

## A design framework for Smart Cultural Objects<sup>1</sup>

### A estrutura do design para Objetos Culturais Inteligentes

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#### Abstract

Nowadays cities, as well as Cultural Heritage, are facing new challenges due to the public financial straits and the increasing need to deliver innovative service to manage a wide heritage. Great expectations are in put the Smart City paradigm relying on the capability of the city to realize and scale up intangible infrastructures based on new typologies of partnerships for the development of services. The paper presents a design framework aimed to transform Cultural Items in Smart Cultural Objects (SCO), meant as sources and recipients of advanced information applied on 'Widespread Built Cultural Heritage'. The aim has been not just to enhance the artifacts with their own quality, but their unique social, communal, anthropological and urban-infrastructure meaning. The ability to manage efficiently heterogeneous data and the levels of global connectivity, as well as the real-time interaction, perception, localization, communication, and identification, made possible by cloud computing and Internet of Things, to allow the changeover from Cultural Objects to SCO. The framework, here exposed, aims to provide an extensive and robust theoretical support to design and to manage the processes of Cultural Objects and Cultural bins, implementing a methodological system and an advanced environment based on ICT technologies for recording, storage, processing, access and presentation of Cultural Heritage (CH) data in a *Smart Management* environment. The framework has been applied in two projects for a prototypical case study of widespread urban CH.

**Keywords:** cultural heritage, human smart city, co-design, internet of things, heritage management and communication.

#### Resumo

Atualmente, cidades, bem como o patrimônio cultural, estão enfrentando novos desafios devido às dificuldades financeiras públicas e à crescente necessidade de oferecer um serviço inovador para gerenciar uma grande herança. Grandes expectativas utilizam o modelo *Smart City* contando com a capacidade de a cidade realizar e ampliar as infraestruturas intangíveis baseadas em novas tipologias de parcerias para o desenvolvimento de serviços. O artigo apresenta uma estrutura de projeto com o objetivo de transformar os itens culturais em Objetos Culturais Inteligentes (OCIs), destinado a fontes e destinatários da informação avançada aplicada sobre "Patrimônio Cultural construída generalizada". O objetivo é não apenas melhorar os artefatos com a sua própria qualidade, mas também o seu significado social, comunal, antropológico e urbano-de infraestrutura única. A capacidade de gerenciar de forma eficiente dados heterogêneos e os níveis de conectividade global, bem como a interação em tempo real, percepção, localização, comunicação e identificação, possibilitadas pela computação em nuvem e Internet das Coisas, permite a passagem de bens culturais para OCIs. A estrutura, aqui exposta, visa proporcionar um extenso e robusto suporte teórico para projetar e gerenciar os processos de bens culturais e caixas Culturais, implementando um sistema metodológico e um ambiente avançado com base em TIC para gravação, armazenamento, tratamento, acesso e apresentação do Patrimônio Cultural (PC) de dados em um ambiente de Gestão Inteligente. A estrutura foi aplicada em dois projetos para um estudo de caso prototípico de PC urbano generalizado.

**Palavras-chave:** patrimônio cultural, *Smart City* humanizada, co-design, internet das coisas, gestão de patrimônio e comunicação.

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## Introduction

In the Cultural Heritage (CH) field, the traditional analysis, conservation, preservation, management, exploitation and communication process is complex, driven from multidimensional data and approaches, fragmented, high-cost and still limited to major Cultural Object (Gaiani, 2012). A Cultural artifact usually involves different research, conservation and maintenance activities, but also arrangement for the visitors. Moreover these works are based on an ongoing collaboration between art historians, archaeologists, architects, scholars, conservators, managers and specialists who work together to solve the same problem. This implies the need for a platform that would allow a real collaborative work between all parties involved. Finally, the process of conservation and restoration requires an increasing degree of automation. In the face of these requirements we are seeing today a total lack of accessibility to the entire corpus of information that should be shared by the specialists and the breakdown of the process into discontinuous isolated parts. The main reason of this deficit lies not only in the large amounts of heterogeneous data (3D models, images, photos, drawings, written documents, etc.) that the process requires and which prevents both the immediate usability is an easy transfer of information but also in complexity and partiality of the systems developed to provide an answer to these problems. In this context, ICT-based technological innovation has not yet made substantial advantages in this context, although desirable, as regards the management and use of assets. It is still weak, for example, the receipt of the paradigm of the Internet of Things (IoT). In this paper, we present a design framework aimed to transform Cultural Items in Smart Cultural Objects (SCO), sources and recipients of advanced information. This is a fundamental revolution in the way we conceive not only the CH system but also how to generate, acquire and transfer the knowledge related to it, and in the management, conservation and communication process. We focus on 'Widespread Built Cultural Heritage' (WBCH), though it constitutes a large part of the European Heritage and are bearers of great cultural and economic interest. It currently plays, unfortunately, a marginal role, but represents an extremely valuable strategic complement to the traditional cultural and touristic circuits in the cities of art.

