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Usability of Data-Oriented User Interfaces for Cultural Heritage: A Systematic Mapping Study

Maria de la Paz Diulio[1], Juan Cruz Gardey, [2] Analia Gomez[1] and Alejandra Garrido[2]

Abstract

This study surveys the state of the art in usability and user experience strategies applied to applications that deal with large amounts of data in the field of Cultural Heritage, highlighting the most prominent aspects and underlining the under-explored. In these applications, large amounts of data need to be wisely presented to help final users at drawing conclusions and making decisions. While sophisticated technology may be used to improve the user experience, it should not be applied to the detriment of usability, which is critical for the success of these applications. We performed a systematic mapping study to classify the literature retrieved in the four largest scientific databases by a structured search string. We classify applications according to purpose, intended users, the way they address and evaluate UX and usability, among others, and include the analysis of combined results through maps.Findings reveal the contradiction that while most articles are intended for the education and tourism of the general public, only half of the studies evaluate usability. Moreover, there is a significant research gap in user interfaces for systems in the context of preventive conservation, for research, assessment and decision assistance.This is the first systematic mapping study combining usability and Cultural Heritage, especially for data-oriented applications. It shows that more research is necessary to assist conservators and researchers, and to address usability from early stages of development.

Keywords

Usability; User experience; Data intensive applications; Web applications; Preventive conservation

Introduction

The user interface of a software application and the interaction that it provides are the only means by which a person can be successful with the underlying tool and the assistance it is meant to provide. Specifically, the web has become the primary means by which people accomplish their daily-life activities (1) and data intensive applications have risen to help generate new knowledge and make informed decisions (2). During the isolation period caused by COVID-19 pandemic, the only access permitted for non-essential activities like art, historic museums, and Cultural Heritage (CH) Institutions is online, and the communication skills of graphic interfaces unveiled. We are particularly interested in usability as a means to ensure user satisfaction and therefore adoption of applications in the CH domain.

Our interest in the area stems from the objective to construct a web application to assist conservators of CH institutions to perform assessment of their indoor microclimate according to the expected climate target, thus aiming at the preventive conservation of organic materials (3) that we can find in libraries, archives and museums. The main environmental factors affecting conservation are temperature (T) and relative humidity (RH) (4), and the new trend in indoor climate preservation, in contrast with the old school that prescribed rigid parameters, proposes new safety ranges that allow mobile targets for T and RH according to the historic climate of each collection (5; 6). This flexibility is more economical in terms of energy, but since it implies calculating a movable safety band, it is more difficult to assess compliance.

Our current objective is to create a web interface for an application to visualize monitored data in a smart format allowing conservators to make decisions towards the climate target. We are especially interested in ensuring the usability of such interface since the early stages of development, through an effective design that accommodates different user backgrounds, and provides a positive user experience (UX), i.e., allows users to easily and efficiently complete the task, increase intimacy and comfort (7).

With the intention of learning from previous research about different approaches to improving usability and UX in CH systems, we performed a systematic mapping study (SMS) following well-known guidelines for conducting secondary studies in software engineering (8; 9). The purpose of a SMS is to provide a structure of the types of publications that answer specific research questions in an area, by creating a system of categories or map which underlines crowded categories and minorities (9). Our SMS includes 56 studies discussing the user interface of systems in the CH domain that deal with large volumes of data. The research question is stated in general terms as *"What are the main innovations in data-oriented user interfaces for CH*

[1]LAyHS. FAU. UNLP, CONICET. Argentina
[2]LIFIA, FI. UNLP, CONICET. Argentina

Corresponding author:
Maria de la Paz Diulio. Calle 47 n162. CP1900 La Plata. Argentina
Email: mpdiulio@fau.unlp.edu.ar

applications?". This general question is divided into 7 sub-questions with the objective of characterizing the strategies proposed to improve usability and UX in the context of different goals, uses and audiences, the development stage at which these qualities are addressed, and the evaluation method used to validate them. We pay particular attention to systems for preventive conservation. The main findings of the SMS are: the main goal of the research is to improve user interaction through semantic tagging and personalization; the largest group of CH systems is intended for education and tourism for the general public while the smaller set is intended for assessment and decision assistance; half of the studies do not perform any evaluation on usability nor UX; those studies that do evaluate usability do it mostly after system release through user testing; moreover, there is a significant research gap in user interfaces for systems in the context of preventive conservation. To the best of our knowledge, this is the first SMS targeting different strategies for usability in user interfaces for CH.

