The 12th International Symposium on Virtual Reality, Archaeology and Cultural Heritage VAST (2011)
M. Dellepiane, F. Niccolucci, S. Pena Serna, H. Rushmeier, and L. Van Gool (Editors)

Virtual Heritage in the Cloud: New Perspectives for the Virtual Museum of Bologna

N. Lercari [1] and E. Toffalori[2] and M. Spigarolo[2] and L. Onsurez[1]

[1]University of California, Merced, USA
[2]University of Bologna, Italy

Abstract

This paper focuses on the integration of Cloud computing tools and user-generated content into an online cultural virtual environment. Our investigation aimed to clarify whether the Metaverse can be used as a spatial interface for aggregation and synestetic visualization of heterogeneous cultural data distributed in the Cloud. The case study we adopted is Nu.M.E. 2010 a virtual reconstruction of Piazza di Porta Ravegnana, a crucial area of late medieval Bologna (Italy), published on the platform Second Life (SL). A newfound awareness and appreciation for the new epistemic scenario introduced by Cloud computing and virtualization techniques has raised the following methodological questions: can Cloud computing help optimize the communication strategy and educational effectiveness of cultural data online? Can historical research and cultural data interpretation benefit from collaborative annotation and user-generated content? The described application entailed the use within SL of some of the most popular virtualization services: Google Maps, Panoramio, Google Docs, and Google Warehouse. The results of our testing activity suggest that Cloud services currently available are in fact useful tools for reshaping an online virtual space into an effective collaborative place, allowing users to share content, take an active part in the interpretation process and, most importantly, to provide valid feedback for cultural reception analysis.

Categories and Subject Descriptors (according to ACM CCS): H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces—Computer-Supported cooperative Work

1. Introduction

The Digital Age is currently entering into a new phase in which computing is no longer synonymous with the traditional model of the physical machine that has characterized computer science since the work of Alan Turing. At present a complete redefinition of the Information and Communications Technologies (ICT) has been brought by early technologies: Virtualization, started in the 1970s, and computational models, such as Utility computing, highlighted in the late 1990s. In the world of the global network connectivity a new paradigm is gaining momentum: Cloud computing. This expression basically refers to the use and access to multiple server-based computational resources via a digital network (WAN, Internet connection using the World Wide Web, etc.) without having to care where the resource is located, nor how it will be delivered. Although computer science is mainly fostering Cloud computing solutions solely for specific fields, such as enterprise and large dataset analyses (e.g. Amazon EC2 - aws.amazon.com/ec2), this pervasive paradigm is defining new ways to produce and share information that are suitable for a broader approach. Cloud computing, in fact, enables a type of knowledge construction which is more natural for human beings since it transforms the epistemic process in a collaborative social activity in which individuals play an active role through the Internet.

The effects of the significant change determined by Cloud computing are reshaping the modalities through which companies, institutions, scholars and the general public deal with data and computers. Therefore such a paradigm is gaining in popularity and complexity, and eventually arrived to play a prominent part in contemporary media, conferences and academic debates. For instance new Cloud data storage platforms are being released and broadly adopted at an increasing rate [www.dropbox.com, www.amazon.com/, skydrive.live.com, www.apple.com/icloud/], all Google utility services. This evidence lets us

DOI: 10.2312/VAST/VAST11/153-160

Figure 1: *View of Bologna in Nu.M.E. 2010 in SL.*

infer that in the personal computing devices business, war has been explicitly declared on the desktop file systems [events.apple.com.edgesuite.net/11piubpwiqubf06/event/, gigaom.com/apple/apple-could-kill-the-finder-would-you-miss-it/, newsstream.blogs.cnn.com/2011/06/06/apples-icloud-a-bold-step-but-not-far-enough].

The purpose of this paper is to address the possibilities in knowledge production offered by Cloud Computing, and to highlight the epistemic outcomes entailed in this technological approach, while exploring the great opportunities that it provides to the field of digital humanities. The following methodological questions raised during our investigation: is the Cloud a valid paradigm for re-contextualization of cultural virtual environments? Can Cloud computing tools help optimizing communication strategy and educational effectiveness of cultural data online? Can historic research and cultural data interpretation benefit from collaborative annotation and user-generated content? How can a process of virtualization developed through the Cloud contribute to digital preservation of virtual heritage? While seeking an answer to these instances, this paper discusses the results of the usage of some popular Cloud services within a cultural virtual environment developed in the Metaverse Second Life.

