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From Ontology Design to User Experience.
A methodology to design interfaces for information seeking purposes

Marco Grasso

University of Bologna
marco.grasso7@unibo.it

Marilena Daquino

University of Bologna
marilena.daquino2@unibo.it

Giulia Renda

University of Bologna
giulia.renda3@unibo.it

Abstract

When designing data-driven web applications, users' informative needs are aligned to knowledge organization (KO) requirements, which are secondly mapped to user interfaces (UI) components, and finally to user experience (UX) journeys. Particularly, when data are served as Linked Open Data, data and user requirements can be associated with competency questions that an ontology should address. However, to the best of our knowledge, there is no full-fledged methodology that systematically adopts ontology requirements to design UI components and UX journeys. In this article we propose a methodology to design web applications for information seeking purposes that leverages well-known ontology design methodologies and UI/UX approaches. We present a case study based on music heritage and we evaluate it via a user study.

Keywords: User eXperience; Linked Open Data; Cultural Heritage; Ontology design

Nel progettare applicazioni web basate sui dati, le necessità informative degli utenti sono allineate ai requisiti di organizzazione della conoscenza, successivamente mappati sui componenti delle interfacce utente (UI) e infine sui percorsi dell'esperienza utente (UX). In particolare, quando i dati vengono forniti come Linked Open Data,

requisiti dati e utente possono essere associati a competency questions che un'ontologia dovrebbe affrontare. Tuttavia, fino a quanto sappiamo, manca una metodologia completa che adotti in modo sistematico i requisiti ontologici per progettare componenti UI e percorsi UX. In questo articolo proponiamo una metodologia per progettare applicazioni web per il recupero di informazioni che sfrutti metodologie di progettazione ontologica ben consolidate e approcci UI/UX. Presentiamo un caso di studio basato sul patrimonio musicale e lo valutiamo attraverso uno studio utente.

Keywords: Web Semantico; Linked Open Data; Progettazione di Ontologie; Esperienza Utente; Metodologia di Progettazione

Introduction [1]

The Semantic Web was envisioned as an enhancement of the current World Wide Web, the latter mainly targeted at human consumption with machine-understandable data and services relying on Linked Open Data [6]. Formal ontologies enrich data with metadata, thanks to a knowledge representation language based on a formal logic which facilitates data integration, sharing, and discovery [21].

One of the main tasks of data consumers on the Web is information seeking. Whereas a search on the Web was usually performed over unstructured data and it was expected to return a list of ranked documents relevant to the query [32], in the Semantic Web, searches are performed via SPARQL queries against structured data, and results are in the form of RDF triples [10]. Since the structure of a SPARQL query is based on terms of the ontology used to describe data, which in turn is derived from a shared conceptualisation of the knowledge domain, a mapping between users' informative needs (queries), ontology requirements (predicates and classes), and final interfaces presenting results could be performed with high confidence. To this extent, we would expect ontology design practices to be closely related to user interfaces (UI) and user experience (UX) methodologies, and vice versa.

On the one hand, the community of ontology design has been increasingly leveraging tools used in the Human-Computer Interaction (HCI) field - such as the definition of personas and scenarios [12], [37] - in early stages and as a means for evaluation [25], [42], [47], [50]. In particular, ontology requirements are traditionally expressed in the form of natural language Competency Questions (CQs) [38], which can be extracted from user stories attributed to personas [42]. On the other hand, it has been demonstrated that ontology-driven approaches have brought significant benefit in reducing interface requirements ambiguity [1], [14] when supporting software development [14], [51], [55], and requirements formulation, e.g. by creating user stories as structured data [53]. Task ontologies and taxonomies for describing interactive user behaviours and UI elements exist [39], [43], [49], and have been used to support the assessment of prototypes and final interfaces. Similarly, ontologies and algorithms addressing HCI design in the design of web applications have been discussed [2], [3]. While such efforts focus on the description of aspects of the HCI discipline, they do not operationalise the descriptive knowledge of domain ontologies (those used to represent the data and not the

[1] Marilena Daquino is responsible for section Introduction, Background, and Methodology. Giulia Renda is responsible for section Related Work and Discussion. Marco Grasso is responsible for sections Case Study, Evaluation, and Conclusion.

UI/UX process) into prescriptive models, i.e. defining how a system is supposed to behave according to ontology requirements (e.g. CQs).

To the best of our knowledge, there is no methodology that assists a research team from early stages of ontology design to the selection of UI/UX approaches. Nonetheless, this is often the case in projects where the knowledge base generation comes with user-friendly interfaces for information seeking, exploration, and discovery purposes [23], e.g. projects dedicated to the dissemination of Cultural Heritage on the Web [27].

In this article we investigate the bridge between ontology design and UI/UX design methodologies to assist designers in prototyping web applications for information seeking purposes. Our aim is to extend the early stage of established UI/UX methodologies, such as Design Thinking [37], [45], with a suitable ontology-driven approach, i.e. the eXtreme Design methodology [42]. We suggest qualitative and quantitative analyses to be performed over ontology requirements, methods to support the ideation of prototypes, and finally an evaluation method to assess the validity of the entire methodology when applied to the design of interfaces for Cultural Heritage collections.

In detail, in section *Related Work* we report on prior works in ontology design and UI/UX studies for information seeking purposes, motivating the selection of two candidates for developing our hybrid approach. Selected methodologies are briefly outlined in section *Background* to better appreciate our contribution to both candidates. In section *Methodology* we present the framework from ontology design to user experience. In section *Case study* we present our framework applied to a real-world scenario, i.e. the requirements collection for a Web portal on music heritage developed for the H2020 project Polifonia. In section *Evaluation* we present a user study performed to validate the case study. We finally discuss results and limitations of our approach in section *Discussion*. Final considerations and future works are outlined in section *Conclusions*.

Related Work

Several methodologies for ontology design have adopted tools from the HCI field. These methodologies privilege a bottom-up approach to elicit requirements during the knowledge acquisition phase, and rely on the intervention of domain experts in (1) defining domain space and vocabulary, (2) sketching motivating scenarios, and (3) extracting Competency Questions from scenarios [13], [20], [38], [42], [52].

The XD methodology [9], [42], formalises practices to collect goals, topics of interest, and tasks from heterogeneous groups of stakeholders and group them under umbrella categories, i.e. personas. In XD research journeys and groups' expectations are recorded in the form of user stories and are classified according to their level of priority. User stories, similarly to user journeys, address the emotional experience of a user - characterised by a space, a time, a role, and an interface - as well as users' interactive behaviours [5], [29]. Stories are recognised as powerful tools for designing experiences, since events described in stories are connected through causal relations and help to frame motivational aspects leading a user to behave in a certain way [19]. To this extent, the knowledge acquisition process is designed around personas or proto-personas [24], which summarise behaviours when searching a knowledge base. For these reasons, XD is a good candidate for a seamless integration with UI/UX design processes.

When requirements are mapped to UI elements for information seeking purposes, two kinds of interactive behaviours emerge. On the one hand, journeys may focus on retaining the user, and a common strategy is breaking down the information and displaying it in small chunks, so as to reduce the cognitive load [26]. On the other hand, studies in Information Science and Digital

Humanities have demonstrated that preventing the user from seeing the "whole picture" may become a factor of frustration, therefore advocating for more *generous interfaces* [54]. Authors have argued that websites users are not always focused on information seeking as their sole task. Casual browsing can also be an effective way for users to discover and refine their objectives, if they have any. Such a form of visual exploration has been previously summarised as "overview first, zoom and filter, then details on demand" [48]. Compromising retention and overview is an important challenge for third generation information systems, that should allow users to first filter out data of interest, and then apply various analysis and knowledge discovery tools on the target [23]. In terms of usability, interfaces harmonising such two different viewpoints should be able to accommodate multiple tasks and user journeys, ensuring context completeness [7].

Design Thinking (DT) [8], [16], [37], [45] is a renowned user-centric approach to problem-solving for designing artefacts, including web interfaces, which organises the workflow in six phases: empathize, define, ideate, prototype, test, and implement. It is based on a hypothesis-driven, abductive, and dialectical approach to map requirements into design ideas. The data collection phase encompasses qualitative investigation (e.g. ethnography, visual anthropology, brainstorming, co-creation, and definitions by example) as well as quantitative analyses [30], and leverages personas, stories, stakeholder maps, user journey maps, and service blueprints to formalise requirements [11]. Although the number of empirical, non-anecdotal, studies based on Design Thinking is limited [18], previous studies demonstrated that the methodology effectively improves the quality of ideas and reduces risks of failure [30].

Scholars have tried to encapsulate the logic of DT into ontologies to evaluate design ideas [43], to formally describe empathy models [41], or other procedural aspects of HCI [2], [3], [39], [49], attempting to bridge ontology-based approaches and UI/UX methodologies. However, while most works focus on the creation of ontologies describing concepts and procedures of DT, they neglect considerations on the overall, prescriptive framework. In fact, the population of ontologies with personas, UI components, and tasks, facilitates the preliminary analysis of requirements, but does not consider the formal domain knowledge, which inevitably affects the analysis, the retrieval of information, and the definition of UI/UX components that are necessarily tied to the domain knowledge.

In summary, new ontologies have been created to instruct us on how formal definitions of HCI field and Design Thinking methods would look like, but not on how to leverage real-world domain ontologies in the Design Thinking process. In this work we aim at filling this gap, suggesting the application of methods and analyses widely recognised as tools of the Design Thinking methodology directly to the domain ontologies.

