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Describing, Comparing and Analysing Digital Urban Heritage Tools: A Methodology Designed with a Multidisciplinary Approach

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Abstract: Urban cultural heritage is taking full advantage of digital technologies. This can be seen in the great number of digital tools for representing and interacting with cultural heritage (digital urban heritage tools) that are intended for the public or designed in the context of research programs and dedicated to a more limited public. These tools do not only display heritage, but also permit interaction with it, even allowing users to contribute with their own data (knowledge, memories, documents, questions, etc.). In this article, we present and apply a methodology for describing, analysing and comparing these tools. After observing the lack of such a methodology, we built DHAL (Digital urban Heritage tools AnaLysis). This methodology allows for qualitative and multidisciplinary analysis of digital urban heritage tools that combine at least two of the following aspects: digital representation of the city, multimedia data documenting the city and its heritage, and participatory functionalities for adding to the digital city. Firstly, we introduce the methodology and the process established for building it. We then show its application, usefulness and full potential in the context our project (Fab-Pat) by testing it on twelve tools. This implementation - one possible among others - allows the positioning of the Fab-Pat tool among similar tools and a detailed description of them. We conclude with a discussion of the methodology's advantages and potential avenues for future developments.

Keywords: Digital Heritage; Urban Cultural Heritage; Multidisciplinary; Analysis; Methodology; Citizen Participation

1 INTRODUCTION AND RESEARCH AIMS

Can urban cultural heritage become accessible to a wide audience through digital technologies? Today, this is the goal of many digital tools¹ for representing and interacting with cultural heritage. We call them digital urban heritage tools. They share existing knowledge in the form of apps or websites that are accessible to everyone or specific to an audience of specialists. In this way, they allow for understanding and perceiving the city, and, with a diachronic approach, its evolution over time. In some cases, participatory functionalities invite professionals and non-professionals to display what urban cultural heritage is for them, participating in creating new knowledge. These tools take various forms. Some are databases (e.g. Australian Heritage Database²), while others offer types of interaction with data such as virtual tours (e.g. Avignon 3D - Berthelot et al. 2015), and some include participatory functionalities (e.g. Transcribe Bentham - Causer and Wallace 2012, Monuments to the Dead in France and Belgium³).

Given this wide diversity, constructive critical analyses have to be conducted in order to describe and compare existing tools, to suggest avenues for improvement of the functionalities they already offer, or to create new ones. An increasing number of research on social media and crowdsourcing in the cultural heritage domain are already enrolled in this challenge (Giaccardi 2012, Carletti et al. 2013). However, there is a lack of systematic methodological approach allowing to convey such analyses, especially qualitative ones. Then, how should we describe, compare and analyse digital urban heritage tools in a qualitative frame? Our research aim in this paper is to propose a scientific methodology that is:

- **systematic**, based on a structured group of terms allowing for a comparison that is as objective as possible;
- **qualitative**, in order to highlight the advantages, disadvantages and avenues for improvement of the tools;
- **multidisciplinary** and therefore multi-viewpoint, for proposing thorough analyses of these tools that involve several disciplines, for instance computer sciences and social sciences.

Such a methodology moreover meets the scope of heritage studies. It is particularly relevant given the recent standard-setting documents issued by UNESCO (Convention for the Safeguarding of the Intangible Cultural Heritage in 2003, Recommendation on historic urban landscape in 2011) and by the Council of Europe (Malta Convention in 1992, Faro Convention in 2005). These documents put to the fore the inclusion and the participation of local populations and heritage communities, a better knowledge and management of heritage, or the innovation and use of digital tools designed for local contexts but reproducible anywhere in the aim of comparison. These digital tools are supposed to capture both tangible and intangible aspects of cultural heritage, and to go beyond the AHD⁴ (Smith 2006) by including any kind of cultural heritage, be it official or not. While several scholars have already studied the impacts of such international documents on specific elements of heritage

¹ These tools are arrangements of heterogeneous components (technologies, objects, people, methods, practices, etc.) that involve norms and rely on the ability of people to act (Marszolek 2005; Diaz-Bone 2017).

² <http://www.environment.gov.au/cgi-bin/ahdb/search.pl> [Last accessed: 07/2019]

³ <https://monumentsmorts.univ-lille.fr/> [Last accessed: 07/2019]

⁴ This is the dominant discourse in the variety of discourses on heritage. Stemming from the Western world, it is a professional discourse that creates a hierarchy of values attributed to heritage, defines what heritage is according to standardized procedures (especially creating lists), and distinguishes good and bad heritage practices. UNESCO and ICOMOS, as well as many national institutions, express this discourse.

(Garduño Freeman 2018), there is no methodology allowing the description and comparison of tools, and hence their potential to meet the aims proposed in these documents. How do they articulate digital representation of cities, multimedia data and participatory functionalities? Do these tools really implement citizen participation?

Although we do not address all these questions in this article, we propose a methodology that could help in answering them. We more particularly focus on tools that combine at least two of the three following aspects: **digital representation of the city** (e.g. maps, 3D modelling, etc.), **multimedia data** (textual data, audio stories, images, videos, etc.) documenting the city and its heritage, and **participatory functionalities** (comments, forums, submission of multimedia, etc.). These aspects are indeed present in many digital urban heritage tools. In addition, they match the recent standard-setting documents which combine urban heritage, cultural heritage documentation and citizen participation.

In this paper, we firstly examine the existing methods of analysing and comparing digital urban heritage tools. Then we present the process of constructing the methodology DHAL (Digital urban Heritage tools Analysis) (section 3.1) before discussing the methodology itself (section 3.2). After that, we propose an implementation of DHAL exemplified on twelve tools (section 4). In this section, we highlight the benefit of this methodology to conduct qualitative analyses on digital urban heritage tools. Finally, we discuss the methodology to point out its advantages and possible future avenues for improvement in section 5 and we finish with an overall conclusion in section 6.

2 STATE OF THE ART

Several methodologies allowing for the analysis and comparison of digital tools have been proposed in recent years. Alatalo *et al.* (2017) compare 3D web applications for participatory urban planning. Their analysis is based on elements related to technological performance (rendering performance, bandwidth needs, etc.) but also on qualitative elements based on the user experience (ergonomics, response time, etc.). The U_CODE research project (Münster *et al.* 2017) propose a searchable database to analyse thirty participatory urban planning projects conducted by local authorities. Farkas (2017) focuses on web-mapping open-source software libraries for creating GIS web clients. He proposes a method of comparing and analysing these software libraries using metrics. Noordegraaf *et al.* (2014) compare and evaluate crowdsourcing platforms developed by heritage institutions. Ginzarly *et al.* (2018) analyse photos on Flickr to identify the way in which users (residents and tourists) perceive heritage at the city scale.