Figure 2: *Reconstruction and iconographical source for daily life scenes in Nu.M.E. 2010*

The case study is *Nu.M.E.* (Nuovo Museo Elettronico della Città) a virtual reconstruction of the early city of Bologna (Italy). More specifically we focused on Piazza di Porta Ravegnana, an area of crucial importance for economic and political power in late medieval Bologna. The implementation of a new version of the *Nu.M.E.* project (named *Nu.M.E. 2010*) gave us the opportunity to put into practice our initial hypothesis on Cloud computing and virtual heritage. *Nu.M.E* is a transdiciplinary initiative involving historiography, computer science, and museum studies. It had been started in the second half of 1990s by Prof. Francesca Bocchi at the Dipartimento di Discipline Storiche, Geografiche e Antropologiche at the University of Bologna. In a time range of more than fifteen years, such a project has pioneered investigation in the digital humanities presenting solutions to several methodological questions derived from the integration of comparative analyses of historical sources, GIS, relational database, 3D real-time visualization and cultural communication [BBG*99].

Figure 3: *The cloth market in 'Piazza di Porta Ravegnana'.*

Since 2008, *Nu.M.E.* has benefited from the contribution of several academic institutions such as University of Bologna, CINECA supercomputing center and the University of California Merced. The collaboration of scholars with different backgrounds and specializations made it possible to achieve new results especially for what concerns the development of novel forms of cultural communication for virtual museums [Ler10a] and the implementation of 3D real-time visualization of historical data through open source technologies [Ler10b]. Using a sources-based approach toward the virtual reconstruction, *Nu.M.E. 2010* analyzed and represented the urban landscape of thirteenth century Piazza di Porta Ravegnana. Medieval monumental buildings, such as Asinelli and Garisenda towers or the Cappelletta della Croce, the surrounding road network (e.g. Strada Maggiore and adjacent streets), and partially covered Aposa creek have been philologically reconstructed in Second Life. In this version of *Nu.M.E.*, our methodology is not only limited to the philological representation of architectural elements. The avatar-based simulation of SL permitted us to recreate medieval daily life scenes in Piazza di Porta Ravegnana, giving users the possibility to embody themselves in digital alter egos and participate to shared experiences of cultural production and reception in the Metaverse. The target audience we address in *Nu.M.E. 2010* is constituted by young students (Junior and Senior high schoolers) and a broad category of visitors interested in the virtual museum of Bologna. To en-

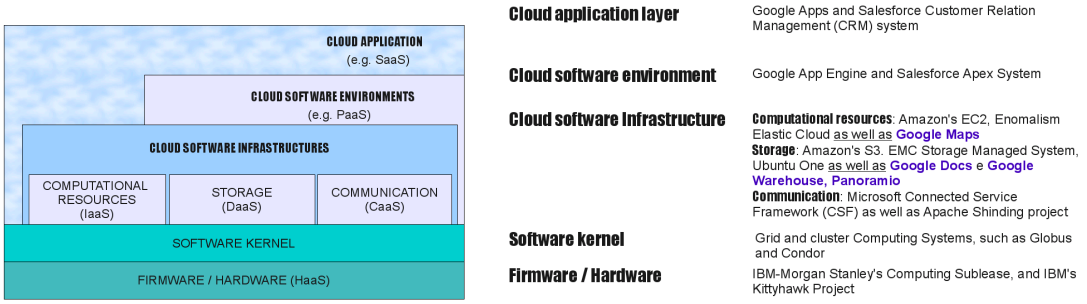

Figure 4: *The cloud computing ontology proposed in [YBDS08] and a summary of examples of some contemporary cloud computing systems, and their prospective classification into the cloud ontology layer proposed.*

large this second category we also include SL users who are fond of cultural contents in the Metaverse.

2. Cloud Computing for cultural heritage and scientific publication

Cloud Computing is an umbrella term which is often used in discordant contexts [Ree09]. It is commonly perceived as a buzzword in that it conveys the idea of something available on the Internet, but that end-users have not to care either where it is physically located, or how it can be reached. On the other hand, Cloud computing is a relatively recent paradigm developed in computer science that enables the possibility to host software and related data as a service and provide it to end-users across the Internet.

For such reasons the expression 'Cloud computing' may signify ambiguity. Generally speaking, Cloud computing is incorrectly used both to refer to geographically distributed data and to the Internet itself. Scientific research, still at an early stage, is trying instead to summarize architectural principles which characterize this paradigm as a unified body of knowledge. The current state-of-the-art lacks in understanding the classification of Cloud systems and their correlation and inter-dependency [YBDS08]. Such a different perception of Cloud computing is probably due to the fact that it is not a new technology, but rather a new operation model that brings together a set of existing technologies [ZCB10].