Background

The eXtreme Design methodology. Ontology design patterns (ODPs) [17] provide solutions to recurring modelling issues. ODPs are extensively used in the eXtreme Design (XD) methodology [42], which is an ontology design methodology characterised by an iterative and collaborative approach to elicit requirements. Requirements are collected in the form of user stories, i.e. a set of sentences which describes by example the kind of facts that the resulting knowledge graph should include. The length of a user story is limited to avoid ambiguity. Competency questions (CQs) are extracted from the story in the form of free-text questions, which act as natural language counterparts of structured SPARQL queries and as general (logic) constraints of the ontology [9]. At each iteration in XD, CQs are selected and matched to ODPs which are included in a unit test. In a unit test, CQs are translated into SPARQL queries and

general constraints are used to create toy data. In [9] authors present a case study based on cultural heritage data recorded in catalogues and propose an extension of XD in order to elicit requirements from heterogeneous groups, since the information recorded in the catalogues is neither self-explanatory nor sufficient to address a complex scenario. They introduce personas to group stories related by goal, subject, task, and expectations. In so doing, ontology developers have an effective means to validate the soundness of their choices based on real-world scenarios.

The Design Thinking methodology. The methodology puts an emphasis on methods to *empathize* and *define*, when designers respectively frame the domain space and make sense of collected insights. Several aiding tools and research techniques can be adopted to collect requirements, such as: surveys or interviews with stakeholders, kick off meetings with the design team, field studies, customer service feedback, or heuristic evaluation (recording frustration factors in prior versions of the product or competitor products) [11]. To elaborate information, designers can adopt *Personas* - i.e. simplified descriptions of users including biographical information, tasks, interests, and expectations - or proto-personas - i.e. profiles that represent the idea of a user according to the view of the team rather than the actual user. *User stories* describe situations or tasks the personas may face. *User Journey Maps* are visual representations of users' research path, and of feelings elicited from the interfaces. *Empathy maps* can be used to record what a user Says, Thinks, Does, and Feels. Similarly, *Stakeholder maps* are visual representations of groups, e.g. early adopters of the final product. A different perspective is provided by *Competitive analysis*, where competitors are bench-marked in order to grasp information on what works well (or not) in their services, and how their users look like [11].

Insights are transformed into workable prototypes (*ideate and prototype*), which are often the result of team activities, such as brainstorming or concept development techniques [30]. Rapid prototyping [31] is a common approach to develop a proof of concept or mockup, that can facilitate communication and feedback between teams and stakeholders. Visualization tools like mind mapping and storyboards are also deemed useful prototypes.

The *test and implement* phases address both the design of experiments to test the solution, and its evaluation. Common methods include user studies, focus groups, or other activities in which feedback is used to refine a prototype in an iterative, trial and error, approach. The evaluation can be performed in a laboratory environment (e.g. mockups) or in the application environment (e.g. a web-ready solution). Metrics are used to evaluate the result, e.g. ease of use, accessibility, usefulness, reliability, efficiency, and user experience [27].

Evaluation of UX design methodologies. Results of the prototype evaluation are often deemed sufficient to validate the UX design methodology adopted to develop the solution too (i.e. the methodology inherits the positive judgment given to the result). For instance, Design Thinking is considered a reliable methodology for UI/UX design, and the literature is replete with anecdotal studies showcasing successful cases. However, scholars have argued that existing UX evaluation methodologies tackle only a small range of problems, e.g. usefulness and ease of use only, and there is no optimal combination of evaluation methods to maximise the range of measured qualities [27]. To this extent, we may argue that the evaluation of the design methodology itself is hampered by the limits of the UX evaluation methodology, and only partial evaluation methods can be developed to test the goodness of a UX design methodology in the first place. In this work we are interested in evaluating the *co-design* aspects underlying our proposed methodology. In particular, we want to test whether the UX elaborated in a case study leveraging our methodology sufficiently matches the expectations of users classified as secondary target of the final web applications.

Methodology: from ontology design to user experience design

We introduce a modular workflow harmonising eXtreme Design and Design Thinking methodologies in order to formalise a way to wisely leverage ontology requirements into the design of user interfaces. The proposed methodology spans from data and user requirements collection to the development of prototypes and their evaluation. The *empathise* phase of Design Thinking is integrated with methods proposed by eXtreme Design, such as the extraction of CQs from user stories and the mapping of CQs to ontology design patterns. Unlike other ontology-driven approaches to UI/UX design, we systematically reuse data/user requirements and domain ontologies in the *define* phase, and we propose a number of analyses to be performed over annotated CQs in order to *ideate* solutions consistent to requirements, to be later implemented in a *prototype*. Lastly, we integrate a user study focused on co-design aspects to *test* both results and our methodology.

In Figure 1 we illustrate the list of activities performed. Activities are grouped under phases defined by Design Thinking. Grey blocks represent activities prescribed by either XD or DT, and white blocks represent our original contribution. Alternative methods are proposed for *define*.

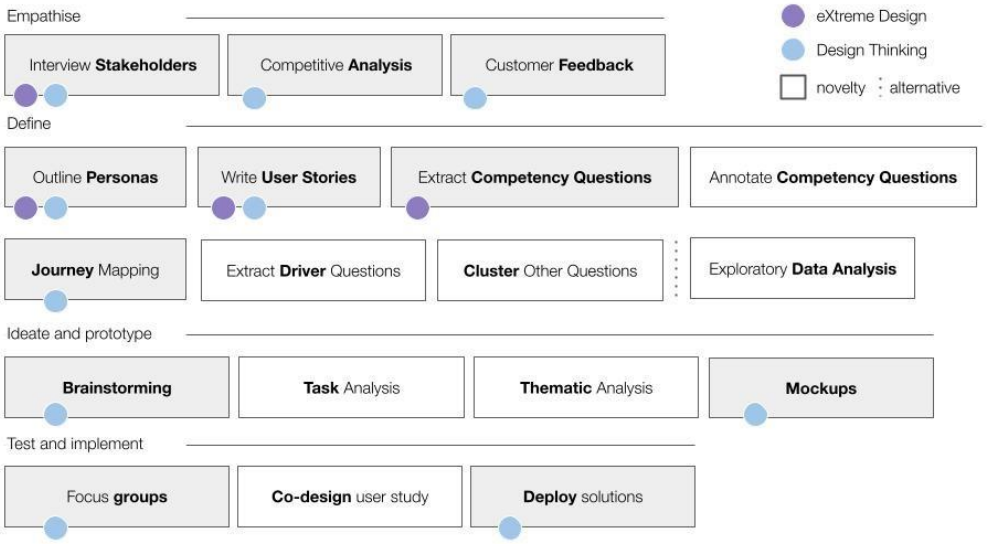

Figure 1. Methodology overview[2]

Interviews with stakeholders are performed to identify requirements of data consumers and users. Interviews address interests, habits, expectations, and frustration factors when interacting with an information system they know. Via interviews we collect: (1) motivational aspects, (2) a list of competitors of the product to be developed, (3) behaviours (journeys), (4) perceived limitations and benefits of competitors, (5) expectations and desiderata, both in terms of content requirements and application requirements. Resources mentioned during interviews are included

[2] All images are published under a CC BY 4.0 license.

in a competitive analysis, along with other competitors found in the exploratory phase, that are analysed by the design team. The analysis addresses the classification of aspects relevant to knowledge organisation, UI design, and brand identity of surveyed solutions. We narrow down the list of resources to those presenting recurring aspects. A user study is performed on the narrow list of competitors, in order to record customer feedback. The study is performed with participants classified as secondary target that were not included in the interviews, in order to integrate results obtained from interviews and the competitive analysis with new contexts of usage. Participants are asked to evaluate two or more web solutions and must answer questions to estimate (1) their information literacy or expertise on the topic, (2) their common tasks and situations, (3) their level of understanding and interest in the contents proposed, and (4) an evaluation of interfaces and experience. In particular, proposed solutions must represent alternative UX approaches to solve the same (or similar) problem tackled, e.g. a google-alike text search over a catalogue or a more descriptive website. Results of the survey include a list of secondary constraints to be taken into account when prototyping, to ensure flexibility of interfaces in different contexts than those depicted by primary stakeholders. Moreover, it would offer a preliminary evaluation of the UI/UX strategy to adopt, whether this is going to be a generous interface or a specialised one.

Interviews and results of the survey are summarised into a number of personas, i.e. stereotypical users presented in the form of textual descriptions. Situations, tasks, interests, and expectations emerged from the interview and the survey are further described in one or more user stories, having the persona as subject. Competency Questions are extracted from stories, via content and syntactic analysis of the text. CQs summarise salient aspects of the story in the form of natural language questions, address ontology and data requirements, and semantic constraints on relations (i.e. properties) and classifications of entities described in data (i.e. classes). CQs are mapped to SPARQL queries, to be used to validate the ontology, and are characterised by a priority level (e.g. must have, nice feature). Answers to CQs can be strings, lists, tables, or graphs of entities. We propose to annotate CQs with (1) ontology patterns, including classes and properties of entities involved, (2) a classification of the scope of data (e.g. historical, musical, bibliographical data), (3) whether the question addresses a task (e.g. a search, share) or a secondary detail, and (4) the type of expected result, which can be also presented as aggregated data, e.g. charts.

Ontology patterns are synthetic summaries of content requirements of a knowledge base and are relevant also to the design of search interfaces on the same. From stories and CQs we also grasp important information for the design of user journeys, i.e. the flow of searches, reading behaviours, and emotional states of the user. We propose two alternative ways to extract journeys from content requirements. If collected personas are rather homogeneous and in a small amount, we identify a driver CQs and cluster other CQs. In particular, driver CQs are one or more CQs that best summarise the scope of data and the task (e.g. search for artefacts grouped under categories). Other CQs are usually focused on contextual aspects, such as secondary detail of data, and can therefore be grouped under the same category. In case personas, stories, and CQs are too many to be singularly addressed, we recommend performing Exploratory Data Analysis (EDA) over annotated CQs. In detail, EDA allows us to summarise the distribution of (1) ontology patterns, (2) scope of data, and (3) expected results, along with their priority level. Notably, ontology patterns can be visualised as flows (e.g. via Sankey diagrams), which nicely resemble user journeys, highlighting most recurring patterns and the expected level of complexity of queries.

