Innovative Cultural Experience (ICE), an Augmented Reality system for promoting cultural heritage

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ABSTRACT

Innovative Cultural Experience (ICE) is an Augmented Reality (AR) system for promoting cultural heritage. ICE combines cutting-edge technologies such as an interactive transparent screen, AR, motion sensors and multimedia material in order to provide a unique personal or mass-touring experience, utilizing information based on material and intangible cultural heritage, through narrative scenarios. Part of the ICE system is an interactive transparent box in which an exhibit can be placed. When a user/visitor approaches the exhibit, multimedia information is displayed on the transparent screen of the box, creating an interactive AR experience for the user. Users can interact with the content which can be text, images, videos, 360 images, 360 videos, 3D models or even play games based on the exhibit that is in front of them. By combining the real exhibit with digital information displayed on top, an interactive AR experience is created. Additionally, users can provide feedback by recording and uploading text, images, and videos to the ICE system. ICE is cognitively neutral (domain independent) technology, which makes it useful for a variety of thematic items (from museum exhibits to folk customs, local recipes, etc.) and it can be used also in education, commercial and in the tourist sectors. This paper presents the architecture of the ICE system, and the technologies used for building it. Initial internal evaluation results show that the system is easy to use, and users tend to stay longer in front of the exhibit, interacting with it, thus collecting more information about it.

CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); Interaction paradigms; Mixed / augmented reality (High Relevance); • **Hardware** → Emerging technologies; Analysis and design of emerging devices and systems; Emerging architectures (High Relevance); • **Computer systems organization** → Architectures; Distributed architectures; Client-server architectures (High Relevance).

KEYWORDS

Augmented reality, Cultural heritage, System architecture, Human computer interaction

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1 INTRODUCTION

Augmented Reality (AR) technology has been increasingly used by various industries as a multi-purpose tool that can allow users to combine virtual information with the real world through easy interactions. There are several researchers that are working with AR in business, marketing, education, tourist industry etc. with positive results revealing the potential benefits of AR technology. Past tourism studies categorized AR as one of the most notable digital technologies which has a great potential in tourism to enhance travel experience into something more interactive, enjoyable and exciting [1].

Museums have experimented with AR since early 2000s [2]. AR technology has been used to enhance visitors' experiences when exploring museum artifacts. AR technology can receive and provide digital information over the real-world objects to allow museum visitors to taste a new experience inside the museum, enhance interaction between visitors, collection objects and their contextualized information [3] and finally better understand the role of each exhibit [4]. AR has been utilized from museums of art, science, history and heritage sites. For example, AR has been used for reconstruction destroyed or modified cultural heritage sites [5], providing digital assets about exhibits in means of verbal descriptions of exhibits, 2D or 3D visual images, or visual animations that convey an exhibit's transformation [6], promoting social experiences into the museum using game-based experiences, or even encouraging visitors' participation through creative content production [2]. Another common problem in museums that AR can provide several solutions is the

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limited accessibility to artifacts by museum visitors. Utilizing AR technology, visitors can interact with 3D replicas of museum objects in a virtual environment mimicking physical environments [7]).

Nowadays, there are 3 ways to view an AR experience:

- Through a mobile device (phone or tablet). A common way to experience AR is through a mobile device. The user opens up the device camera and sees the real world with digital augmentations added to it. The quality of the experience heavily relies on the quality of the camera and the processing power of the device. When a lot of moving 3D augmentations are displayed, the processing power that is needed in order to be displayed correctly and in high quality is significant. In most cases, AR experiences are provided through mobile applications. Many of them require the support of ARCore and ARKit by the device, Google's and Apple's libraries for AR experiences. It must be noted that ARCore supports specific devices, and it is not based only on Android version of the device. AR experiences can also be provided through a webpage, by using only the browser and not a specific application. This is the case of Web-based Augmented Reality (WebAR), a relatively new technology that does not require a mobile application to function. WebAR has limited features since supporting frameworks are still undergoing development, thus it provides less-complex animations, video and limited image target detection and interactivity.
- Through a Head Mounted Display (HMD). HMDs are small displays or projection technology integrated into eyeglasses or mounted on a helmet. The displays of these devices are transparent. They do not block the user's vision but superimpose digital content on the user's view of the real world. An example of HMD is Microsoft HoloLens [8]. The cost of these devices is significantly higher than mobile devices, although recent hardware and software advances have reduced their cost. Depending on the device, an HMD can be connected to a computer or a mobile device or run independently.
- Through transparent screens. Transparent display screens are used to display dynamic or interactive content through a transparent surface allowing viewers to see what is shown on the screen whilst still being able to see through the display. They can also be interactable through touch. Currently, they are used in many applications such as product displays where images are floating around the product on show. They are also used in museums, theme parks and visitor attractions, to provide a memorable and engageable experience. In the car industry, head-up displays (HUDs), project critical information above the dashboard for the driver to see without looking down, utilizing transparent screens. Some refrigerators from LG are also using transparent screens so that a user won't have to open the door to see inside the fridge and provide useful information to the user at the same time.