Scientific research in computer science field is today addressing Cloud computing mainly for developing transactional web applications (i.e. enterprise applications) related to Clouds such as Amazon EC2, as opposed to the social media oriented Google-like Cloud approach. Conversely we believe that computer science should not ignore the empowerment of individuals actively engaged in envisioning a new participatory model for the future of cultural creation (O'Reilly, www.oreillynet.com/lpt/wlg/3017). The concept of computation for computer systems is becoming obsolete. Currently, a computer's behavior is strongly oriented toward social networking (Apache Shinding OpenSocial container, shindig.apache.org). Applications are orchestrated starting from building blocks (e.g. Virtual Machines - VMs), rather than being entirely programmed. Thanks to Virtualization, the concept of the computer system ceases to be physical [DG05].

In computer science, virtualization is traditionally the art of implementing Virtual Machines (VMs). A VM is a software environment which executes other software (either an individual or a full system) in the same manner as the machine for which the software was developed. For instance, a VM appliance maintains the ability of treating application suites as appliances by 'packaging' and running each of them in software environments (VMs) that can be easily migrated and deployed into cross-platform computer systems. This behavior highlights an interesting employment of virtualization and Cloud computing to contribute to digital preservation of virtual heritage initiatives like *Nu.M.E.*. Until a decade ago, VMs were delivered as a minimal VM image. This means that users had to spend time installing programs in the same way they would have done in a real machine. On the contrary a virtual appliance is a VM image which shows a fully pre-installed and pre-configured application and related operating system environment, according to the specific end-users requirements. This feature also defines a new way of deploying network applications. VMware Marketplace (www.vmware.com/appliances) was the first company to offer graphical tools to manage such virtual appliances.

For the above mentioned reasons, a virtual appliance can be suitable for virtual heritage applications in order to store an application (and freeze it) in the environment (a software suite) which is able to run it whenever it is required, as well as to share the same application on the Web without having to care about hardware or software constraints. Complex projects, such as for example *Nu.M.E.*, often make use of different techniques and tools; many of them cannot be executed, compiled or installed on a computer anymore, either because they have been completely redesign, or because they became obsolete over the years. By means of

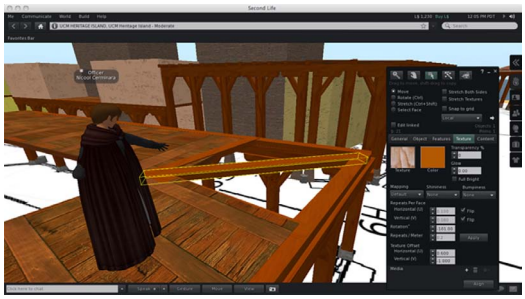

Figure 5: *Historical buildings modeling in Nu.M.E. 2010.*

virtualization techniques, this problem could be solved: by virtualizing the Operating System and the application itself, the software enabling visualization of the virtual museum of Bologna will be operational and available in the future to any device. However virtualization as a cornerstone of digital preservation is not the only point of contact between the concept of Cloud computing and the world of cultural heritage. As far as digital humanities are concerned, scientific papers have been giving some attention to resources networking and Cloud tools in terms of reshaping of social interaction and multi-modal communication [VH07], regarding non-scientific data such as personal memories. On the other hand, the phenomena of cooperative knowledge management and crowd-sourcing have provided data for social and behavioral studies as well as for marketing-related analysis [acm10]. The field of study we are targeting is more specifically the adoption of the Cloud for cultural ePublishing, that is, to make cultural heritage data - and in particular 3D data - available and retrievable on the Web.

At current stage, digital publishing of cultural contents - including 3D - shows some significant trends, such as preference for non-textual interfaces leading to a non-linear browsing design (maps and content aggregators instead of static webpages or documents) [ATP09], resource delocalization (archives, repositories) as opposed to metadata indexing of locally stored collections (databases) [DTT*10], semantic resource description [ND06], [KFH09] and the embedding of "deep" description data [[BBH*10], [MF10], [DLBS*11]], and content design for an increasingly spread access to online information from non-browser applications and mobile devices.

