A TUI To Explore Cultural Heritage Repositories on The Web

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Abstract

This article presents a paper-based Tangible User Interface (TUI) that facilitates the production of complex queries on a Cultural Heritage (CH) repository. The system helps to easily make use of the data elements and Boolean logic that describe the collections. This research presents a design methodology divided into two main phases: A User Experience (UX) and User Centred Design (UCD) where potential users' behaviours are analysed, followed by the development and evaluation of the TUI prototype.

The TUI uses off the shelf electronics and a paper-based set of tokens to engage the user with the system, thus facilitating the exploration with CH collections through querying.

Author Keywords

Tangible User Interface; Querying; Cultural Heritage; Table top Interaction, Paper-based TUI

ACM Classification Keywords

Human-centered computing → User centered design, Empirical studies in interaction design, Information visualization

Introduction

Cultural Heritage (CH) organisations are increasingly using Semantic Web technologies to describe their collections. Although this enhances the quality of information used to describe these, it has also increased its technical and conceptual complexity. For example, to query this data, users have to use a specific syntax, data fields, controlled vocabularies, and Boolean logic. This research focused on understanding how a TUI could reduce the technical and conceptual layers of complexity required to query these CH collections on the Web. The research case study used data from Europeana, that provides access to 12% of all digitised European collections through its API. This paper (1) introduces the TUI system and discuss the challenges of querying the collections; and (2), presents the interaction design methodology, which was divided into two main phases: First, a User Experience (UX) and User Centred Design (UCD); followed by the Design and Evaluation process that aimed to understand how users produce queries and the complexity behind them.

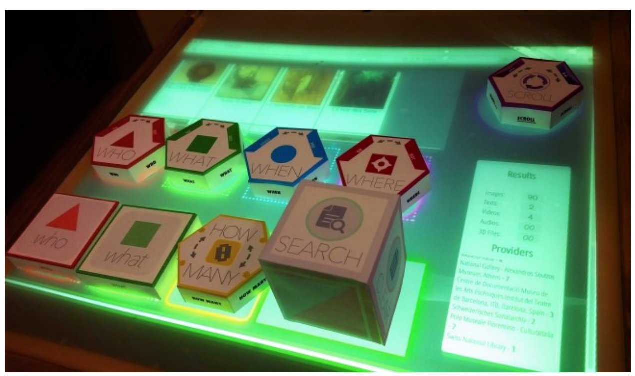

Figure 1. TUI System

A Tangible System to query Cultural Heritage knowledge on the Web

The TUI presented in this paper helped participants to produce complex queries applying the data fields, concepts and Booleans, as well as to refine their queries through Europeana's API, thus accessing billions of records from over 4,000 organisations across Europe.

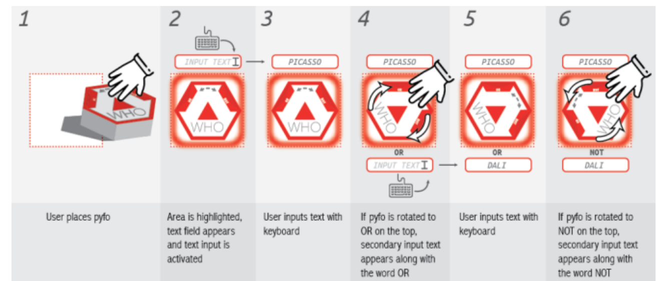

Figure 2. Interaction Process in TUI

The system was designed as a table-top TUI, where users place a series of *pyfos*[1] or tokens that represent aggregated data fields and an input field where strings of text can be typed. Each pyfo is colour coded and represent an aggregated field (Figure 1). There are six hexagonal primary pyfos aligned on the top that represent WHO, WHAT, WHEN and WHERE. A set of secondary rectangular pyfos represent a secondary WHO and WHAT for faceted searches. On the top right there is a scroll pyfo, as well as a pyfo marked with HOW MANY which will limit the amount of results retrieved in the API call. Query results are displayed as a scrollable list with their title and thumbnail. On the bottom right, there is a list of CH organisations and the amount of records retrieved by each. Finally, there is a SEARCH and CLEAR cubic pyfo to enter the API call or

[1]The term pyfo, is used here as coined by Shaer et al., [7] (i.e. physical objects used as tools as part of an interactive system) and is used to avoid confusion with the terms 'object' or 'token' that can also be related to computer science or CH artefacts which in those cases have a different meaning.

