Towards Modeling of Digital Ecosystems for Cultural Heritage

Danail Dochev[1], Radoslav Pavlov[2], Desislava Paneva-Marinova[2][0000-0001-5998-687X], Lilia Pavlova[3]

[1] Institute of Information and Communication Technologies, Bulgarian Academy of Sciences, 25A, G. Bonchev Str., 1113, Sofia, Bulgaria
[2] Institute of Mathematics and Informatics, Bulgarian Academy of Sciences, 8, G. Bonchev Str., 1113, Sofia, Bulgaria
[3] Laboratory of Telematics, Bulgarian Academy of Sciences, 8, G. Bonchev Str., 1113, Sofia, Bulgaria
dochev@iinf.bas.bg, radko@cc.bas.bg, dessi@cc.bas.bg, pavlova.lilia@gmail.com

Abstract. The aim of the present paper is to give a brief information about the innovative functionalities and potential of the Digital Ecosystems for Cultural Heritage. The main features of digital ecosystems are shortly presented. A brief overview of some recent European projects dedicated to research and development of digital cultural ecosystems sketches their specifics, reveal some common characteristics and some development trends.

Keywords: Digital Ecosystems, Cultural Heritage, Digital Cultural Assets

1 Introduction

In the last decades, the digital ecosystem paradigm is one of the main topics actively analysed by IT researchers and practitioners. The digital ecosystems are meant to connect people, data, processes and things by the shared use of digital platforms. The idea is to create a collection of flexible services that can quickly be adapted to the dynamically changing needs. From the users' point of view, an ecosystem refers to enrichment and more convenient use of different communication channels on which they access and publish content.

The aim of the present paper is to give a glimpse on the innovative functionalities and potential of the Digital Ecosystems for Cultural Heritage concerning digital content production, its management, distribution, aggregation, enrichment and reuse. It addresses wider audience of readers, professionally connected with cultural institutions.

Digital Presentation and Preservation of Cultural and Scientific Heritage. Conference Proceedings. Vol. 9, Sofia, Bulgaria: Institute of Mathematics and Informatics – BAS, 2019. ISSN: 1314-4006, eISSN: 2535-0366

2 Digital Ecosystems Architectures

The metaphor of digital ecosystem was coined in the beginning of XXI century to focus on system properties of self-organisation, scalability and sustainability normally connected with natural ecosystems. The usual definition of a digital ecosystem includes primarily features like sustainability, bounded information asymmetry, risk control and gracious failure. These features are expected to be achieved mainly by self-organization of the digital ecosystem, rather than by achieving explicit design goals as in conventional development of IT systems.

Briscoe and De Wilde (Briscoe & Wilde, 2006) propose the Digital Ecosystem architecture to be regarded as extension of Service-Oriented Architecture (SOAs) with distributed evolutionary computing, allowing services to recombine and evolve over time, constantly seeking to improve their effectiveness for the user base. Individuals within a Digital Ecosystem are applications (groups of services), created in response to user requests by using evolutionary optimisation to aggregate the services.

Digital ecosystems can be regarded as nets underneath the emerging technologies applied in the Digital Platforms — microservices, containerization and serverless computing are all components that fit within specific, decentralized business ecosystems.

Microservice architecture organizes an application as a collection of loosely coupled services. These services should be made as granular as possible to keep relative simplicity within each service module. Monolithic applications locate all their functions in a single structure that is based on a relational database while microservices split individual functions into different containers.

Platform as a service, or PaaS, is cloud computing model that provides users with hosted development kits, database tools, and application management capabilities. In this approach third-party vendors provide users with virtual resources to build, deploy, and launch software applications, thereby reducing the need for back-end software development.

Infrastructure as a service (IaaS), is a cloud computing model that provides users with hosted computing infrastructure. In IaaS model third-party vendors provide users with virtual resources (server space, network connections and IP addresses) to host, build, test, and scale websites and applications. Companies may use IaaS clouds as scalable platforms for new applications or to expand existing applications to larger audiences (Briscoe & Marinos, 2009) (g2crowd learning hub, n.d.).

This type of distributed network allows technologies like blockchain, machine learning as a service (MLaaS) or even internet of things (IoT)-connected devices to exist as components within the ecosystem, leading to more secure and intelligent networks that can be run and managed on third-party platforms.

Extensive usage of artificial intelligence and conversational systems, like messaging platforms and virtual assistants, and including them in a digital ecosystem to enrich the way customers communicate, seems to be main trend in current developments (Hardin, 2018).