Once all the materials are available, brainstorming sessions help to make sense of results, leading the discussion over mockups. To support this activity, we propose to integrate two more analyses devoted to the design of interfaces only, namely: a task analysis, where CQs are aggregated by

the user task previously annotated, sorted by complexity of the task, and separated accordingly into different sorts of interfaces; a thematic analysis, based on the distribution of classes and their position in ontology patterns (i.e. as input, intermediate, or output), in order to understand most common access points to data (e.g. plenty of CQs address information about people, hence "people" should be a category for browsing/filtering/searching in the final interface). It's worth nothing that at this point designers may want to revisit groupings of tasks/themes/CQs and propose more than one interface.

Mockups or early prototypes can be evaluated differently, according to the objectives and the level of detail required to move the result in a production environment. Focus groups with small groups of stakeholders involved in the definition of requirements provide meaningful feedback, helping to reframe requirements that were unclear or incorrect. Usability tests and heuristic evaluation with 3-5 people groups are considered sufficient to discover up to 90% of issues [36]. However, when a website has several highly distinct groups of users, additional user tests are needed. To include the secondary target user in the evaluation, we propose a user study focused on co-design. The initial user study (Customer feedback) guided participants in the evaluation of a working solution, and the judgement provided was biased by a number of factors that could have not been foreseen (e.g. participant may or may not have known the website, they did not like the UI, they did not understand the lexicon). In a co-design user study, participants have to imagine themselves into a comfortable scenario (e.g. "you are at home studying"), are provided with a task (e.g. "you want to discover new music") and must share insights on how they would achieve their goal. Results of the survey contribute to preliminarily evaluate the mockups (despite these are not given to participants), since they provide measurable values for metrics like user satisfaction, efficiency, and effectiveness, of a broad span of alternative solutions, hopefully including the ones designed in the mockups. If results are satisfying, mockups are implemented, and solution are deployed in production. More tests are performed in between - e.g. test-driven development, unit tests, and final user tests - but these are not covered in this proposal, that is mostly focused on design evaluation.

Teams. Activities borrowed from eXtreme Design mainly involve ontology designers and domain experts in the mapping of requirements onto competency questions. Moreover, data engineers are required in order to analyse data and identify most common data journeys, that is, the most likely combinations of pieces of information that are needed to answer competency questions. Web designers are also involved when performing task and thematic analyses, and when developing the initial prototype. Stakeholders and secondary target users (i.e. those that are not involved in the initial collection of requirements) are involved in the refinement of requirements (via brainstorming activities), and in user tests, to validate data and user journeys.

Case Study: the design of web interfaces for Polifonia

Polifonia[3] is a project funded by the European H2020 framework devoted to the dissemination of European music heritage resources. Ten pilot projects have been designed to collect data sources (e.g. texts, audio files), extract information, and transform data into Linked Open Data (LOD) to populate a knowledge graph, in turn leveraged by user-friendly web interfaces. Given the variety of data and audience in scope, having a solid methodological approach to drive the development, from knowledge acquisition to web design, is of great concern. In fact, existing

[3] https://polifonia-project.eu/

examples to create vast data aggregators in the cultural heritage domain, e.g. Europeana, inevitably suffer from design issues, such as ontology limitations [40] or the lack of narrative elements facilitating exploration [33].

For these reasons, Polifonia is our motivational scenario to develop a methodology that prevents us from perpetuating old errors (and probably making a hundred new ones). In this section we present results obtained at each step of the workflow, adding considerations on how bits and pieces are put together to realise four web applications, namely: musoW[4], a catalogue of music data available online to support developers and music journalists; MELODY[5], a Linked Open Data storytelling environment to let domain experts and data engineers creating data stories; Corpus[6], an interface for text retrieval and linguistic analysis; finally, the Polifonia web portal[7] to collect data from pilots and functionalities of aforementioned tools to be served to music enthusiasts and lay users. For the sake of brevity, we present only the design process of the web portal, which makes use of EDA to elaborate journey mappings. All the documents referenced below are available online, on GitHub[8] and Zenodo[9].

Interview stakeholders. Around 30 stakeholders are selected among project members and acquaintances with a similar background. Most of them are scholars, music historians, musicologists, but also music producers and cultural heritage professionals. Ontology and data engineers lead the interviews. Interviews follow a script, which addresses (1) the way stakeholders interact with music data, (2) their purposes, (3) which applications they use or know they could use, (4) what type of searches they do, and, if they have requests that cannot be satisfied by current solutions, (5) how they would envision a new tool or service. Interviews are recorded and transcribed to be later reworked into user stories, and recordings are deleted.

Competitive analysis. Web applications mentioned in interviews and other websites that serve music content to broad audiences are surveyed by web designers. In total, we surveyed 22 websites of projects, companies, portfolios, magazines, and social media platforms relevant to the music heritage domain, and we produced a table for comparison and analysis[10]. Surveyed aspects[11] include: goals (e.g. engage, inform, customer support, sharing), information architecture (e.g. hierarchical, sequential, audience-driven, generous), content organisation (e.g. index-based, flat, daisy model), visual hierarchy techniques (e.g. based on colour, typography, proximity), interaction patterns (e.g. infinite scroll, animations, steps, slideshows), sound design (if any), user actions (login, share, search, navigation, feedback), and visual identity features (style, colour palette, shapes). A summary of results is illustrated in Figure 2.

[4] https://projects.dharc.unibo.it/musow/

[5] https://projects.dharc.unibo.it/melody/

[6] https://polifonia.disi.unibo.it/corpus/

[7] https://polifonia.disi.unibo.it/portal/

[8] https://github.com/polifonia-project/web_portal

[9] https://doi.org/10.5281/zenodo.6669816

[10] Competitive analysis: https://github.com/polifonia-project/web_portal/tree/main/analysis

[11] Definitions: https://github.com/polifonia-project/web_portal/blob/main/analysis/definitions.pdf

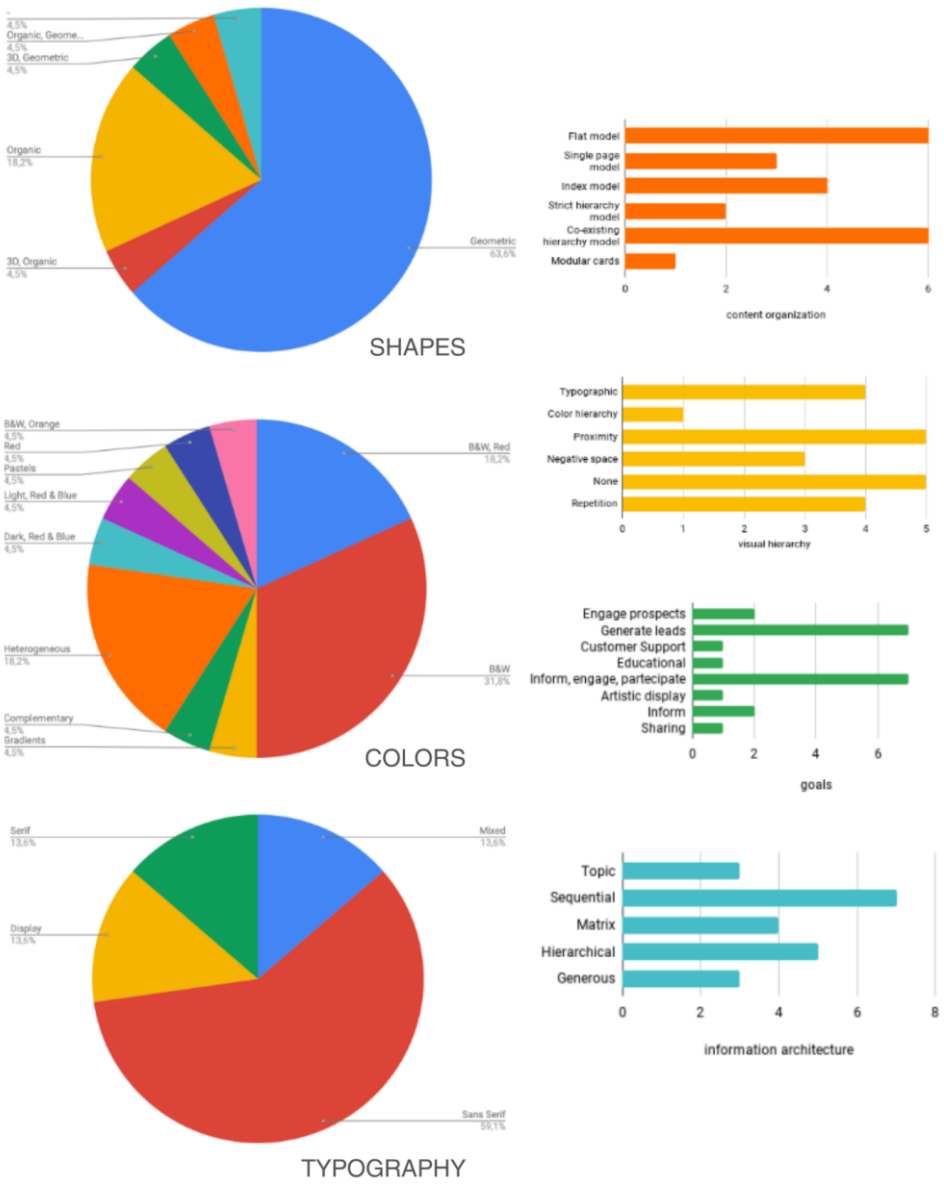

Figure 2. Competitive analysis

Surveyed applications either focus on generating leads, attracting users and raising their interest into some product or activity or providing information to engage users in participatory activities. Information is often provided sequentially, creating a step-by-step flow to let the user achieve their goal. A hierarchical organisation of content is also rather common, where important information is shown first and details are differentiated by size, colour, contrast, etc. In such cases, proximity is used to group pieces of information of similar importance, and repetition of

visual patterns is used to highlight similarities. Fewer examples offer generous interfaces and/or group information by topic. Most applications use a flat model to organise content in a few pages. When serving large contents, more sophisticated models are in place, such as indexes and different access points to the same information (coexisting hierarchies). In terms of visual identity, surveyed solutions are mostly characterised by a minimalist look and feel, including geometric shapes, large usage of black and white colours, and sans serif fonts. In conclusion, two broad groups of online services can be recognised, which can be categorised as music streaming services and magazines, wherein large contents are served via (coexisting) index models.