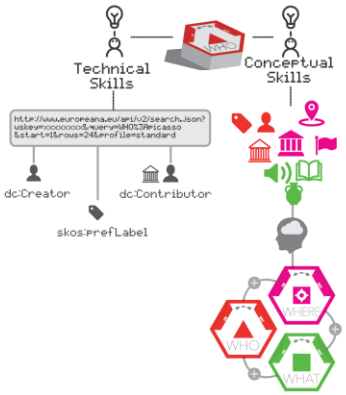

Figure 3. Complexity Skill Layers

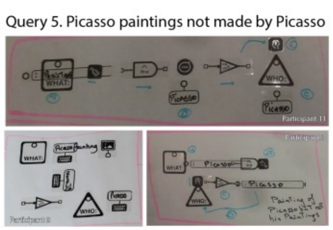

Figure 4. Top-Sticker tools for UX/UCD process. Bottom-Stickers used in Query 5 by Participant

to remove all fields and clear the displays. Hexagonal pyfos (e.g. WHO, SCROLL, WHEN) are can be rotated to display Boolean logic. When the user rotates the pyfo clockwise, it displays another text input field below the pyfo and ads the OR Boolean element (Figure 2). The same process is repeated by adding NOT when is rotated counter clockwise. This way, users can build queries such as: WHO:Picasso+NOT+Dali using the WHO hexagonal pyfo. This is the same for the WHAT and WHERE pyfos. Only the WHEN pyfo uses the Boolean TO to delimit the time period range for the query. Rotating this pyfo to the left will activate the text field to input the start date and to the right will activate the end date. Therefore a query that uses Europeana aggregated fields could search for WHEN:Medieval+TO+1800.

Engaging with CH Concepts

CH repositories use controlled vocabularies such as the Europeana Data Model (EDM), that make information interoperable across diverse CH organisations. They describe implicit and explicit concepts [10, 11], as well as providing structure between them [10:94]. Nevertheless, querying such content require users to link a wide range of data elements and heritage knowledge. In addition, users also need to know the syntax in order to write the query even through an API. It cannot be expected from users to produce queries this way, since the vast majority of queries in Europeana and on the Web use no more than two keywords and not conceptual reference [5, 6, 12-14]. This research identified two main areas or layers of interaction that users needed to engage with to produce such complex queries: (1) a technical and technologic layer that focuses on query languages, data elements and syntax; and (2) a conceptual complexity layer that focuses on logic and the relation of concepts (Figure 3). The first layer refers to examples such as the aggregated field WHO, used in one of the pyfos, combining the DCMI element dc:creator, dc:contributor, the FOAF element foaf:name and the SKOS elements skos:prefLabel and skos:altLabel [17]. The second layer refers to the mental complexity required to make sense and relate the different concepts behind the data model. For this, TUIs can help engaging with the conceptual complexity since they have been proven beneficial for learning and exploring knowledge (Conceptual Layer) [21-23], as well as reducing the interaction complexity (Technologic Layer) [24, 25]. There are over 30 examples produced from Europeana's hackathons that fail to facilitate the engagement with the technical and conceptual elements [26], where such TUI benefits can be useful. That said, there are examples such as CubeQuery [27], Stackables [28] and Navigation Cubes [29] that showcase the benefit of using TUIs to query large databases similar to the ones in CH, but they do not embrace the specificity of the ontologies behind the data models. In addition, Tangible Atoms [30] and Ullmer et al., [31] system explored real estate information, and showcae the benefits of Token and Constrain (TAC) for combining complex sets of information.

Design Methodology and evaluation

The interaction design methodology is split in two main phases: a UX/UCD experiment, followed by the design of the TUI prototype and its evaluation.

UX/UCD Experiment

This phase aimed to understand how users might approach the data elements if they already had the

Data element	%
WHO	7.1
WHERE	13.1
WHEN	9.1
WHAT	16
TEXT	6.7
Booleans	6.4
AND	9.2
Extra metadata	15.5

Table 1. Results of frequency count of main tools

[2]**UX/UCD Queries:**

1. 18th century Europeana objects from France
2. Objects that contain the name “Sofia” in their title.
3. Objects which contains the word "painting" in its description
4. Images of Picasso the painter (person) but not his painting (Picassos).
5. Find Picassos (paintings) that are not made by Picasso (person).
6. Pottery artefacts found in London
7. Open query

tools to do it. Previous research has indicated that ‘think aloud’ exercises in observational approaches are a good way in Human Computer Interaction (HCI) to gain insight into how a system might be used [32-34]. This experiment merged such observational approaches with pre-designed stickers that depicted possible query tools as a wireframing devise, which can be used to annotate and keep track of user actions [35].

