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Enhancing Intangible Cultural Heritage through Ontology: the BISTÌRIS Model for Sardinian Traditional Costumes

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Abstract

The valorisation of territory and its cultural expressions is essential for preserving local identity and fostering a deeper understanding of intangible heritage. In this context, semantic tools such as ontologies offer a powerful means to structure, interlink, and enrich representations of cultural knowledge. In this paper, we present BISTÌRIS, an ontology designed to represent Sardinian traditional costumes, an emblematic and diverse form of intangible cultural heritage. Grounded in domain expert knowledge and developed following a structured methodological approach, BISTÌRIS provides a semantic framework tailored for the analytical description of garments. The ontology enables the comparison of costumes across different Sardinian communities and historical periods, highlighting local variations and the evolution of dressing practices. We describe the development process of the ontology and present the populated knowledge graph, which supports semantic queries and facilitates advanced exploration of costume features. The ontology is evaluated through reasoning-based validation, practical query scenarios derived from real research questions, and feedback from domain experts.

Keywords

Semantic Web, Cultural Heritage, Ontologies, Traditional Costumes, Knowledge Graphs

1 Introduction

Cultural heritage incorporates the richness and diversity of human civilisation, offering tangible and intangible expressions of a community's identity, values, and historical experience. Among the many aspects of cultural heritage, traditional costumes occupy a crucial position, embodying a community's

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values, beliefs, history, and social norms through visual and material expression [1]. In territories like Sardinia – an Italian island located in the Mediterranean Sea – where cultural identity and traditions are deeply rooted, these garments are of great significance and serve as powerful symbols of the rich heritage of the island [2]. They are not considered mere fabric pieces but tangible expressions of history, craftsmanship, and creativity, often featuring unique designs, colours, and materials specific to their culture, making them valuable cultural artefacts [3]. Despite their cultural importance, traditional costumes are increasingly endangered by forces such as modernisation, shifting social structures, and the decline of artisanal traditions. In response, researchers, museums, and local communities have prioritised efforts to protect this cultural legacy for future generations. Beyond mere preservation, the systematic study and digital documentation of traditional attire can open new opportunities for cultural valorisation and territorial development. By enhancing the visibility and accessibility of local heritage, such initiatives can foster cultural tourism, sustain traditional crafts, and contribute to regional economic growth. In the case of Sardinia, traditional clothing reflects centuries of cultural stratification and local reinterpretation of external influences. This has produced distinct and localised variations, with each community developing unique attire that reflects its historical and social context. Morphological analysis of garments has revealed affinities with costumes from other Mediterranean cultures and documented significant changes over time, especially during two pivotal periods: the 19th century, marked by renewed interest in folklore and artistic documentation, and the 1930s, when tradition encountered contemporary fashion influences [4].

Over the last two decades, Semantic Web technologies have become fundamental instruments for the representation and management of cultural heritage data. Ontologies and Knowledge Graphs (KGs) support structured, interoperable representations that enhance analysis, comparison, and access [5–8]. At the same time, the growth of historical semantic archives dedicated to cultural artefacts has significantly advanced the field, enabling richer and more comprehensive representations of cultural heritage. Digital libraries such as Europeana [1] [9] now host a wide range of items related to traditional costumes, including those from Sardinia, for example a portrait of a young woman in traditional Sardinian costume, dating from 1930, provided by Istituto Luce [2]. While existing cultural heritage ontologies, such as CIDOC Conceptual Reference Model (CIDOC CRM) [10], Records in Context Ontology (RIC-O) [11] and ArCo [12] provide robust foundations for describing general aspects of cultural objects (e.g. provenance, dating, authorship, materials), they are not designed to capture the multidimensional complexity of traditional costumes. As a result, key elements including variations, component-level structures, symbolic meanings and dressing practices, remain insufficiently modelled highlighting the inherent challenge of representing these artefacts. In fact, modelling traditional costumes is particularly demanding since they are simultaneously material artefacts and carriers of intangible meanings, individual and collective, static in their physical form yet evolving in their social interpretation. Capturing this multidimensionality requires a modelling strategy capable of representing compositional structures, temporal variability, and socio-symbolic dimensions within a coherent semantic framework. This observation motivates the following research question: How can an ontology-based model represent and empirically validate the multi-layered structure of complex cultural artefacts, such as traditional costumes, whose meaning emerges from the interplay of material, structural, and socio-symbolic dimensions? To address this

[1] https://www.europeana.eu/en
[2] https://www.europeana.eu/it/item/08602/SerieLL01_005242

challenge, we adopt a competency-question–driven modelling workflow that integrates conceptual design, data population, and empirical validation through query answering and expert feedback, ensuring that the resulting ontology can be both theoretically solid and practically verifiable.

