Towards an Ontology-Driven Framework for Context-Aware Data Visualization in Cultural Heritage

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Abstract

In cultural heritage research, data visualization plays a central role in supporting the interpretation of heterogeneous datasets, including spatial records, analytical measurements, and three-dimensional models. However, most existing visualization systems rely on predefined representations that insufficiently account for the contextual conditions in which data are accessed, such as user role, task objectives, usage environment, and available technological resources. This paper introduces an ontology-driven framework for context-aware data visualization in the cultural heritage domain. The proposed approach is based on an explicit formalization of context through a dedicated Context Ontology (ContextO), which models the relationships among users, data, goals, interaction channels, and spatial conditions. Building on this model, we present ReXplora, a framework that exploits semantic representations and rule-based reasoning to guide visualization composition. Visualization is conceived as a modular process based on reusable visual blocks, which are dynamically selected and combined according to contextual constraints inferred from the ontology. The contribution of this work lies in bridging context modeling and adaptive visualization design through an explicit ontological layer, enabling transparent and explainable visualization strategies. The proposed framework provides a conceptual and methodological foundation for the development of flexible, context-aware visualization systems supporting cultural heritage research activities.

Keywords

Context-aware Visualization, Ontology-driven Systems, Cultural Heritage Data, Semantic Modeling

1. Introduction

Data visualization has become a fundamental instrument for the analysis, interpretation, and communication of cultural heritage data. Contemporary heritage research increasingly relies on heterogeneous digital resources, including spatial datasets, diagnostic measurements, excavation records, and three-dimensional models, which are produced and consumed across different disciplinary, professional, and operational contexts [1]. Visualization techniques are widely adopted to support exploratory analysis and knowledge construction; however, their effectiveness strongly depends on the conditions under which data are accessed and interpreted [2]. Most existing visualization systems adopt predefined visual representations or fixed interaction paradigms that only marginally account for contextual variability. Factors such as the user's role and expertise, the analytical goal of the activity, the characteristics of the data, the physical or spatial setting, and the technological channel through which visualization is accessed are often treated implicitly or addressed through ad hoc configuration mechanisms. As a result, visualization strategies tend to be static, opaque, and difficult to adapt or reuse across different scenarios, limiting their suitability for complex and evolving research practices in the cultural heritage domain [3]. In recent years, context-awareness has emerged as a key concept in adaptive and intelligent systems, emphasizing the importance of tailoring system behaviour to situational conditions [4]. Early

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studies have defined context in terms of location, identity, nearby objects, and time [5][6], while later contributions have proposed broader interpretations encompassing any information that characterizes the situation of an entity involved in an interaction [7]. Despite this extensive body of work, in the field of data visualization, and particularly in cultural heritage applications, context is rarely modeled explicitly in a formal and machine-interpretable manner. When contextual factors are considered, they are typically embedded in procedural logic or user interface design choices, making adaptation mechanisms difficult to inspect, explain, and extend [8]. This paper addresses this gap by proposing an ontology-driven approach to context-aware data visualization for cultural heritage research. We argue that context should be treated as a first-class conceptual entity, formally represented and reasoned upon, rather than as an unstructured collection of parameters. To this end, we introduce ContextO, a context ontology designed to model the relationships among users, data, goals, interaction channels, spatial conditions, and technological resources. The ontology provides a shared semantic framework that enables contextual knowledge to be explicitly represented, queried, and inferred using Semantic Web technologies [9]. Building on this model, we present ReXplora, a framework that exploits ontological reasoning to guide visualization composition. In ReXplora, visualization is conceived as a modular and adaptive process based on reusable visual blocks, an approach inspired by prior work on visualization grammar and modular visual design [10], [11]. Each visual block encapsulates a specific visual function,such as spatial representation, comparison, or temporal analysis, and is associated with semantic descriptions specifying the contexts in which it is appropriate. Visualization strategies are dynamically derived through rule-based reasoning over contextual constraints, enabling explainable and context-sensitive adaptation without relying on opaque or hard-coded decision mechanisms [12]. The contribution of this work is threefold. First, it introduces a formal ontological model for representing context in cultural heritage visualization scenarios. Second, it proposes a framework that integrates context modeling and adaptive visualization design based on ontology-driven reasoning mechanisms. Third, it outlines a methodological basis for the development of reusable and transparent context-aware visualization systems, with potential applicability across heterogeneous research activities in the cultural heritage domain. The remainder of the paper is organized as follows. Section 2 reviews related work on context modeling and adaptive visualization. Section 3 presents the ReXplora framework and its visualization model. Section 4 describes the design methodology and structure of the Contexto Ontology. Finally, Section 5 discusses limitations and outlines directions for future work.