In this experiment, a series of stickers were designed which depicted the aggregated fields (e.g. WHO, WHAT), as well as some of the specific domain ones, interaction elements such as keyboard input on a field, or selecting range in a map. The stickers also depicted cultural elements (e.g. artefact, book), and Boolean logic (e.g. NOT or OR). If there was a specific action or tool that was not available, a replacement sticker was used and annotated. Users were given a series of randomized queries where they placed the stickers on a paper surface and linked concepts, data elements and Booleans. Text strings for input fields were made by writing with a marker on an input field sticker and indicating another sticker for keyboard input. For this experiment, 21 participants from the CH sector (e.g. History, Archaeology) were recruited. Participants were presented with an opening questionnaire designed to identify their search behaviours, CH background and generation, and whether they were aware of any data models or Semantic Web technologies. The results showed that the vast majority of participants (18) were able to access the website and physically visit the organisation holding information about their research and 19 use the Web for their research. However, only 6 participants use search operators in Google’s diverse search services, and only 3 felt they were experts when searching on the Web. Most participants (13) felt that the quality of information in Google Search was fair, while 10 felt that in academic search engines such as Google Scholar and Web of Science was very high. Only 2 participants felt that both search services were difficult to use. Despite this, although participants were able to pick out valuable information from their searches, their queries lacked the specificity to reduce uncertainty about what they were looking for. It is for this reason that most participants (11) indicated that one of the main issues when searching for information, was that it was scattered through too many sources.

Participants were asked to reproduce 6 different queries using the stickers and to produce a query based on their own academic research (UX/UCD Queries[2]). After the experiment, participants were presented with an exit survey about their experience with the querying process. After performing a frequency count, stickers were grouped into major group. For example, the tool WHERE (13.1%) encompassed its use through a geo-pin (3.2%), region selection (2.8%) and text description (7.1%) (Table 1). The main objective was to annotate their main strategies when producing queries. In addition, the sequence in which participants placed such tools was also annotated. It was noted that participants began their queries from general concepts (e.g. WHAT), and then proceeded to refine the term (e.g. WHAT – Artefact). The Boolean AND was counted as an independent element, since it was noted that participants used it as a mental aid to link concepts and not as a Boolean operation (Table 1).

Participants began their queries with general concepts such as WHAT or WHERE. After defining such concept, followed by a general term and refined in further detail the specific metadata elements such as data provider,

Query	
1. Find paintings by Leonardo Da Vinci	
2.Cats provided or that come from Egypt…	…look for mummy cats also from Egypt
3. Objects (anything) dated between 1525 and 1527	
4. Find any ceramic from Spain…	…ceramic not tiles from Spain and not from France
5. Sculptures or paintings that were made by Rodin and not by Picasso	
6. Medieval coins held in the United Kingdom	
7. Fashion objects from 1800 to 1900 from Italy…	… or from Wales

Table 2. Evaluation queries given to participants

type of media (e.g. image, 3D). Participants segmented queries similarly to faceted queries with no less 2 main sections (concept), plus facets (Boolean or metadata). They used no less than 2 overarching concepts in a total of 4 different tools. All participants showed high disposition to search by using complex queries. Also, all participants produced queries related to their research, such as "sites that contain evidence of pottery style B" and "coins made by the King Offa found in a region of a map, that date from 750 to 850" and "carved stones of Abbes Hilda from the Anglo-Saxon period from Whitby Abbey in Yorkshire".

Development of a Tangible User Interface (TUI) Prototype and Evaluation

The UX/UCD experiment, showed that users were more likely to begin their queries using aggregated fields and use them as main concepts. Each aggregated field was assigned a colour and shape (e.g. WHO-red triangle, WHAT-green square). This visual representation help users relate concepts and actions to any given object [36]. The main pyfos which activated the Boolean options through rotation, used a hexagonal prism. The faces of the hexagonal prism provided the affordances or sensorial responses related to balance, direction and gravity [36, 37], where in this case, it invited users to rotate it and placing it in the desired space and position. Secondary pyfos had no Boolean options, thus no rotation. For this reason, they are squared shapes, which contrary to a hexagon with more sides, it can be perceived as a more static object and invites less to rotate. All pyfos were made of paper, where using such basic volumes should require very little skill to build. The system was developed using off the shelf electronics such as a webcam and projector, as well as Web standard technologies such as HTML5 and JavaScript. It was designed using TUIO [8] as a main interaction protocol and connected it to the browser using a npTuioClient [9] to read the TUIO fiducials in the pyfos.