Background and Related Work

Cultural Heritage provides the sum of tangible and intangible expressions that represent a community. Its preservation is so crucial that different cultures place cultural institutions were created to understand, care, add value, and manage Heritage. Almost every cultural institution has a website to provide information, plan visits or give virtual tours. Even social media can help the institution to hear the voice and engage not only the community, but the staff (10). However, not many institutions allow the user to interact with information, and only a few permit to carry out a task and generate new information, and as the task demands for more interaction, the interface demands better usability performance.

Usability is defined by ISO/IEC 25010 as "the degree to which a product or system can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (11). There is a cultural dimension biasing the effectiveness of usability: users from different cultures, place different weight on effectiveness, efficiency, and user satisfaction (12).

There are several methods to evaluate the usability of a user interface. Inspection methods are performed by usability experts or designers, by reviewing the conformance of the interface with a set of guidelines, or checking the possible occurrence of usability problems based on heuristics. Empirical methods involve real users and the analysis of usage data (13). The most popular is user testing, where a usability expert observes a representative sample of end users while they perform a predefined sequence of tasks with the system, and collects quantitative and qualitative measures (14).

Usability can be addressed in the different stages of the application's development process: right from the beginning before development starts, as advocated by User Centered Design (15) or during design, evaluating interface mockups, during implementation over a prototype, or even after the application has been launched, using the application's production environment.

Before starting the development of our own case study, we performed a secondary study of previous work to learn about the different strategies used for data-oriented applications in CH. There are two kinds of secondary studies: systematic literature reviews (SLR) and systematic mapping studies (SMS). While a SLR provides a comprehensive analysis of the area with respect to the research questions (8), a SMS has been proposed as a more appropriate strategy when the topic is very broad, to provide a course-grained overview with a classification of primary studies (9).

There are several works in the area of usability that use the SLR and SMS strategies. The most significant is the SMS from Fernandez et al. (13), to summarize the knowledge about usability evaluation methods in web applications over the past 14 years. In spite of many authors recognize the importance of including usability as early as possible in software development (16), Fernandez et al. found that 90% of the 206 primary studies performed user testing at the implementation phase. In this line, Ormeño and Panach performed an SMS to identify methods that capture usability requirements, although they found a clear deficiency in available methods and tools (17).

Usability is a valuable quality attribute also among mobile applications. Alturki et al. (18) present a SLR which highlights the most important usability attributes of mobile apps that developers may consider for developing usable applications. Going into domain-specific usability evaluation, Diaz et al. (19) present a SLR about the metrics reported in the literature to assess usability of e-commerce websites in order to understand new aspects of current software categories uncovered by standard methods of quantitative usability assessment.

Approaching the CH area, while it is not a systematic study, Lam and Sajjanhar (20) make a literature review on heuristic evaluation for CH archiving websites' interfaces. They were particularly interested in finding heuristics that may accommodate cultural dimensions in interface design, as well as adaptive websites based on culture and technologies for CH websites' interfaces. We left out of this SMS some articles retrieved by the search string since they do not present a user interface (UI) explicitly. Such is the case of Borgeat et al. (21), Glosiene & Manzhukh (22) and Rizvi et al. (23).

To the best of our knowledge, this work presents an original contribution since we have not found any other SMS or SLR on this particular area. Thus, we trust that this contribution will fill an important gap in the field and be a foundation for future research.

Methodology for the mapping study design

We have performed a SMS following the guidelines provided for conducting secondary studies in software engineering, specifically those by Kitchenham and Charters (8) and Petersen et al. (9). The methodology included three main stages:

- *Definition of research question and study search*: we first stated the research question and sub-questions for the SMS and established the search string accordingly. The search for the same search string was repeated in all selected electronic libraries.
- *Study selection*: after finishing the search, duplicates were removed as well as studies prior to 2003. Then

three authors applied four exclusion criteria, yielding a final number of 56 studies.
- *Data extraction and classification*: data extraction was performed incrementally. This stage included a keywording step to create a classification scheme that fits the population of selected primary studies.

The rest of this section describes the details of the above stages in relation with the research question and search strategy, the criteria for study selection, and the data extraction and classification scheme.

Research question and search strategy

The goal of this work is to analyze the different aspects that researchers underline with respect to the usability of interfaces for CH applications that face challenges with respect to the amount of data to analyze and /or display. This goal may be defined with the following research question:

What are the main innovations in data-oriented user interfaces for CH applications?