Building on this workflow, we present BISTÌRIS [3], an ontology designed to represent the morphological, cultural, and temporal variations of traditional costumes. Our ontology formalises complex ethnographic knowledge and provides a reusable framework for representing other multifaceted cultural artefacts. The ontology was developed – building on a preliminary version presented in [13] – within the framework of the *e.INS: Ecosystem of Innovation for Next Generation Sardinia* [4], under the activities of *Spoke 2* [5], which aims to promote the sustainable economic development of Sardinia by transferring innovative technological knowledge to museums, cultural associations, and small and medium-sized enterprises operating in marginal areas of the tourism and cultural heritage sectors. BISTÌRIS provides a coherent semantic framework capturing the geographical, temporal, and stylistic dimensions of traditional costumes. The ontology enables scholars to identify recurring patterns, such as colour usage or garment layering, and to perform comparative analyses across communities and historical periods. From a research perspective, BISTÌRIS illustrates how complex, layered artefacts can be formally represented, linking compositional and contextual knowledge for advanced analytical querying. By enhancing digital accessibility and ensuring semantic interoperability, BISTÌRIS supports the documentation and preservation of intangible heritage while enabling applications in sustainable cultural tourism, educational participation, and local economic development. Examples include the creation of digital thematic itineraries promoting lesser-known traditions, semantic tools for regional culture research, and open datasets reusable by local institutions for cultural initiatives. To the best of our knowledge, this is the first ontology specifically designed to model the multi-layered complexity of traditional costumes. Although rooted in the Sardinian context, the ontology was designed to be reusable across related heritage domains. To facilitate this and make its adoption even more straightforward, we provide a lightweight version, BISTÌRIS *Lite*, which removes Sardinia-specific classes and constraints to facilitate broader adaptation.

The remainder of this paper is structured as follows. In Section 2, we report some related work pertinent to the domain under consideration. Following that, Section 3 describes the ontology design process and development, encompassing the methodology, requirement collection, conceptualisation, implementation, ontology reuse, and population. The evaluation of BISTÌRIS is presented in Section 4, followed by a discussion of its applications and usage scenarios in Section 5, where the ontology is also applied to illustrate examples from other cultural contexts, i.e. Sicilian and Greek traditional costumes. Finally, Section 6 outlines the main conclusions and future directions for this work.

2 Related Work

In the domain of cultural heritage ontology development, there has been a growing interest in creating semantic representations to preserve and promote cultural diversity. Various initiatives

[3] The ontology's name derives from a Sardinian word meaning *clothes* or *dresses* in English. Visit the project page: `https://aimet-lab.github.io/BISTIRIS/home/index.html`