Our framework aims to provide an extensive and robust theoretical support to the design and management processes concerning Cultural Objects and Cultural bins and is based on a broader definition of the original concept of Smart City as expressed by its creator William J. Mitchell (2001): "Cities are systems of systems, and that there are emerging opportunities to introduce digital nervous systems, intelligent responsiveness, and optimization at every level of system integration [...]. Furthermore, through cross-communication among digital nervous systems [...] it becomes possible to coordinate the operation of different systems to achieve significant efficiencies and sustainability benefits".

Second, our framework aims at transposing the concept of Human Smart City (HSC), developed in the context of some European Projects (Periphèria and My-Neighbourhood). That means a city addressed to steer

public and societal issues via ICT-based solutions on the basis of complex multi-stakeholder partnerships, including the same municipalities (Concilio *et al.*, 2014; Deserti and Rizzo, 2014b). These solutions are developed and refined through public and collaborative services (Baek *et al.*, 2010; Pueri *et al.*, 2013), or else services that are co-designed and co-produced among citizens and public and private stakeholders. The HSC approach relies on two main pillars: (i) ICT is only a component of the solutions; (ii) solutions can be seen as forms of social innovation.

Finally, the concept of services city-user/community centered is central, mainly the concept of User-generated content (UGC) as central to technique to add knowledge on Cultural artifacts. We could define UGC as "any form of content, such as blogs, wikis, discussion forums, posts, chats, tweets, podcasting, pins, digital images, video, audio files, and other forms of media that were created by users of an online system or service, often made available via social media websites" (Moens *et al.*, 2014, p. 7), and we remark that the advent of UGC marked a shift among media organizations from creating online content to providing facilities for amateurs to publish their own content.

Therefore, in our view, we aimed to define a new paradigm for implementing ICT within the development of Smart City (SC) projects, in which ICT is only a component of the solutions, and solutions can be seen as forms of social innovation, taking the form of a constellation of small initiatives generated by creative communities and collaborative organizations (Meroni, 2007). The central factors are not technological, but human, social and political, and CH is not a problem but a strategic factor for action.

The approach we suggest aims at overturning the design process of the SC solutions from the dominant paradigm that moves from technology to solutions to the emerging one that moves from problems, to solutions considering all the available resources (design thinking approach).

The starting point of our framework is therefore the observation that Smart interaction with the WBCH is still very limited for two reasons:

- (i) for citizens there are still limited opportunities to gain 'specific cognitive abilities' (perception, understanding and use), allowing to interact easily with digitized assets of CH;
- (ii) settings used to interact often do not take into account those cognitive and perceptual variables that should provide for an easy and as much as possible 'natural' use.

Summarizing, if it is true that a massive Smart interaction is still problematic, it is necessary to face the problem from two points of view: the dissemination of a wider digital literacy, and the adjustment of the setting of exploitation to actual user abilities, at the same time amplifying and connecting existing grassroots social initiatives with a process of public and collaborative services (Deserti and Rizzo, 2014a).

Overall, our framework is aimed at implementing a methodological system and an advanced environment based on ICT technologies for recording, storage, processing, access and presentation of CH data in a *Smart*

*Management* environment; these data are meant to be reusable for different purposes by different users (heritage management, scientific study, tourism, education) on conservation technologies (preservation, maintenance and restoration) and sustainable exploitation of CH, with particular reference to urban and extra-urban contexts (villas, historic gardens, parks and villages). Main technologies activating the framework are IoT and cloud computing that enable global connectivity and *Machine-to-machine* (M2M) processes. IoT allows real-time interaction, perception, localization, communication, and identification, as well as managing efficiently heterogeneous data, a key feature for CH field. Finally, our framework allows the integration of existing structures (for example the information systems of public and private conservation institutions, research centers, museums), considering technological synergies used as a basis for offering features, services, and integrated methods. This is due to the characteristic of being 'multi-scale', i.e., it can be used in different scenarios, from the territorial area (many episodes diffused in a wide area) to the urban context (many episodes concentrated in one city). The rest of the paper is organized as follows: The second section illustrates the application background and context. The third section describes our framework and some design applications. The concluding remarks are presented in the fourth section.