This paper presents the architecture of the ICE system an AR system for promoting cultural heritage. ICE combines cutting-edge technologies such as an interactive transparent screen, AR, motion sensors and multimedia material in order to provide a unique personal or mass-touring experience, utilizing information based on material and intangible cultural heritage, through narrative scenarios. It also provides the system's modules. For every module, the paper describes the technologies used and provides operation details. Furthermore, it presents the results of an informative internal evaluation of the prototype along with limitations and future work.

The remainder of this paper is organized as follows: An overview of the ICE system is given in the next section. Then, all the ICE system modules are presented in the following sections. Section 3 depicts the Backend Management System where all administrative procedures take place. Section 4 describes the AR module, where information is presented through AR to the end-users, while Section 5 presents the Knowledge Base, where all information regarding exhibits, users and statistical data are stored. Finally, Section 6 presents some early findings from an initial internal evaluation of the ICE system and conclusions of this study are depicted in the end.

2 AN OVERVIEW OF ICE SYSTEM

The purpose of the ICE system is to provide interactive AR experiences for users. The system was designed primarily for use in exhibitions and museums, although it can also be used for educational purposes, promoting tourism or even for marketing. An exhibit is placed in an interactive transparent box. The box on one side includes a transparent screen. Transparent screens or see-through displays are currently available in the market. Transparent screens allow users to see what is shown on the screen while still being able to see through them. Transparent screens are currently also used in head-mounted displays (HMDs) where images are projected onto a transparent screen. Transparent screens offer AR experiences with better visual quality than mobile devices (phones and tablets). Since users see through the screen and not through the feed from the camera.

The ICE system uses a device called HypeBox [9], a transparent display solution which enables users to see real products and at the same time interact with digital content on the touchscreen. It is essentially an aluminum housing box with a transparent touchscreen on one side. An exhibit can be placed inside the device. The device is connected to a computer with an HDMI cable and touch events from the touchscreen are sent to the computer through a USB cable. The device is also equipped with small speakers. The device is highly compatible and supports all major operating systems (Android, Windows, Linux and Mac OS X).

The HypeBox is connected to a computer that runs a desktop application. The application retrieves information regarding the exhibit from the server. When a user approaches the exhibit, a proximity sensor signals the desktop application, and the screen of the transparent box displays all the available information. Users can interact with all the multimedia elements that are displayed on the transparent screen and see the exhibit at the same time, thus viewing an AR experience. Finally, users can leave valuable feedback by recording an image or a video using the embedded camera, or simply by text. There are also sensors that are tracking users' movement in order to get data regarding the time spent in front of each exhibit or the path that users take inside a museum.