The scope of this question includes applications attending different purposes and audiences, developed with the aim of promoting knowledge about valuable goods, as well as assisting the work of conservators, and other uses in CH. Since it is very abstract and involves many concepts, it has been divided into seven research sub-questions. These are:

- **SQ1.-** What is the main goal that the research pretends through the user interface?
- **SQ2.-** What is the potential use of the system?
- **SQ3.-** Who is the intended user of the system?
- **SQ4.-** Is the system intended for preventive conservation?
- **SQ5.-** What is the strategy proposed to improve user experience?
- **SQ6.-** When is usability of the user interface addressed?
- **SQ7.-** How is usability of the user interface evaluated?

We conducted the search strategy on 4 digital libraries containing peer-reviewed scientific literature: Scopus, Science Direct, ACM and IEEE Xplore. The search area was open to articles of any discipline that includes the string concepts, and the search period was set from 2003 to 2018.

The search string was defined three sub-strings: user interfaces, cultural heritage, and data, with the inclusion of alternative terms and synonyms. For instance, the alternative terms for data are those that start with eval like "evaluation" (see Table 1).

Table 1. Search string composition.

Concept	Alternative terms and synonyms	
"user interface"	graphic interface OR mobile app	AND
"cultural heritage"		AND
"data"	eval*	

Criteria for study selection

The total number of studies that matched the search string, after removing 12 duplicate and pre-2003 entries was 113. Then, three of the authors applied four exclusion criteria. The first three criteria to reject studies were straightforward: *i)* all papers written in other language than English; *ii)* all papers that lack of proper methodology, and *iii)* all papers where the full text was unavailable, resulting in 107 articles. Finally, each experimenter applied a fourth exclusion criteria: *iv)* all articles irrelevant for our research question, i.e., those that did not present a user interface for a data-oriented CH system. This criteria is subjective, since to include an article, each experimenter independently read title and abstract (and possibly conclusion) to check if it provided an answer to the research question. Discrepancies were solved by majority of the authors, including discussions in some cases, yielding a final number of 56 selected studies. Additionally, a test to measure consensus was performed. The level of agreement between the authors, and thus, the reliability of inclusion of a candidate study in the SMS, was assessed by applying Fleiss' Kappa: a statistical measure for assessing the reliability of agreement between a fixed number of raters when classifying items. The Fleiss' Kappa obtained was 0.862, which, in the scale (24), indicates an "almost perfect" level of agreement between raters.

Classification scheme

With the purpose of ensuring a solid and coherent classification, firstly two authors, a senior researcher together with a post-doc fellow, performed a pilot data extraction with 10 studies to create a common understanding of the concepts to extract and a raw classification. Secondly, all authors decided on the classification for sub-questions SQ4, SQ6 and SQ7: SQ4 has just a yes/no answer, and the classification for SQ6 and SQ7 was obtained from an SMS on usability evaluation methods (13). Thirdly, we performed a systematic and iterative keywording phase (9). Petersen et al. describe *keywording* as an efficient classification process that ensures that the resulting mapping is representative of the selected studies. To approach this process,we independently extracted keywords from the title and abstract of about a third of the selected studies, in the context of each sub-question. These keywords were then consolidated to create a first classification scheme with the set of possible answers for sub-questions SQ1, SQ2, SQ3 and SQ5. This scheme was later revised and improved while analyzing the other two-thirds of the studies, by merging synonyms into the most frequent terms, adding more general concepts that include specific ones, and removing specifics.

The rest of this section describes the final classification for each research sub-question.

- SQ1.- What is the main goal of the research?
    1. *Improve recommendation*: the system has the capability to personalize the content of the user interface based on users' preferences and their previous behavior within the system.
    2. *Improve interaction*: the goal is to maximize the experience of the user with the cultural heritage artifacts that the system promotes.

3. *Provide repository*: the target is to develop a digital database to preserve cultural historical archives and to provide a broader access to their documents.

- SQ2.-What is the potential use of the system?
  1. *Assessment and decision assistance*: the system may analyze a condition in the user context, on which it may provide judgment, feedback or personalized content.
  2. *Orientation and search*: the system is intended to assist the exploration of large amounts of information about CH items.
  3. *Education and tourism*: the scope of the system is promoting or assisting touristic or learning activities.

- SQ3.- Who is the intended user of the system?
  1. *General public*: the user is not required to have any special trait, profession or type of knowledge.
  2. *Researcher*: the system is intended as a research tool.
  3. *Conservator - Restorer - institutions staff*: the user is concerned with the restoration, cataloging, classification, and other activities related to the conservation of CH artifacts. This category includes museologists, librarians, archivists, conservators, restorers.