2. Related work

Context has been extensively investigated in the field of adaptive and ubiquitous computing, where it is commonly regarded as a key factor for tailoring system behavior to situational conditions. Early definitions conceptualized context in terms of location, identity, nearby objects, and time, emphasizing spatial and environmental aspects of interaction [4], [5].Subsequent work broadened this perspective, defining context as any information that can be used to characterize the situation of an entity involved in an interaction between a user and an application [7]. These contributions laid out the conceptual foundations for context-aware systems by highlighting the importance of situational information in system adaptation. Several surveys and theoretical frameworks have further explored context modeling strategies, distinguishing between different categories of contextual information and approaches to their representation [8]. However, much of this work focuses on context as an implicit or application specific construct, often embedded in procedural logic rather than explicitly formalized in a reusable and machine-interpretable form. As a result, context- aware behavior is frequently implemented through ad hoc mechanisms that limit transparency, extensibility, and reuse. In parallel, the visualization community has extensively investigated how visual representations support data exploration and analytical reasoning. Foundational work has emphasized visualization as a cognitive activity aimed at gaining insight rather than producing graphical artifacts [2], [10]. Grammar-based approaches and modular visualization models have been proposed to support systematic design and reuse of visual encodings and interaction patterns [11], [12]. Interactive visualization techniques have also been shown to enhance analytical tasks by enabling users to explore data dynamically and iteratively [13]. Despite these advances, the integration of explicit context modeling into visualization systems remains limited. In many visualization frameworks, adaptation to users, tasks, or environments is handled through fixed configurations or interface-level customization, without a formal representation of the underlying contextual knowledge. This limitation is particularly evident in cultural heritage applications, where heterogeneous users, data types, and usage scenarios coexist, and where visualization requirements can vary significantly depending on disciplinary practices and research goals [1]. Some recent approaches have explored semantic technologies and ontologies to improve interoperability and knowledge representation in cultural heritage and information systems. Semantic Web frameworks enable the explicit formalization of domain concepts and relationships, supporting reasoning and inference over structured knowledge [9]. However, while ontologies have been widely adopted to represent contextual knowledge in cultural heritage and information visualization, their use as an explicit driver for adaptive visualization, particularly in terms of transparent and explainable visualization composition mechanisms, remains comparatively underexplored. This work positions itself at the intersection of context modeling, semantic technologies, and data visualization. Unlike existing approaches that treat context implicitly or procedurally, we propose an explicit ontological representation of context that directly informs visualization design decisions. By combining a context ontology with a modular visualization model based on visual blocks, the proposed framework addresses the need for reusable, inspectable, and context-aware visualization strategies in the cultural heritage domain.

3. From Context to Visualisation: the Rexplora Framework and its Context Ontology

ReXplora is a framework designed to support context-aware data visualization by explicitly leveraging contextual knowledge represented through an ontology. Rather than directly mapping data to predefined visual representations, ReXplora conceives visualization as a decision process guided by contextual constraints. These constraints derive from multiple factors, including the user's role, task objectives, data characteristics, interaction channel, and usage conditions. The framework operationalizes the context ontology by instantiating contextual information within a semantic layer that can be queried and reasoned upon. In this sense, ReXplora acts as an intermediary between contextual knowledge and visualization design, enabling visualization strategies to be derived dynamically rather than selected a priori. This approach shifts the focus from static visualization configurations to adaptive visualization composition driven by explicit semantic descriptions.

3.1. Context-driven visualization model

Within ReXplora, visualization is modeled as a function of contextual dimensions rather than as a fixed rendering pipeline. Conceptually, the visualization outcome can be understood as the result of a context-dependent selection process, where contextual factors constrain the space of admissible visualization strategies. This process does not aim at producing a single optimal visualization, but rather at identifying a set of suitable visual solutions consistent with the current context of use. Contextual dimensions considered in the framework include the user and their expertise, the analytical goal of the activity, the nature of the data, the interaction channel, and the spatial or situational conditions in which visualization takes place. These dimensions correspond to the core scopes modeled in the Context Ontology and provide a semantic basis for visualization adaptation. In particular, as can be seen in the following function, we have instantiated the concept of a function where we express that:

$$Context = f(c, d, u, i(g)) \rightarrow v \quad (1)$$

In particular, below we briefly describe the concepts underlying the expressed function, which will also become the known scopes of the Context Ontology.