These methods have the advantage of offering relevant approaches, criteria and indicators. However, they are focused on types of tools that are more specific than those we want to analyse: participatory urban planning (Alatalo *et al.* 2017; Münster *et al.* 2017), web-mapping (Farkas 2017), crowdsourcing (Carletti *et al.* 2013; Noordegraaf *et al.* 2014), digital tools for citizen heritage (Lewi *et al.* 2016), 3D reconstitution (Münster *et al.* 2016) and urban landscapes (Ginzarly *et al.* 2018). Moreover, these methods often stem from the questioning of a single discipline, whereas, following the recommendations of Münster *et al.* (2016), a multidisciplinary approach is needed in order to offer a more comprehensive analysis. Finally, our goal is to propose a qualitative analysis, whereas most of these methods have the goal of rating tools in order to classify them or to create typologies based on comparing them.

Several typologies have been proposed for analysing and classifying participatory digital tools. They reveal that certain indicators are interdependent, such as the choice of tasks and the type of

moderation (Lewi et al. 2016). They also offer a categorisation according to specific entries. For example, the typology of participatory projects by cultural institutions developed by Oomen and Aroyo (2011) contains four categories based on the tasks proposed to contributors (correcting, transcribing and contextualising; completing, collecting and categorising; crowdfunding; and curation). Taking the specific case of crowdsourcing, Ridge (2013) deepens these tasks and evaluate them in order to propose a more efficient citizen participation leading to data of better quality. The typology of Lewi et al. (2016) is composed of three categories (curated sites, content-hosting site and social networks) based on the contributors' involvement in the functioning of the tool. Wiggins and Crowston (2010, 2014) are the only ones who propose a very complete typology of citizen science projects - be they digital or not. However, the typologies are relative to a specific type of tools that are unconnected to digital heritage.

This examination of existing methods shows that each of them can contribute to the collection of indicators that we want to establish. However, none of them is adequate by itself for attaining our objective of **systematic, qualitative, and multidisciplinary analysis** of urban digital heritage tools. In order to meet this need, we present a new methodology in the following sections: DHAL.

3 DHAL, A METHODOLOGY FOR DESCRIBING, ANALYSING AND COMPARING URBAN DIGITAL HERITAGE TOOLS

3.1 METHODOLOGY FOR CONSTRUCTING DHAL

DHAL is made up of a collection of indicators⁵ allowing for the detailed description of tools combining urban data, multimedia data and participatory functionalities (Figure 2). We have grouped these indicators into categories⁶ and sub-categories⁷ that we present in the following sub-section (Table 1). The construction of the indicators and their grouping stems from an iterative process depicted in Figure 1. Four stages compose this process: i. Formalising of indicators, ii. Tests on tools, iii. Comparison with standards and typologies, and iv. Comparison with field work. In order to refine the categories and indicators and to make this integrated approach more consistent and as complete as possible, we have iterated through these stages several times.

⁵ In italic in the following.

⁶ In bold in the following.

⁷ Underlined in the following.

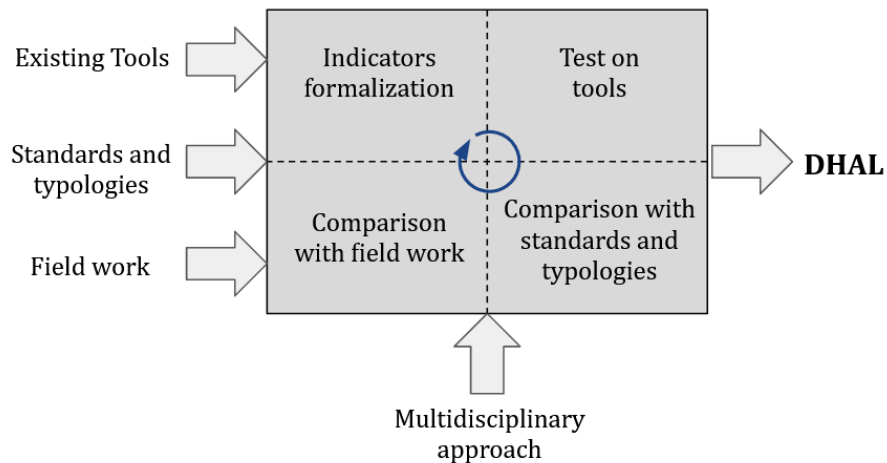


FIGURE 1 - PROCESS OF CREATING DHAL

DHAL’s construction in stages joins several sources. Firstly, it is based on the description and analysis of existing tools. Because of their diversity, they indeed implement many different methods and functionalities. Analysing them hence has a heuristic function for establishing indicators (e.g., *richness of content* presented in detail in section 4) in the objective of proposing a systematic analysis methodology. We selected and analysed fifty-four tools (presented in the appendix) that matched the three aspects of interest (digital representation of the city, multimedia data documenting the city and its heritage, and participatory functionalities). Most of the fifty-four tools have been developed in France. This choice has been made for several reasons. Firstly, our project takes place in France, and we wanted to compare our tool to other existing ones (cf. section 4). We indeed make the hypothesis that participative and heritage traditions vary from one country to another⁸, and then influence the way to implement them in digital tools. However, thirteen of the fifty-four tools are foreign or international, which broadens the scope of our analysis and allows to compare the differences. In addition to have a heuristic function for establishing indicators, this step brought us to generalize and categorise the indicators (Figure 2).

The indicators and categories that emerged with the analysis of existing tools have been seen in the context of existing standards and typologies. A large number of methods indeed rely on description norms and standards such as CIDOC-CRM (Doerr 2003; Araújo *et al.* 2018; Messaoudi *et al.* 2018) and Dublin Core (Weibel 1997; Kakali *et al.* 2007; Samuel 2016). In order to make the analysis of tools easier and to improve interoperability with tools and other analysis methodologies, we made the choice of relying on standards and typologies when possible. In this way, some of DHAL’s indicators stem directly from CIDOC-CRM and Dublin Core or are equivalents found after the fact in these standards (see CIDOC and DC respectively in Figure 2). For instance, we have replaced “temporal dimension” of the urban data with *time-span*⁹ from CIDOC-CRM and “proposed media”

⁸ Several scholars underline the difference between France and Great-Britain in terms of heritage (Vecco 2010; Rautenberg 2012) and citizen participation (Huxley *et al.* 2015).

⁹ See definition of time-span page 26 of the current official version (6.2.3) of CIDOC-CRM, accessible here: http://www.cidoc-crm.org/sites/default/files/2018-05-16%23CIDOC%20CRM_v6.2.3_esIP%28XDP%29%28XM%29.pdf [Last accessed: 07/2019]

with *relation*¹⁰ from Dublin Core. Typologies of citizen science tools allowed us to add indicators such as contributors' *interests and motivations*, the timing of participation (*when*), and certain **objectives** of the tools.