- SQ4.- Is the system intended for preventive conservation?
  1. *Yes:* the authors express that the main o secondary objective of the research is the conservation of CH.
  2. *No:* the purpose is oriented to other matters of CH different from conservation, like education or search.

- SQ5.- What is the strategy proposed to improve user experience?
  1. *3D interaction*: the interface permits users to interact with 3D virtual representations of CH artifacts.
  2. *Touchless interaction*: the interface admits other types of interactions that do not require touch or mouse, like gesture-based interaction.
  3. *Augmented reality*: the CH artifacts in the real world are augmented through overlaid computer-generated images enhancing the users' perception, as an immersive aspect of the real environment.
  4. *Semantic tagging*: interfaces where the user may enrich content by labeling elements with some semantic meaning, which is usually applied to improve recommendations. This category also includes works that aim at organizing the CH content in a semantic database.
  5. *Personalization*: the interface is personalized based on users' behavior and contextual data.
  6. *Other*: the strategy for UX is not represented by the above, for example the use of different information-visualization techniques, multimodal interfaces, remote monitoring, etc.
  7. *None*: the study does not propose any improvement to the UX.

- SQ6.- When is usability of the user interface addressed?
  1. *Not addressed*: the research does not consider the usability of the user interface.
  2. *From requirement elicitation*: usability is considered before development starts, as a non-functional requirement of the application to be elicited at the same time and with the same importance as the functional requirements.
  3. *From design stage*: usability considerations appear during the design of the graphical interface, right before implementation.
  4. *At implementation stage*: usability is addressed while the application is being coded.
  5. *After system release*: usability is evaluated after the application has been launched.

- SQ7.- How is usability of the user interface evaluated?
  1. *Not evaluated*: usability has not been considered.
  2. *Heuristic evaluation*: the usability expert or designer analyses the interface looking for well known heuristics that may predict usability problems.
  3. *Cognitive walkthrough*: one or more evaluators work through a series of tasks to analyze the application from the perspective of the user.
  4. *User testing*: an evaluator observes participants interacting with a user interface as they complete a predefined sequence of tasks to detect usability problems.

Results

The search strategy first output 125 studies, from which 12 duplicates were rejected, and another 57 were excluded by applying exclusion criteria, yielding the final 56 studies. Figure 1 shows a Sankey Diagram with the number of studies from each database that were finally included in the results.

The data extraction process created a classification of the studies. Table II shows the number of studies and percentage in each category. The following sub-sections present a qualitative analysis of results for each sub-question in the proposed classification.

Figure 1. Articles retrieved from the four databases are separated in duplicates, excluded, and included studies

Table 2. Results of the systematic mapping

Results	#Studies	(%)
SQ1.- What is the main goal of the research?		
Improve recommendation	16	29%
Improve interaction	27	48%
Provide repository	13	23%
SQ2.- What is the potential use of the system?		
Assessment and decision assistance	10	18%
Orientation and search	16	29%
Education and tourism	30	54%
SQ3.- Who is the intended user of the system?		
General public	39	70%
Researcher	9	16%
Conservator - Restorer - Staff	8	14%
SQ4.- Is the system intended for preventive conservation?		
No	46	82%
Yes	10	18%
SQ5.- What is the strategy proposed to improve user experience?		
3D interaction	6	11%
Touchless interaction	3	5%
Augmented reality	8	14%
Semantic tagging	12	21%
Personalization	11	20%
Other	6	11%
None	10	18%
SQ6.- When is usability of the user interface addressed?		
Not addressed	26	46%
From requirement elicitation	3	5%
From design stage	7	13%
At implementation stage	7	13%
After system release	13	23%
SQ7.- How is usability of the user interface evaluated?		
Not evaluated	27	48%
Heuristic evaluation	6	11%
Cognitive walkthrough	2	4%
User testing	21	38%

Main goal of the research

The first sub-question aims to determine the main goal that the research pretended to achieve through the interface. In this regard, 48% of the articles focus on improving interaction with the CH assets to capture the user's attention. This goal is mainly achieved by incorporating technology in cultural visits, and intensifying the tourist experience through the interface (25; 26; 27; 28; 29; 30; 31; 32; 33; 34; 35). Bernardini et al. (36), Floch (37) and Kim (38) present applications where visitors generate content by adding information. Intangible CH and linguistics are also the subject of several studies (39; 40; 41). Some studies incorporate geo-localization (42; 43; 44).