Channel: it is inserted into the context as the entity responsible for communication, through which information is transmitted. The channel also interpreted as a *medium*, is the entity that transmits data, and these include: a mobile app or smartwatch, a web browser, and a personal device. It influences information presented, how the user can interact with the data, and which functions are available in that context [14].

Data: it can be understood that the concept of data is common across all scientific disciplines, which provide the empirical basis for research activities. The concept of dataset is common across almost all scientific disciplines, where data provides the empirical basis for research activities. Yet, this central concept has been poorly explored. Although the term appears regularly in articles, documents, and reports, as well as in informal conversations among scientists, there is no consolidated and specific definition. Nonetheless, the term *dataset* appears to be in common use, which suggests that there is at least a general shared understanding and indeed, our literature review, summarized below, clearly identifies several recurring themes [15],[16].

Interest: understood as a set of needs, motivations, preferences and purposes that guide user behaviour in systems, services and communication processes.

Goal: The concept of goal-directed action, however, has wider significance. Goal directedness is "a cardinal attribute of the behaviour of living organisms. It may be observed at all levels of life: in the assimilation of food by an amoeba, in the root growth of a tree or plant, in the stalking of prey by wild animals, and in the activities of a scientist in a laboratory" [17]. At all levels of explanation, cognitive factors play a role in explaining both the choice of action and its degree of success. For example, goals, if chosen by people themselves, are based on factors such as their beliefs about what they can achieve, their memories of past performances, their beliefs about the consequences, and their judgments about what is appropriate for the situation. And their degree of success will depend on their awareness of whether they are actually acting in line with the goals (feedback) and their knowledge of appropriate strategies for the task. Based on [18] It's the person who sets the goal. Goals are the starting point for design. Norman also distinguishes between: explicit objectives (those declared by the user) and implicit objectives (those that the user does not say, but that the designer must foresee). According to Garret instead, in [19], it's underlied that User goals correspond to the deepest and most fundamental level (the "Information Structure" and the "Interactive Structure"), which inform all other design decisions, from the visual surface (the interface) to the underlying strategy, to ensure an effective, user-centered digital experience Locke and Latham's goal - setting theory starts from a very simple introspective observation: *when we act consciously, we always do so with a purpose, guided by our personal goals* [20] . This tendency to orient ourselves toward specific goals, however, is not a human peculiarity, but rather a characteristic common to all living beings, regardless of the presence of awareness.

Visualisation: The visualization community has not yet found a theory of visualization that most people would consider fundamental. Visualization ideation is the process of brainstorming, conceptualizing, and generating new ideas for data visualization. The difference between visualizations and traditional entertainment media is the information and story conveyed in information visualization environments are usually much more complicated than those typically shown in films or the theatre, or on television programs and commercials [21]. "*Visualization is solely a human cognitive activity and has nothing to do with computers*" [21]. Also an interview with visualization pioneer Ben Shneiderman, Information visualization is a powerful interactive strategy for exploring data, especially when combined with statistical methods. Analysts in all fields can use interactive information visualisation tools for more effective detection of faulty data, missing data, unusual distributions, and anomalies, deeper and more thorough data analyses that produce deeper insights, and richer understandings that enable researchers to ask bolder questions.

User: The user is a central actor in information systems development processes and as such is subject to extensive study in theory and practice. The user in getting involved in the design process as well as in fitting into a predefined role is of great importance to system development. For designing visualizations in the CH field, the user is a critical factor. Users are very diverse, from museum curators to humanities scholars, and therefore, people with a professional or scientific interest in cultural heritage data. For this reason, different user categorizations exist based on sector and technical expertise [3].

Place / location: "Location refers to an absolute point in space with a specific set of coordinates and measurable distances from other locations. Location refers to the "where" of place. Locale refers to the material setting for social relations, the way a place looks. Location includes the buildings, streets, parks, and other visible and tangible aspects of a place. Sense of place refers to the more nebulous meanings associated with a place: the feelings and emotions a place evokes" [22].