**SCO's framework and its background**

The last evolution of the IT infrastructure assumed as support for its concept of Smart City by Mitchell could be

summarized mainly by three key technologies, where the Web is the hero:

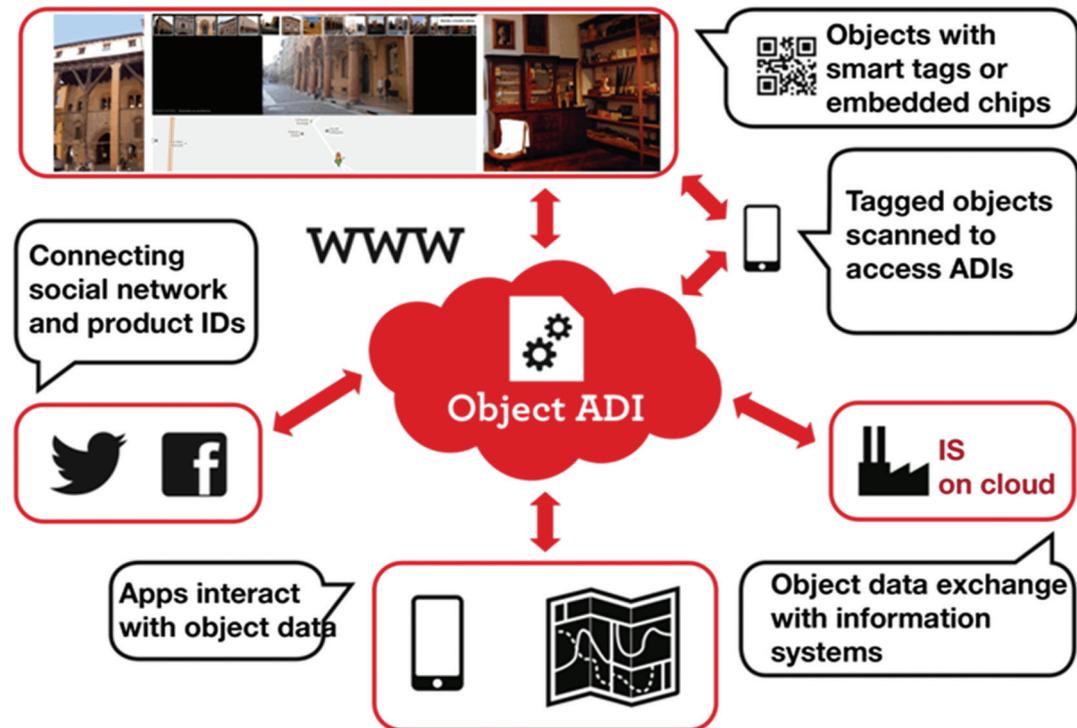
- (a) 'Web 2.0': new applications that enable users to actively participate in creating, sharing and aggregating Web contents, rather than in their mere passive visualization. The phenomenon is known as *community-generated data* (UGC) and it is a family of impressive size Open Data (OECD, 2007).
- (b) 'Web 3.0' or 'Web of Data': characterized by being real-time, while the activator subject consists of sensors attached to the objects (Kamilaris *et al.*, 2010).
- (c) The centrality of mobile communications and the use of smartphones as a medium of *mobile communication* and *sensing* together with cloud computing technologies (Lane *et al.*, 2010).