The second group contains 29% of the articles, which aim to improve recommendations or interpret the user's expectation to provide a better output. Those can be personalized tours according to the user's preferences (45; 46; 47; 7; 48; 49) or users that produce content as a social network for other users (50; 51; 52).

The final 23% is targeted at creating or improving the use of digital repositories, includes contributions that analyze an online exhibition to evaluate its usefulness for educational purposes (53), or repositories to give access to emblem books (54), ancients manuscripts (55) and public cultural archives (56).

Potential use of the system

The larger group, education and tourism includes 54% of the cases. On the education side of the category, Graf et al. (42) interconnects venues, objects and stories to increase learnability in museums. In the same trend, Mikovec et al. (57) uses a serious games platform to acquire, present, interact and educate through CH data. Other interfaces improve education through engaging the users (53; 58). Related to tourism, georeference permit to link narratives and add layers of information on intangible CH (37; 43; 35; 44; 56). We may find interfaces that maximize tourist experiences according to their interests (25; 45; 52; 47; 48; 59; 39) or recreate the historic environment representing the original façades of restored buildings (33; 60).

The category orientation and search assistance, with 28% of the research articles includes interfaces that assist users finding particular items. For example, a service to library users that permits book annotations through a mobile app (30); a help to analyze coin iconography and their chronology and geographic location (61); another one that tests the efficiency and the performance of the search between large display tablets and grouped tablets(62); and some are proposed for the proper retrieval on repositories (26; 63).

Finally, for assessment and decision assistance, the search retrieve 10 articles, 19% of all. The most relevant for our own research is the study by Mecocci & Abrardo (64), as they present an interface to perform long term monitoring of temperature, relative humidity and masonry cracks with remote control. There are also tools to assist specific tasks in archaeology (28) and in virtual restoration through images (65). Two articles devoted to music are: Volioti et al. (66), and Dondi et al. (67), describing a noninvasive spectroscopic analyses of the surface of a musical instrument to determine its history.

Intended user

The largest group is conformed by 39 articles about interfaces intended for the dissemination of CH to the general public. Some authors focus on users with no previous experience (57; 59), provide contextual information to outdoors locations for tourists (68; 45; 48), while others focus on a particular user's age, like school children (39; 69; 53). There are 3 studies about applications for the general public that are intended for preservation of CH; while it sounds odd that the intended users are not conservators, these applications aim at preserving heritage by digitizing and creating online exhibitions or recommending a museum tour to disseminate identity heritage and cultural diversity (53; 39; 69; 53).

There are 9 studies where the intended users are researchers. In this group we may find applications to provide a richer mode of accessing knowledge like through ontology-based information retrieval (70), the exploration of complex databases (28; 71) or specialized search (26; 62). Others are focused on allowing in-depth analysis of CH artifacts like coins located on digital maps (61) or the surface of historical violins (67). Moreover, Martin-Rodilla et al. (72) propose guidelines for rich applications as a solution for the problems emerged in the interaction between humans and data-analysis applications.

The smaller group is for applications devoted to conservators, restorers and institution staff. We are specially interested in these 8 studies since we share the same intended audience on our future endeavor. Half of these studies are intended for preservation (73; 64; 55; 40). In the case of Mecocci and Abrardo (64), mentioned before, unfortunately did not report on any usability evaluation. The only case that presents a usability evaluation is the study of Tranouez et al. (55), which shows results of an early user test with historians and librarians. From the other 4 studies not intended for preservation, we highlight the work of Hildebrand et al. (63), aimed at improving the cataloguing stage of museum professionals with an enriched vocabulary, as the only one that presents a usability evaluation (user testing).

Systems oriented towards preventive conservation

The results for this subquestion revealed that 82% of the studies showed interfaces that were not intended for preventive conservation of CH. The remaining 18% are fundamentally related to preserve fragile original valuable pieces by digitalization (28; 54; 55; 53; 40). Besides, some of them are more related to our own research on monitoring environmental variables (64). There is also a mobile application to assist historic building inspection and damage identification (73). Finally, the use of spectroscopy is applied to analyze musical instruments' surface (67).

Strategy proposed to improve the user experience

The goal of this sub-question is to determine the method or the technology presented by the research article to improve the UX. The majority of the articles (21%) propose certain semantic organisation of the CH information to help people find what they are looking for. In many of these works (58; 63; 70; 7) ontologies and others structures are used to standardize the information to highlight historical and cultural associations (26; 58; 55), and to generate recommendations (50; 52; 7). The aggregation of digital archives with its geospatial information is also proposed (59; 56).

