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Interoperable multimedia mobile services in cultural heritage sites

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Abstract

According to the ancient Romans, "Delectare, docere, movere" are the goals of eloquence. To be accepted by museums, landscapes and archaeological sites, technology has to win the same challenge. Is technology unobtrusive enough to avoid compromising the emotional involvement that makes a visit to a cultural site unforgettable? Can it achieve a dissemination of the information in such a way that it is understood better? And how can technology be used to increase visibility and understanding of the numerous sites that are not yet able to attract the amount of people they deserve?
This paper presents the authors' vision on these questions, reporting on the activities carried out by the "mobile and ambient systems" work group of EPOCH as part of the CIMAD project.
A central part of CIMAD is the creation of services for visitors and archaeological sites as well as making parts of the overall vision a reality. The CIMAD services are based around the MobiComp context infrastructure, enabling the services to exchange context information and information to be displayed to the user. As the EPOCH network is beginning to dissolve we will discuss possible next steps, associated risks and opportunities of continuing this project.

Categories and Subject Descriptors (according to ACM CCS): H.3.5 [Online Information Services]: Mobile Guides, Museum and CIMAD

1. Introduction

Cultural Heritage (CH) is becoming a greater attraction factor for tourism worldwide and many countries are aiming to offer lower-cost, but higher-quality content and services that can provide better visibility and improved understanding to their museums, sites and landscapes.

In order to improve CH perception in a cost-effective way, many actors should be involved, i.e. tour operators, service providers, CH sites owners, telecom operators and technology providers, and many integrated services should be provided. The role of technology is to provide tools to enable service implementation and deployment. Services should address Site management, Data Collection and Content Delivery.

A structured approach to the use of technology in CH is required and EPOCH has taken on this challange of "overcoming fragmentation in open cultural heritage" and has devised a reference architecture for all CH related taskes from data collection to data presentation. The architecture is discussed in another section of this issue and its abstract view is shown figure 1.

This paper concentrates on the mobile user's view of the architecture, where mobile users can be researchers, visitors and museum staff. Their context is characterized by their position, activity, profile, preferences and by the devices they use to interact with both physical and digital CH.

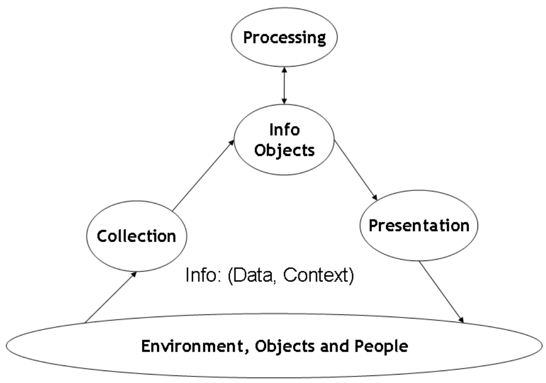

Figure 1: *EPOCH architecture.*

Mobile users need services integrated within the environment and widely accessible, requiring them to be available on a wide range of user equipment. Ideally, they should be automatically customized to the user's profile and preferences, and they should be smoothly and selectively accessible wherever they are needed.

The key to this accessibility and interoperability are seamless connectivity and seamless services; requiring platform interoperability (same services run on different platforms), data interoperability (services work on a common representation of data, and are independent from their data sources) and we need also network interoperability, to be always connected to the best available network, as well as session interoperability, to support seamless working session migration.

Figure 2 shows how this vision is approached by EPOCH: in order to separate services from their heterogeneous data sources EPOCH has adopted an ontology to describe cultural heritage objects and a common representation of context. CH data objects, coming from a

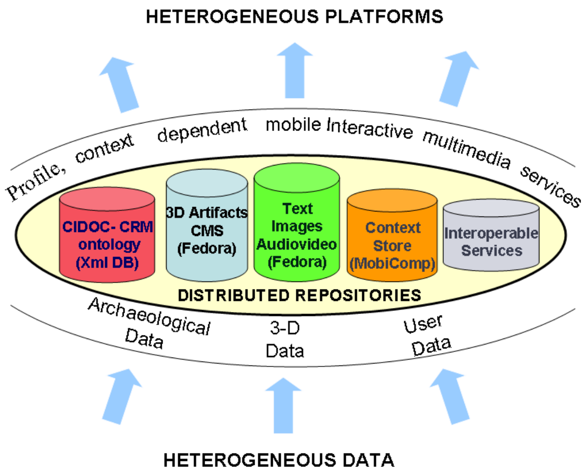

Figure 2: *Interoperability for service integration: the mobile user perspective.*