3.2. Visual blocks and modular composition

A key design principle of ReXplora is the decomposition of visualization into modular units, referred to as visual blocks. Visual blocks encapsulate specific visual functions, such as spatial representation, comparison, temporal exploration, or analytical detail. Each block represents a reusable visualization component that can be combined with others to form more complex visualization structures. Visual blocks are associated with semantic annotations that describe the contexts in which they are applicable. These annotations specify constraints related to user roles, data types, goals, and interaction channels, allowing the framework to reason their suitability in a given situation. By treating visualization as a composition of visual blocks, ReXplora promotes modularity, reuse, and flexibility across heterogeneous application scenarios.

3.3. Reasoning and adaptation mechanism

Visualization adaptation in ReXplora is achieved through rule-based reasoning over contextual knowledge. Context instances derived from the ontology are evaluated against a set of reasoning rules that determine which visual blocks are compatible with the current context. The result of this reasoning process is a context-aware visualization configuration, expressed as a composition of visual blocks rather than as a rigid, predefined layout. This mechanism supports explainable adaptation, as visualization decisions can be traced back to explicit contextual conditions and reasoning rules. Unlike procedural or hard-coded adaptation strategies, the ontology-driven approach allows visualization behaviour to be inspected, extended, and reused across different domains and scenarios. The role of ReXplora is therefore not to replace visualization design practices, but to provide a structured semantic framework that supports consistent and transparent adaptation decisions.

4. ContextO: Ontology Design and Methodology

The Context Ontology was designed to support the explicit representation of contextual factors influencing data visualization in cultural heritage research. Its primary objective is to formalize the relationship between visualization strategies and their context of use, enabling contextual knowledge to be represented in a structured, machine-interpretable form and exploited by adaptive visualization mechanisms. This approach is grounded in established principles of context modeling and Semantic Web technologies, which emphasize explicit knowledge representation and reasoning as enablers for system adaptability (e.g., [5], [8]).

4.1. Requirement elicitation and scope definition

The ontology design process was grounded in a structured requirements elicitation phase aimed at identifying the contextual dimensions that most significantly affect visualization practices in cultural heritage research. This activity was conducted through an exploratory investigation involving domain experts from the CNR – Institute of Heritage Science (CNR ISPC), including archaeologists, art historians, and cultural heritage scientists with expertise in diagnostic and analytical methods. The identification of contextual dimensions reflects prior studies on the diversity of data practices and user needs in cultural heritage research environments [1]. The outcome of this phase was the definition of a set of core contextual dimensions, corresponding to users, data, goals, interaction channels, spatial conditions, and technological resources. These dimensions define the scope of ContextO and operationalize the assumption that visualization and context form a tightly coupled epistemological unit in scientific research activities, particularly in data-intensive cultural heritage domains [2].

4.2. Ontology engineering methodology

The development of ContextO followed the Simplified Agile Methodology for Ontology Development (SAMOD), an agile ontology engineering approach that promotes an iterative and incremental process driven by motivating scenarios and competence questions [23]. SAMOD was selected for its emphasis on early validation, close collaboration between domain experts and ontology engineers, and continuous alignment between conceptual modelling and application requirements. Two complementary roles were involved in the process: the Domain Expert (DE), responsible for providing domain knowledge and usage scenarios, and the Ontology Engineer (OE), responsible for formalizing this knowledge into an OWL-based model. For each motivating scenario, competence questions were defined to validate the ontology's ability to represent and retrieve the intended contextual knowledge. This validation strategy is consistent with established best practices in ontology engineering and Semantic Web–based knowledge representation [24].

4.3. Ontology structure, implementation, and validation

ContextO models context as a structured entity composed of interrelated conceptual dimensions. Each dimension is represented as a set of ontological classes connected through explicit semantic relationships, enabling a clear separation between abstract contextual concepts and their concrete instantiations. This design choice supports reasoning and inference mechanisms that allow implicit contextual knowledge to be derived from explicitly stated facts, a core principle of OWL-based knowledge representation [8], [18]. The ontology was initially designed using graphical modelling tools (Draw.io [25] with the Graffoo framework [26]) and subsequently implemented in OWL using Protégé (version 5.6.5) [27]. Logical consistency and coherence were verified using the HermiT reasoner (version 1.4.3.456). Compliance with the defined competence questions was further validated through SPARQL queries executed within the Protégé environment. These validation steps ensure that ContextO provides a robust semantic foundation for contextual reasoning within the ReXplora framework, and in the next contribution, will be shared. Figure1provides a conceptual overview of the relationship between the ContextO ontology, the ReXplora framework, and the modular visualization components. Instead, Figure 2 provides an example of the proposition of the different visualization aware of the context.