These technologies not are only a technological advancement but they represent a new revolution in the knowledge acquisition, management and communication. Veltman (2012, p. 9) explains clearly:

*The earliest Internet focused on bits and on born digital words and images on computer screens. The Internet of things is linking the electronic world of computers with objects in the physical world. Present day links are indiscriminate. Future links need to be tagged as relating to persons (who), things, ideas (what), spatial (where), temporal (when), procedural (how) and causal (why).*

IoT brings us closer to the idea of Smart city that Mitchell (2007, p. 5) does reside in "the increasingly effec-

**Active Digital Identity**



**Figure 1.** From Cultural Objects to Smart Cultural Objects.

tive combination of digital telecommunication networks (the nerves), ubiquitously embedded intelligence (the brains), sensors and tags (the sensory organs), and software (the knowledge and cognitive competence)". But in the Smart City a vital component is given by the CH implicit to the concept of Smart City as social engine (Shapiro, 2006) and raw material of knowledge to be conveyed through the 'cross-communication among digital nervous systems'. Therefore, the Smart City became the engine for knowledge and conservation of CH conceived as a Smart City, in which a network of SCO generates and broadcasts knowledge actively and dynamically, instead of seeing it as passive devices to be managed is needed (Fresa, 2013). This means that the implicit knowledge in Cultural Objects is not only accessible in institutional sites deputies to their preservation and use, but it is 'distributed' through the city, directly and dynamically enacted by the same objects as associated with their own perceived reality. A SCO, in fact, thanks to the network connection, is an object capable of taking an active role: to be immediately recognizable, to communicate information about itself, to connect to other objects. Therefore, the CH system is conceived as a system capable of generating knowledge and accessing to the collective knowledge generated through itself. As a result, the educational system, which is the system of institutions that produce (or should produce) educational effects through the relationship established between the subject and object of knowledge (Martini, 2012), completely changes its appearance: from network of institutions that *hold cultural objects* to network of SCO that 'bring with them', as perceived together with the knowledge associated with them, the possibility of acquisition, transmission and creation of knowledge. For example, UGC and IoT allow you to invert the classic mechanism of knowledge acquisition by allowing not only to acquire general knowledge, but also specific knowledge (documents) and personal (interpretive). Two are the most significant impacts.

A first relapse of these systems is the ability to conceive cultural objects as objects to be interpreted rather than simply as objects to be preserved and protected. This is, e.g., the purpose of the project Tales of Things (Barthel *et al.*, 2013) a tagging service that makes use of QR Codes and RFID tags to allow ordinary users to attach to an object stories and memories.

A second relapse of UGC and IoT systems is related to the spontaneous geo-location and creation of geo-localized data. This is described by the concept of 'citizens as sensors', where citizens are considered a dynamic source of information to feed spatial data infrastructures (Goodchild, 2007), defining new issues and new role that individuals and communities should play. This demands a new literacy for both professionals, who are entrusted with the protection, management, preservation and use of CH, and users (scholars, citizens, tourists). If in the near future we expect citizens to be able to fulfill and promote a culture of sustainability of our Heritage, then we must assume a responsibility in relation to the ability to 'educate' in such culture, since it is not the result of spontaneous opportunities in which each one can run more or less sporadically, but the result of deliberate practice, converging towards pursued design achievements in different institutional contexts of interest.

Within this context, a prime problem, already connected to the application of IT to traditional processes, concerns the usability of digital objects and their user experience, or rather, the conditions for their effective use. A digital object, in fact, an object characterized by a specific dominant *representational form* (Martini, 2012) whose understanding and interpretation depends on the specific perceptual and intellectual interaction it has with the subject. However, mainly the Institution where the object is physically or virtually placed defines this interaction. In other words, the form in which the object offers itself to the user is an *established form* in function of the use and the transmission of knowledge. In this sense, a digitized cultural object means a particular *text of knowledge* developed by the Institution (e.g., a museum) considering the use of that object in transmission and training key. This process of *mise en texte du savoir* (Chevallard, 1991) is generally equivalent to the work of adaptation that makes the cultural subject approachable and tailored to be enjoyed in a conscious way. This may mean: select it; give it a certain organization relating to the recipients, contexts, and purposes. In a word, that is *trans-form it*, literally, to give it some 'form'. The application of this construct to the Institutions conceived as knowledge and training system involves a work of transposition that can be very briefly traced back to:

- *The structuring of cultural objects and knowledge associated with them in the fields of activity and experience.* That is, the *setting* of enjoyment have to qualify as perceptual experiences, intellectual and emotional;
- *De-personalization and re-personalization objects.* When a cultural object 'enters' into an Institution it is separated from the contexts in which it originated and from the people who produced it. The fictional reconstruction (e.g. virtual) of such semantic contexts is a basic condition for the conscious use and acquisition of knowledge;
- *Programming of knowledge related to the object.* The knowledge related to a certain object is potentially very large, therefore, its accessibility requires that it has to be selected and organized in the form of a given path.