We also carried out a field work (interviews and workshops) among people and organizations involved in cultural heritage (public institutions, local cultural heritage associations and citizens) in Lyon, France. This field work led to the addition of indicators relating to **accessibility and visibility** and to the ways of **contributing content**. Moreover, as the methodology was constructed in an academic setting, it seemed essential to us to focus on the **thoughts on the tool**, whether internal or external, particularly in order to improve it.

Finally, the methodology has been built with a multidisciplinary approach, especially in **computer science** and **social sciences**. We indeed believe it is important to have a multidisciplinary approach in constructing such a methodology as the tools analysed stem from different disciplines and domain of expertise. Hence, certain indicators come from the field of social science, especially those that imply a qualitative investigation of what users do with the tool (e.g. required *skills, modes of resistance*¹¹). Others, such as those related to the content and its mode of representation, come from computer sciences. In a similar fashion, some categories such as **objectives** and **thoughts on the tool** are more related to research issues in the social sciences, while others, such as **content** and **navigation in content** are more related to computer sciences. The confrontation of the disciplines led to refine and harmonize the indicators both at the vocabulary level (discussions on the distinction between information and content, multimedia and data, system and tool, etc.) and at the level of their usefulness (explaining the relevance of certain indicators that were not immediately clear for researchers in another discipline). Thus, in addition to being a methodology, DHAL has a heuristic function in the implementation of scientific plurality and illustrates the need to work conjointly across disciplines.

3.2 PRESENTATION OF THE METHODOLOGY

The methodology DHAL is made up of a collection of indicators that allows users to describe and compare digital urban heritage tools. These indicators stem from the phase of the methodology's construction presented in section 3.1. In order to facilitate understanding and use of DHAL, we have organized these indicators according to seven categories presented and described in Table 1.

The proposed methodology DHAL (containing the categories, sub-categories and indicators) is presented in Figure 2 as a mind map. The mind map format offers both better readability and easier use of DHAL. For example, it allows to describe and analyse systems by navigating in the branches (i.e. the categories and sub-categories) and to omit the branches that correspond to an aspect not managed in the tool being analysed. In this way, in the case of a non-participatory tool, it is possible to remove the branch **contributing content** - i.e. the branch related to describing the participatory aspect of the tools.

¹⁰ <http://dublincore.org/specifications/dublin-core/dcmi-terms/2012-06-14/?v=elements#relation> [Last accessed: 07/2019]

¹¹ Resistance can take the form of not using the tool, misusing it, or not respecting standards and policy charters.

Category of Indicators (7)	Description
General Information	Describing the people involved, the activity period of the tool, the economic model, the type of heritage represented, the theme (urban, architectural, industrial, etc.), the target and actual audience or the impacts and consequences related to the tool.
Objectives	Describing the tool's objectives (promoting, collecting, informing, etc.)
Thoughts on the tool	Describing thoughts on the tool, whether they are academic or professional (internal or external) or participatory (how and at what stages of the project).
Content	Describing urban and multimedia data and any additional content, in terms of type, quantity, spatial and time-span, etc.
Navigation in content	Describing the modes of access to multimedia (presented as a list or as hotspots, organization, display modes) and navigation in data content (spatial, temporal, or thematic). This category also allows for describing possible additional functionalities, such as gamification.
Contributing content	Describing who participates, how (methods implemented for allowing and/or encouraging participation, appropriation of modes of participation by contributors, etc.), when (limited or unlimited duration of participation), and why (interests and motivations for participation). Other indicators address the methods of moderation and indicate the presence of a policy charter for participation.
Visibility and accessibility	Describing the methods established to make the tool visible and accessible. The name of the tool, the indicators relating to media and the press, and the sharing functionalities (the participants sharing their actions) are mainly related to the tool's visibility while the other indicators are related to its accessibility.

TABLE 1 - INDICATOR CATEGORIES AND DESCRIPTIONS

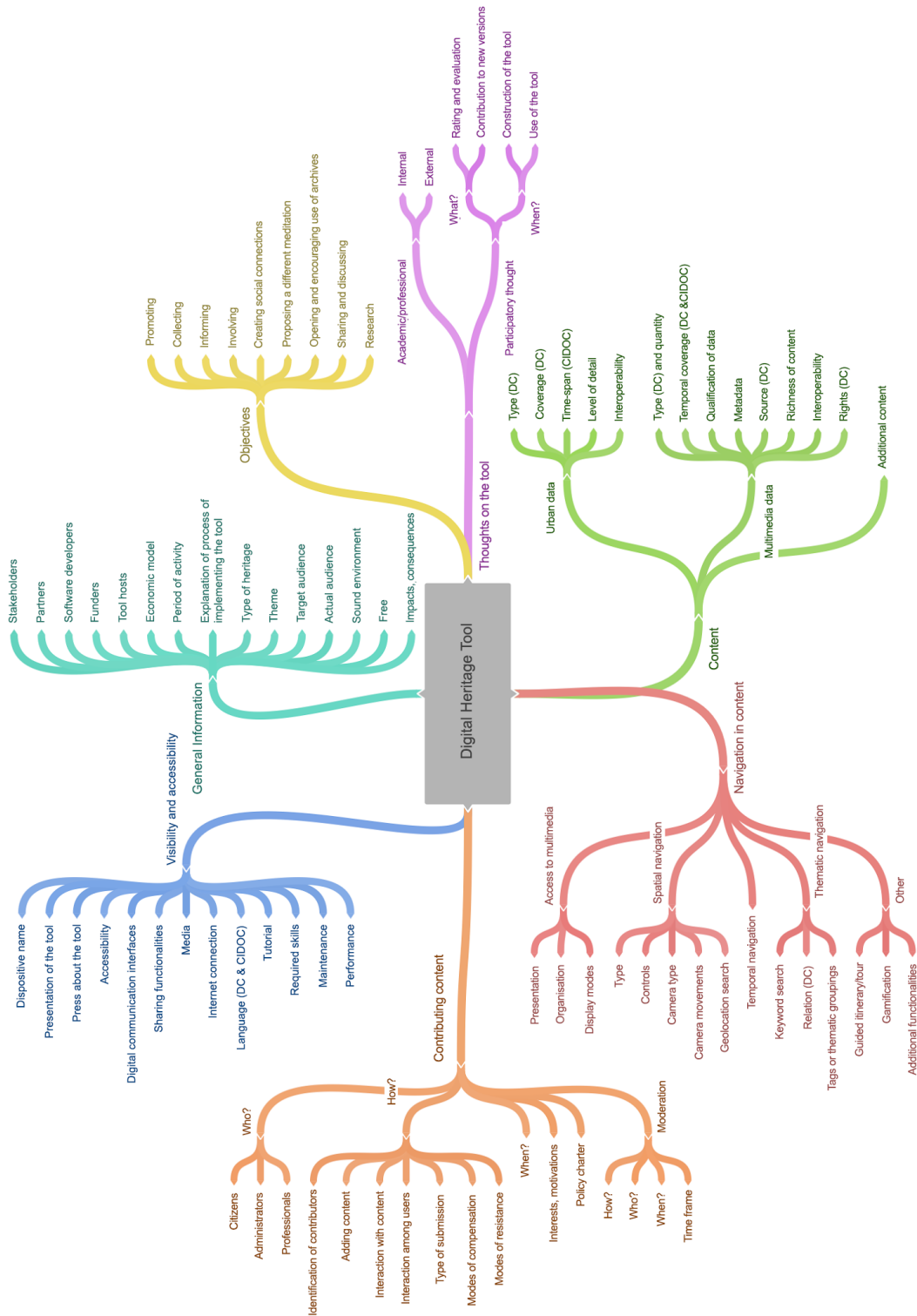


FIGURE 2. REPRESENTATION OF THE METHODOLOGY DHAL AS A MIND MAP MADE UP OF 7 CATEGORIES (BRANCHES) AND INDICATORS (LEAVES). THE TERMS DC AND CIDOC MEAN THAT THE TERM USED FOR THE INDICATOR COMES FROM DUBLIN CORE OR CIDOC-CRM RESPECTIVELY