wide range of sources, e.g. from archaeological sites or from intermediate interpretation and processing steps such as 3-D modeling, are given as semantic meaning by a CH ontology and are stored in a *content* management system. Context data, no matter where it originated from, e.g. coming from sensors in the environment or from direct user input, are wrapped into context elements to achieve a common format — they are managed by a *context* management system. The most suitable services should be offered to the users based on their current context.

The proposed approach is not a "Near Market" view, since the picture outlined is expected to become a reality in the second half of the next decade, as it builds on technologies, systems and tools that are envisaged by the European 7th Framework Program whose time-span extends to 2013.

The goal of this paper is to demonstrate the potential of the proposed approach with a prototype framework based on current technologies — which are mainly in a development state. A prototype framework, called CIMAD (standing for "Common Infrastructure/Context Influenced Mobile Acquisition and Delivery of cultural heritage data"), supports demonstration level services which can simplify CH management and exposure. Services range from site management to visitor management and include, e.g. registration services, visitor flow monitoring, visitor guiding with support for user orientation and content delivery. The range of supported services could be extended for example with tools for site survey and data acquisition.

CIMAD is meant to seamlessly support heterogeneous device types with different form factors and usage models, i.e. custom made devices hired on site, privately owned PDAs and smart phones, and different location technologies, e.g. WiFi based and GPS based ones. Even if necessarily incomplete and preliminary in many respects, CIMAD demonstrates a future application development scenario, supporting the integration of services applicable to many CH environments. In order to provide such services, CIMAD builds on top of two infrastructure components supported by EPOCH: a context management system called MobiComp [Rya05] and a content management system built on top of the Fedora digital repository [UoV]. A work in progress demonstration of CIMAD services, named "Smart Museums, Sites and Landscapes — From Visitor Guides to Collection Monitoring" was setup and tested during a number of EPOCH sponsored events across Europe. This research is being carried out by an international research team which emerged from within the EPOCH framework.

In the section 2 the CIMAD framework is described, followed by the description of MobiComp in section 3 and Fedora in section 4. The implemented services are described in section 5 and a conclusion is presented in section 6.

2. CIMAD Framework

A wide range of CH applications have been developed in the past, mostly isolated and developed from scratch, not very flexible and hardly reusable. However, in the field of context-awareness an increasing number of applications are being developed out of modular re-usable building blocks which are combined through a context infrastructure [DSA01, Win01, CR02]. Based on such a context infrastructure, CIMAD aims to introduce the same modularity to the area of CH applications, by providing a common framework that allows overlapping functionalities and context elements to be re-used. The goal of CIMAD is to speed up and simplify the development process of CH applications — aimed both at developers and field experts with limited IT knowledge. The most widely used functionalities in CH applications are:

- Dynamic adaptation of content, for example to device characteristics, user preferences and profile.
- Seamless data acquisition in fieldworks, for example with contextualization of notes and pictures.
- User context detection from sensors, with a focus on position detection followed by guidance.
- Context abstraction for detecting meaningful user states, for example walking or looking at a particular exhibit.

Through an extendable basis of modules for the most widely used functions, the overall goal of the common framework is enabling a wide number of developers, with different levels of experience, to efficiently develop modular context-aware multi-channel CH applications which are interoperable. The modules developed by different developers form the asset of CIMAD, speeding up the development process of new applications through re-usability of existing modules. Aiming to cater for the different levels of users ranging from archaeologists, museum curators to experienced developers is one of the biggest challenges of CIMAD. This challenge is confronted through a flexible structure, providing support and guidance at different levels — for further details please refer to [RMR*07].

One of the main applications that can be set up within CIMAD is a visitor guide. As an example, the implementation process of a CIMAD interactive multimedia guide could look like the following:

- Cultural heritage specialists, i.e. museum curators or site experts, prepare the multimedia content and select the appropriate user interface.
- Curators prepare a "map component" associating each exhibit to its "context", e.g. physical location.
- Curators identify the criteria for organizing multimedia content into "thematic" or "geographic" tours.
- The site management team together with the developers select the desired devices and technologies for delivering the guided visits, i.e. PDAs and location technology used. Based on the selected devices and technologies the developers construct the visitor guide.