On the other hand, an effective use of CH can be reached taking into account appropriate conditions (perceptual, cognitive, motivational and affective) of personal and active relationship of the subject with the cultural object. This means, i.e., that the mere availability of information relating to a certain cultural object is not enough to ensure its effective use, it must, instead, be complied with certain conditions, such as the ability to access this information at different levels of specialization, different linguistic registers, different cognitive styles, different times etc. and surely the user experience as basic complementary quality of user-centered experience.

Within this field, the user experience, a key issue is related to interaction design as a subject area responsible for designing the user experience of interactive products meant not only as concept that includes only the usability and learnability of the product but also as design driven interactive tools (Beyer and Holzblatt, 1998) able to a more appropriate usability and learnability of the products, but

also able to ensure the pleasure and the aesthetics of interaction, represents a key point in suggesting new ways to support and augment design practice for public spaces, through a tangible interaction. In this area, we highlight that the integration of technological objects and physical objects can foster enjoyment, engagement, and, ultimately, learning, but, most of all, it may promote a variety of social behaviors among visitors interacting together with the hybrid artifact.

The emergence of augmented interfaces for integrating physical and digital interactions bring us towards a combination of search, annotation, and presentation mechanisms afforded by digital content. The concept of tangible interaction is not restricted to the idea of controlling digital data and includes tangible appliances or remote control of the real world (Garzotto and Rizzo, 2007). This approach focuses on designing the interaction itself (instead of the interface) and on exploiting the richness of sharing meaning for social construction of the interaction.

Another relevant factor is the dynamism of the system. The interaction, in case IT-base, should be modified and re-implemented over time, to avoid repetitiveness and quick obsolescence of the experience enjoyment. More generally, the conditions for an effective and aware use are defined in relation to variables that affect both cultural subject and object. Regarding the subject, it must take account of some macroscopic individual variables of learning: the cultural level, the degree of fluency, the preferential mode of reception, the timing of attention etc.; regarding the object, we must take into account: the different degrees of specialization of knowledge available, their different epistemic organization, their different modes of representation, and so on. This means that the degree of effectiveness of a particular interactional *milieu* will be a function of the individual variables and of epistemic variables taken into consideration. In summary, the effectiveness of the use depends on the relationship established between subject and object, and the latter by the ability to design interactional *milieux* able to transpose the variability of individual and epistemic factors in a dynamic form.

## First projects of SCO application to Cultural Heritage

The variety and complexity of issues involved suggests that the transition of the WBCH from inanimate system to SCO requires the development of specific projects, to address the unsolved problems of knowledge creation and management and the formation of participative mechanisms with the final aims of: (a) design of a set of services for small cultural environments today not available; (b) enhancement and valorization of the CH through its extensive communication; (c) conservation of the CH through the use of preventive monitoring techniques.

Specific and innovative features that need to be developed are basically:

- (i) services oriented to different user profiles: e.g. technical managers and tourists;
- (ii) integration of designed systems to the existing structures (e.g. the information systems of public and private conservation institutions, research centers, museums, etc...) and at different scales, from the territorial area (many episodes diffused in a wide area) to the urban context (many episodes concentrated in one city).

From a technological point of view, the purpose is the exploitation of WBCH through the use of ICT and the IoT paradigm in order to connect the CH to the community of 'cultural users'. Our aim is not to give an exhaustive solution but to determine actions for the key area of the process, mainly the use of:

- (a) smart technologies (collection and management, archiving, access, visualization, education, community), which are open-source, if possible;
- (b) bottom-up mechanisms (from citizen to manager) rather than classic top-down mechanisms;
- (c) the same database for any type of user, simply by displaying the database at the correct level of knowledge and detail for the current user, through filtering techniques;