4.4. The reasoning and validation

The study aimed to evaluate ReXplora's ability to adapt visualization strategies to different operational contexts, distinguishing in particular between field use, which requires rapid on-site inspection, and laboratory analysis, which supports controlled interpretation and reporting. Using data streams from temperature and humidity sensors, the primary task was the comparative inspection of temporal patterns. To this end, ReXplora, specifically the Contextual Ontology, was configured with the *SignalBlock* and *TemporalBlock* components, enabling the generation of time series visualizations suitable for trend comparison and anomaly detection. The following example (scenario and skill question) was applied within the international platform Spatial hEritage scieNce oNline Sensor Environment (SENNSE) [28] - Bernardini Library of Lecce, Italy.

The situations encountered here are diverse and have allowed us to verify how visualization is the result

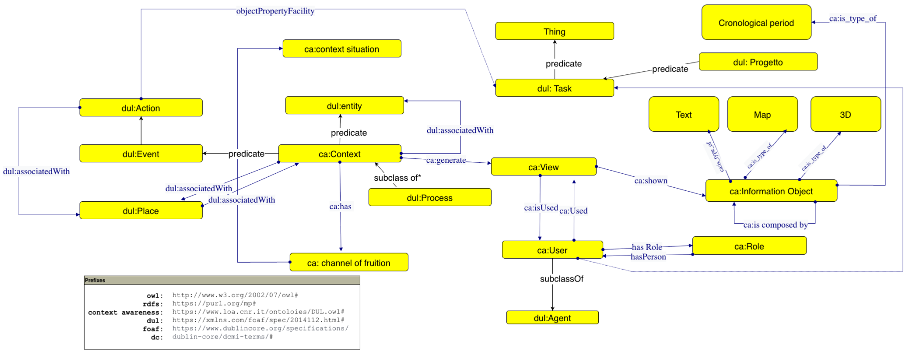

Figure 1: Conceptual architecture of the ReXplora framework, showing the role of the ContextO ontology in supporting context-aware visualization composition through semantic reasoning and modular visual blocks

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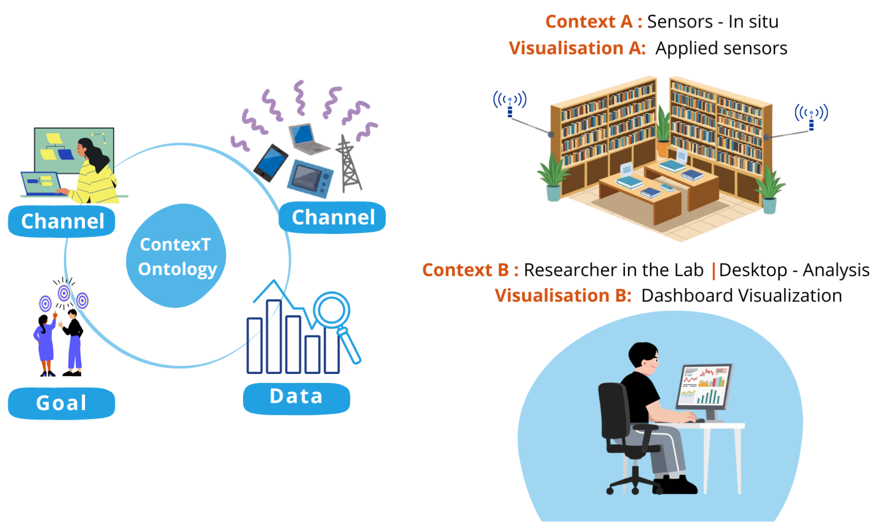

Figure 2: Example of context-aware data visualization

of a combination of the task the user [User] is performing [Goal] and the data [Data] they are using. For example, in the first case (Figure 3), data from the sensor devices are displayed in different contexts: the laboratory context, and the same data is also displayed in the real context of the Library. In the second case, it is possible to appreciate which visual blocks are composed coherently with respect to the Library context, the goal, the data type, and the visualization, see Figure 4.

Scenario: The user (or dashboard designer/engineer) wants to have a global view of which visual blocks exist.