The second largest group contains 20% of the articles, which are focused on the adaptation of the content based on the users' preferences or interests. There are works that get the users' feedback either explicitly through questionnaires (47) or by automatically observing their behaviour (46; 71; 74), to create personalized content that users may find interesting. This group also includes works that let the end-users personalize the content on their own. Examples of these works are customizable user interfaces to explore digital archives (75), and frameworks to augment environments (51), and to allow CH professionals to design content-rich websites (29).

Another set of articles (14%) strive for the introduction of augmented reality (AR), which range from personalized electronic guides for visitors through different reconstructed archaeological sites (36; 73), to mobile applications in which the images of different cultural artifacts such as buildings or books are augmented with contextual information (38; 30; 31; 44). Regarding the 11% of articles that are oriented to 3D interaction, many of them present user interfaces with virtual 3D models of cultural artifacts, where the users can explore the artifacts choosing the desired orientation of 3D objects and viewing extra-information of the artifacts (27; 32; 64; 33). While some of these works use the 3D modeling to provide a reconstruction of historic buildings that may be inaccessible, Mecocci et al. (64) developed a 3D interface to provide a full interactive remote control on the heritage buildings that are being monitored.

Moreover, 5% of studies propose some kind of touchless interaction to facilitate different activities related to cultural heritage. For instance, the work proposed by Volioti et al. (66) that allows music composition with gestures and the natural user interface presented in (41) to support the analytical tasks of historical dictionaries and corpora.

The category "others" includes 11% of the selected works that do not fall in any of the aforementioned categories. These works propose techniques such as the reconstruction of documents from digitized images to improve their readability (76), large interactive displays for data exploration and analysis (62), multimedia edition of geospatial narratives (37) and digital storytelling (43).

Finally, the rest 18% of the articles do not use a specific method to maximize the UX, and even some of them do not address UX at all.

Usability evaluation: stage

This question is intended to analyze at which stage of system development the usability is considered. We were surprised to find that almost half of the studies (46%) do not address the usability of the user interface at all. This result is clearly something that research should strive to change in the near future if CH systems are expected to multiply and succeed.

Among the studies that do address the usability of user interfaces, only 3 studies (5%) do it at requirements elicitation. They are Bugalia et al. (27), Floch & Jiang (37) and Carmagnola et al. (50). All these works recognize that usability is essential to make the system intuitive, to increase user engagement in CH and provide natural interaction, so they gathered requirements from the beginning, and developed the system to suit them. In the case of Floch & Jiang (37), they adopted a scenario-based approach and the use of storyboards to gather early feedback from final users and cultural experts. There are 13% of studies that address usability evaluation at design time. Among them, the study from Yuen and Ramaiah (53) is the only one intended for preservation, in this case, of a historic photographic collection. The usability evaluation in this study was performed over an interface mock-up of high fidelity, to seek approval from real users and customers before development started, similarly to other papers in this category.

There are 7 studies (13%) that consider usability during implementation. Among them, 2 studies are intended for preservation, of musical instruments in one case (67), and of ancient manuscripts in the other case (55). The rest of the studies, which account to 23%, performed the evaluation after system release. While this is the most common stage in which usability is considered, research in Human Computer Interaction, and specifically, User Centered Design, advice against it, since there are changes that are far more costly and difficult, if not impossible, at this stage, some of which may involve architectural changes (16).

Usability evaluation: mode

This question is intended to classify studies with respect to the usability evaluation method proposed for the user interface. Besides the 26 studies that do not address usability, there is one more paper that considers usability during implementation but does not report on any usability evaluation performed (67), which overall amounts to 48% of studies that do not show any method of usability evaluation (a disturbing percentage). The rest of the studies use 3 possible evaluation methods: heuristic evaluation (10%), cognitive walkthrough (4%) and user testing (38%).

The studies that perform heuristic evaluation during the design stage recognize the benefits of discovering usability problems early, which makes them easier to fix (53) and allows for an iterative design (52). They do not mention specialized heuristics or guidelines for CH as suggested by Lam and Sajjanhar(20), except for the study by Martín-Rodilla et al. (72). The latter suggests a new set of guidelines which are not specific to CH but allow to evaluate the design of data analysis applications, which for instance include those applications that monitor environmental variables. There are 2 studies that apply cognitive walkthrough (51; 7). This kind of evaluation is also performed at design time, with the benefits described before, but in this case, instead of following guidelines, the usability expert performs the same tasks and activities that a real user would, and records critical information and problems along the way. In both cases, usability evaluation is complemented with user testing after release.