At the same time 3D content accessibility through the Web is advancing at an increasing rate, with a dynamic supply of APIs and visualization plug-ins [en.wikipedia.org/wiki/Web3d], and has witnessed in the last months (2010-11) remarkably innovative examples - mainly WebGL-based - of in-browser enabled 3D view.

Even though scientific metadata repositories and archives do not usually allow for 3D data handling, and cutting-edge 3D model repositories often comply with aesthetic purposes (e.g. 3D artists collections or architectural components) or address highly specialized scientific fields (such as medicine of chemistry), some 3D repositories have been developed specifically for CH, offering interesting opportunities both for scientific dissemination and for communication to the public [e.g. shapes.aim-at-shape.net/, www.3dcoform.eu/, archive.cyark.org/, www.map.archi.fr/nubes/]. These advances allow us to think of 3D data as one of the future formats for interaction with data, archaeological data sharing, storage and publishing through connected networks [Tof10].

In the last years, a certain number of studies in digital heritage have been exploring the integration of archaeological datasets and collections into popular Cloud services [Ash08]. Among these early adopted platforms, as far as 3D data publishing is concerned, primacy goes without any doubt to Google Earth, a virtual geographical information software with strong media and web-content integration, released in 2005, later integrated as a browser plug-in and mobile application (2008). Google Earth has been the subject for both theoretical analysis [Mye10] and case-study applications in digital archaeology [[FAG*08], [AGB10], [BHMS10], [RFF10]]. The reason for this preference is clearly the wide adoption of such platform, that entailed the side effect to made it the first massively diffuse 3D viewer - along with Adobe Acrobat Reader, that supports U3D contents since version 7.0 (2005) - and by far the one with deepest web-content browsing capabilities.

Figure 6: *A detail of the 'Cappelletta della Croce'.*

3. "Mapping" the Cloud in the Metaverse

Fulfilling Marshall McLuhan's prophecy, the Digital Age transformed cultural production into an extensive manifestation of ephemeral information; the bits that propagate horizontally through the electric media [McL64]. In our perspective, the contemporary version of the Internet can be seen as a semi-undefined virtual space in which software, data and services occupy an unspecified place in the end-user perception. From a communication point of view, such a reticular and interconnected set of information can be represented through the metaphor of an immense and shape-shifting cloud. The term Cloud computing itself was, in fact,

inspired by the cloud symbol which usually represents the Internet in flowcharts and diagrams.

For mentioned reasons the epistemic approach proposed in this paper aimed to emancipate cultural communication from the vertical, linear, and passive model introduced by traditional media, such as the Press, Radio and TV through the metaphor of a cloud. At a glance this perspective may entail some downsides such as the great complexity involved in handling such a set of heterogeneous information distributed in the Internet, and the ephemeral nature of the conceptual category that we use to access the knowledge.

Our initial hypothesis was to clarify whether the 3D interactive space typical of an online collaborative virtual environment can be used as a "map" (as a model able to reduce the complexity of vast historical datasets and several geographical services scattered in the Cloud). This would comply with the value attributed by Lev Manovich to the concepts of database and interactive 3D space as new cultural forms [Man01]. We planned to introduce into the cultural Metaverse (representing the late medieval Bologna) a new feature; the possibility for the end-users to access cultural information present on the Internet through a series of browsers mapped on simple, rectangular shapes, metaphorically a set of "maps" dedicated to the interpretation of the Cloud.

A new phase in our research started in the spring 2010 when a new version of the official client needed to access the Metaverse was released (SL viewer 2.0). It was full of useful new functions including an appealing graphical interface and a more realistic lighting and shading (SL viewer 2.4). More specifically we focused on the new available Shared Media function, a feature that allows for mapping of a Web browser window on a basic graphical primitive (prim) (wiki.secondlife.com/wiki/Category:Shared_Media). In our perspective, such a function - bringing the Web into the Metaverse - constituted the enabling technology for integrating the Cloud into this medium. Hence a new stage of *Nu.M.E.* was launched. We started off by offering to the users of our virtual environment the capability to access distributed data in the form of scientific documentation, historical sources, media objects, experiences and additional information. In this preliminary phase, in order to test the convenience of our starting idea, we started by organizing a series of collaborative activities directly in the cultural Metaverse of Bologna. Such operations were made possible via some popular Cloud services: Panoramio, Google Docs, and Google Warehouse. The results of our testing confirmed that currently available Cloud tools are actually valid instruments for virtual heritage. They could, in fact, work together in reshaping an online virtual space representing a medieval city into an effective environment for participatory cultural communication. This is because Cloud services allow users to share contents and historical knowledge, take an active part in the interpretation process of the urban landscape and, most importantly, to provide valid feedback for cultural reception analysis.