Customer feedback. To make sense of insights gathered from the competitive analysis, nonexpert users' experiences have been integrated. Quantitative and qualitative data about user's interactions and experience with music related digital products have been collected through a questionnaire. The conducted survey consisted of 46 questions, broadly categorised into three main areas of interest: (1) user habits, (2) expectations, and (3) causes of frustration. These topics were explored using an experience-based methodology that integrates field studies, ethnographic research, and contextual inquiry [46]. In exploring user habits (1), the survey focused on interactions with popular music streaming services like Spotify, Apple Music, and Tidal. For user expectations (2), the inquiry centred around responses to online music magazines, including Resident Advisor, Rateyourmusic, and Last.fm. Finally, to understand frustration sources, participants were introduced to two distinct music websites: Spotify Fun Study[12] and Expodcast[13], each chosen for their unique UX designs. Spotify Fun Study offers data-driven insights into global fan-artist connections, featuring an interactive interface that transitions from simple information displays to complex data visualizations. In contrast, Expodcast is a baroque-style immersive virtual exhibition with episodic storytelling, presenting information, both textual and visual, in a dense, non-progressive manner.

The survey was conducted with 154 [14] undergraduate communication science students aged 20-30. Only 10% of participants have a music education, and their listening habits skew towards popular music genres. 60% engage regularly with music content, primarily to create personal collections. In their online behaviour, users show simple expectations towards a clean and organized look and feel for reading environments. While exploring music magazines and project websites, they showed a tendency to skim through content, preferring articles that are thematically organized with clear, simple schemes (Figure 3). Full article engagement is low (30%), as users typically scan for specific interests. When interacting with music project websites, users were drawn to graphics and visually pleasing data visualizations, despite not being overwhelmed by information density. The Spotify Fun Study was preferred by 70% of users over Expodcast, largely due to its clarity and organization. Together with the progressive disclosure of content, the look and feel of the websites is among the most appreciated aspects. Participants' preferences lean towards efficient text search capabilities, spontaneous discovery paths, and visually appealing interfaces. When recommendations are present, users tend to overlook them, favouring a more hands-on approach of immersive navigation and exploring content through direct links and scrolling. The most favoured interaction style is the gradual unveiling of content. The browsing behaviour is characterized by minimal reading, with a stronger preference for

[12] https://fanstudy.byspotify.com/

[13] https://expodcast.cmbv.fr/en

[14] Survey and results at: https://github.com/polifonia-project/web_portal/blob/main/questionnaires/survey_march2022.csv

interactive elements and immediate feedback. Overall, these findings emphasize the importance of clarity, organization, and aesthetically pleasing design in engaging non-expert users.

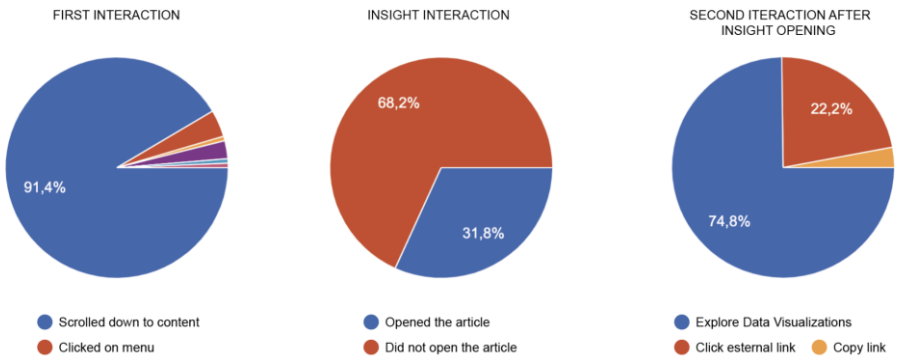

Figure 3. Lay users' interactions with music project websites

Outline Personas. Domain experts of Polifonia collected 27 Stories and 17 Personas, with the intent of mapping out representative scenarios[15]. Experts are 30- to 40-year-old, highly educated with degrees in arts or music. They are employed in private companies or public institutions and work as researchers. Their objectives focus on discovering new music information, collecting data about artists and venues, and enhancing research documentation. The user group is homogeneously skilled, with two-thirds being music professionals and the rest having professional experience in fields outside of music. Given the results of the Competitive Analysis and Customer feedback, three personas have been added to cover the entire spectrum of users that might interact with the web interfaces, e.g. non-expert, and generic user representation. The persona-creation process has been guided by two established [28] methodologies:

- Qualitative method: personas are based on small-sample qualitative research, such as interviews, usability tests, or field studies.
- Quantitative method: a survey is used to gather a large sample of users, and the personas emerge from statistical analysis.

For instance, to create the persona called Laurent[16], a systematic approach was employed. This involved gathering information about his age, gender, educational background, language proficiency, interests, occupations, and personality traits. His knowledge and skills in music journalism, coupled with his strong will and organizational capabilities, were highlighted. His online behaviour was meticulously detailed, noting his daily device usage, preference for applications, and frequent online purchasing habits. This comprehensive description helps in understanding Laurent's needs, preferences, and behaviours. By encompassing both his

[15] https://github.com/polifonia-project/stories

[16] https://github.com/polifonia-project/stories/tree/main/Laurent_Music_Journalist

professional expertise and personal traits, a holistic view of Laurent is presented, useful for tailoring content, features, and services.

Write User stories. In Polifonia, each Persona is linked with one or more Stories, which are crafted based on user goals and narrative scenarios. The formulation of goals, scenarios, and competency questions is based on the data collected from the aforementioned interviews and surveys. For instance, Laurent's story reads as follows: *Laurent is a music journalist that maintains the "Music Journalism Insider" newsletter. His objective is to delve into music-related archives to enrich his newsletter. Every week, Laurent features outstanding music pieces, industry news, and interviews with professionals in the field. His work is powered by his use of music catalogues, personal experiences, and a desire to broaden the scope of music journalism. Laurent's work could be enhanced by technologies that facilitate the discovery, exploration, and visualization of archival and historical music resources.* The scenario of his weekly activities provides insights into his regular tasks, interests, and the resources he relies on. Key resources like music catalogues, online archives, and tools like Google Trends that Laurent uses are identified to understand his workflow and information needs. This is coupled with understanding the potential technologies that could aid his work, highlighting areas where his experience could be improved.

Extract Competency Questions. The findings from the user research were thoroughly analysed, with a keen focus on identifying recurring themes, including common tasks, prevalent challenges, information needs, and decision-making criteria specific to each persona. From this analysis, targeted competency questions were formulated, addressing the identified needs and challenges. These questions were crafted to reflect the realistic inquiries potential users might have. To establish and evolve the "project mental model" [15], each story is further expanded to include a set of competency questions and resources. To ensure the questions were both authentic and relevant, they were validated with stakeholders, and refined based on the feedback received. This iterative refinement process was crucial in maintaining the accuracy and relevance of the questions in line with the evolving needs of the users. The competency questions listed below have been derived from the story and persona of Laurent.

- CQ1: Can I search for a musical content by applying filters (genre, historical period)?
- CQ2: What types of resources can I find?
- CQ3: Is the music resource X complete or incomplete?
- CQ4: Is a dataset attached to resource X?
- CQ5: Can I add resources as a user?
- CQ6: How can I share what I find on the website?

While primarily serving ontology design purposes, questions highlight functionalities and features that would be most beneficial for Laurent in discovering, utilizing, and sharing music related content effectively in his work. They reflect his need for a comprehensive and user-friendly system that aligns with his professional pursuits in music journalism. They also serve as a guiding framework for feature development, content strategy, and user interface design, ensuring that the final product is closely aligned with the target audience's needs and expectations.

		CQ ID	Coverage	exp.	CQ	Input	Path	Output	Web page	Sea int
2	David	David1-CQ7	full	-	Where were the places (in which they played)?	Agent	hasInstrumentOrVoice (inverse) > Musical performar	Place	maybe	yes
3	David	David1-CQ6	partial	-	Who were teaching the musicians?	Agent	hasInstrumentOrVoice (inverse) > Musical performar	Annotation	no	yes
4	Ortenz	Ortenz2-CQ20	full	-	What places did musician Z visited in her career?	Agent	performer (inverse) > Musical performance > place c	Place	maybe	yes
5	Ortenz	Ortenz2-CQ21	full	-	Where did she perform?	Agent	performer (inverse) > Musical performance > place c	Place	maybe	yes
6	Ortenz	Ortenz2-CQ22	full	-	Where did she live?	Agent	places	Place	maybe	yes
7	Ortenz	Ortenz2-CQ23	full	A	Did musician X and performer Y ever met?	Agent	performer (inverse) > Musical performance > perform	Agent	no	yes
8	Ortenz	Ortenz2-CQ23	full	B	Where did musician X and performer Y met?	Agent	performer (inverse) > Musical performance > place c	Place	no	yes
9	Ortenz	Ortenz2-CQ23	full	C	When did musician X and performer Y meet?	Agent	performer (inverse) > Musical performance > date	Timespan	no	yes
10	Ortenz	Ortenz1-CQ6	partial	-	In which source there is evidence of children as target audience and m	Agent	audience (inverse)	Source	maybe	yes
11	Ortenz	Ortenz2-CQ23	partial	-	Did musician X and performer Y ever met? Where, when, and why?	Agent	performer (inverse) > Musical performance > perform	Agent	no	yes
12	Ortenz	Ortenz2-CQ23	partial	D	Why did musician X and performer Y met?	Agent	performer (inverse) > Musical performance > type	Type	no	yes
13	Ortenz	Ortenz2-CQ24	partial	-	In what context the meeting happened?	Agent	performer (inverse)	Musical pe	no	yes
14	Ortenz	Ortenz2-CQ32	partial	-	How can we characterize the relation among the participants?	Agent	audience	Annotation	no	yes
15	Ortenz	Ortenz2-CQ33	partial	-	Was there a power relation? (e.g. Patron / Musician)	Agent	any	Agent	no	yes
16	Sofia	Sofia1-CQ1.2	full	-	What is the time relationship between different musicians, e.g. who was	Agent	any	Agent	yes	no

Figure 4. Sample of Annotated Competency Questions' spreadsheet

Annotate Competency Questions. To quantitatively analyse collected Competency Questions, an annotation method has been devised in a spreadsheet[17] document to provide a structured description of questions in terms of content and presentation aspects (Figure 4).