CQ 1- Which are active sensors in sensor's context?
[Channel, Data, Context]

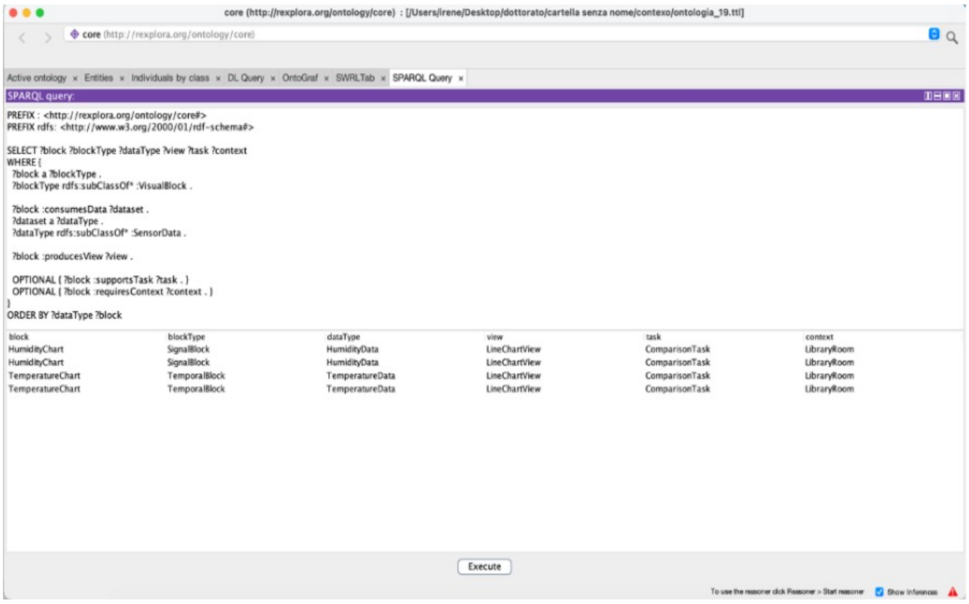

Figure 3: the figure shows the output from the Protégé tool related the CQ1

CQ 2 - What visual blocks are present in the system, how are they configured with respect to sensory data, view type, task, and context?

[Visualization, Data, Context]

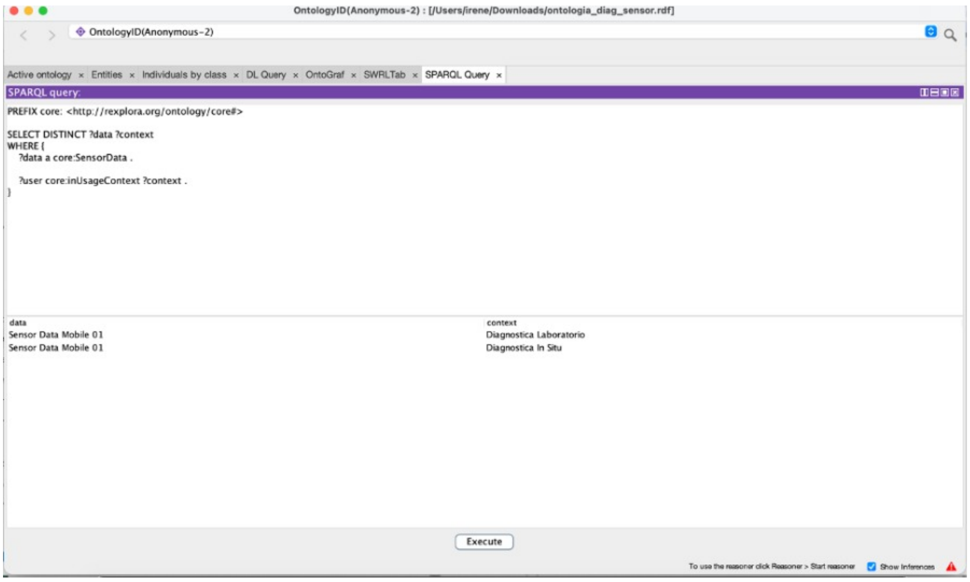

Figure 4: the figure shows the output from the Protégé tool related the CQ2

5. Discussion and Conclusions

This paper presented an ontology-driven approach to context-aware data visualization in the cultural heritage domain, addressing the limitations of visualization systems that rely on static representations or implicit contextual assumptions. By treating context as a first-class, explicitly modelled entity, the proposed approach enables visualization strategies to be derived through semantic reasoning rather than predefined configuration logic.