3. Context Management: MobiComp

MobiComp [Rya05] is a context management infrastructure tailored to the needs of CH. Its core element is the ContextService, acting as a store for context information and enabling coordination between the components of context-aware applications. The storage components behind the ContextService interface can be configured to support different scales of context-aware applications: simple standalone applications, multiple applications on a single device and applications spanning multiple devices. Three components exist for interacting with MobiComp: trackers, listeners and aggregators. A tracker is a MobiComp component that acts as a context producer. Trackers register their availability and capabilities by sending appropriate information to the ContextService. Their purpose is to collect raw context data from sensors, such as GPS receivers, and other dynamic or static sources, including configuration files for device capabilities and user-preferences. Trackers transform their input into context elements which are then put into in a database. Therefore, applications that need context information retrieve it directly from the MobiComp server and do not have to care about the actual context sources.

A listener is a MobiComp component that receives notification of ContextEvents from the ContextService and performs some action based on the context element carried by the event object. They receive event notifications whenever a context element is put into or removed from the store. On receiving a notification, the listener may get the element from the store and use it as required.

An aggregator is a MobiComp component that combines the behaviour of both a tracker and a listener. Aggregators monitor events from the ContextService, rather than a sensor device, and apply a transformation before returning a new element to the database. Aggregators can combine several low-level sensor elements to produce an element at a higher level of abstraction. For example, temperature, door, window and light sensor information might be used to determine room occupancy. Other aggregators may perform simple transformation services, i.e. converting latitude and longitude coordinates from a GPS sensor to coordinates on an appropriate local or national grid. Many non-trivial context-aware applications utilise a number of complex context aggregators, e.g. the FieldMap application described in [vLR01]. To ease communication between infrastructure components, context elements are represented in the form of a XML document based on ConteXtML [Rya05]. The elements carry a production timestamp, a default validity period, and a privacy level indicating how they may be disseminated through the ContextService.

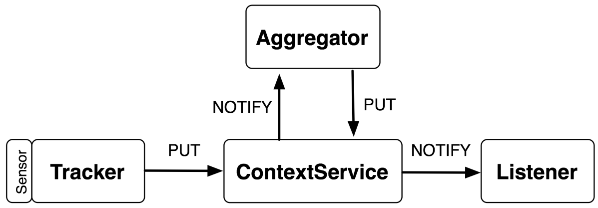

Figure 3: *MobiComp infrastructure.*

Through the above mentioned components the desired interoperability described in the introduction is achieved for context information — how it can be achieved for descriptions and multimedia related to artefacts and exhibits is described in the next section.

4. Fedora Content Store And The Content Adaptation Layer

Fedora [UoV] is the content repository system adopted by EPOCH. In addition to the content repository, Fedora provides a collection of tools and interfaces for creating, managing, and disseminating "Fedora digital objects" (FDO) stored within the repository. A FDO allows the original format of an object to be stored, along with metadata, i.e. in the format of the Dublin Core [DCM]. Through format adaptation components it is possible to perform a format conversion of an FDO in real-time, allowing requests from external applications for a specific format to be satisfied, e.g. HTML, PDF and JPEG. For example, a scaled-down or a greyscale version of an image can be retrieved according to the device characteristics. The requests and retrievals are performed through standardised interfaces based on REST and SOAP — within the CIMAD architecture the "Content Adaptation Layer" (CAL) is used.

Fedora enables the multi-channel paradigm, by allowing FDOs which were produced once to be adapted at run time according to the user and device context. In figure 4, the interaction of an application with Fedora is shown. The application publishes context on MobiComp through trackers and the CAL retrieves it through listeners. Once Fedora is aware of the context, it can provide the application with content which has been adapted to best fit that context.