3 Ecosystems of Digital Cultural Assets

The paradigm of *ecosystems for digital cultural assets* (also called digital cultural ecosystems, DCEs) appears to respond to the growing willingness to share the wealth of cultural resources and continuous research and study of cultural treasures. These systems virtually assemble various digital collections, archives, virtual museums, digital libraries and cultural heritage sites in order to facilitate the access to their resources, bringing cultural content to new audiences in novel ways (Paneva-Marinova, Pavlov, & Kotuzov, Approach for Analysis and Improved Usage of Digital Cultural Assets for Learning Purposes, 2017).

In nature, an ecosystem is an area where organisms interact with one other as well as with the non-living parts of the environment. In the digital cultural ecosystem, various "digital organisms" (*viz.* collections, archives, virtual museums, digital libraries, cultural heritage site, etc.) also interact with one another as well as with the living part of the environment (*viz.* users). Formally, a digital cultural ecosystem can be huge, covering joint content management systems of one country or a region (similarly to a large forest or lake in the nature), but it can also be small, such as a virtual museum or a private collection of artefacts (the nature analogues: a puddle of water or only a tree). "Digital organisms" "work" through services and tools to satisfy their users. DCEs aggregate heterogeneous resources leaning on interoperability support of its building blocks.

The European activities in this field are promoted and supported by the Horizon 2020 programme of EC H2020-EU.3.6.3. - Reflective societies - cultural heritage and European identity in the priority REFLECTIVE-6-2015 - Innovation ecosystems of digital cultural assets. Activities under this programme aim to:

- "stimulate new research perspectives for the humanities and social science communities, promote further the use of digital cultural heritage allowing its reinterpretation towards the development of a new shared culture in Europe.
- provide innovative and creative methods for approaching cultural assets and generate applications and services to access and exploit the rich and diverse European digital cultural heritage in a sustainable way.
- foster collaboration between those with primary expertise in the interpretation of cultural data and researchers with complementary expertise in digital and interactive frameworks" (European Programme Digital Cultural Assets, n.d.).

In the Bulgarian NSF project "Innovation Ecosystems of Digital Cultural Assets" (CultEcoSys) (CultEcoSys-Project, 2017) we perceive digital libraries (DLs), virtual museums, cultural websites, *etc.* as small ecosystems for digital cultural assets. These environments provide to their users wide range of applicable services and tools for re-using and repurposing digital assets (or objects, DCOs), paving the way for wider exploitation of cultural resources and boosting innovation (Paneva-Marinova & Pavlov, R., 2018). Fig. 1 depicts user's activities for content manipulation in digital cultural ecosystem. Fig. 2 depicts its main content units and flow.