Each question is first classified based on content characteristics. For the sake of simplicity, CQs have been divided into three thematic areas, which also correspond to the main expertise areas of Polifonia partners, namely:

1. Bibliographic data: structured data addressing cataloguing and historical information of real-world entities (e.g. artifacts, people, places) and abstract concepts (art performances, events). These data are represented by 156 CQs. Among these, 81 address bibliographic data only; 62 also focus on linguistic data; 23 also on music data; of the latter 10 focus on all three types.

2. Music data: structured and unstructured data (audio) about content music features (melody, harmony) and characteristics (modality, tonality). These data are represented by 66 CQs. Among these, 38 focus on music data only; 23 also on bibliographic; 15 also on linguistic data; 10 on all.

3. Linguistic data: semi-structured and unstructured data (free-text) about music-related text sources (e.g. lyrics, newspapers). These data are represented by 80 CQs. Among these, 13 focus on linguistic data only; 62 also on bibliographic; 15 also on music; 10 on all.

The identification of Main Entities and Additional Entities/Properties offer a mapping between natural language questions and ontology design patterns, with an additional comment section for supplementary notes. Crucially, the system also incorporates decision-making aspects such as whether to include the question in browsing/querying interfaces and the type of support required for addressing it. This dual focus on content characterization and operational decision-making facilitates an organized approach to handling the questions.

The system also delves into the presentation and user interaction aspects essential for the web portal. It outlines how the information will be displayed (Output), combines questions with specific web pages, and considers their integration with the search interface. The annotation system also emphasizes the role of visualization, detailing the type of visual aids to be used and

[17] https://github.com/polifonia-project/web_portal/blob/main/analysis/annotated_competency_questions.csv

the method of data aggregation. By addressing both the content and presentation aspects, we ensure that the questions are not only relevant and informative but also effectively integrated into the digital platform.

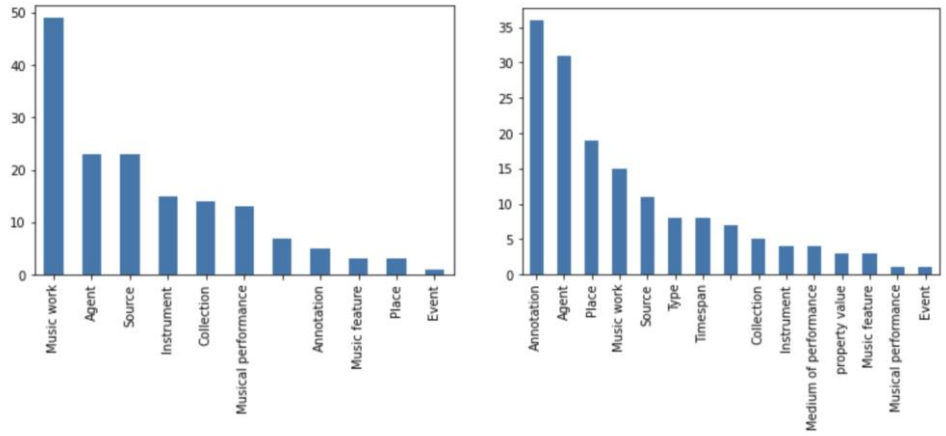

Figure 5. Distribution of input entities (left) and Distribution of output entities (right)

Exploratory Data Analysis. Some pieces of information shall be prioritized when served via the web portal. In order to do that, as aforementioned, Competency Questions have been mapped to ontology classes and properties, so as to derive information on common data patterns.

In Polifonia, most CQs address the analysis of Music works, Agents, and Sources, followed by CQs focused on Instruments, Collections, and Musical performances (Figure 5 left). Expected outputs (say, answers) of CQs include mostly Annotations, i.e., specific pieces of information characterizing the input or another entity, and Agents, followed by related Places, Music works, and Sources (Figure 5 right). The relations between input and output entities have also been analysed. CQs starting from Music works mainly address related Music works, Agents, Sources, Places, and Annotations, followed by Collections, Media of performance and Time-related information. Agents mainly address related Agents, Places, and Sources, while Sources predominantly address Annotations. Instruments are usually related to Agents, Places, and Annotations, while Collections mainly address Annotations and Time-related information. Finally, Musical performances generally direct to Agents, Types, and Annotations (Figure 6).

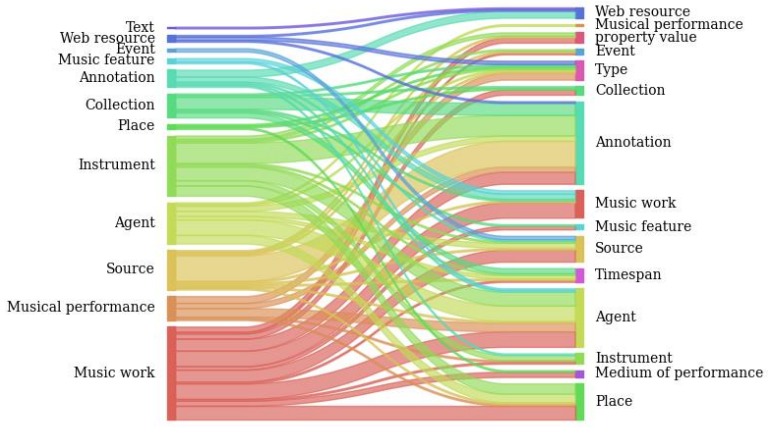

Figure 6. Distribution of bigrams input/output

Brainstorming. After the detailed analysis of data and competency questions, brainstorming sessions are where the insights and detailed understandings from the data analysis are transformed into actionable and innovative ideas. It's a collaborative and dynamic activity where team members, equipped with the knowledge gained from earlier analyses, engage in the creative process of developing mock-ups proposals. This stage is critical for ensuring that the data-driven insights are not only understood, but are also visually and practically interpreted, leading to the design of user-centric and effective solutions. The aim is to translate the complex findings from the data into intuitive, practical designs that align with the project's objectives. These sessions act as a bridge between theoretical analysis and practical implementation, turning abstract concepts and Competency Questions into concrete, visual references.

Task analysis. Task analysis is the examination of the actions and cognitive processes a user must engage in to complete a specific task. This analysis can predict how users might interact with products in development. A common method within this field is Hierarchical Task Analysis, which breaks down a complex task into a hierarchy of smaller tasks, often referred to as hierarchical decomposition [44]. Expanding upon this, the method discussed here employs the principle of goal composition [35]. It starts by identifying the primary goals of users within the system. Then, to enrich these primary goals, a range of potential additional features are conceptualized by merging them with overarching meta-goals. In the scope of this study, goals were extracted from Competency Questions and each one was linked to a macro-goal representing the desired outcome (Figure 7). The macro-goals, along with their corresponding number of CQs, include: Share content (4), Search content (4), Personalize content (4), Learn more about content (6), Find relation between different content (15), Find answer to specific question (51), Explore sources of content (3), Discover new content (1), and Discover content (3).

Subsequently, these goals were matched with user tasks. Each task provides a unique approach to achieving a goal, offering insights into how users work towards their objectives. High level tasks are then broken down into sub-tasks, which detail the step-by-step procedures from accessing the web portal to achieving the related goal (Figure 8). To visually document this analysis, a diagram has been created (Figure 9).

Thematic analysis. As highlighted in the Exploratory Data Analysis, bibliographic and historical data have been targeted as a priority in the development of the Polifonia web portal interface for music heritage exploration. This reasoning assumes that a category shared by the majority of CQs is relevant to different target users.

Consequently, a more detailed thematic data analysis has been performed to understand information patterns, entities and property patterns, and to define strategies for content design. In particular, each Competency Question can be described in terms of a starting node, an ending node, and a property path. The latter can be a direct path (e.g. "Where was an artist born?") or present intermediate nodes (e.g. "Where was the music work performed?"). Information patterns extracted from Competency Questions have been summarized in a flowchart (Figure 10).