5. CIMAD Services

As part of the Interactive Salon, an EPOCH event, a number of CIMAD prototype services supporting visitors and staff have been demonstrated. Some of the services run stand alone on "any" PDA or Smartphone, e.g. Symbian and Windows mobile ones, equipped with a web browser. These services demonstrate the extent of interoperability which can be achieved across platforms. Other services run on a server and can be invoked by any client application, e.g. through web pages — an example is the Path Finder, a service to provide the best path between two points on a site. Other services are based around wearable sensor kits, e.g. inertial sensors and RFID readers — not yet available on most PDAs and Smartphones. They extend the functionality of available PDAs and smart phones, and demonstrate the capabilities of future mobile devices. The additional functionality provided by the sensor kits currently consist of indoor positioning and tracking. These services are interesting because they

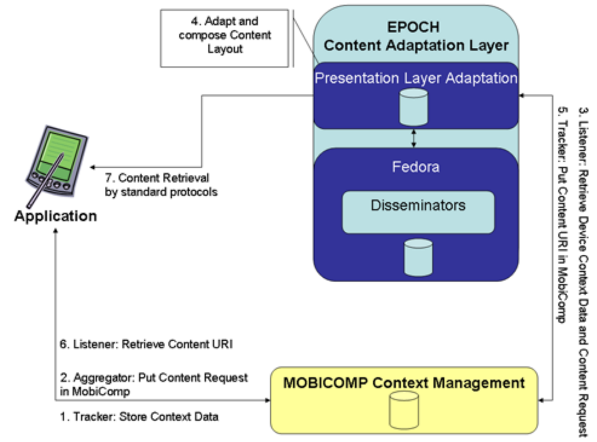

Figure 4: *Fedora content store and CIMAD integration.*

demonstrate that with insignificant impact on the hosting environment, i.e. a small number of RFID tags spread in the environment, they increase the effectiveness of an application.

Several different implementations of visitor guides based on various CIMAD components were proposed within EPOCH — the collection of guides can be seen in figure 5. Next the main services are described individually; for further information and a description of the individual components used please refer to [RMR*07].

Figure 5: *All guides Guide.*

- One of the guides, realised on a PDA and based on IR beacon location, displays information about the exhibit the visitor is standing next to. The MobiComp components used for this guide are for example an IR beacon tracker and an URL display listener, in addition to an aggregator able to convert the IR beacon stream to a sequence of URLs, forming the "virtual path" of the visitor through the museum. The IR technology of this guide can be exchanged with RFID to create a guide which does not require line of sight.
- Another guide is based on computer vision components developed by colleagues at ETH, Zurich. This is a Museum Guide [BFvG05, RMR*07] implemented on a Tablet PC using a conventional USB webcam to acquire images and to present users with a viewfinder window. When a user wants to get information about an exhibit, the information button on the tablet needs to be pressed when the exhibit is within the viewfinder window. If the exhibit is recognized using an image recognition algorithm as depicted in figure 6, corresponding exhibit information is displayed.

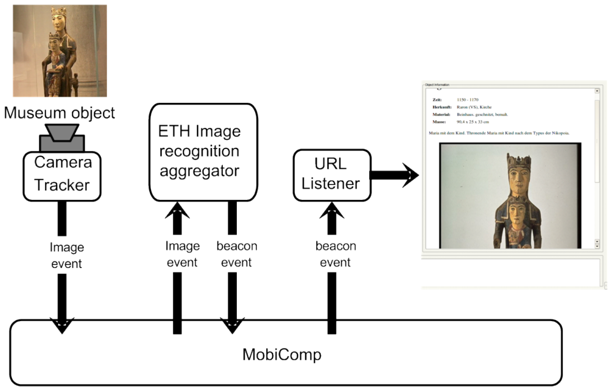

Figure 6: *Camera tracker Guide.*

- The semacode based guide can be run on standard mobile phones with a built in camera and a GPRS connection — the guide is installed on the phone via a "Bluetooth Kiosk". The visitors can take pictures of semacodes [Sem] situated next to exhibits they are interested in. Instead of an image recognizer like in the above guide, a semacode recognition aggregator finds and decodes the semacode tag in the captured image. This external module uses the Semacode.org software development kit [Sem]. Based upon the url decoded, the corresponding exhibit information is displayed on the screen of the mobile phone. The similarities between the guides highlight that the modularity of the MobiComp approach is powerful and allows for components to be re-used and bundled together quickly and easily under the CIMAD architecture.