Evaluation of TUI System

For the evaluation of the system, 11 participants were recruited. They were presented with an entry survey to identify their digital and search skills, and background. Only 7 of them worked in the heritage sector. Furthermore, only 3 participants took part on the UX/UCD phase. It can be said that despite that they were aware of the kind of content they could find in Europeana's collections, they were not necessarily aware of the API's data elements. Almost no participants knew what the Semantic Web was (9) and few used Booleans when searching on the Web (2). When searching the Web, 3 participants identified themselves as experts, 6 as competent, and 2 as novice. Participants were asked to reproduce 7 different queries in a random order (Table 2). Some of these had a second stage refinement. They were also offered the opportunity to produce their own queries. Completion time was measured, paused and restarted for the second refinement stage of the query. The open query was also timed.

Evaluation Results

Although the validity of the query was not considered since they could be interpreted in different ways, there was a 100% completion rate. This is to say that all participants produced the queries using the diverse data and logic elements. When solving queries, participants spent in average 1 minute 6 seconds on the first query of the experiment. That time was dramatically reduced to an average of less than 50

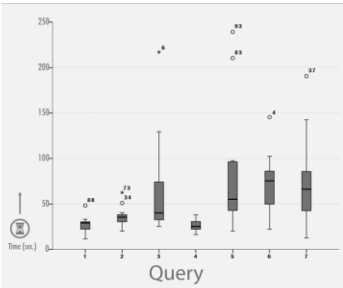

Figure 5. Completion time by query

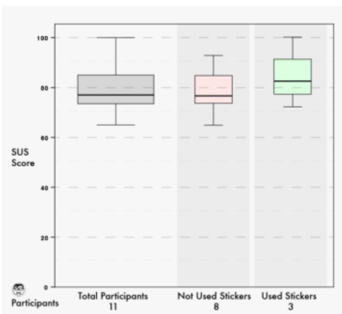

Figure 6. Usability results for final evaluation

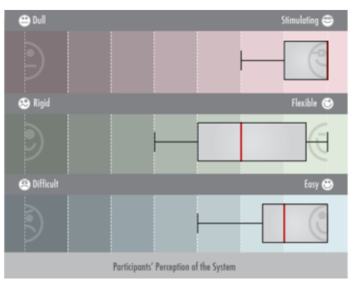

Figure 7. Participant's perception of the system

seconds for the following queries. The system showed fast learnability since participants had to manipulate no more than 2 actions when trying to produce the queries. For example, when using Booleans, which required rotation, only 4 of 11 participants rotated the pyfo in the wrong direction, and realised quickly that they had to rotate it to the other direction. Queries 3, 5, 6 and 7 took longer to complete, while 1, 2 and 4 were completed in under 40 seconds. This could be attributed to a low level of complexity in the queries. Time completions were also compared to the place in which each query appeared, and the results suggest that users spent more time focusing on the conceptual elements instead of learning how to use the system. For example, in query 6, participants had to conceptualise the term ‘medieval’. Three participants used numbers to define start and end years as a WHEN, while the remaining 8 defined it as a WHAT. Participants which used WHEN were from the CH sector, thus suggesting they had more information about the content, but still managed to produce the query.

A usability evaluation was also carried out based on the System Usability Scale (SUS) [38]. Participants were given 20 questions to help quantifying the strengths and weaknesses of the system. The SUS provides a symbolic quantitative value with a maximum number of 100. This value is used as a reference where, 50 – 60 would be the lowest value of accepted usability issues if the system is to be released. The TUI scored highly in the SUS score (Figure 8). It was also decided to split the scores of the 3 participants who took part in the previous experiment with the stickers. These participants gave a higher usability score but not significantly. The results showed that the system helped users to devise an exploration strategy and re-adapt it when needed. For example, 5 participants agreed and 6 strongly agreed that the system allowed them to experiment with different ideas for the queries. The system did not present any major interaction issues. Nevertheless, it was noted that participants had to drag their attention away from the pyfos when typing on the keyboard, thus disrupting the interaction flow. The perception of the system was positive. Participants found the interface easy to use, they indicated that the system was stimulating and that it motivated them to think and be conscious about the things they were trying to find. This became evident when they produced the queries, since they kept on re-arranging the pyfos until they were happy with the query and entered the query at the end.

Conclusion

This paper presented a TUI that helped users to produce complex queries on CH collections on the Web. The TUI helped users to produce queries that combined multiple data elements, concepts and Boolean logic. It was designed by integrating users processes through an UCD/UX that eased the design of the prototype. This research aimed to reduce the gap in the way CH organisations offer access to their ever-growing collections. It showcases the benefits of using TUIs to query databases. On one hand, it can promote constructivist learning, helping users to engage with the collections’ conceptual complexity. On the other, it facilitates the production of extensive query strings from diverse data fields used to describe the collections. The TUI presented in this paper, introduces an initial concept that can be adopted by CH organisations to further their engagement with their online collections.

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