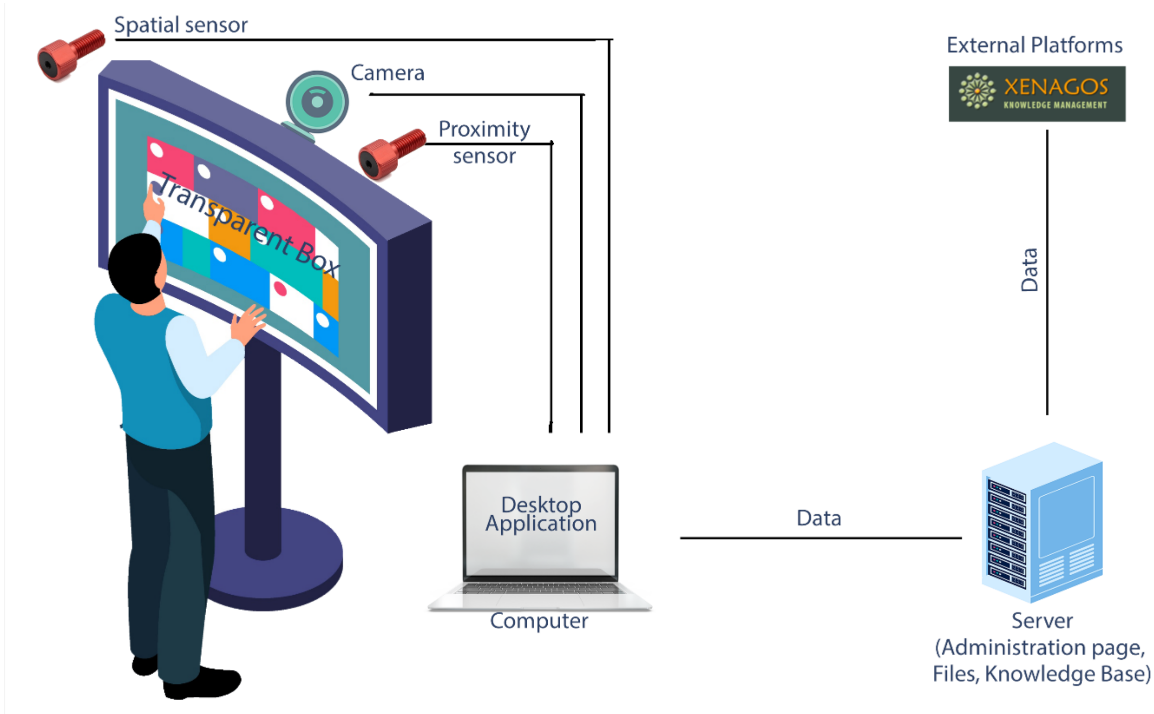

Figure 1: A general view of the ICE system

Information can be imported to and extracted from the Knowledge Base in order to be used by other systems such as XENAGOS [10], an innovative knowledge management and content presentation system designed especially for museums, cultural sites, cities, and large expos. Interconnectivity of the ICE system with other content presentation systems will assist in the commercial exploitation of the system. A general view of the system is depicted in Figure 1.

The ICE system consists of 3 modules:

- Backend Management System
- AR module
- Knowledge Base

These modules are depicted in Figure 2 and their functionality is described below. All three modules are connected through the server of the system, which contains the files and the database where all data is stored.

3 THE BACKEND MANAGEMENT SYSTEM

The web-based Backend Management System (BMS) supports all administrative actions through the administration page. It supports several types of user roles with some of those being explicit and some implicit. The roles are as follows:

End-User: Users in this category will use the system's HypeBox interactive display, browse through the multimedia information of an exhibit and view the AR experience. For example, visitors of a museum who will stand in front of HypeBox's interactive transparent touchscreen and navigate through the desktop application to view information about an exhibit, belong to this category. In addition, end-users can record through the camera and submit to the system their impressions or opinions about the exhibit. This feedback will be valuable to the organization that hosts the exhibits and can be published in the organization's website to further exploit positive comments.

Organization Employee: The organization owns one or more HypeBox devices and have multiple exhibits to display. The organization employees define the content that will be played on each of the HypeBox device screen depending on the audience and educational level that will see the exhibit that is placed inside. For example, before elementary school students visit a museum, the organization employees, using their credentials (username and password), should set the content to be played on each of the HypeBox device screen to be appropriate for elementary school students.

Organization Administrator: Users of this type are responsible for uploading/editing and maintaining all the multimedia information in the system for each exhibit that belongs to the organization. The submission of the data is done through the BMS administration page where an Organization Administrator enters with his/her credentials (username and password). Furthermore, this type of users manages all "Organization Employee" users and can add/remove them or edit their information. Additionally, this type of role has access to the statistics that the system receives from the spatial sensors of the organization. Also, upon submission of feedback by the "End-Users" through video, image, or text, the organization administrator approves or rejects the material based on its suitability. Once the material is approved, it is available on the organization's website.