In the following section, we present a qualitative analysis of twelve tools using DHAL. In the interest of concision, we do not present the analysis according to all the indicators but have selected only some in each category.

4 IMPLEMENTATION OF DHAL

We have chosen to implement DHAL in the context of the Fab-Pat research project¹². This project brings together researchers in both social science and computer sciences along with specialists working in the museums, libraries or heritage offices of the city of Lyon (France). One of the objectives of this project is to propose a digital tool to allow heritage professionals and non-professionals to meet and discuss what Lyon's heritage is. In order to do this, we are developing a tool for representing digital cities in 3D, with a temporal dimension representing its evolution in time, and that can be enhanced with multimedia data documenting the city that can be added in a participatory way. DHAL is of use in the building process of this tool. It indeed allows to assess existing digital urban heritage tools in order to provide insights on functionalities and methods for representing cultural heritage and creating and sharing knowledge.

We selected **twelve** tools to illustrate the implementation of DHAL on this specific use case - the Fab-Pat research project. Our selection was guided by the needs of this project and its main questions - how to articulate urban and multimedia data, how does participation look like in similar tools? For instance, among the twelve tools, five have participatory functionalities. Four are virtual 3D tours that display multimedia objects using various modes of interaction. Six offer geolocation of cultural heritage. As a consequence, analyses arising from the implementation do not pretend to any exhaustiveness nor to reflect the diversity in digital urban tools. In addition, we remind that DHAL is adaptable to the needs and questions of its users. We then only propose one possible implementation on a specific use case, but any user is free to refine the indicators, or to choose other ranges than we did. Section 5 addresses some possible other implementations of DHAL.

The **general information** gives an overview of tools. The twelve tools are available for *free*. They have been *created* between 2003 and 2015. Some of the oldest have been improved through time and according to financing: they added participatory functionalities, they extended their spatial coverage, they developed versions for Smartphones, etc. Except those downloaded on Smartphones, they all need an *Internet access* to be used. In terms of *types of heritage*, most tools present some element of official heritage (AHD) and five present memorial or unofficial heritage. Out of these five tools, one (3¹³) is interested only in unofficial heritage, one (9) only in official heritage and three (10,11,12) are interested in both official and unofficial heritage. It should be noted that the integration of participatory functionalities seems to go hand in hand with openness to less official heritage, either because the desire of the stakeholders is to bring this out, or because this is naturally what the contributors add. Within these types, tools generally present a main *theme*: urban and/or architectural heritage, and archival heritage. We noticed an absence of rural heritage. Finally, the twelve tools involve various actors. There is a wide range of *stakeholders*: associations, local authorities, private digital companies, public organisations, universities and research committees. These are those in charge of a tool. One has to notice that a partnership between a university and

¹² <http://imu.universite-lyon.fr/bilan-2016/fabpat-sharing-the-shaping-of-heritage-approach-and-issues-concerning-the-historical-urban-landscape-hul-2016/> [Last accessed: 07/2019]

¹³ The twelve tools analyzed in this section are numbered in the table of the Appendix.

public organisations - as it is the case for the Fab-Pat project - is not at odd. These stakeholders may develop themselves their tool or they may rely on a service provider to *develop their software* (1,2,4,5,7,9,10,11). Among the four tools involving a university or a research (3,4,8,11), two called upon a service provider for software development (4,11), which implies that no computer science laboratory was involved - contrary to the Fab-Pat project - but that the tool involved only researchers in social sciences fields (which is confirmed by the list of partners). Finally, it should be noted (and verified in considering a larger number of tools) that no tool involving a collaboration between disciplines experienced failure. These stakeholders lastly depend on public *funding* (3,4,5,8,11).

A second category of indicators relates to the **objectives** - which may be numerous - of a tool. In Figure 3, the participatory tools are represented in light grey and the non-participatory tools are represented in black. Objectives indeed take an interesting turn when they are related to the participatory dimension. *Collecting* documents and information is clearly the purpose of participatory tools (3,6,11,12), but they are not limited to this, since they most often also have objectives of *sharing* (3,6,12), *creating social connections* (3,9,12), and *mobilising* users (3,6,12). Non-participatory tools encourage a *different mediation* of heritage (1,2,4,5,7,8) and *opening and encouraging use of archives and heritage* (1,2,7,8). Out of the four tools with a research objective (3,4,8,11), two are participatory (3,11) and two are not (4,8). The latter group mainly aims to compare 3D reconstructions to scientific knowledge. Finally, it is interesting to note (and to identify using DHAL) that a planned objective may not be attained and that an objective that was not initially planned may emerge as the tool is used. For example, a tool that had the objective of *collecting* and *promoting* data can lead to the *creation of social connections* even though this was not one of its initial goals (for instance 11).