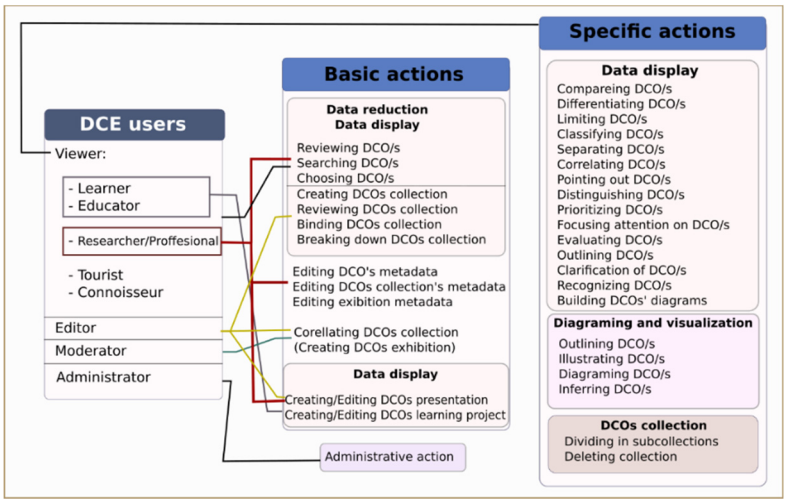

Fig. 1. DCEs user's activities

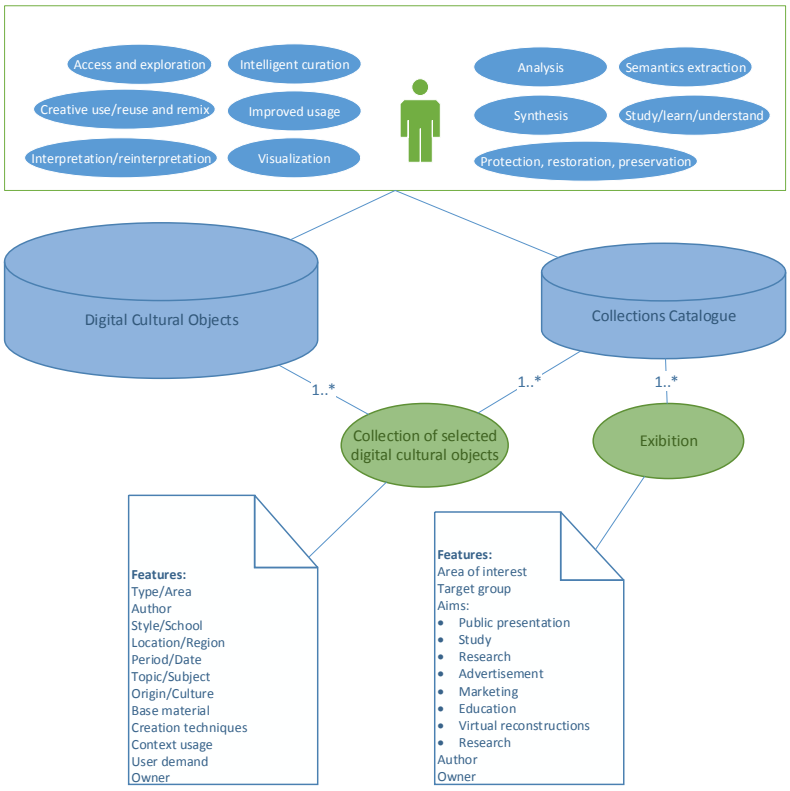

Fig. 2. DCEs content units and flow

4 European Projects Dedicated to Research and Development of Digital Cultural Ecosystems

The aim of the present section is to give a brief overview of some recent European projects dedicated to research and development of digital cultural ecosystems and to sketch their specifics and reveal some common features. The following projects are selected to be regarded as they are to some extent representative for the current state-of-the-art: “Accessible Resources for Cultural Heritage EcoSystems” (ARCHES) (ARCHES, 2016), “Empowering Reuse of Digital Cultural Heritage in Context-aware Crosscuts of European History” (CrossCult) (CROSSCULT, 2016), “Methods for Managing Audiovisual Data” (MeMAD) (MeMAD, n.d.), “Smart Assets for re-Use in Creative Environments” (SAUCE) (SAUCE, n.d.), “Organizing, Promoting and ENabling HEritage Re-use through Inclusion, Technology, Access, Governance and Empowerment” (OpenHeritage) (OpenHeritage, n.d.). They are covered in the table below with brief information about:

- number and national variety of the project partners;
- project main objectives;
- project focus on specific features – specific user groups, given types of digital cultural assets, specific social impact, specific IT methods and tools etc.;
- addressing interoperability among digital collections;
- planned main project results.

Project, period, programme	Partners	Objectives	Focus on	Interoperability among digital collections	Planned results
ARCHES - Accessible Resources for Cultural Heritage EcoSystems. 2016 – 2019 REFLECTIVE-6-2015: Innovation ecosystems of digital cultural assets	12 partners from Austria. UK, Spain, Serbia	Research analysis and development of innovative applications, functionalities and experiences based on reuse and redevelopment of existing digital resources. Scenarios at 6 big museums, engagement with broader audiences (e.g. children, the elderly, other potentially marginalised groups) and extension to other sectors, mainly education and tourism.	More inclusive cultural environments for those with differences and difficulties associated with perception, memory, cognition and communication	Considering the Conceptual Reference Model by the Int. Committee of Documentation of the Int. Council of Museums (CIDOC-CRM), Lightweight Information Describing Objects (LIDO), Europeana Data Model (EDM).	Online accessible software platform, applications for handheld devices and multisensory activities using state of the art technologies (augmented reality, avatars, relief printers and models, context-sensitive tactile audio guides, metadata and advanced image processing techniques)
CrossCult - Empowering reuse of digital cultural heritage in context-aware crosscuts of European history 2016 – 2019 REFLECTIVE-6-2015: Innovation ecosystems of digital cultural assets	10 main partners from Luxembourg, Greece, Spain, France, Italy, UK, Finland, Malta. 10 associated venues and companies	Creating unique cross-border perspectives by connecting existing digital historical resources and by creating new ones through the participation of the public. Providing long-lasting experiences of social learning and entertainment.	Lowering cultural EU barriers. Helping the better understanding and re-interpretation of European history to be understood in a wider context.	General datasets: upper-level ontology for cultural heritage; venue ontology representing the venues experiences, their infrastructure and exhibition characteristics; user ontology for different user modelling approaches; classifications of terms and vocabularies.	CrossCult electronic platform integrating technological modules for: User Profiling; Recommenders; User trackers; Association Discovery; Context Analysis Services; CrossCult Social Networking Services; Visualization and user experience elements.