Goal	Web Portal	Data Stories	Task
Share content	Yes	Yes	Share project on social media
			Share pilot on social media
			Share suggestion on social media
			Share search result
			Share data
			Copy page link
Search content	Yes	Yes	Generic simple query
			Generic advanced query
			Pilot specific simple query
			Pilot specific advanced query
Personalize content	Yes	Yes	Rearrange content
			Chose language
			Pin favourite content
Learn more about content	Yes	Yes	Read additonal information
			Go to the expert version
			Read about the research approach
Find relation between different content	No	Yes	Combine content to find relationship
Find answer to specific question	No	Yes	Go to content of interest and investigate
Explore sources of content	Yes	Yes	Reach internal source
			Reach external source
Discover new content	Yes	Yes	Get new suggestions
Discover content	Yes	Yes	Navigate suggestions page
			Reach project map
			Reach parteners information
			Reach pilots information
			Reach pilot dashboard
			Reach entitites

Figure 7. Macro-goals matching with user tasks

Search content	Yes	Yes	Generic simple query	Access web portal
				Find search box on homepage
				Initiate query
				See result in dedicated page
			Generic advanced query	Access web portal
				Find search box on homepage
				Initiate query
				See result in dedicated page
				Add filtering options
				Launch query again
				See result in dedicated page
			Pilot specific simple query	Access web portal
				Go to pilots page
				Choose a pilot
				Access dedicated page
				Find search box on page
				Initiate query
				See results on the same page
			Pilot specific advanced query	Access web portal
				Go to pilots page
				Choose a pilot
				Access dedicated page
				Find search box on page
				Add filtering options
				Launch query
				See result on the same page

Figure 8 High-level task breakdown for search content goals

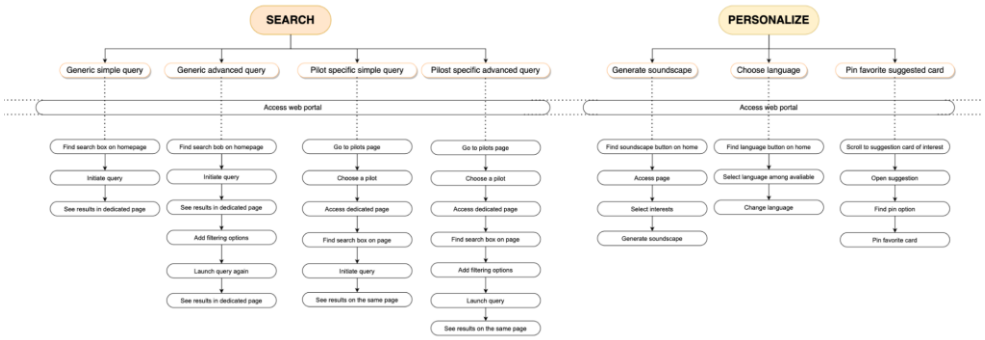

Figure 9. Diagram of search and personalize sub-tasks

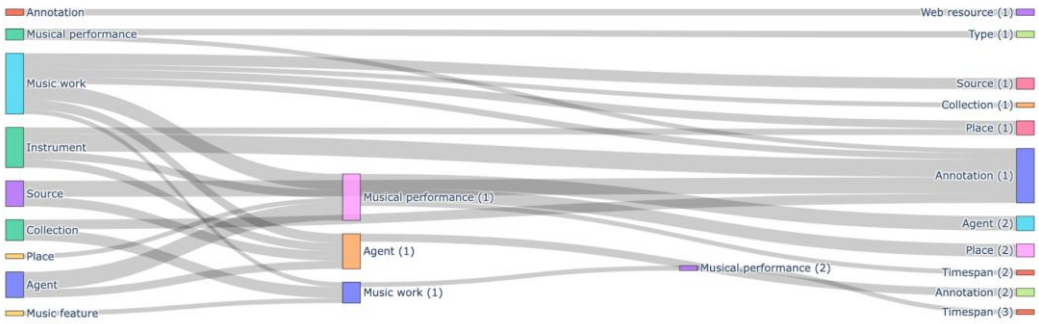

Figure 10. Information patterns that occur at least three times extracted from competency questions

The analysis of the most recurring patterns leads to the definition of 8 recurring discovery patterns which will be leveraged in the web portal as thematic sections. Sections can be summarized as follows:

1. Documentary evidence of topics. Users have a topic in mind and look for documents referencing that topic. When exploring documents they want to know more about people (roles, audience), and connected topics.
2. People connected to events. Users have a person in mind and want to collect information on related events (e.g. performances, biographical events, historical context).
3. Soundscape of places. Users have a place in mind and want to grab all music-related information that characterize the place, such as events, music works, and information on the history of instruments.
4. Music genres and related networks. Users have a genre (or composers relevant to the genre) in mind and want to discover people and works directly or indirectly related (e.g. influences).
5. Scores and music works. Users have a piece of music in mind and want to retrieve scores, documents, and multimedia files searching by bibliographic metadata.
6. Melodies and music works. Users have a piece of music in mind and want to retrieve scores, documents, and multimedia files searching by melodic patterns.
7. Lyrics and music works. Users have a piece of music in mind and want to retrieve scores, documents, and multimedia files searching by lyrics.
8. Music instruments. Users want to know more about the historical evolution of instruments.

Mockups. Mockups represent the next and more in-depth iteration of the design approach. The designers' work encompasses a four-phase creation process, each phase building upon the brainstorming and data analysis phases. The initial phase involves crafting a comprehensive graphical representation of the web portal's structure, called blueprints, focusing on the components and their interrelationships. The blueprint stage is where the data analysis comes in

handy. Here, designers focus on developing a comprehensive graphical representation of the web portal's entire structure (Figure 11). It's akin to creating a map that outlines all the critical elements of the user interface, and how they connect. This phase is crucial because it sets the stage for all subsequent design work, ensuring that every element is placed with a clear understanding of its role and relationship to others in the system.

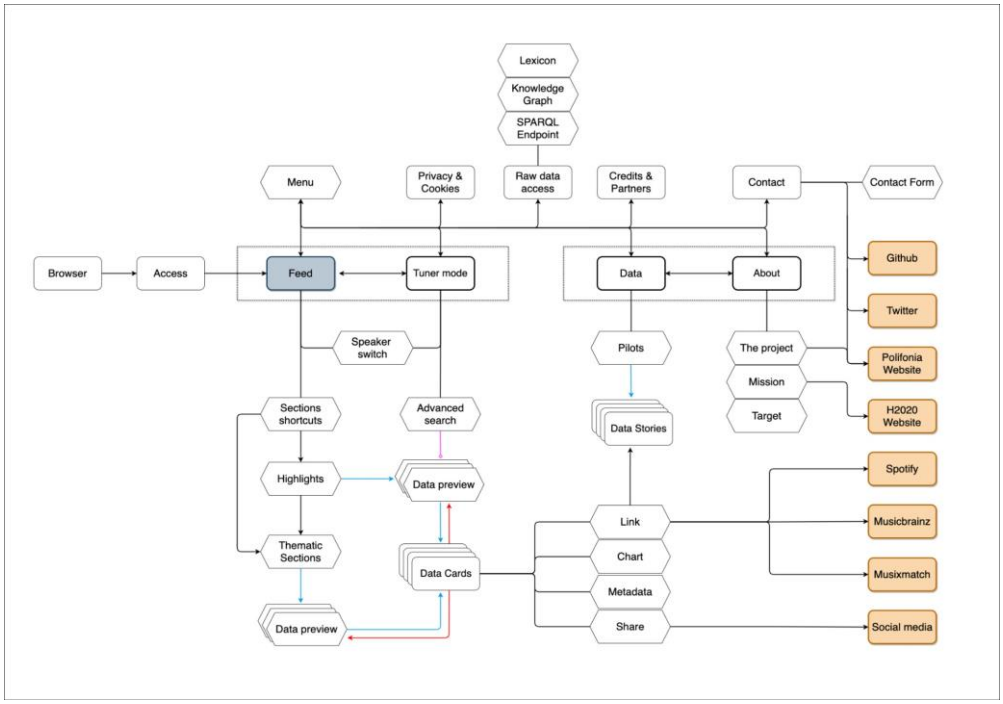

Figure 11. Polifonia Web portal's blueprint

Building upon the groundwork laid by the blueprints, wireframes are created to enhance clarity and detail to the portal's functionality. This phase shifts the focus to the interaction and relationship of elements, rather than their aesthetic appeal. Wireframes act as a skeletal framework (Figure 12) for the portal, illustrating how users will interact with the interface, the flow of information, and how different screens connect. This stage is essential for visualizing the user experience and the portal's functionality in a more concrete way, setting the stage for the visual elements that will be added later. Here, the brainstorming phase is essential for generating creative ideas and conceptualizing the initial layout and functionality of the portal.

The mockups phase is where the design of the application is framed in visual aids. Here, the static wireframes are transformed with the addition of stylistic and visual User Interface details. This includes the integration of colours, styles, graphics, typography, and other visual elements that give the portal its unique look and feel. Mockups provide a realistic preview (Figure 13) of what the final pages will look like, allowing designers and stakeholders to see and feel the user interface before it is fully built. This phase is critical for finalizing design elements, ensuring that the portal is not only functional but also aesthetically pleasing and aligned with the brand identity.

The final step in this process involves the creation of mockup prototypes, blending the interface skeleton from the blueprints and wireframes with the general look provided by the mockups. This early prototype is a functional and interactive simulation, encompassing most of the features intended for the final product. It allows users and pilot leaders to experience the resources in a semi-realistic environment and test the design's usability before it is actually put into development.

Focus groups. Following the completion of the mockups, we progressed to a critical phase involving expert collaboration: conducting a focus group to gather qualitative insights that complement our quantitative data. In this phase, participants were given access to the early prototype and mockups of our web portal, enabling them to independently assess and interact with the interface. During this phase, participants were encouraged to participate in group discussions, fostering an environment where collective opinions and shared needs could be openly expressed. Initially, they were encouraged to form their own judgments and navigate the system on their own, with the freedom to inquire about any aspects they found unclear or intriguing. Following this self-guided exploration, we provided a detailed walkthrough, clarifying each element of the interface. This approach was designed to discern whether the portal was intuitively comprehensible to users or if additional guidance was necessary to enhance their understanding and experience.