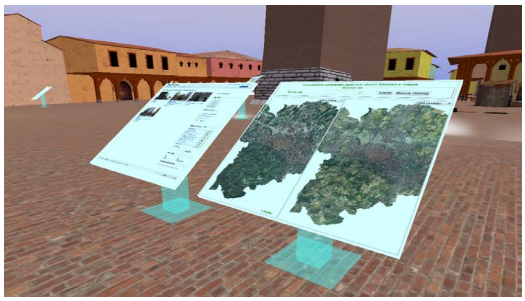

Figure 7: *Shared Media: a browser window mapped on a prim in SL.*

The communicative strategy that we derived from these new features permitted us to improve user experience and collaborative activity of *Nu.M.E.* The employment of user-generated contents and other Web resources, like 3D repositories, directly in the VE, made it possible to define new ways to create and communicate educational contents in a more participatory way. The "map" became interactive. At this stage of the research we received validation for the potential that Cloud computing can adduce to virtual heritage and cultural communication. It became suddenly clear that the Metaverse, as an aggregator of free and interactive 3D contents and cultural information published online, may become a manifold of deep data spread on the Internet. This in turn has become a perfect virtual place in which users can collaborate to the definition of peculiar historical meanings, and eventually a spatial interface for an endless amount of knowledge distributed in the Cloud. The strength of this approach let us to envision a communicative scenario in which new models of interactive digital narratives becomes available, thanks to the creation of a fil rouge among contents available in the Cloud. In contemporary media theories it is possible to identify a phenomenon that presents continuities and analogies to this idea: crossmediality. Such neologism defines a new communicational paradigm that is changing media landscape through the creation of a multi-dimensional narrativity developed through a variety of different devices, languages and communicative contexts [[Jen06], [Gio09], [RR09], [ATP09]]. While a crossmedial narration brings originality and new forms of creativity to the whole media landscape, our perspective on Cloud computing creates new epistemic possibilities to virtual heritage. This because cultural and media contents scattered in the Cloud are too often in the form of unrelated or abstract information that cannot be decoded by the end-user. Through the collaborative process of understanding, developed by users of the Metaverse, such information and data acquire a precise historical meaning and gain an ontological value. Using Lev Manovich theory on new media [Man01], we can therefore conceive the cultural Metaverse of Bologna as a cultural interface for data

and services present in the Cloud that describe the history of this Italian city. Therefore, our investigation permits us to infer that the Metaverse, when enhanced by Cloud computing, is not only an interface for a complex body of information dislocated through the Internet; it also becomes a meta-medium able to communicate a multitude of different and complex cultural meanings present in the global media environment.

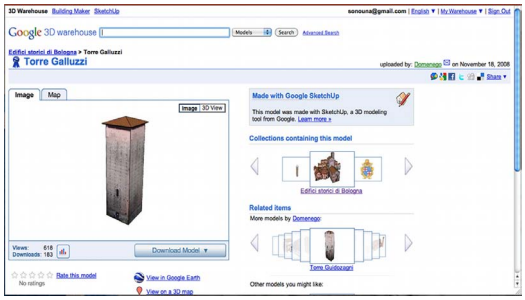

Figure 8: *Interactive 3D models and collections in Google Warehouse.*

4. Implementation: proposed activities for visitors

Based on the preliminary remarks here briefly addressed, we decided to present the users of the Metaverse with three different activities involving social Cloud tools. Such services, being external to Second Life, were made available through the Shared Media feature inside the virtual world. Navigation is constrained within a certain Web domain, and allows login-logout of the user from services without interruption of the browsing experience. This function does have some limitations, but the Second Life interface includes a switch button to external browser navigation, so that any operation not supported within Shared Media can be completed in a standard browser window.

Another tool used for the setup of the simulation is the SL box: a simple prim (in form of a textured cube) that can contain pictures, text or audio data made available to the residents.