MeMAD - Methods for Managing Audiovisual Data 2018-2020 HORIZON 2020 ICT	9 partners from Finland, France, UK, Belgium.	Develop novel methods and tools for digital storytelling. Deliver methods and tools to expand the size of media audiences. Develop an improved scientific understanding of multimodal and multilingual media content analysis, linking and consumption. Deliver object models and formal languages, distribution protocols and display tools for enriched audiovisual data.	Media companies that want to utilise automatic content descriptions to help the management of large video collections and enable the reuse and adaptation of previous materials for completely new purposes within the Creative Industries, especially in TV broadcasting and in on-demand media services.	Utilisation of artificial intelligence in the media industry, especially in the description, translation and subtitling of video content. Developing automatic language-based methods for managing, accessing and publishing pre-existing Digital Content.	Planned use cases: Content delivery services for the re-use by end-users/ clients through media indexing and video description. Creation, re-use and re-purposing of the new footage and archived content in digital media production through media indexing and video description. Improving user experience with media enrichment by linking to external resources. Automated subtitling/ captioning and audio description.
SAUCE - Smart Assets for re-Use in Creative Environments 2018-2020 HORIZON 2020 ICT	9 partners from Spain, Germany, UK, Ireland, Czech Republic, Switzerland	To produce, pilot and demonstrate a set of professional tools and techniques that reduce the costs for the production of enhanced digital content for the creative industries by increasing the potential for re-purposing and re-use of content. To develop real-time control systems for authoring animated content using smart	Research and use of new cutting-edge technologies like light-fields to address media production chain steps that lose information (e.g. artistic effects like reduced depth of field and motion blur, or the integration of	Research and develop a framework and tools for automatically classifying, validating and finding smart assets, using deep learning and semantic labelling techniques to describe and draw inferences from two dimensional and three-dimensional data.	Create tools to unlock value in previously-created content by editing or automatically adapting its properties (e.g. appearance, scale, motion) to the current production needs. Create tools to allow content to be more easily re-used and re-purposed, by developing light-field technology for the creative industries in terms of capture, storage, distribution and processing.

		assets, automatically synthesizing new scenes from existing ones and integrating smart assets into virtual production scenarios with editable cameras and lights.	synthetic content into captured natural scenes).	Research and develop a framework and tools for automatic transfor-mation and adaptation of smart assets to new contexts, purposes, users and environments, and for synthesis of new smart assets from existing one.	Create management, animation and production tools to keep digital content accessible, discoverable and malleable by using procedural techniques and high level semantic knowledge.
OpenHeritage – Organizing, Promoting and ENabling HEritage Re-use through Inclusion, Technology, Access, Governance and Empowerment 2018-2022 HORIZON 2020	16 partners from Hungary, UK, Belgium, Austria, Italy, Germany, Spain, Poland, Portugal,	To identify and test the best practices of adaptive heritage re-use in Europe. To develop and test an inclusive governance model and a supporting toolbox for the adaptive re-use of cultural heritage assets.	Creation of sustainable models of heritage asset management by inclusive governance of cultural heritage sites together with development of heritage communities.	The work with existing digital collections is not a specific objective of the project.	Practices – online database of current practices and policies listing national regulations, connecting them with diverse local initiatives, documenting the work in the sites with pictures, videos and a short analysis. Heritage Labs – online platforms to create/ strengthen communities around the Cooperative Heritage Labs (adaptive reuse laboratories of OpenHeritage).

5 Conclusions

As it has to be expected the project specifics (focus on user groups, specific digital assets, specific image processing, diverse communication channels etc.) have substantial influence on the functional requirements, developed architectures and repertoire of offered services.

All recent projects apply modern innovative IT technologies – e.g. virtual and augmented reality, geolocalisation, semantic web instruments, use of Linked Data resources, metadata, avatars, relief printers and models, context-sensitive tactile audio guides, advanced image processing techniques.

Most of the research and development efforts are especially directed to services helping not just to reuse but also to repurpose digital cultural assets for different needs. To ensure such functionalities an advanced digital asset management system is needed, which facilitates secure storage, searchable metadata, file conversions, and easy sharing of digital assets (Holmes, 2018).