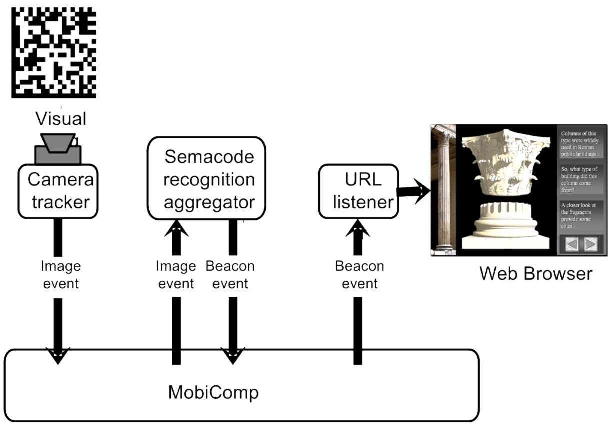

Figure 7: *Semacode Visitor Guide.*

- A visitor guide for the archaeological site of Palmyra in Syria is implemented on a standard PDA. The application is based on a CIMAD map component that listens to "location change" events and reacts updating the visual map —see figure 8— of the site and

Figure 8: *Palmyra Visitor Guide: Map.*

Figure 10: *Inertial tracking guide.*

presenting a location dependant interface to the user once a Point-Of-Interest is reached — see figure 9. The MobiComp components are a GPS tracker and a location listener. Content is adapted to the requirements of the PDAs through Fedora and the CAL.

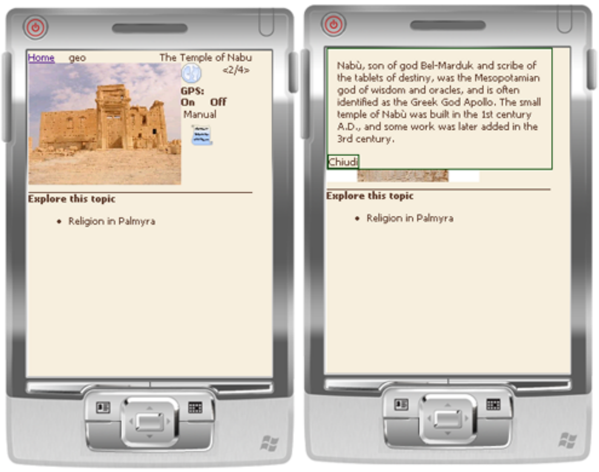

Figure 9: *Palmyra Visitor Guide: Content Presentation.*

- Yet another guide is the "Content navigator", which a user can run solely on a device with a web browser and connectivity — not requiring any other user hardware or software. When the Content navigator is loaded on the user's web browser, the browser parameters, i.e. the screen resolution, are determined automatically and are send to the server based content repository together with user preferences entered on the webpage. Once this data is received by the server, a disseminator is activated and the right content is provided to the user in the right format for the user's device and displayed through the web browser. The content is adapted by Fedora, where it is stored as FDOs.
- The inertial tracking guide does not require any user interaction, it automatically displays information about the exhibit the user is closest and facing to. User position and orientation are provided by an inertial location tracker strapped around the users waste — see figure 10. The tracker provides an estimate of the current user position, with respect to a pre defined starting point. Any type of beacon, ranging from an object recognizable by a camera to an RFID tag can be used to set the tracker's initial position. If RFID tags are used, the tags are distributed around the site, providing the possibility to reposition the tracker when a significant position error has been accumulated — inherent in the inertial tracking system.
- All of the above mentioned guides may benefit from the Path-Finder, a service providing the shortest path between a source and a destination point. The destination point may be chosen by the user, or it could be automatically recommended by a thematic tour service. The starting point can also be set by the user, or it could for example be the current location of a nearby exhibit, recognized through an RFID tag. For an example screen shot please see figure 11. The guide can be installed on a Web server or directly on the user's device. In order to function in a given museum or site, a map is required. This map can, for example be scanned by the curator and easily converted into the required graph format by the "Path Finder Remapping Utility", which runs on any desktop computer and comes with a demo application — enabling the graph creation by non experts. The "shortest" path is searched on the graph with an A* algorithm [Pea84]. Beside providing the shortest path between two conspicuous points, the "Path Finder" may also help the visitors of cultural heritage sites to find their way when looking for a specific exhibit, an emergency exit, the book shop, or any other location within a museum or site, even if they do not explicitely know their position. To this end a tool to estimate the user current position is needed. An ideal combination is the inertial tracking guide and the path finder; by dynamically evaluating the shortest path between the current position and the destination, the user can continuously be guided to a predefined target, very much like GPS navigation systems. This novel type of guide, that we could call ENDD, Epoch Navigation and Discovery Device is currently being tested at the Museo Civico Archeologico in Bologna, that kindly agreed to host the test within an informal co-operation with EPOCH's mobile and ambient systems group. For performance and scalability reasons ENDD is currently using a version of the Path Finder installed on the user's device.