I

The first proposed activity is the interaction with a collection of 3D models hosted within the platform Google Warehouse (sketchup.google.com/3dwarehouse/). The 3D models are made available through the browser in COLLADA-based format (Collada and .kmz) and consist in simplified versions of the models that surround the user's avatar in the virtual landscape of *Nu.M.E. 2010*. The interface allows the user to perform a certain number of actions, mainly:

- Download the 3D models (and open them with the Google SketchUp modeling software);
- Visualize the "NuME" collection as well as other related collections of user generated models in which other users decided to include our models (e.g. relative to medieval urbanism, to historical buildings of Bologna, towers architecture, or just personal taste);
- Visualize data regarding the reconstruction process, such as the position of each building on the present-time map (and the correspondent view, through the Google Maps and StreetView engine), descriptive metadata and copyright attribution;

This alternative form of interaction with the 3D environment implies the possibility for the user to:

1. 1.Handle the models (a simplified version) directly, modify them or compare them with others, gaining a deeper understanding of the reconstructed structures;
2. 1.Include the models in new, alternative collections, based on personal criteria, thus attributing them new meanings and highlighting new relations with other similar products;

II

The second proposed interaction, which we pictured as an effective educational activity, is photograph annotation through the web service Panoramio (www.panoramio.com/). A SL box is provided for visitors with pictures showing the current state of the reconstructed area. Textual instructions are also provided, asking the users to look for the corresponding virtual view in the Metaverse and take a snapshot. The interface of Panoramio allows for the following actions:

- View the pictures of the area in the project's profile, positioned in the current view map;
- Upload the snapshot as a personal content on the user's profile together with additional information and tagging;
- Organizing the newly created content in collections and groups, and position it on the integrated map in the corresponding spot;

The intended outcomes for visitors are:

- Be engaged through a game-like activity in the search for correspondences and differences among past and current aspect of the city;
- Take active part in the production of dissemination content related to the project, and have the chance of contributing with a personal interpretation through later use of this content (grouping, tagging, reusing);

III

As a last example use of social Cloud tools inside the Metaverse, we included a panel with a feedback form through which users can provide precious usability and communication feedback that can help us improve the virtual museum

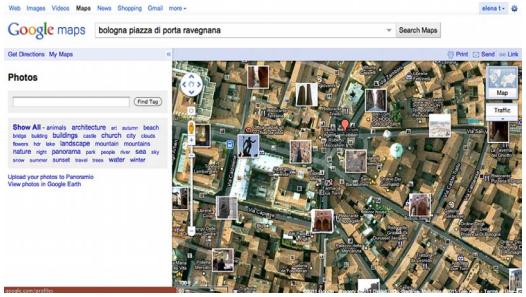

Figure 9: *Picture from the Web service Panoramio positioned on the current map of the area.*

of Bologna, especially for what concerns perceived quality and effectiveness. The form was realized through Google Docs Spreadsheets, published on the web and made available through a third Shared Media browser panel.

The form questions should be carefully chosen in relation to specific purposes and address an effective statistic management of data, for example privileging yes/no questions or limited possible answers, over open and unstructured ones. The results of the feedback campaign in our case will be used for:

1. Optimization of the communication strategy;
2. Planning and usability of the virtual environment;
3. A basic profiling of the involved users;

Other possible applications include for example the possibility for the user to subscribe to information services, get in direct contact with the authors of the virtual reconstruction, and in case of collaborative environments designed for "expert users", even take active part in the decision process of reconstruction.

5. Conclusions

In this paper we have tried to provide the theoretical framework for a fertile integration between Cloud computing and cultural virtual environments, specifically for what concerns virtual museums and education. As is often the case, everything we describe was realized using widespread and freely available Cloud tools, not specifically developed for the needs of cultural heritage.

In our perspective a newfound interest for both the real implementation capabilities offered by Cloud computing and reconfiguration of its cultural value, can bring innovation to the digital humanities as well as to computer science. Such integration can take place in different ways. As an example, Virtualization (i.e. the enabling technology for Cloud computing) and Software as a Service (SaaS), which is the formula usually employed to refer to software in the Cloud, can help digital preservation of virtual heritage products through the possibility of "freezing" an application with its whole operating environment, therefore emancipating it from the obsolescence of its hardware and software components.

Beyond technological aspects, however, since 2010 we have been investigating the cultural value of Cloud computing as a novel paradigm for knowledge construction in the digital humanities. A new opportunity for testing our working hypothesis came about through the technical enhancement of the hosting platform we were using for the virtual museum of Bologna, and was made possible by the widespread availability of novel and powerful Cloud services. Understanding the great potential held within the capability to give access to the Cloud directly from the Metaverse, we setup some example activities to test validness and strength of a new methodology for cultural communication.