The core contribution of this work lies in the integration of three complementary elements: a formal context ontology (ContextO), a modular visualization model based on reusable visual blocks, and a reasoning-driven framework (ReXplora) that connects contextual knowledge to visualization composition. Together, these elements provide a transparent and inspectable mechanism for adapting visualization strategies to heterogeneous users, data types, tasks, and usage conditions. Unlike procedural or interface-level customization approaches, the ontology- driven model supports reuse, extensibility, and explainability of visualization decisions.

From a methodological perspective, the work demonstrates how ontology engineering practices, such as requirements elicitation through motivating scenarios, competence questions, and iterative validation, can be effectively applied to visualization- oriented systems. The resulting model does not aim to prescribe specific visual outcomes, but rather to constrain and guide visualization design choices in a context-sensitive manner. This positioning allows the framework to complement existing visualization grammars and interactive analysis techniques rather than replace them.

At the same time, the proposed approach has clear limitations. The quality and relevance of the generated visualization strategies depend on the completeness and accuracy of the contextual information available at runtime, as well as on the expressiveness of the reasoning rules associated with visual blocks. Moreover, the current work focuses on conceptual modeling and methodological validation, without yet providing empirical evidence derived from user studies or deployment in real-world case studies. These aspects limit the assessment of the framework's effectiveness in supporting concrete analytical tasks.

Future work will address these limitations by applying the ReXplora framework and the ContextO ontology to a concrete cultural heritage case study, enabling user- centered evaluation with domain experts. Further developments will also explore the refinement of reasoning rules and the integration of empirical feedback to improve adaptation quality. In the longer term, the proposed approach could be extended to support interoperability with existing cultural heritage knowledge graphs and visualization platforms, reinforcing its role as a reusable semantic layer for context-aware visualization systems.

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7. Declaration on Generative AI

During the preparation of this work, the author(s) used GPT-5.2 in order to: Grammar and spelling check. After using these tool(s)/service(s), the author(s) reviewed and edited the content as needed and take(s) full responsibility for the publication's content.

References

[1] J. D. Richards, Twenty years preserving data: A view from the united kingdom, Advances in Archaeological Practice 5 (2017) 227–237. doi:10.1017/aap.2017.11.

[2] S. K. Card, J. Mackinlay, B. Shneiderman, Readings in information visualization: using vision to think, Morgan Kaufmann, 1999.

[3] B. Shneiderman, The eyes have it: A task by data type taxonomy for information visualizations, in: B. B. BEDERSON, B. SHNEIDERMAN (Eds.), The Craft of Information Visualization, Interactive Technologies, Morgan Kaufmann, San Francisco, 2003, pp. 364–371. URL: https://www.sciencedirect.com/science/article/pii/B9781558609150500469. doi:https://doi.org/10.1016/B978-155860915-0/50046-9.

[4] J. Heer, B. Shneiderman, Interactive dynamics for visual analysis: A taxonomy of tools that support the fluent and flexible use of visualizations, Queue 10 (2012) 30–55. doi:10.1145/2133416.2146416.

[5] A. K. Dey, Understanding and using context, Personal Ubiquitous Comput. 5 (2001) 4–7. URL: https://doi.org/10.1007/s007790170019. doi:10.1007/s007790170019.

[6] B. Schilit, M. Theimer, Disseminating active map information to mobile hosts, IEEE Network 8 (1994) 22–32. doi:10.1109/65.313011.

[7] G. D. Abowd, E. D. Mynatt, Charting past, present, and future research in ubiquitous computing, ACM Trans. Comput.-Hum. Interact. 7 (2000) 29–58. URL: https://doi.org/10.1145/344949.344988. doi:10.1145/344949.344988.

[8] T. Strang, C. Linnhoff-Popien, A context modeling survey, in: Workshop Proceedings, 2004. URL: https://elib.dlr.de/7444/, lIDO-Berichtsjahr=2004, Potential plagiarism at http://dl.comsoc.org/cocoon/comsoc/servlets/GetPublication?id=9014634.

[9] L. Wilkinson, The Grammar of Graphics, Springer Berlin Heidelberg, Berlin, Heidelberg, 2012, pp. 375–414. URL: https://doi.org/10.1007/978-3-642-21551-3_13. doi:10.1007/978-3-642-21551-3_13.