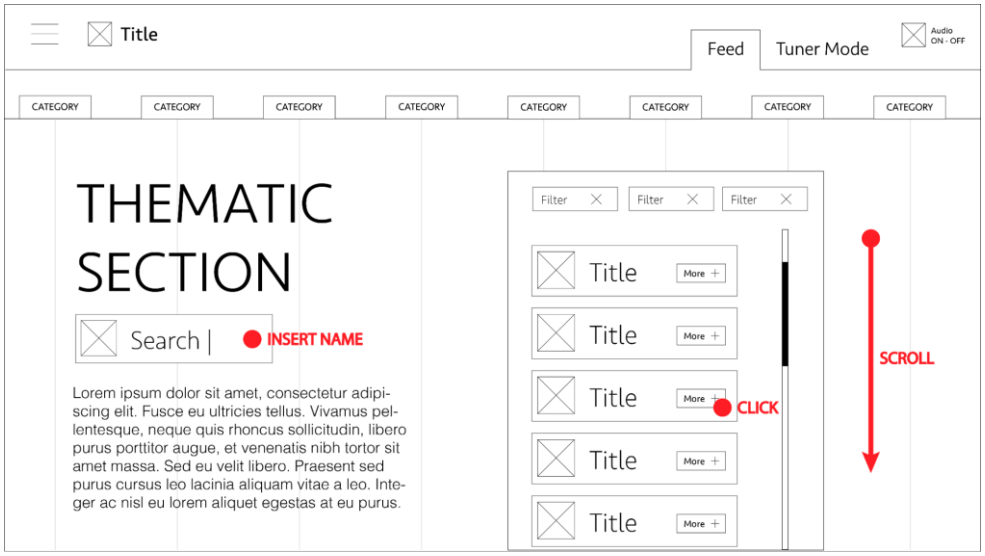

Figure 12. Wireframe of one interface of the Polifonia Web portal

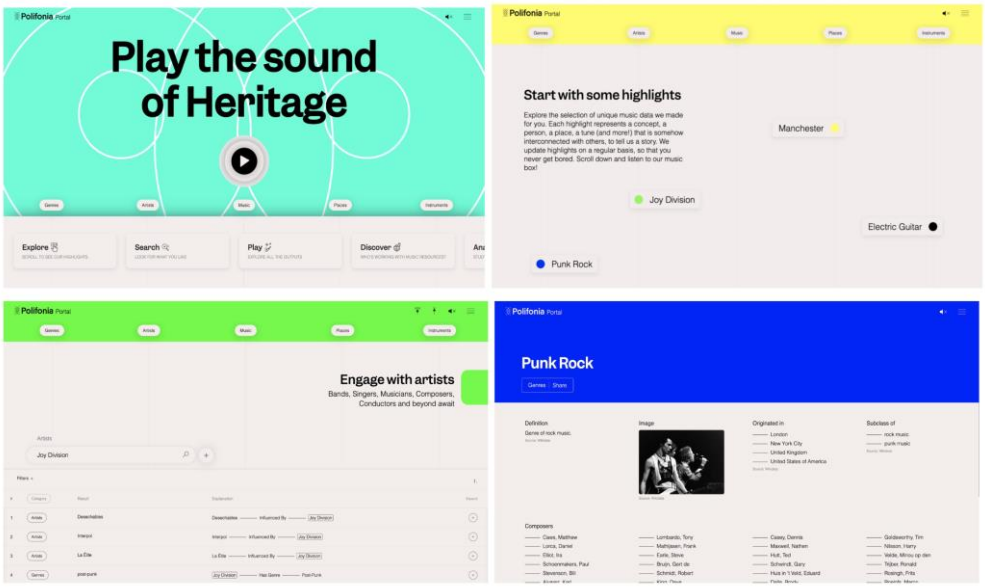

Figure 13. Mockups of four interfaces of the Polifonia Web portal

This interactive setting was instrumental in revealing common desires and viewpoints, insights that might have remained hidden in more structured, task-oriented evaluations. The qualitative nature of this focus group was pivotal in uncovering subtle yet significant aspects of user perception and experience. These insights were particularly valuable in understanding how users interact with generous interfaces. These interfaces are designed to encourage serendipitous discovery, operating on the principle that users may not always have a clear goal when they begin their exploration. Instead of directing users along a predetermined path, these interfaces offer a wealth of possibilities, inviting exploration and chance findings. Furthermore, this phase of the project enabled us to identify usability issues or barriers that might hinder the user experience, allowing us to make informed adjustments and enhancements to the interface.

Evaluation

The evaluation method adopted in this study is a participatory design approach. Different from traditional user testing methods, this approach integrates 18 experts - selected for their proficiency in user experience design and their in-depth knowledge of the music domain - and 186 lay users. The primary objective is to investigate the efficacy of co-design methodologies [22] in enhancing the web portal development process, ensuring that it is user-centred and aligns closely with the needs and expectations of the end users. This methodology is rooted in the principles of co-design [4], emphasizing collaboration, user involvement, and iterative design processes.

On the one hand, experts are requested to participate to interactive sessions, wherein one or more tasks are assigned to them (e.g. retrieve all artists influenced by a certain singer). However,

experts are not merely testers but active contributors to the design process [34]. Indeed, the sessions are structured to facilitate real-time exploration, discussion, and comprehensive feedback on the prototype.

On the other hand, when investigating preferences of the secondary target, i.e. lay users, these do not behave as testers at all, i.e. they are not provided with any web application and they are not asked to perform any task. Instead, they are asked to imagine the web environment they would like in a certain context (e.g. you are at home studying/working, and you would like to listen to new music) and to describe how they would achieve their task. Proposing two different types of co-design tests allows us to evaluate both the idea and the expectations in two different settings, namely: the more traditional setting of evaluating a given interface, and a less traditional one where users are asked to imagine a web application and a number of features, tasks, and desiderata without being biased by a given proposal.

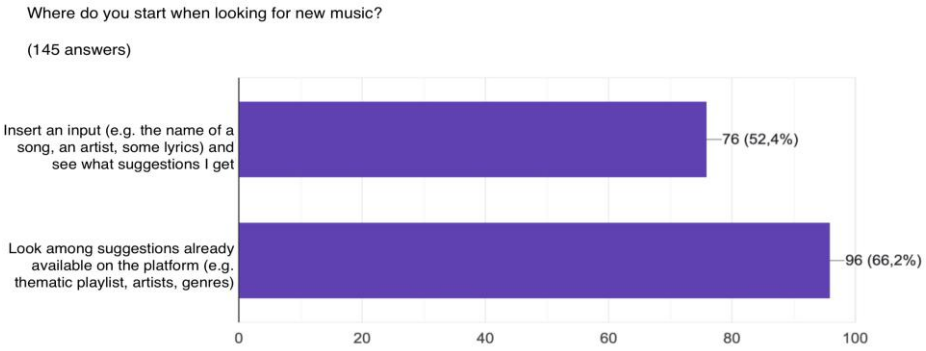

Figure 14. Users need platforms to suggest them new music (66,2%)

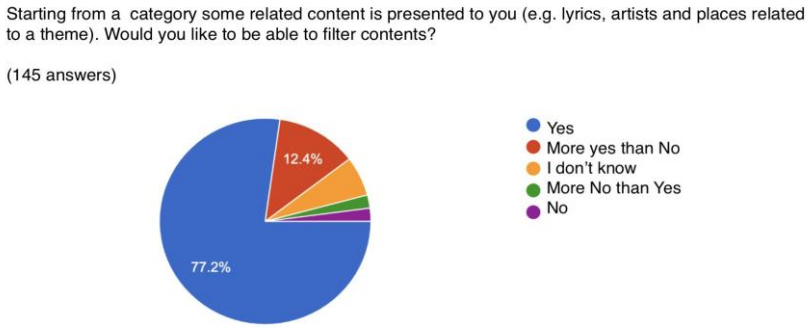

Figure 15. Users appreciate the possibility to filter their results.

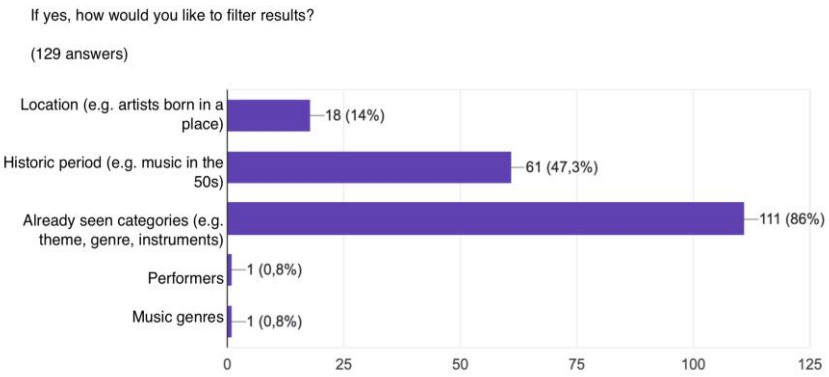

Figure 16. Users would like to have filters based on known categories.

The lay users test results reveal several key insights into participants' preferences for a music web portal. A significant 86.9% showed interest in a portal integrating music data. Additionally, 61.4% were keen on searches that start with specific inputs and guide them through a variety of information. The concept of serendipitous discovery was positively received, with 57 participants recounting favourable experiences with such discovery journeys. Moreover, 66.2% of participants expect the platform to offer suggestions as a launchpad for their exploration (Figure 14), leading to personalized user journeys. These journeys are preferred to begin with or be based on music genres, artists, and general topics, with *music genre* being the most frequently mentioned term in open ended responses (154 times). This feedback was instrumental in establishing the five main entry points to the Polifonia knowledge graph (narrowing down the aforementioned thematic analysis, which returned 8 categories), encompassing the categories, highlights, and search sections. Interestingly, the survey highlighted a demand for a seemingly straightforward feature absent in existing music data discovery platforms: filter options. Notably 77.2% of participants valued the ability to filter search results (Figure 15) using established categories to refine their search outcomes (Figure 16).

During the co-design sessions with experts, the participants engaged in a series of tasks designed to simulate real-world use and to provoke discussion on various aspects of the web portal's design and functionality. The tasks ranged from navigating the homepage to performing specific content retrieval exercises. A significant aspect of these sessions was the open-ended exploration phase, allowing experts to freely interact with the portal, thus providing holistic feedback on the overall user experience. The results from the co-design sessions indicated overall satisfaction with the simplicity of completing the proposed tasks, as shown in Figure 17. However, there were mixed responses regarding the ease of finding the necessary features to accomplish tasks (Figure 18), suggesting room for improvement in navigability and feature accessibility.