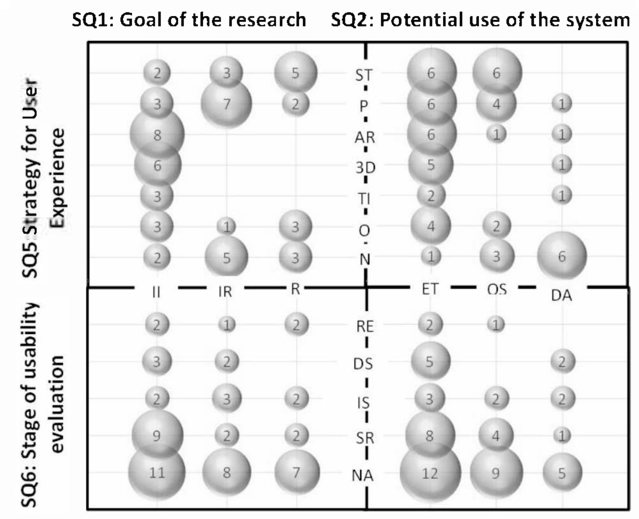

Figure 2. Mapping results of the combination of research sub-questions **SQ1** (II: improve interaction; IR: improve recommendation; R: repository) **SQ2** (ET: education and tourism; OS: orientation and search; DA: assessment and decision assistance) **SQ5** (ST: semantic tagging; P: personalization; AR: augmented reality; 3D: 3D interaction; TI: touchless interaction; O: other; N: none) **SQ6** (RE: from requirements elicitation; DS: from design stage; IS: from implementation stage; SR: after system release; NA: not addressed)

Going into user testing, it is by far the most popular evaluation method used. We found 21 studies in this category, which account to 38%. The benefits of user testing over cognitive walktrough is that the application is tested with real users under close-to-real conditions (not completely real because the tasks are predefined and the user is usually observed by the expert). Thus, it is a recommended evaluation method. The drawback of user testing appears if it is the only evaluation method used, because it discovers problems tardy in some cases. Among the studies that perform user testing, only 2 of them are intended for preventive conservation (55; 39).

Mapping results

The studies about the user interfaces in the CH field began to grow on the mid 2000, with a noticeable spring on 2013. That jump drives the appearance of relevant publications about usability on CH interfaces that form the group of selected publications retrieved by the search. The 56 selected publications that passed the quality assessment constitute the 44% of the potential pre selected articles. The rest of this section describes how the seven research sub-questions were combined to create a group of maps depicting a high level view of the classification of primary studies about user interfaces devoted to CH. These maps allow further analysis about how the results from each sub-question are related to the others, and highlights the possible research gaps. Firstly, Fig. 2 shows the mapping results obtained from research sub-questions SQ1 goal of research and SQ2 potential use of the system in comparison with research sub-questions SQ5 strategy to improve the user experience and SQ6 stage of usability evaluation.

If we observe the quadrant that relates SQ1 with SQ5, it is easy to detect a large vacancy area in systems that aim at improving recommendations or provide repositories through touchless interaction, 3D, and AR. These systems are more likely to use semantic tagging or personalization, or none strategy at all. Looking at systems with the goal of improving interaction, they use a wide range of strategies, being AR the most popular, followed by 3D interaction.

Moving to the quadrant that relates SQ2 with SQ5, we may see that all strategies to improve the UX in systems dedicated to education and tourism are similarly popular, except for touchless interaction with only 2 studies. The most popular strategy for orientation and search systems is semantic tagging, while there is a lack of research on the use of 3D in this area. In the case of assessment and decision assistance, we may see the poor use of strategies to improve the UX.

Considering the stage of usability evaluation (SQ6) in the bottom quadrants, we may see that beyond the goal of research (SQ1), most systems do not evaluate usability, with the exception of studies devoted to improve interaction, mostly evaluated after system release. In relation to the potential use of the system, those intended for education and tourism perform usability evaluation at different stages, mostly after system release and during design. Moreover, it is peculiar that most systems are evaluated after system release, with the exception of assessment and decision assistance systems.

Secondly, Fig. 3 shows the combination of sub-question SQ2, potential use of the system and SQ3 intended user in relation to SQ4, whether the system is intended for preventive conservation and SQ7, mode of usability evaluation. Observing the top quadrants, among the few systems intended for preservation, they are evenly distributed with a modest majority of systems devoted to decision assistance for institution's staff.