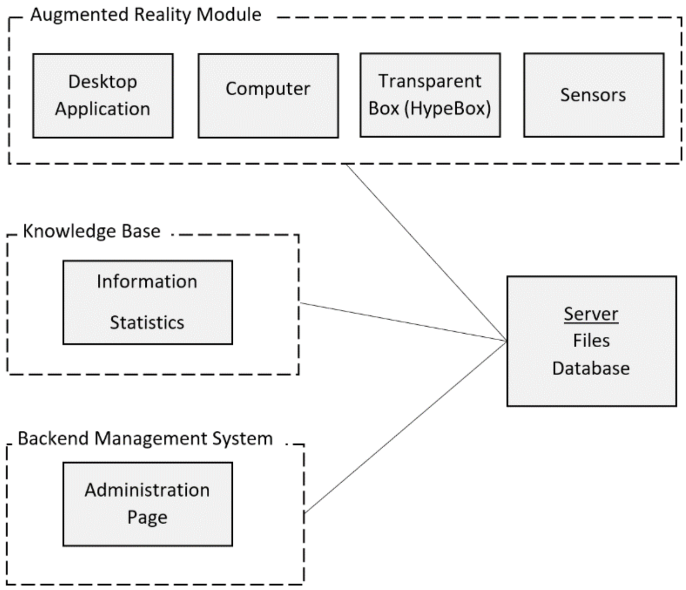

Figure 2: Modules of the ICE system

System Administrator: This type of user is responsible for managing the system, managing all users of the "Organization Administrator" category as well as taking backups. He/she logs in the BMS administrator page with his/her credentials (username and password).

4 AUGMENTED REALITY MODULE

The AR module consists of the desktop application that runs on the computer and the HypeBox interactive (and transparent) touchscreen that encloses the exhibit and is connected to the computer. The desktop application communicates with the server and receives information and files about the exhibit that is placed inside the HypeBox. The information about the exhibit is then displayed to the end-users. The transparent and interactive screen of the HypeBox combines the real world with the digital (AR) as it projects digital information on top of the real exhibit.

The end-users can view both the exhibit and digital information about it at the same time. The desktop application starts with a black screen and communicates with the proximity sensor. As soon as a user approaches the HypeBox, the application is activated and the contents of the HypeBox, i.e. the exhibit, are revealed.

The organization employee executes the desktop application and logins to the BMS with his/her credential. Then, the exhibit that will be displayed to the HypeBox is selected. The organization employee only has access to specific exhibits that belong to the organization and can be viewed on all HypeBox devices owned by the organization. The organization employee can also select the educational level depending on the end-users that will view the exhibit. For example, different information will appear on the HypeBox screen for elementary school students and for adults. Thus, the information displayed is adaptive depending on the visitor target group.

After selection, the desktop application communicates with the server which sends the exhibit data for the specific educational level. The data is stored locally, and the application is ready to display the multimedia content. At first, the application displays a black background with the organization's logo and is activated when the proximity sensor alerts the application that end-users are approaching the HypeBox screen. End-users can then view, through the interactive touch screen, all the multimedia content available to them. Available content can be text, images, videos, 360 images, 360 videos and 3D models.

End-users can zoom in and out and move all multimedia elements using their fingers on the interactive touch screen. Also, based on the exhibit, two memory games are available to end-users. In the first game, users must identify pairs of identical images and in the second game to move image tiles into the correct position in order to reveal the final image. In both games, game images are taken from exhibit images. The AR module interface is depicted in Figure 3.

5 THE KNOWLEDGE BASE

The ICE system, includes a database that contains all available information regarding exhibits, users, and statistical data, described as Knowledge Base (KB). KB service is built based on HTML and JavaScript using Tailwind UI CSS [11]. There are specific specifications for the type of files that can be uploaded to the KB as information to the exhibits:

Text: .txt or .json files
Images: .jpg files with resolution from 8MP to 20MP
360 Images: .jpg files with resolution higher than 12MP
Videos: .mp4 files with resolution from Full HD to 4K
360 Videos: .mp4 files with resolution higher than 4K
3D Models: .glb files with size up to 50MB