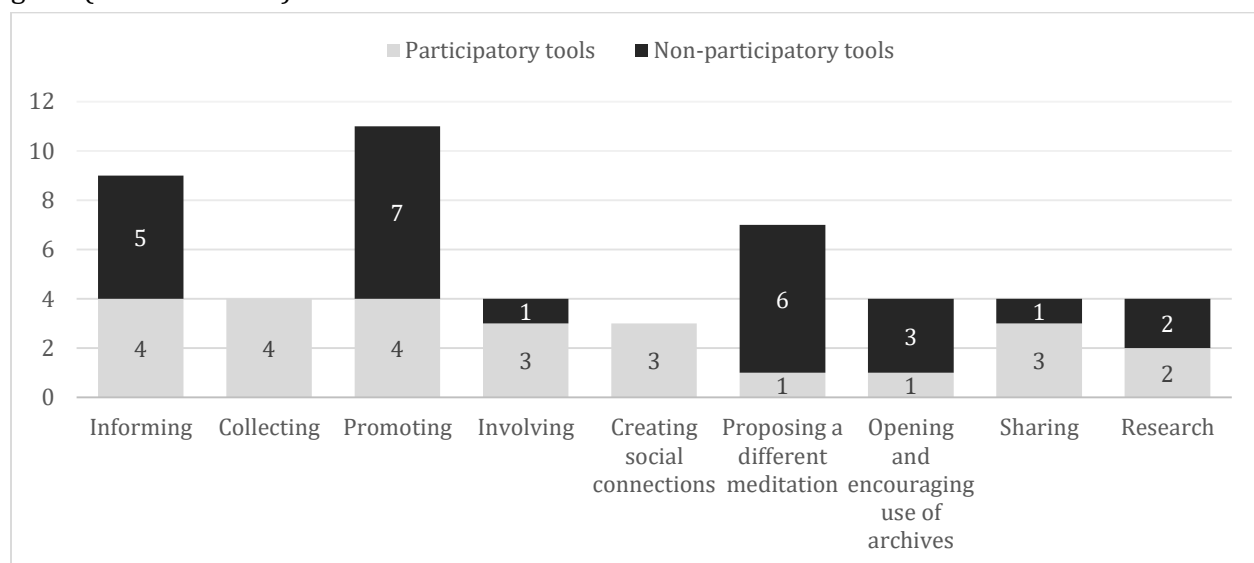


FIGURE 3 - OBJECTIVES OF THE TOOLS. THE PARTICIPATORY TOOLS ARE REPRESENTED IN LIGHT GREY AND THE NON-PARTICIPATORY TOOLS ARE REPRESENTED IN BLACK

The **content** of the tools in terms of urban data can be of different *types*: 2D map (3,5,6,7,8,9,10,11,12), panoramic pictures (1,2,4), or 3D models (2,3,8). It is also interesting to note that some tools offer multiple modes of representation of urban data (3D models and 2D maps, for example) that can serve different uses. For instance, a 3D model for the reconstruction of a monument and a 2D map to specify its geolocation on a larger map. Correlating the *type* and *coverage*

indicators shows that the tools offering a 3D model (2,8) have relatively limited *coverage* (limited to a monument) - while the Fab-Pat tool allows to manage digital 3D models of cities. This mode of representation is especially used for virtual tours of buildings that have been reconstructed in their prior condition. Finally, most tools limit the *time-span* of their digital urban model to a specific year - while the Fab-Pat tool intends to propose a wider time-span with digital modelling of specific states of parts of the city in the past.

Time coverage of multimedia data is however wider, as these data are generally more accessible than 3D models for instance. Moreover, some tools (1,4,6,7,8,10,11) aim to collect these multimedia data related to the past - as it is the case for the Fab-Pat tool. The *metadata* associated with this multimedia vary. One tool (2) offers no metadata, seven (1,3,5,6,7,8,9) offer only three or four (name, date, description, creator), three (4,11,12) add more specific information (architectural movement, date of destruction, conflicts involved) and one (10) leaves the user free to add metadata. In the case of participatory tools, the metadata is generally linked to the mode of participation used. If the submission is open to every contribution, little metadata is required which generally implies that the data will be less structured. Finally, tool can be qualified using the *richness of content* indicator, which is composed of three categories:

- Basic (2,6,9): the content includes text, current photos, and little metadata. Content is presented as photo slideshows and hotspots providing information on points of interest.
- Intermediary (1,3,4,5,7,11,12): in addition to the basic content, there are audio files, archival photos, maps, and a great deal of metadata.
- Advanced (8,10): in addition to the intermediary content, there can be videos, audio-guides with geolocation information, or comic strips. The modes of representation can allow for temporal comparison (comparison of photos of the same area at different dates for instance).

In the category **navigation in content**, *access to multimedia* mainly occurs through a *presentation* in the form of lists (1,3,4,5,6,8,10,11,12) or using geolocation on the tools' urban models (1,2,3,4,6,7,8,9,10,11). Three tools (4,6,7) offer *organisation* by theme or era. *Thematic navigation* of multimedia (e.g. access to medias through semantic information or through common themes) is very frequently present in the twelve tools. Seven of them (3,5,6,9,10,11,12) offer *keyword search* in the title and associated metadata, only two (4,5) contain direct *relations* between multimedia, and six (3,4,6,7,9,10) offer *thematic grouping of multimedia* (e.g. medias related to themes such as architecture, history, etc.). One tool offers adding *tags* defined by users, allowing navigation through the multimedia. *Temporal navigation* in data is rarely possible or is limited to a few dates (1,4,8,12). Only three tools do not propose *spatial navigation*. Other propose *camera* rotations (1,2,4), guided or semi-guided moves (1,3,10) and free moves (6,7,9). Most tools allow a *geolocation search* by clicking on geolocated points of interest. Both spatial and temporal navigation have to be improved - as intended in the Fab-Pat tool - by, for instance, implementing a continuous navigation in urban and multimedia data in space and in time. Finally, four tools (5,8,9,10) offer *gamification* mechanisms. For three of them (5,8,10), this takes place as games (quizzes, etc.) and for the remaining one (9), by mechanisms for participation compensation (change of status, etc.). These mechanisms are all used in participatory tools that have been successful.

In terms of **contributing content**, seven tools are not participatory (1,2,4,5,6,7,8): only the *administrators* can add or modify content. In the five others (3,9,10,11,12), users can also contribute in various ways (Table 2): *adding content*, *interaction with content*, or *interaction among users*.

Contributing content: how		
Adding content	creating a file or a collection	4 (3,10,11,12)
	adding multimedia documents	2 (3,11)
Interaction with content	modifying	1 (12)
	commenting	3 (3,9,10)
	rating	1 (10)
	sharing	1 (9)
Interaction among users	comment tools	4 (3,9,10,12)
	discussion page	1 (12)

TABLE 2 - WAYS OF CONTRIBUTING CONTENT

Additions and interactions occur in following norms. First of all, the five participatory tools require the *identification* of the contributor by signing in (3,9,10,12) or providing an email address (11) when the contribution is made. The contributors only rarely benefit from compensation by a change in status (9). The form of contribution is most often guided - i.e. structured with required fields to fill out (title, description, localisation, etc.) while others are optional (date of construction or modification, architect, etc.). In the case of four tools (3,10,11,12), contributors can get help from a *tutorial* that explains how to contribute, and they must observe a *policy charter* (9,10,12) that regulates, for example, discussion in the comments section. Three tools also have visible *moderation*. In the case of pre-moderation (11), any new content to be added must be validated by administrators before becoming public. It should be noted that the only tool that proposes only adding content, with no possibility of interaction, is also the only one that has pre-moderation. With post-moderation (9,10), content that is not compliant may be removed after having been made public if it is flagged by a user.

Contributors participate only in the context of the use of the tools and not in its construction. However, they can take part in **thoughts on the tool**, either by giving it a *rating* (10), or by making *contributions to new versions* (9,11). In this way, in terms of participatory thinking, elements (particularly blog posts) lead us to believe that discussions took place regarding the use of the tool and that modifications were made following these discussions. *Professional or academic thoughts* concerns only three tools (3,8,11) whose development is accompanied by either scientific papers or a blog managed by academics reporting on the project's progress.