Thanks to encouraging preliminary results, we were then able to find further, that building this kind of "mashup" or hybrid Web service - access to the Cloud as an embedded gadget within the Metaverse - is fully aligned with the recent evolution of the Web as a spread repository of data, accessible though various, non browser-centric interfaces. Gadgets, widgets and apps are both available as service containers inside customizable mashup webpages (like iGoogle of Facebook, or virtually any HTML page through the <iframe> tags) or distributed for desktop (e.g. for the MacOS Dashboard or as side apps for the Chrome browser, https://chrome.google.com/webstore) and mobile devices (Smartphones, Tablets, eReaders...), constituting the new generation of containers for networked bits of information.

Even though culturally relevant resources are generally scattered on the Web and grouped by type/media format, we think the Metaverse, with its spatial metaphor, can be an excellent logic framework and an ontological nexus to convey information from the "outside" through this kind of nested access. For instance, a spatial reconstruction of a historical context, designed for collaboration between experts or academic users could provide unified and contextualized visualization of dispersed primary sources, independently of their digital format and hosting platform, grouped around the specific topic that is the subject of study.

Information - in the form of media collections - becomes part of the social media landscape, and is subject to sharing, recombining, and meaning attribution processes from the user community. This collective knowledge management process influences the medium used by freeing it from its representative function and by envisioning a new information aesthetic that entails integration between the Metaverse and the Cloud.

The described scenario suggests that future work in this direction could eventually lead to the possibility for expert users to contribute and modify directly the actual interpretation presented in the virtual environment through the process of collaborative annotation and linking to new sources,

comparisons, and various other information residing in the Cloud. Among our immediate interests for the future is yet another very promising class of applications, (which we mentioned in relation to one of our proposed activities) that is the achievement of valid feedback to be used in cultural reception analysis. We believe specific user-studies for virtual museums, still under development, would benefit strongly from the integration of these newly available mashup tools right inside the virtual environment.

References

[acm10] Comp-you-ter. *XRDS: Crossroads, The ACM Magazine for Students 17*, 2 (2010).

[AGB10] APOLLONIO F. I., GAIANI M., BALDISSINI S.: Architectural 3DModeling for a 3D GISWeb-Based system. In *VAST 2010. The 11th International Symposium on Virtual Reality, Archaeology and Cultural Heritage - Short and Project Papers* (2010), Artusi A., Joly-Parvex M., Lucet G., Ribes A., D. P., (Eds.), pp. 83–86.

[Ash08] ASHLEY M.: Deep thinking in shallow time: Sharing humanity's history in the petabyte age. In *Shared spaces and Open Paths to Cultural Contents* (Athens, 2008).

[ATP09] ASHLEY M., TRINGHAM R., PERLINGIERI C.: Last house on the hill: Digitally remediating data and media for preservation and access. In *Proc. VAST 2009. The 10th International Symposium on Virtual Reality, Archaeology and Cultural Heritage* (2009), pp. 109–116.

[BBG*99] BOCCHI F., BONFIGLI M., GHIZZONI M., SMURRA R., LUGLI F.: The 4d virtual museum of the City of Bologna, Italy. In *Proc. of ACM SIGGRAPH '99* (1999), ACM, pp. 8–11.

[BBH*10] BERNDT R., BUCHGRABER G., HAVEMANN S., SETTGAST V., FELLNER D. W.: A publishing workflow for cultural heritage artifacts from 3d-reconstruction to internet presentation. In *Digital Heritage. Third International Conference, Proc. EuroMed 2010* (2010), Ioannides M., Fellner D., Georgopoulos A., Hadjimitsis D. G., (Eds.), LNCS 6436, Springer-Verlag, pp. 166–178.

[BHMS10] BOSS M., HOCHREUTHER L., MEISTER M., SEILER K.: Ancient sparta in google earth - new perspectives in landscape archeology. In *Fusion of Cultures, Proc. CAA 2010* (2010), Melero F. J., Cano P., Revelles J., (Eds.).

[DG05] DAVOLI R., GOLDWEBER M.: Virtual square in computer science education. In *ITiCSE'05* (2005), pp. 301–305.

[DLBS*11] DE LUCA L., BUSAYARAT C., STEFANI C., VÃL'RON P., FLORENZANO M.: A semantic-based platform for the digital analysis of architectural heritage. *Computers & Graphics 35*, 2 (2011), pp. 227–241.