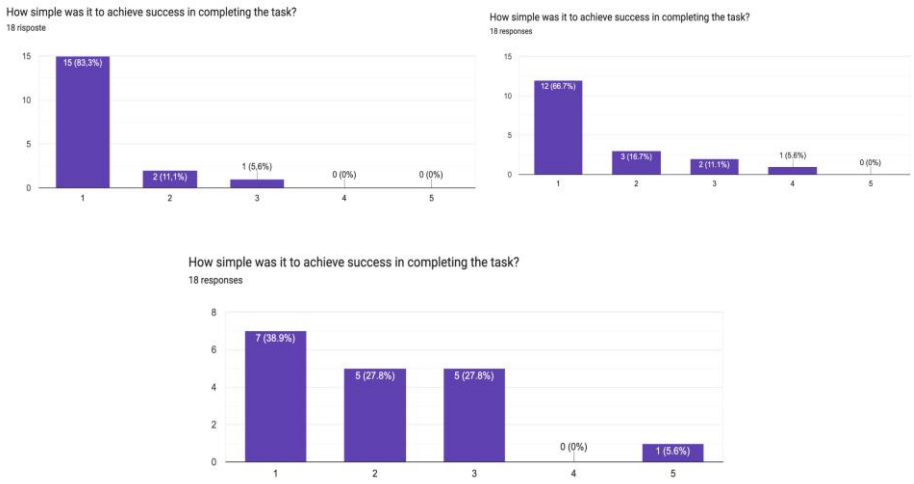

Figure 17. Despite tasks increasing complexity, the success rate is always high (1 = Very easy; 5 = Very difficult)

Participants were active in reporting not just on task completion but also in identifying bugs or issues, contributing 38 messages encompassing comments, issues, and suggestions. This proactive feedback was instrumental in uncovering technical challenges and system errors. As a result, substantial modifications were made to the original prototypes. These changes were focused on enhancing user experience by simplifying the design, such as highlighting keywords throughout the portal for intuitive navigation and dividing filters in search sections into subcategories with a reset option. Further, to avoid confusion, clickable and non-clickable elements were distinctly differentiated. To manage content presentation and prevent cognitive overload, pagination options like "Load more" were implemented. Cross-browser issues were also addressed, ensuring a consistent user experience across different platforms.

Moreover, the lexicon used in titles, subtitles, and paragraphs was refined based on expert feedback, as were the names of the five main categories: genres, artists, music, places, and instruments. These categories serve as primary entry points into the Polifonia data, and their optimization was crucial for enhancing user interaction with the portal. The group discussions provided collective opinions and identified common desires and preferences. This qualitative approach was particularly revealing, uncovering aspects of user perception that might not have been evident in the more structured, task-based performances. Importantly, it shed light on the design of generous interfaces – those which encourage serendipitous discovery and exploration without assuming the user has a specific goal in mind. This insight was pivotal in framing UI/UX elements that cater to a broad range of user interactions with the portal. Overall, the combination of quantitative and qualitative feedback from the co-design sessions led to the understanding of user needs and preferences, guiding significant improvements in the web portal's design and functionality. The collaborative approach not only pinpointed usability issues but also provided a clear direction for enhancements, resulting in a more intuitive, user-friendly, and effective web portal.

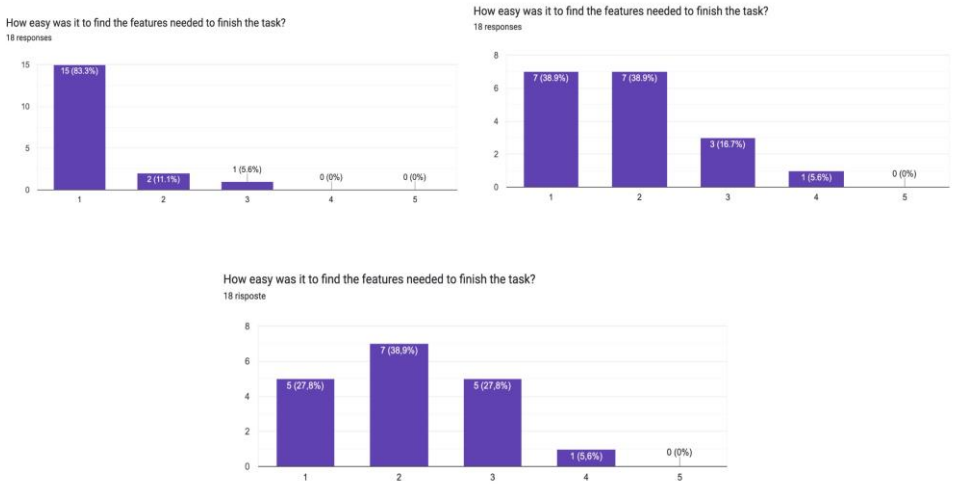

Figure 18. Features to accomplish tasks are easy to find regardless of their complexity (1 = Very easy; 5 = Very difficult)

Discussion

We established a process that integrates ontology requirements into UI/UX design for two main purposes: (1) to generate ideas and prototypes aligned with data needs, and (2) to allow the UI/UX design to continually adapt and refine these ontology requirements. By conducting exploratory analysis of Competency Questions, we gained insights into data needs and established priority areas. Analysing data patterns helped us anticipate types of content interactions and their significance. Additionally, user studies focusing on competitive analysis and co-design methods aided in adjusting our services to meet the expectations of a diverse user base, from experts to novices. Our initial findings support two key hypotheses: (1) CQs with similar interaction patterns can be categorised together; (2) entities significant in numerous CQs tend to be important to a broad user spectrum. Consequently, this allows us to apply our workflow to a reduced set of CQ groupings rather than individual personas, thus saving time.

By systematically aligning user requirements with data and ontology requirements, we ensure that the resulting interfaces are user-friendly and semantically rich, facilitating more effective information-seeking, exploration, and discovery. There are several potential benefits for Digital Humanities (DH) applications. The methodology's foundation on LOD principles ensures that data from various sources can be seamlessly integrated. This is particularly beneficial for DH projects, which often involve diverse and heterogeneous datasets belonging to cultural heritage institutes and research projects. The adoption of our methodology in DH projects – or, broadly, in web environments targeted on the cultural heritage domain – allows one to enhance the usability of data, facilitate connections across domains, foster the design of coherent and efficient user interfaces for information seeking, and enable serendipitous discoveries at the same time. Our approach significantly improves user engagement by leveraging user-centric design practices from both the HCI field and design thinking methodologies. This is crucial in DH applications where user interaction with the content is a key aspect of the research process. Using personas, user stories, and competency questions helps us to ensure that interfaces are tailored to the

specific needs and preferences of various user groups. Moreover, one of the notable challenges in DH is enabling users to discover unexpected connections and insights. Our methodology's emphasis on creating generous interfaces that balance retention and overview can significantly enhance the user's ability to explore and discover new information serendipitously. This is particularly relevant for projects dealing with cultural heritage, literature, and historical archives.

While our process of integrating ontology requirements into UI/UX design has shown promising results, it is important to acknowledge its limitations to provide a balanced view. Firstly, the dependency on the quality and comprehensiveness of the exploratory analysis of Competency Questions is a significant limitation. If the CQs are not well-formulated or if they fail to cover the full spectrum of the data and user needs, the user journeys – addressed in the insights and priority areas of the proposed prototype - may be incomplete or skewed. This could also lead to a misalignment between the ontology requirements and the actual expectations of the target user. Secondly, the approach relies heavily on iterative refinement based on user feedback and data pattern analysis. While this iterative process can be considered one of the strengths of the process and hence of the result, it can also be time-consuming and resource-intensive. Small-scale projects or those with limited resources may find it challenging to engage in multiple iterations of design and testing. Furthermore, our hypothesis that CQs with similar interaction patterns can be categorised together and that entities significant in numerous CQs are important to a broad spectrum of users, while supported by these findings, may not hold true in all contexts. The methodology has been so far tested for designing interfaces for the exploration of music and cultural heritage, generating three rather different types of application, namely: a crowdsourced catalogue, a data story editor, and a web portal for knowledge discovery. However, it may require adjustments when applied to different domains (e.g. hard sciences). In such contexts, different user groups may have unique interaction patterns or prioritize different entities, which our methodology might not capture. Future research and development should aim to address these challenges, refining the methodology to make it more robust and scalable to a wider range of projects and user requirements.

Conclusion

The study demonstrates that the integration of ontology design with UI/UX decision-making is a powerful strategy for overcoming challenges in projects focused on the dissemination of cultural heritage data. This innovative approach, bridging the gap between data analysis and user interface design, has shown its potential in enhancing user experience while ensuring the accurate representation of complex data structures.

In the next future, we plan to conduct extensive monitoring activities on the Web portal to estimate user engagement and evaluate user journeys. Analysing how users interact with the portal will provide us valuable insights into the effectiveness of our UI/UX designs and ontology structures. This will not only help in refining our current methodologies but also assist in creating more user-centric designs in future projects.

The successful application of this methodology in our case study serves as a preliminary validation of its effectiveness. By employing this strategy in the development of diverse applications – a digital catalogue, an authoring platform, a linguistic corpus interface, and a web portal designed for engaging the general public – we have witnessed firsthand its versatility and impact. Each application, catering to different user needs and interaction styles, benefitted from the nuanced understanding of data and user requirements facilitated by our approach.

Looking to the future, we aim to expand the application of our methodology beyond its current scope. We plan to test its applicability in a variety of scenarios to further establish its adaptability and effectiveness. This expansion will not only validate the methodology in contexts other than cultural heritage but will also provide insights into its scalability and adaptability to different data scales and user demographics. Understanding how our approach scales with larger datasets, more complex ontologies, and diverse user groups is essential for its application in large-scale projects. We are particularly interested in investigating how the methodology can be adapted for big data environments and how it performs under the pressure of rapidly changing data landscapes and user demands.

The initial success of integrating ontology design with UI/UX decisions in cultural heritage projects is just the beginning. Our future efforts aim to broaden the scope, increase the scalability, and deepen the sophistication of this approach, making it a useful tool in the field of data-intensive application design.

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