Visibility and accessibility are based on certain characteristics, such as the name of the tool which may or may not facilitate its search engine optimisation. Eight tools have a text with a *presentation of the tool* or even of the project that they are part of. Six (4,6,7,10,11,12) are presented directly on the

tool and two (3,5) on a dedicated website. Most tools are *accessible* from many other sites via links (1,2,3,4,5,7,8,9,10,11). However, only half of them (4,7,9,10,11,12) are associated with other *digital communication interface* such as Facebook, Twitter, or Instagram. Moreover, nine (2,3,4,5,6,7,8,9,11) are accessible in only one *language* (French or English), while three (1,10,12) offer at least two (French, English, German, etc.). Finally, half of the tools (1,3,7,10,11,12) offer a *tutorial* to explain how to use them.

This implementation of DHAL allows to relate the Fab-Pat tool to similar ones in terms of urban data, multimedia data, and participative functionalities. It then underlines specificities of the Fab-Pat tool. For instance, it states its innovative aspect by willing to articulate a 4D (3D and time) digital models of cities, multimedia data related to the past, and the participation of citizens for enhancing the digital model with these multimedia to share and build urban cultural heritage. Moreover, although its community of actors (stakeholders, software developers, funders) and its objectives are by no way new, it is based on an academic multidisciplinary approach going from social sciences to computer sciences, which is not always the case in the tools analysed. It also intends to propose a continuous navigation among urban and multimedia data through time at the scale of a neighbourhood, or a city. A combination of these aspects seems quite new in comparison with the tools analysed. It finally relies on various thoughts, descriptions and comparisons about what works or not in terms of citizen participation, which allows to propose the best participative functionalities. Consequently, this tool could perfectly meet the aims of international documents in terms of citizen participation, development of digital tools, or interest for unofficial heritage.

Beyond its implementation for the Fab-Pat project, DHAL also turns out to be useful in a wider analysis of tools. It indeed shows that aspects not thought when creating a tool can be brought to the fore when using it. For instance, objectives of tools are generally extended depending on the appropriation of the users. Hence, the common computer science approach consisting in proposing adaptable tools based on adjustable software components makes perfect sense. In addition, it sometimes shows lacks regarding some functionalities. For instance, while thematic navigation in multimedia is often managed, spatial and temporal navigation are not always the first concern of administrators while it might enhance possibilities in sharing cultural heritage and knowledge. A possible explanation might be that data is missing or not always available to properly cover these aspects. One might also argue that managing spatial navigation in 3D with a diachronic dimension is still a hot topic of investigation in computer sciences and that it asks for a lot of resources to be implemented.

5 Discussion of DHAL

In addition to DHAL's usefulness for the Fab-Pat project, several advantages emerged during its construction and implementation. First of all, the variety of indicators allows for a thorough and specific view of the tools analysed. The use of DHAL thus leads to an overall view of the tools that is more significant than using typologies and other methods presented in section 2. Next, the analysis can be refined by relating indicators to each other as shown in section 4. For example, it is possible to gather elements regarding a tool's success by comparing indicators such as *target audience* and *actual audience*, by focusing on *impacts and consequences* (e.g. certification, prizes, number of downloads or views, etc.) and, in the case of participatory tools, by looking at the number of multimedia files contributed by users outside the circle of administrators. Finally, formalising the indicators of DHAL allows us to make timely discoveries regarding the functionalities of certain tools.

All these opportunities offered by using DHAL allow for a qualitative analysis of tools, which can help when studying them or when constructing new ones (as in the case of Fab-Pat).

DHAL can also be used to conduct a quantitative analysis of tools. After having defined specific objectives, it is possible to assign a weight to the indicators. For example, the need to find a fun participatory tool can lead to grant more weight to the indicators *gamification*, *mode of compensation*, and *interaction with content*. This use of DHAL allows for rating tools in order to classify them, the highest-ranked being the one that meets the predefined needs the best overall. To go a bit further, it is also possible to make certain indicators (or categories) discriminating. An indicator (category) is discriminating if a tool with a score that is zero or that is below a certain threshold for this indicator (category) therefore receives an overall score of zero so that it is placed at the bottom of the classification. For example, if one of the needs is the participatory aspect, then the category **contributing content** can become discriminating. Thus, if a system has a score of zero for this category, its overall score will be zero. This kind of quantitative analysis can be useful in particular for classifying tools in order to select the one that is most appropriate to specific needs.

A possible improvement concerns defining ranges for the values of indicators. These are indeed defined according to one's specific needs and on the basis of the characteristics of the tools analysed. For example, *coverage* of urban data includes in our case monument, area of a city, city, country, and world. However, this list can create problems. For example, how should we categorise a multi-scale tool that represents both monuments and a city? We made the choice of classifying the tool in the category of the largest area that it represents. This list could also be different for other types of tools, such as those related to rural areas with values such as municipal territory, natural countryside, etc. We hence let the user define its own ranges, based on the explanations and examples given in this article. However, providing some predefined ranges could be an enhancement for the future.

In order to refine the indicators, it may also be relevant to detail those related to *impacts and consequences* (number of downloads, certifications, prizes, user notes) by relying on the metrics proposed by Farkas (2017). We could also detail those related to *interaction among users*: while we have mentioned those that take place online, those that may take place offline or in another digital space are absent. This is also the case for *interaction with content*, which can consist in correcting, transcribing, localising, describing, etc. We did not carry out this subdivision due to our objective of general description of the tools. However, indicators may be refined depending on the type of tools analysed and on specific analysis needs. Hence, DHAL provides structured guidelines in the form of indicators and categories for analysing digital urban cultural heritage with a systematic, qualitative and multidisciplinary approach.

Finally, the implementation of DHAL showed that some indicators might be difficult to fill out. For instance, it is necessary to know well the tools analysed in order to find information about *target audience*, *actual audience*, *modes of resistance*, and *motivations and interests of contributors*¹⁴. One might indeed need to conduct a qualitative investigation of users of the tools to fill out these indicators.

¹⁴ Concerning motivations, we refer readers to the extensive literature on the subject (Coleman et al. 2009; Arends et al. 2012).

6 CONCLUSION

There is a growing number of digital tools for representing and interacting with cultural heritage. The methodology DHAL proposed in this paper contributes in filling a gap for comparing and analysing these tools. Its structuration according to categories and indicators originating from several sources and with multidisciplinary point of views allows for a systematic, qualitative and multidisciplinary approach. It focuses on tools articulating at least one of these aspects: digital representation of cities, multimedia data documenting heritage and participatory functionalities to add multimedia data. This methodology and its multiple uses then fits recommendations made in international standard-setting documents produced by UNESCO or the Council of Europe, and might be useful to implement better citizen participation, better knowledge, and better management of heritage, be it official or not.