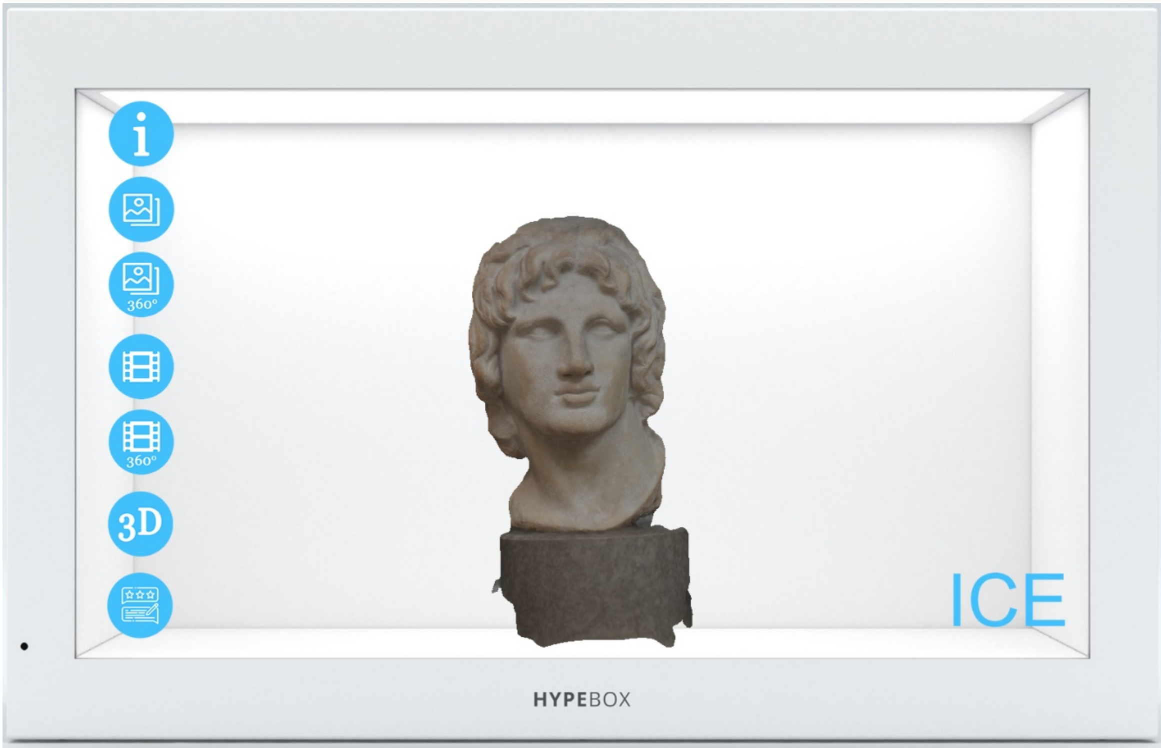

Figure 3: AR module interface

For the purpose of the project, material will be gathered from 10 indoor exhibits for three categories: Culture, Education and Commercial/Tourist, i.e. a total of 30 exhibits. All the information in the KB will be available in three languages: Greek, English and Turkish.

6 INFORMATIVE EVALUATION RESULTS

One of the project objectives was to check whether the ICE system is efficient for end-users and for all other types of registered users (Organization Employee, Organization Administrator and System Administrator). In order to get initial feedback about the implemented prototype, internal evaluation took place. The goal of the internal evaluation was to test the ICE system and collect participants' feedback and comments on UI, functionality, usability and quality of the provided AR experience. In order to track users' intention to use this technology at their visits in a museum the technology acceptance model (TAM) [12] was used. The TAM models how users come to accept and use a technology. The model suggests that when users are presented with a new technology, a number of factors. such as Perceived usefulness (PU) and Perceived ease-of-use (PEOU), influence their decision about how and when they will use it.

The questionnaire that was used for experiment participants was a four-part questionnaire, with 18 questions. The first part contained demographic questions. The following 2 parts contained 5-point Likert scale questions regarding the perceived usefulness and perceived ease-of-use [13]. The participants were asked to specify the extent of their agreement or disagreement using this scale. The scale ranged from "strongly agree" (1) to "strongly disagree" (5). The final part of the questionnaire, was consisted by open-ended questions about their overall experience asking them what they liked or disliked to the application and their suggestions for improvements along with specific problems they have identified.

All of the team involved in the ICE system along with external experts participated in this internal trial. Participants tested all 4 user roles. End-users were assigned to test the AR experience and the usability of the UI when standing in front of the HypeBox transparent screen. They also submitted video, image and text as feedback. Participants that acted as Organization Employees tested the usability of the desktop application when logging in and assigning an exhibit to the application. Users that were assigned the Organization Administrator role uploaded multimedia information to exhibits, viewed the statistics by the sensors of the system and checked whether end-users' feedback is suitable for publication. Finally, the System Administrator checked administrative functions, user registration and role assignment.

