes related to this item. To this end, entries of museum exhibits were created in the CuRe system, and their correlations with places and routes were identified.



(a)



(b)

Figure 14. (**a**) AR view screen; (**b**) AR scanning screen.

Towards offering a quick method to transfer the user from the real world (the museum area) to the digital world (the mobile app), an image recognition mechanism was employed that supports the identification of exhibits just by pointing the camera at them. The mechanism uses as a source the live feed from the device's camera and compares it against a list of pre-defined and pre-processed images of exhibits stored in the platform's database. When the user opens the corresponding screen and points to a museum exhibit, the application will identify the object (if available) and display a preview box with basic information. Additional information and related entries will show up by tapping on the infobox (Figure 14b).

8. Conclusions and Future Work

In this article, we presented the CuRe platform that facilitates a cloud-based repository of CH resources to support web-based narratives on CH resources provided through map-based or story-based representation approaches. The platform has considerable potential to improve the quality and learning value of digital cultural resources through the introduction of an affordable, ready-to-use, and cost-effective theoretical and technological framework for the representation and experiential presentation of cultural elements. The adopted approach for the implementation of the platform ensures that the results can be reused. Furthermore, the platform, by uniting digital experiences with physical experiences, has the potential to increase the awareness of citizens regarding the cultural environment and to further engage them to actively participate in the formulation and varied forms of expression of culture and CH.

At the time of writing (November 2021), both the platform and mobile application are officially online and have been accessed by users as part of the dissemination activities of the CuRe project. It is expected that this will provide the possibility of conducting a usability study to assess the combination of web-based and location-based narrative provision in terms of user experience and user satisfaction.

Regarding future improvements on the Cure platform, several directions can be followed. First, a valuable addition for the mobile app would be the integration of text-to-speech functionality for allowing the oral presentation of narratives while, for example, on the go for a point of interest. The second improvement would be to open up the platform for public contributions and discourse on historic events. This of course would require moderation on the discussions and the publication of content. Finally, the platform could be facilitated as part of the educational process by schools and academic institutions by allowing the creation of a narrative that is available to a closed group of subscribers, thus allowing teachers and professors to employ it as a tool to enhance the teaching of history. Both these extensions can be supported by the infrastructure and require only technical work for the implementation of dedicated UIs to support the use cases of each of the possible extensions.

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