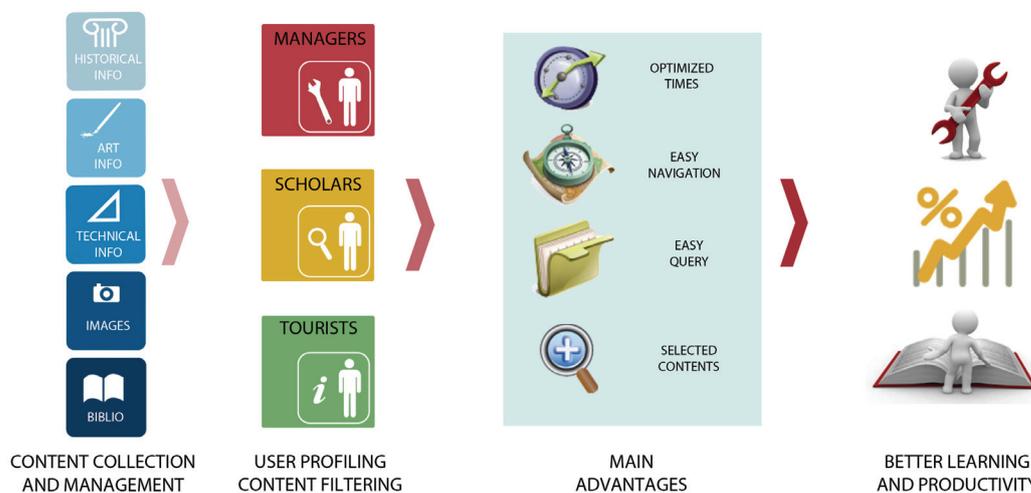


Figure 2. Shared knowledge and bottom to top mechanism for a SCO system.

- (d) education as the main issue in the planning and design of ITC applications;
- (e) smart education processes as engines of professional development.

Within the framework outlined here it is essential, moreover, that the design refers to specific contexts.

Authors recently collaborated on two projects for the system of porticoes of Bologna, which is a case study prototypical of widespread urban CH. The aim of these projects is not only to enhance the arcade as an artifact with great architectural quality, which has become the image of the city over the centuries, but also to enhance the arcade's unique social, communal, anthropological and urban-infrastructural meaning. In this sense, the arcade appears as a complex and supremely representative case of widespread CH for which a project of enhancement and dissemination of knowledge takes a paradigmatic value even in the simplest cases.

Overall, our project intends to undertake two different actions:

(i) construction of an integrated data management system based on the hypothesis of the reuse of the same data for every user, retrievable at the requested level of knowledge and detail. The basis of this framework is the idea that every single citizen could participate in every phase of cultural knowledge and SCO lifecycle: from data

capture to data communication. Our development is, then, based on bottom-up knowledge that exploits participatory mechanisms. This platform will be able to be integrated with the systems in use in the organizations that are responsible for the CH (i.e., IS of public and private institutions, museums, research centers, etc.), with the goal of generating synergies in knowledge creation and process management;

(ii) construction of an educational system for citizens (city-users, tourists, students) and new training tools for the ICT education specific for CH operators usually untrained in ICT applications. CH is characterized by the presence not only of text, but, mainly, 2D and 3D data. Our focus is on 2D and 3D data not usually covered by traditional educational system, mainly devoted to textual application. For this purpose, the construction of the educational system provides three activities: systematization of knowledge and acquisition of research in the field of 3D education, in particular through the identification of key concepts. This process involves learning variables of the subject and epistemic variables of the object from which will depend on the effectiveness of the training solutions adopted; development of a conceptual model of learning in the digital environment specific to 3D learning and calibrated to the different requirements of the users. The development of such a model involves the identification of the