[10] A. Satyanarayan, D. Moritz, K. Wongsuphasawat, J. Heer, Vega-lite: A grammar of interactive graphics, IEEE Transactions on Visualization and Computer Graphics 23 (2017) 341–350. doi:10.1109/TVCG.2016.2599030.

[11] N. Gershon, W. Page, What storytelling can do for information visualization, Commun. ACM 44 (2001) 31–37. URL: https://doi.org/10.1145/381641.381653. doi:10.1145/381641.381653.

[12] D. Benyon, P. Turner, S. Turner, Designing Interactive Systems: People, Activities, Contexts, Technologies, Pearson Education (Addison-Wesley), Harlow, England, 2005. ISBN-10: 0321116291.

[13] T. A. Defanti, M. D. Brown, Visualization in scientific computing, volume 33 of *Advances in Computers*, Elsevier, 1991, pp. 247–307. URL: https://www.sciencedirect.com/science/article/pii/S0065245808601680. doi:https://doi.org/10.1016/S0065-2458(08)60168-0.

[14] A. Senent Boza, S. Morales Conde, How to effectively transmit knowledge, Cirugía Española (English Edition) 103 (2025) 800109. URL: https://www.sciencedirect.com/science/article/pii/S2173507725000870. doi:https://doi.org/10.1016/j.cireng.2025.800109.

[15] S. Pepler, K. O'Neil, Preservation intent and collection identifiers (2008).

[16] P. Oliveira, F. Rodrigues, P. R. Henriques, A formal definition of data quality problems, in: Proceedings of the 10th International Conference on Information Quality (ICIQ 2005), MIT, Cambridge, MA, USA, 2005, pp. 403–417. URL: http://18.4.38.158/ICIQ/Documents/IQ%20Conference%202005/Papers/AFormalDefinitionofDQProblems.pdf, semantic Scholar Corpus ID: 145050446.

[17] E. A. Locke, The ubiquity of the technique of goal setting in theories of and approaches to employee motivation, Academy of Management Review 3 (1978) 594–601. URL: https://doi.org/10.5465/amr.1978.4305786. doi:10.5465/amr.1978.4305786.

[18] D. Norman, The Design of Everyday Things, revised and expanded ed., Basic Books, New York, 2013. URL: https://doi.org. doi:10.3139/9783446447448.

[19] J. J. Garrett, The Elements of User Experience: User-Centered Design for the Web and Beyond, 2 ed., New Riders, Berkeley, CA, 2011.

[20] H. L. Tosi, Review of the book: A theory of goal setting and task performance, by e. a. locke & g. p. latham, Academy of Management Review 16 (1991) 474–478. doi:10.5465/amr.1991.4278976.

[21] R. Spence, Information Visualization: An Introduction, Springer, 2001. doi:10.1007/978-3-319-07341-5.

[22] T. Cresswell, Defining place, Place: A Short Introduction. Malden, MA: Blackwell Ltd 12 (2004).

[23] S. Peroni, Samod: an agile methodology for the development of ontologies, in: Proceedings of the 13th OWL: Experiences and Directions Workshop and 5th OWL reasoner evaluation workshop (OWLED-ORE 2016), 2016, pp. 1–14. doi:https://doi.org/10.6084/m9.figshare.3189769.

[24] O. Signore, Introduzione al semantic web, in: Atti del Convegno "Web Senza Barriere 2008", W3C Office in Italy, Roma, Italia, 2008. URL: https://www.w3c.it/papers/wsb08.pdf, tenutosi a Roma, 7-9 maggio 2008. Disponibile online presso il W3C Italia.

[25] JGraph Ltd., draw.io, 2025. URL: https://www.drawio.com/, accessed: 2026-05-30.

[26] R. Falco, A. Gangemi, S. Peroni, D. Shotton, F. Vitali, Graffoo: Graphical framework for owl ontologies, 2026. URL: https://essepuntato.it/graffoo/, accessed: 2026-05-30.

[27] Stanford Center for Biomedical Informatics Research, Protégé, 2025. URL: https://protege.stanford.edu/, accessed: 2026-05-30.

[28] A. Bucciero, A. Chirivì, R. Colella, M. Emara, M. Greco, M. A. Jaziri, I. Muci, A. Pandurino, F. V. Taurino, D. Zecca, Iot-based platform for wireless microclimate monitoring in cultural heritage, Heritage 9 (2026). URL: https://www.mdpi.com/2571-9408/9/2/57. doi:10.3390/heritage9020057.