We presented one of its possible uses by implementing it on twelve tools selected according to their relevance in the context of the Fab-Pat project. This implementation shows that it is useful for comparing a tool to other existing tools in order to gather information about methods and functionalities allowing for the representation and sharing of cultural heritage knowledge. In addition to allowing relevant qualitative analyses, DHAL also allows for implementing a multidisciplinary approach, both for its creation and for its usage. Finally, it underlines features of tools that are not always thought or that raise issues in computer and/or social sciences, in terms of participation or spatial, temporal and thematic navigation. We believe that these aspects should be further developed in the future in order to better articulate digital representation of cities, multimedia data and participatory functionalities.

If tools could be further developed, so do DHAL. We proposed a version of DHAL with structured guidelines that any user of the methodology can adapt to his objectives. In that way, DHAL is a flexible methodology. Among other, it could be used for quantitative analyses, which we have sketched out in section 5. Finally, it might be interesting to propose an associated software easing the use of DHAL and allowing an automatic comparison of the tools once they have been analysed with DHAL. We then invite researchers in various disciplines, and practitioners, to use DHAL and to improve it according to their needs.

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Appendix: List of 54 tools analysed

The following table lists the tools used for constructing DHAL (section 3.1). The tools in bold are the twelve selected for implementation (section 4).

tools	Place	Description	Link	N°
Chapelle Royale of the Château de Versailles	Versailles, France	Successful virtual tour using 720° panoramic photos	http://www.chapelle.chateauversailles.fr/ [Last accessed: 4/2018]	1
Past virtual tour of the Château de Chenonceau	Chenonceau, France	Virtual tour of the Château de Chenonceau in the past combining 720° panoramic photos with a 3D model	http://www.ecliptique.com/chenonceau/index.html [Last accessed: 4/2018]	2
PastPort	Port Melbourne, Australia	Participatory platform for collecting local history that is geolocated on a map.	http://www.citizenheritage.com/pastport-app/ [Last accessed: 4/2018]	3
Chapelle d'Ecouen/Chantilly	Chapel of the Château d'Ecouen / Chantilly, France	Virtual tour using 3D reconstructions and panoramic photos. Several eras available	http://musee-renaissance.fr/sites/musee-renaissance.fr/files/complement/chapelle/index.html [Last accessed: 4/2018]	4
Industrial Heritage of Lyon	Rhône, Lyon, France	Classical geolocation app for industrial heritage in Lyon	http://patrimoine-industriel-rhone-alpes.in-situ-concept.fr/ [Last accessed: 4/2018]	5
Sites and Cities	Left bank of the Rhône, Lyon, France	Geolocation of architectural heritage of Lyon's left bank on a Google map	https://www.google.com/maps/d/viewer?mid=1EnWlqCH8TRUtWkhfdqnv9navlVU&ll=45.7434189059372%2C4.895138719970646&z=13 [Last accessed: 4/2018]	6
Archivist	Alsace, France	Smartphone app combining geolocation of photos on a 2D map and augmented reality	https://www.facebook.com/larchiviste.eu/ [Last accessed: 4/2018]	7
Avignon 3D app	Avignon, France	3D reconstruction, geolocation, hotspots and augmented reality to reconstruct a damaged site	https://play.google.com/store/apps/details?id=com.gmt.avignon3d&hl=fr [Last accessed: 4/2018]	8

OhAhCheck (recently renamed <i>Sites et Cités Remarquables de France</i> ["remarkable sites and cities of France"])	France	Participatory geolocation app, augmented reality and photo reconnaissance to identify heritage sites in a participatory way. App has not been very successful	http://www.ohahcheck.com/ [Last accessed: 4/2018]	9
Izi.Travel	Large cities, world	Participatory, collaborative platform of audioguides on heritage that has been successful	https://izi.travel/fr [Last accessed: 4/2018]	10
Inventory of Monuments to the Dead	France and Belgium	Participatory inventory underway that has been fairly successful	https://monumentsmorts.univ-lille.fr/ [Last accessed: 4/2018]	11
Archi-Wiki	Strasbourg	Participatory site based on the "wiki" principle (collecting new information, correcting errors, etc.) that has had a little success	http://www.archi-wiki.org/ [Last accessed: 4/2018]	12
Chenonceau, 2D virtual tour	Château de Chenonceau, France	Virtual tour combining 720° photography with geolocation on a 2D map	http://www.podibus.com/Chenonceau_VR/#3 [Last accessed: 4/2018]	
Immersive Journey: The Strasbourg Cathedral	Strasbourg Cathedral, France	Use of virtual reality to promote cultural heritage	http://www.voyageenimmersion.com/ [Last accessed: 4/2018]	
Virtual tour of the Lyon Musée des Beaux-arts	Lyon, France	Virtual tour of a museum in Lyon using 720° panoramic photos	http://www.mba-lyon.fr/mba/sections/fr/musee-beau-art-lyon/visites-360/visites-panoramiques [Last accessed: 4/2018]	
Virtual tour of the Reims Cathedral	Reims, France	Classical virtual tour of a religious site that still exists using 720° panoramic photos	http://www.cathedraledereims.fr/spip.php?article822 [Last accessed: 4/2018]	

Virtual tour of the Abbey Church in Conques	Conques, France	Virtual tour combining 720° photography with geolocation on a 2D map	http://ecliptique.com/conques/ [Last accessed: 4/2018]
Virtual tour of Rodez	Rodez, France	Classical virtual tour with 720° photography used for many heritage sites	http://tourisme.grand-rodez.com/rodez/visites-virtuelles [Last accessed: 4/2018]
Virtual tour of several tourist sites in Lyon	Lyon, France	Typical virtual tours with 360° photography in Lyon	http://www.blog-in-lyon.fr/visite-virtuelle-lyon-decouvrez-lyon-360/ [Last accessed: 4/2018]
Lyon Patrimoine.org	Lyon, France	Virtual tours with 360° panoramic photos, videos of 3D models, documents, and tours of Lyon heritage	http://www.patrimoine-lyon.org/3d-plans-visites [Last accessed: 4/2018]
Versailles, 3D model	Versailles, France	Virtual tour of Versailles at several time periods from 1624 to 2012 using 3D models. Also available as a smartphone app	http://www.versailles3d.com/fr/decouvrez-les-maquettes-3d/ [Last accessed: 4/2018]
3D tours of the gardens of Versailles	Versailles, France	Virtual tour using 3D models of the gardens of Versailles from the early 2010s	http://www.chaostoperfection.com/ [Last accessed: 4/2017]
In the walls of the Casbah	Algiers, Algeria	Successful virtual web-documentary tour	http://casbah.france24.com/ [Last accessed: 4/2018]
Monluc, multiple memories	Lyon, France	(Successful) web-documentary virtual tour attempting to add an (unsuccessful) participatory aspect about Lyon.	http://www.patrimonium.fr/montluc/ [Last accessed: 4/2018]
Goldsmith's Bench	Château d'Ecouen, France	Web-documentary video tour using 3D as well as traditional informational content on a technical subject	http://musee-rennaissance.fr/sites/musee-rennaissance.fr/files/complement/bancdorfevre/index2.html [Last accessed: 4/2018]
MobiTour app	France	Classical geolocation heritage app available for several French cities	http://www.mobitour.fr/ [Last accessed: 4/2018]