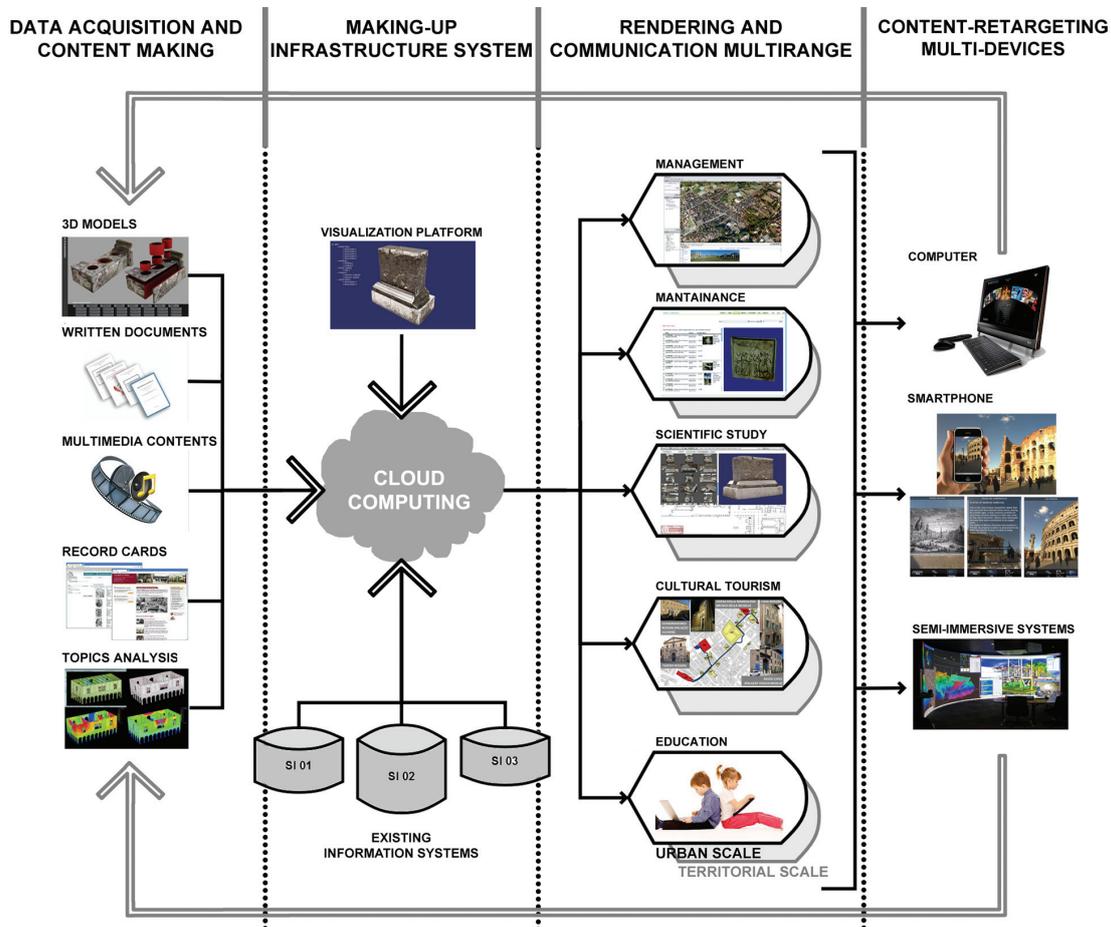


Figure 3. Design of an integrated data management system for a SCO City.

relationship between the effectiveness of the method and its relationship with subjects and objects of learning; establishment of processing evaluation devices for the measurement of effectiveness and assessment for professional skills.

The theoretical and methodological bases of these actions are, principally, in the research areas of strategies and concepts for 3D visualization and navigation. To them is entrusted, among other things, the challenge of defining a set of key concepts, from the most basic to the most complex, the definition of the learning model and its features, and the construction of a framework capable of activating cognitive, management and communication processes in the field of CH. From a technological point of

view, these project aims at merging new web-based communication technological solutions (IoT), at accomplishing an intelligent synthesis of signals and images (smart computing), and at exploiting the use of high-resolution mobile devices with integrated sensors (advanced mobile devices), using these resources for education, participation in knowledge formation, and the use of knowledge. Our solutions, regardless of the purposes for which they are designed to, are based on low-cost and easy-to-use technologies, optimizing the usage of resources and spaces. In this way systems strongly oriented to the modern concept of Open Data will be obtained, particularly to the generation of data available as Open Data/Open Linked Data.