Regarding the mode of usability evaluation in the bottom quadrants of Fig. 3, it is positive to see that most decision assistance systems are somehow evaluated, and the preferred mode is user testing. Moreover, while guideline reviews or heuristic evaluations are the least popular evaluation methods, there is a clear vacancy regarding search systems and those intended for researchers and institutions' staff. One of the reasons for this may be the lack of specialized guidelines for interfaces devoted to CH, as highlighted by Lam and Sajjanhar (20).

Conclusions and future work

This article presents a SMS about usability considerations for user interfaces of data-oriented systems in the CH domain. Applying a survey allowed finding all available studies that address specific research questions, in a repeatable way. The added advantage of a SMS is the resulting classification of studies, highlighting both hot topics as well as those lacking research, while showing the results in a graphical, very clear way: the maps.

The main contribution of this study is providing to other researchers and developers of CH applications an in-depth characterization of the strategies proposed to improve usability and UX in the context of different goals, uses and

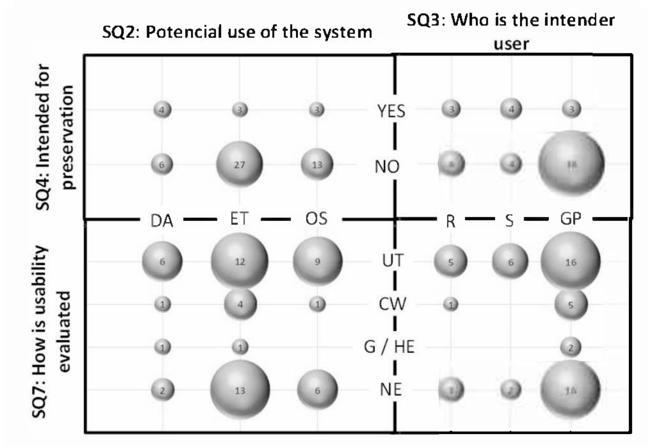

Figure 3. Mapping results obtained from the combination of research sub-questions **SQ2** (DA: assessment and decision assistance; ET: education and tourism; OS: orientation and search), **SQ3** (R: researcher; S: institutions' staff; GP: General Public), **SQ4** (Yes and No) and **SQ7** (UT: user testing; CW: cognitive walkthroug; G/HE: guideline/heuristic evaluation; NE: not evaluated)

audiences, and about how and when this improvement is validated. Moreover, it includes maps that relate different sub-questions underlining crowded topics and empty areas.

It is disconcerting that even though all the retrieved articles had all the concepts of the search string in the title, keywords or abstract, more than the half had to be discarded for not presenting any substantial outcome regarding our research question. We assume this is a consequence of the specificity of the objective (user interfaces that deal with data-intensive content applied on cultural heritage) and the generic string concepts (user interface, data, Cultural Heritage).

Regarding our research question, we learned that the main innovations in data-oriented UIs in the field of CH are focused on education and tourism for the general public, and engage the user with semantic tagging, personalization and augmented reality. They have varied goals, with a stress on improving interaction between the user and the data. Moreover, scarce research has been conducted about user interfaces developed for preventive conservation systems. We found only 1 study for preventive conservation which is close to our specific research in that it monitors environmental variables and aims to an improved interaction for decision assistance (64). Unfortunately, it does not provide any information about usability or UX assessment. This is the case for half of the selected studies in this SMS. The ones that do address usability have a different target: mostly designed for the general public to benefit tourists and visitors. We understand that the service sector is economically profitable and that is why it is capable of financing these types of applications, leading the trend with many UX strategies and user testing evaluation in early stages. We perceive that in the near future, the service sector will keep growing as the COVID-19 pandemic enhanced virtualization. Applications serving staff, research, and conservation can leverage those experiences.

In future work, we pretend to develop an interface to analyze micro-climatic data of libraries, and especially, book deposits to improve preservation in a sustainable way, and permit the staff to make grounded decisions with clear feedback and a high degree of usability. The results of this SMS teaches us that an adequate user interface demand to consider usability from the requirements elicitation, to discover the problems and solve them in an early re-design of the system interface (50), and make enhancements according to the testers feedback (37). Moreover, the best choice to achieve this is through high fidelity mock-ups, or storyboards (53), to test the interface with real users that detect potential usability problems that are fixed in early stages of design.

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