Cityscape, architectural heritage	Lyon, France	Classical geolocation app for modern architecture in Lyon	http://cityscape.fr/fr [Last accessed: 4/2018]
citymap2go	World	Tour app for large cities by geolocation of heritage that has had great success around the world	http://www.ulmon.com/#get-the-app [Last accessed: 4/2018]
Heritage tour of La Rochelle	La Rochelle, France	Classical geolocation heritage app	https://play.google.com/store/apps/details?id=fr.larochelle.visitepatrimoine&hl=fr [Last accessed: 4/2018]
Bridges of the Rhône	Lyon, France	Classical geolocation app for the heritage of bridges of the Rhône	http://ponts-rhone-alpes.in-situ-concept.fr/ [Last accessed: 4/2018]
CartoBleuet	Bleuets neighbourhood, Créteil, France	Geolocation of immaterial heritage with the collaboration of neighbourhood residents	http://plaine-centrale.webgeoservices.com/mapviewers/586/?format=browser [Last accessed: 4/2018]
Geocaching	World	Popular worldwide game combining geolocation, research and discovery of heritage	https://play.google.com/store/apps/details?id=com.groundspeak.geocaching.intro&hl=fr [Last accessed: 4/2018]
TerraAdventure	Limousin, France	Use of geocaching by institutions to promote heritage	http://www.terra-aventure.fr/fr/ [Last accessed: 4/2018]
Lyon, 1939-1945: History in the City	Lyon, France	2D geolocation of important events from World War II in Lyon	http://cartes.lyon.fr/1939-1945/ [Last accessed: 4/2018]
Traboules Tour app	Lyon, France	Smartphone app combining geolocation of photos on a 2D map and augmented reality	http://www.traboules-lyon.fr/ [Last accessed: 4/2018]
Perpignan 3D app	Perpignan, France	2D geolocation, augmented reality, 3D models, photos, hotspots, etc. for discovering several sites in Perpignan	https://itunes.apple.com/fr/app/perpignan-3d/id1031634198?mt=8 [Last accessed: 4/2018]

Capture the Museum	Edinburgh Museum, Scotland	Game combining geolocation and augmented reality created by an institution (museum) to promote its collections	http://www.capturethemuseum.com/ [Last accessed: 4/2018]
Random mediation of heritage of southern Paris	Paris, France	Geolocated audio tour where several factors (localisation, speed of movement, path taken, etc.) influence the information provided during the tour	http://www.heritage-experience.fr/ [Last accessed: 4/2018]
Audio tour of the Château de Versailles	Versailles, France	Geolocated audio tours of the Château de Versailles	https://play.google.com/store/apps/details?id=com.sycomore.chat_eaudeversaille.activity&hl=fr [Last accessed: 4/2018]
Audio tour of the gardens of Versailles	Versailles, France	Geolocated audio tours of the gardens of Versailles	https://play.google.com/store/apps/details?id=com.orange.versaillesjardins&hl=fr [Last accessed: 4/2018]
GuidoGo	Europe	Participatory, collaborative platform (mobile app and web) of audioguides on heritage that has been fairly successful in France	https://www.guidigo.com/ [Last accessed: 4/2018]
ASK Brooklyn Museum	Brooklyn Museum, USA	Use of geolocation by a museum to replace the “traditional guide” with audioguides	https://play.google.com/store/apps/details?id=ask.brooklynmuseum.org&hl=frApplication [Last accessed: 4/2018]
Participatory inventory of rammed earth buildings in Lyon	Lyon area	Participatory inventory of buildings made of rammed earth in the Lyon area	http://patrimoine-terre-lyonnais.patrimoineaurhalpin.org/ [Last accessed: 4/2018]
Architectural Inventory of Villeurbanne	Villeurbanne	Participatory inventory underway in Villeurbanne	http://lerize.villeurbanne.fr/vie-du-rize/inventaire-participez/#more-3341 [Last accessed: 4/2018]

Aioli	World	Platform for adding semantic annotation or additional resources (texts, images, videos, etc.) to heritage objects	http://www.aioli.cloud/en/ 4.1.1.1.1 [Last accessed: 4/2018]
Clameur	World	Participatory platform for gathering and sharing material and immaterial heritage that has not been very successful	http://www.clameurs.fr/presentation/ [Last accessed: 4/2018]
Memoirs of the 4th district of Lyon	4th district of Lyon, France	Sharing immaterial heritage through collaborative geolocation of anecdotes in the 4th district of Lyon	https://www.google.com/maps/d/viewer?mid=1qqYjXMmegn-mjMEXuPCnyZjyyPs&ll=45.78063389031291%2C4.819135412658625&z=14 [Last accessed: 4/2018]
Troubadour Story	Lyon, France	Participatory and collaborative platform of geolocated audioguides on the heritage of Lyon that has not been very successful	http://www.troubadourstory.fr/ [Last accessed: 4/2018]
Geolocation of photos of marius.marseille.fr	Marseille and surrounding towns	Geolocation of old photos on a 2D map. Overlay of old maps. Participatory functionalities are planned	http://beaubiat.fr/geolocaliserMarius/#12/43.2967/5.3631 [Last accessed: 4/2018]
Lyon in 1700	Lyon	Faithful 3D reconstruction of the city of Lyon in 1700 with clarification of the process of setting up the tool	http://lyon-en-1700.blogspot.be/ [Last accessed: 4/2018]
Mysteries in Versailles	Versailles	Free geolocated game to explore the Château de Versailles and its gardens in a fun way	https://play.google.com/store/apps/details?id=com.furetcompany.versailles&hl=fr [Last accessed: 4/2018]
Inside the Stones	England	Virtual tours of Stonehenge through classical images or panoramic photos containing hotspots that give access to multimedia (videos, texts, images, etc.)	http://www.english-heritage.org.uk/visit/places/stonehenge/history/stonehenge360/ [Last accessed: 4/2018]

Sondaqui	Aquitaine region, France	Presentation of the immaterial heritage of the Aquitaine region through lists, 2D geolocation and thematic groupings of media	http://www.sondaqui.com/ [Last accessed: 4/2018]	
Survey of London	Neighbourhood of Whitechapel, London	Participatory tool containing a lot of multimedia (photos, text documents, videos, audio, etc.) added by historians, residents and people interested in the location. The documents are geolocated on a 2D map.	https://surveyoflondon.org/ [Last accessed: 4/2018]	