[DTT*10] DOERR M., TZOMPANAKI K., THEODORIDOU M., GEORGIS C., AXARIDOU A., HAVEMANN S.: A repository for 3D model production and interpretation in culture and beyond. In *VAST 2010. The 11th International Symposium on Virtual Reality, Archaeology and Cultural Heritage* (2010), Artusi A., Joly-Parvex M., Lucet G., Ribes A., Pitzalis D., (Eds.), EUROGRAPHICS, pp. 97–104.

[FAG*08] FRISCHER B., ABERNATHY D., GUIDI G., HOFSTEE P., MEYERS J., MINOR B., MULLER P., SALVEMINI A., THIBODEAU C.: Rome reborn. In *Proc. SIGGRAPH '08* (2008), ACM.

[Gio09] GIOVAGNOLI M.: *Cross-media - Le nuove narrazioni*. Apogeo, Milano, Italy, 2009. p. 63.

[Jen06] JENKINS H.: *Convergence Culture: Where Old and New Media Collide*. NYU Press, New York, NY, USA, 2006. p. 3.

[KFH09] KOLLER D., FRISCHER B., HUMPHREYS G.: Research challenges for digital archives of 3d cultural heritage models. *ACM journal on Computing and Cultural Heritage 2(3)* (2009).

[Ler10a] LERCARI N.: Nuove forme di comunicazione per Nu.M.E. (2010). In *La storia della città per il Museo Virtuale di Bologna. Un decennio di ricerche nel Dottorato di Storia e Informatica*, Bocchi F., Smurra R., (Eds.). Bononia University Press, Bologna, Italy, 2010, pp. 217–225.

[Ler10b] LERCARI N.: An open source approach to cultural heritage: Nu.M.E. project and the virtual reconstruction of Bologna. In *Cyber-Archaeology*, Forte M., (Ed.), BAR. Archeopress, Oxford, UK, 2010.

[Man01] MANOVICH L.: *The language of new media*. Leonardo books. MIT Press, Cambridge, MA, USA, 2001.

[McL64] MCLUHAN M.: *Understanding Media: the Extensions of Man*. McGraw-Hill, New York, NY, USA, 1964. pp. 7–21.

[MF10] MOUSSA W., FRITSCH D.: A simple approach to link 3D photorealistic models with contents of bibliographic repositories. In *Digital Heritage. Third International Conference, Proc. EuroMed 2010* (2010), Ioannides M., Fellner D., Georgopoulos A., Hadjimitsis D. G., (Eds.), LNCS 6436, Springer-Verlag, pp. 482–491.

[Mye10] MYERS A.: Fieldwork in the age of digital reproduction - a review of the potentials and limitations of google earth for archaeologists. *The SAA Archaeological Record* (Sept. 2010), pp. 7–11.

[ND06] NICCOLUCCI F., D'ANDREA A.: An ontology for 3d cultural objects. In *VAST 2006. The 7th International Symposium on Virtual Reality, Archaeology and Cultural Heritage* (2006), EUROGRAPHICS, pp. 203–210.

[Ree09] REESE G.: *Cloud application architectures*. O'Reilly, Sebastopol, CA, USA, 2009.

[RFF10] RAMOS J., FERRE M., FIZ I.: Tarracomap: Development of an archaeological application on google maps navigation system. In *Digital Heritage. Third International Conference EuroMed 2010. Short Papers* (2010), Ioannides M., Fellner D. W., Georgopoulos A., Hadjimitsis D. G., (Eds.), Archaeolingua, pp. 226–229.

[RR09] RESMINI A., ROSATI L.: Information architecture for ubiquitous ecologies. In *Proc. MEDES '09* (New York, NY, USA, 2009), ACM, pp. 29:196–29:199.

[Tof10] TOFFALORI E.: E-Publishing opportunities and 3D repositories for cultural heritage on the web: a state of the art 2010. In *Digital Heritage. Third International Conference EuroMed 2010. Short Papers* (2010), Ioannides M., Fellner D. W., Georgopoulos A., Hadjimitsis D. G., (Eds.), Archaeolingua, pp. 198–204.

[VH07] VAN HOUSE N. A.: Flickr and public Image-Sharing: distant closeness and photo exhibition. In *CHI '07 conference on Human factors in computing systems* (2007), ACM, pp. 2717–2722.

[YBDS08] YOUSEFF L., BUTRICO M., DA SILVA D.: Towards a unified ontology of cloud computing. In *Proc. GCE08* (2008), IEEE.

[ZCB10] ZHANG Q., CHENG L., BOUTABA R.: Cloud computing: state-of-the-art and research challenges. *Journal of Internet Services and Applications 1*, 1 (2010), pp. 7–18.