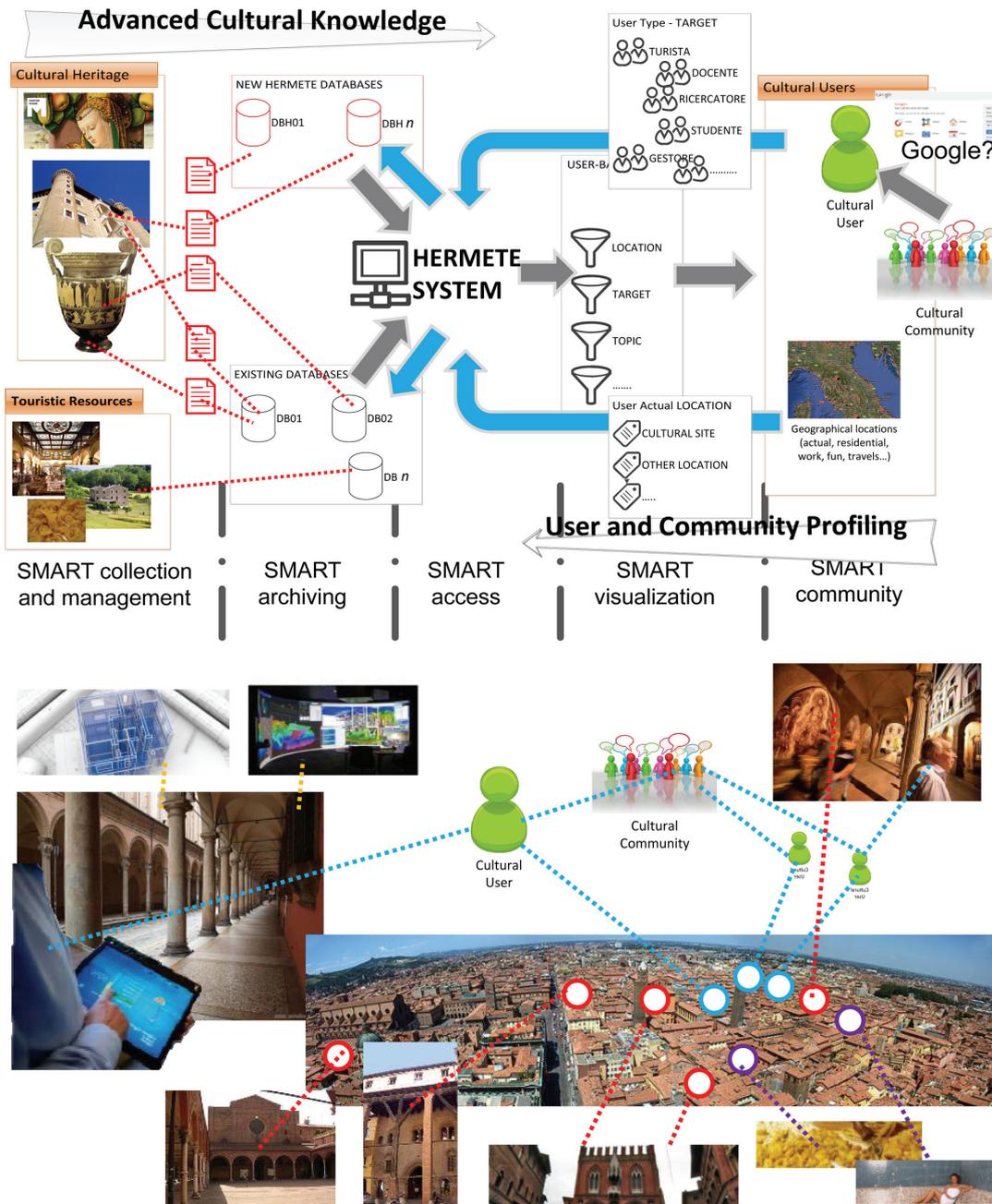


Figure 4. Bologna porticoes SCO system design: relations between management and fruition.

## Conclusions

Thanks to the last evolution of the IT infrastructure assumed as support for the concept of Smart City, it can become the engine for knowledge and conservation of the Built Heritage, allowing the management of a complex and necessarily integrated process that encompasses the entire *lifecycle* of a WBCH: knowledge, exploitation, communication and management. Within this framework, Smart City can be thought as an information and cognitive system, at the same time collector, transmitter and generator of culture. UGC and IoT applied to widespread Built CH allow us to invert the classic mechanism of knowledge acquisition by allowing not only to acquire general knowledge, but also specific and personal knowledge, obtaining two significant impacts: the ability to conceive cultural objects as objects to be interpreted rather than simply as objects to be preserved and protected and the establishment of 'citizens as sensors' thanks to the creation of geo-localized data. Even if some issues need to be still largely investigated, these projects offer huge opportunities for those cities, small or medium, which represent an extremely valuable strategic complement to the traditional cultural and touristic circuits in the main cities of art. These opportunities consist of the provision of a set of services not otherwise available in small cultural environments, the enhancement and valorization of the CH through its extensive promotion, targeted at the potential users and, last but not least, the conservation of the CH through good practices and the use of preventive monitoring techniques.

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