Participants in the international projects under consideration are renowned European museums with big volumes of digitized exhibits organized in various digital collections. So special attention is paid on development and practical application of different semantic descriptions, metadata schemes and features extracting mechanisms (ARCHES, D1.2 "Data Management Plan – 1st version", 2017) (CROSSCULT, D2.4 "Refined digital cultural resource data & data structure", 2018) (CROSSCULT, D2.5 "Upper-level Cultural Heritage Ontology", 2018) (MeMED, 2018) (Padfield, Kontiza, Bikakis, & Vlachidis, 2019). The aim is to form a kind of smart search framework to allow third party asset management systems to publish data to the search framework for ingestion, classification, transformation and search. The data architecture of a smart search framework should be extensible and interoperable with third party ontologies and domains to support tagging, classification and reasoning across those domains. This should contribute to achieve "smarter" content by making it fully adaptive: adaptive to context, to purpose, to the user and to the production environment (SAUCE, D4.1 "Smart Search Framework", 2018).

Acknowledgements.

This work is partly supported by the Bulgarian NSF under the research project №DN02/06/15.12.2016 "Concepts and Models for Innovation Ecosystems of Digital Cultural Assets".

References

ARCHES. (2016). *Accessible Resources for Cultural Heritage EcoSystems, project web page*. Retrieved March 20, 2019, from http://arches-project.eu/

ARCHES. (2017). *D1.2 "Data Management Plan – 1st version".*

Briscoe, G., & Marinos, A. (2009). Digital ecosystems in the clouds: towards community cloud computing. *IEEE, (corp. ed.) 2009 3rd IEEE International Conference on Digital Ecosystems and Technologies (DEST 2009)* (pp. 103-108). New York, USA: Institute of Electrical and Electronics Engineers (IEEE).

Briscoe, G., & Wilde, P. D. (2006). Digital Ecosystems: Evolving Service-Oriented Architectures. *IEEE First International Conference on Bio Inspired mOdels of NETwork, Information and Computing Systems (BIONETICS)*. Retrieved from https://arxiv.org/abs/0712.4102

CROSSCULT. (2016). *Empowering reuse of digital cultural heritage in context-aware crosscuts of European history, project web site*. Retrieved March 20, 2019, from http://www.crosscult.eu/

CROSSCULT. (2018). *D2.4 "Refined digital cultural resource data & data structure"*.

CROSSCULT. (2018). *D2.5 "Upper-level Cultural Heritage Ontology"*.

CultEcoSys-Project. (2017). *Concepts and models for innovation ecosystems of digital cultural assets, No. DN02/06/15.12.2016 (project web page)*. Retrieved June 1, 2019, from http://cultecosys.math.bas.bg

European Programme Digital Cultural Assets. (n.d.). Retrieved June 1, 2019, from https://europlan.pixel-online.org/ news.php?id=260

g2crowd learning hub. (n.d.). Retrieved May 10, 2019, from https://learn.g2crowd.com/microservices

Hardin, T. (2018, January 18). *Digital Platform Trends: The Digital Ecosystem*. Retrieved May 20, 2019, from https://learn.g2.com/trends/digital-ecosystem

Holmes, N. (2018). *The Guide to Repurposing Content with Digital Asset Management*. Retrieved June 1, 2019, from https://www.widen.com/blog/the-difference-between-reusing-and-repurposing-digital-assets

MeMAD. (n.d.). *Project "Methods for Managing Audiovisual Data"*. Retrieved June 2019, from https://memad.eu/

MeMED. (2018). *D2.1 "Libraries and tools for multimodal content analysis"*.

OpenHeritage. (n.d.). *Project "Organizing, Promoting and ENabling HEritage Re-use through Inclusion, Tech-nology, Access, Governance and Empowerment"*. Retrieved June 1, 2019, from http://eutropian.org/open-heritage/

Padfield, J., Kontiza, K., Bikakis, A., & Vlachidis, A. (2019). Semantic Representation and Location Provenance of Cultural Heritage Information: the National Gallery Collection in London. *Heritage*, 648-665.

Paneva-Marinova, D., & Pavlov, R. (2018). Improving Learner Experience within Educational Nooks in Digital Libraries. In I. Bouchrika , N. Harrati, & P. Vu, *Learner Experience and Usability in Online Education* (pp. 174-193). Hershey, PA, USA: IGI Global.

Paneva-Marinova, D., Pavlov, R., & Kotuzov, N. (2017). Approach for Analysis and Improved Usage of Digital Cultural Assets for Learning Purposes. *International journal "Cybernetics and Information Technologies", 17*(3), 140-151.

SAUCE. (2018). *D4.1 "Smart Search Framework"*.

SAUCE. (n.d.). *Project "Smart Assets for re-Use in Creative Environments"*. Retrieved June 1, 2019, from https://www.sauceproject.eu/

Received: June 10 2019
Reviewed: June 30, 2019
Finally Accepted: July 10, 2019