The informative evaluation took place at June 2022. The ICE system was tested by 12 internal users onsite, for finding possible problems and rate their experience and the application perceived usefulness and ease-of-use as end-users. These participants additionally tested the system as other types of registered users. On the other side, five experts (Human Computer Interaction doctors and professors, experienced programmers on identical projects etc,) checked remotely the ICE system functionality for Organization Administrators and System Administrators and mention the strengths and weakness of the system. The experts also commented on the other roles of users since researchers have sent them specific use case videos of the system.

In particular, 12 (internal users onsite) people from 18-45 years old were asked to do certain actions at the HypeBox according to a predefined scenario. They had about 10 minutes to interact with the artifact using the provided AR functionality. They had to discover, without any external help, the system's functionality and view all the digitally provided information. During this time a researcher was watching them keeping notes on their actions. After the end of that time, they were asked to answer a questionnaire and furthermore had discussion with the researcher about their opinion with the system.

The same process was also followed for the role of Organization Employee. However, this time the 12 participants had to follow some predefined actions written in a scenario. At the end of the experiment again they had to answer a related questionnaire.

On the other hand, the experts were working remotely, through the online management system of the ICE. They acted based on a document with a predefined number of actions that they have to complete using system functionality. At the end of the experiment, they had an interview with the researchers. They had to provide researchers with comments on each action they did regarding possible problems that they found, their suggestions for improvements and their overall satisfaction. Additionally, they watched two sample videos demonstrating how the ICE system works for end-users and Organization Employees and discussed with the researchers for possible improvements. The initial results were promising and proposals for new implementations were made.

According to the demographic results all the end-users were used to using touch-screen devices such as mobile phones and tablets. They have everyday access to the Internet but most of them were not programmers or IT specialists. The end-users evaluation results and the provided feedback suggested that ICE was considered both useful (4.5) and ease-of-use (4.1). All 12 participants mentioned that ICE is a system that they would like to see in the museums and liked the way that allows museum visitors interact with the artifacts. They believed that visitors can have an enhanced experience that will increase their satisfaction over their visit to the museum. What they liked the most was the AR provided information and the interaction with the virtual content. However, they proposed some improvements mainly on the system menu and the provided icon set. Some of the icons were not easily translated to their real meaning and their comments helped researchers to reconstruct system graphics. The discussion that took place after the end of the experiment, confirmed their answers in the questionnaire. Overall, ICE is a system that they intend to use whenever is available in a museum.

Similarly, the five experts who worked on the backend management system of ICE, completed sets of actions per different roles of users. After the completion of their tasks, they had a short interview with the researchers so as to provide their comments regarding the system. All of them were satisfied regarding the application and its providing functionality. They found some inconsistencies to system menus and came up with suggestions for improvements. They also proposed some better organization of the provided forms and screens so as to clear represent the required information. Some other improvements were made based on the provided system messages. Their comments helped make the messages clear and friendly to the users. They liked the application and they felt that is adequate for museum officers and employees, and they were able to use it without difficulties.

Overall, the internal informative evaluation results revealed that the ICE system succeeds in providing museum visitors with an innovative and useful way to enhance their experience. The proposals of all the participants were taken into consideration and several improvements have been implemented in the next version of the ICE system.

7 CONCLUSIONS

AR has the ability to add more to what users see. While AR experiences can be available to users through mobile devices or head-mounted displays like HoloLens, the ICE system uses a transparent box that includes an interactive touchscreen called HypeBox to provide AR experiences to users that visit a museum. ICE can also be used in education, commercial and tourist sectors. This paper presented the architecture of the ICE system and its modules. Through ICE, end-users can see real exhibits with augmented information on top. They can interact with the multimedia information and provide feedback regarding their experience. ICE also uses gathers information regarding users' movements at closed spaces. This information will provide valuable feedback to the organization in order to improve their services. ICE also supports personalized content presentation based on the target group of end-users. Finally, ICE can connect to other knowledge management systems like Xenagos to retrieve or to provide multimedia content. Initial evaluation results show that ICE is a complete solution that can provide services to a museum, a school, or any type of organization that needs to display items to end-users providing an AR experience.

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