In order to demonstrate that the CIMAD architecture can be used horizontally, supporting services for all mobile museum actors, i.e. not only visitors but also staff and management, two prototype man-

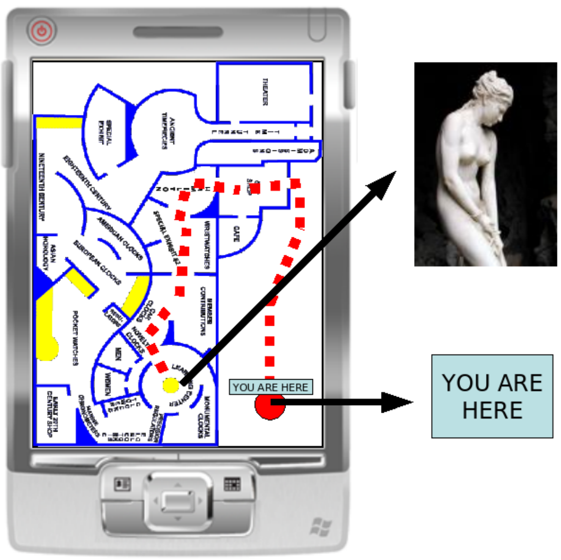

Figure 11: *Path Finder: after clicking on an exhibit icon, the system calculates the shortest path from the user's location to the selected exhibit.*

agement services were demonstrated and deployed during the Interactive Salon. One is a museum presence monitor which keeps track of the number of visitors currently in the exhibition and of the overall total number of visitors. The monitor application is notified by the visitor location tracker when a visitor enters or leaves the exhibition.

The other one is a meuseum registration desk service, which registers visitors who wish to use a context aware guide with the CIMAD services. The visitor's details (profile and preferences) are entered and the chosen guide is selected. This information is made available to all applications through the ContextStore and also triggers the configuration of the chosen guide for this particular visitor. Visitors can remain anonymous or can sign up for post-visit online services. For further information regarding implementation and details about the individual CIMAD building blocks used in the services please refere to [RMR*07] and [RRM*06].

6. Conclusions

This paper describes the mobile and ambient systems group's vision of the EPOCH mission "Overcoming Fragmentation in open cultural heritage". Starting from the consideration that increasing visibility and understanding of Cultural Heritage sites is an usatisfied social need [Ant07], this paper focused on how mobile technology could contribute. No isolated, individual solution with a large number of functions is desirable, while an infrastructure supporting seamless connectivity between interoperable contents is needed. Also a new interaction model is envisaged, where the users define their goals, e.g. "guide me to that particular exhibit and tell me if there is something interesting for me along the way", rather than select a function, i.e. "show me the map" or "show me the list of exhibits". Eventually this approach requires that the objects in the environment interact with each other, providing services and multimedia content to anybody. Objects equipped with identification devices and filled with multimedia content will make the environment user friendly and interactive. Research needs to solve performance and system issues in order to meet interoperability, scalability and privacy requirements. These are considered primary issues both in the long term and mid-term european reserch agenda, respectively within 7FP and related initiatives. Cultural heritage will keep its primary role in offering test beds to new technologies, new systems and new services, and EPOCH, as a 6FP NoE had the opportunity to anticipate similar research currently in the agenda of other priority domains. CIMAD —a prototype framework for interoperable context-aware applications— was described in this paper, together with its components, and with several examples of services for museums and archaeological sites.

Lessons were learned and issues requiring further research were identified. For example, it was found that occasionally, total separation between applications and data sources, as depicted in 2, cannot be achieved with current architectures and performance levels. There is also the need to further evaluate the proposed solutions, as well as to define a strategy to consolidate the EPOCH vision. EPOCH is coming to an end with its final event in Roma, which is a unique occasion to demonstrate the potential impact of the EPOCH architecture together with the associated models of interaction with cultural heritage. However, the event should celebrate the beginning of a new research cycle, not its end.

7. Acknowledgements

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