[4] `https://www.einssardinia.it/`

[5] `https://eins-spoke2.uniss.it/`

have resulted in general-purpose ontologies designed to model cultural objects in a broad sense, including traditional costumes. Within this broader landscape, it is important to distinguish between *ontologies*, *metadata schemas*, and *knowledge graphs*. Ontologies provide formal, explicit specifications of shared conceptualisations [14]; metadata schemas provide a structured set of elements used to describe information resources, often designed for interoperability and cataloguing rather than logical reasoning [15]; and knowledge graphs represent structured, semantically grounded data interlinking entities and relationships for querying and reasoning [16]. Among the most prominent ontological models is CIDOC CRM [10], a foundational ontology for representing information about cultural heritage collections. It provides a comprehensive upper ontology for encoding historical events, actors, objects, and their relationships. However, while highly expressive, its generality often makes it unsuitable for fine-grained modelling of specific object types such as garments or costumes details without significant extensions. Similarly, RIC-O [11] is a domain ontology proposed by the International Council on Archives to describe archival records and their historical contexts. Although it enables the representation of cultural artefacts and their provenance, it does not specifically address the morphological and symbolic complexities of traditional attire. Another relevant initiative is the Europeana Data Model (EDM) [9], which aggregates metadata schema designed to ensure interoperability among heterogeneous cultural heritage repositories. While it supports semantic interlinking of digital objects, it primarily serves as a descriptive aggregation framework rather than a formal ontology. EDM supports the semantic interlinking of heterogeneous digital objects but remains primarily focused on interoperability rather than on detailed internal descriptions of artefacts such as traditional costumes. Specialised ontologies and vocabularies have also emerged to address more specific aspects of cultural heritage documentation. A notable large-scale initiative is ArCo [12], the Italian Cultural Heritage Knowledge Graph, which combines a network of interlinked ontologies with a populated knowledge base describing over 820,000 items from the Italian National Catalogue of Cultural Heritage [6], managed by the Central Institute for Cataloguing and Documentation (ICCD). ArCo thus operates both as a collection of domain ontologies by covering aspects such as denotative descriptions, cultural context, and digital provenance, and as a publicly accessible KG that instantiates these ontologies with real-world data. Within ArCo, several vocabularies offer concepts and properties relevant to the analytical description of traditional costumes. For example, the *Denotative Description Ontology* encodes measurable physical characteristics of cultural objects, such as length, materials, construction techniques, and conservation states. The *Clothing Description Ontology*, which was previously available, enabled the modelling of garment features, including structural components (e.g. pockets, collars, cuffs), the presence of decorations, and construction details such as seams and cuts, but unfortunately it is no longer accessible. An example of how ArCo represents a Sardinian traditional costume can be seen in the metadata description of a women's dress from the town of Fonni, housed at the Sardinian Museum of Anthropology and Ethnography in Monserrato (Cagliari) [7], with part of this metadata reported in Table 1. While the description includes important information such as object composition, materials, geographical origin, and conservation status, the analytical modelling of costume variations and morphological details remains limited.

[6] `http://www.iccd.beniculturali.it/` (accessed: accessed: 2025-11-18).

[7] Metadata accessible at: `https://dati.beniculturali.it/lodview-arco/resource/DemoEthnoAnthropologicalHeritage/2000219383.html` (accessed: 2025-11-18).

Metadata Property	Value
dc:title	dress
dc:description	Traditional women's dress consisting of: handkerchief, white cotton shirt with embroidery, bodice ending at the front with two points, red cloth jacket, 2 woollen skirts, apron.
dc:identifier	2000219383
foaf:depiction	https://www.sigecweb.beniculturali.it/images/fullsize/ICCD1023190/ICCD11925037_UCAMSAE00104.jpg
arco:catalogueNumber	00219383
arco:regionIdentifier	20
dc:coverage	Monserrato (CA)
dc:rights	State property
pico:materialAndTechnique	various

Table 1. An example of metadata description of a Sardinian traditional costume, as provided by ArCo. These descriptions were originally in Italian and have been translated into English.

Another relevant effort is the Costume Core metadata schema [17] which emerges as a metadata schema with controlled descriptive fashion terminology for garments and accessories. It achieves this objective using photographs and textual descriptions as well as incorporating properties such as main colour, secondary colour, costume's components, skirt type and sleeve type. However, *Costume Core* was primarily developed for describing two-piece evening or day dresses, characterised by simpler compositions, varieties, and colour ranges compared to the majority of traditional costumes. A summary of the focus and limitations of the analysed ontologies and models is provided in Table 2. In this context, it is clear that existing ontologies either lack the necessary granularity or are not tailored to capture the symbolic, structural, and diachronic aspects of traditional dress.

Ontology/Model	Focus	Limitation
ArCo [12]	Italian cultural heritage objects, including basic garment descriptions	Provides physical descriptions; limited detail for costume variations and historical changes.
CIDOC CRM [10]	General cultural heritage ontology covering events, actors, artefacts.	Requires significant specialisation to model detailed garment features and variations.
Costume Core [17]	Metadata schema for historical garments and accessories.	Oriented towards modern two-piece dresses; insufficient for complex traditional costumes.
EDM [9]	Metadata aggregation and interoperability across cultural institutions.	Focused on aggregation; lacks fine-grained modelling of object structures.
RIC-O [11]	Archival records and historical context representation.	Focused on documents and archival units; limited support for artefact morphology.

Table 2. Comparison of existing cultural heritage ontologies and models with respect to their ability to represent traditional costume features.

Beyond ontology modelling, several recent studies have explored complementary technological approaches to the analysis, visualisation, and preservation of traditional costumes and intangible cultural heritage in general. For example, the integration of KGs and virtual reality has been employed to create immersive, interactive systems aimed at enhancing public engagement with textile heritage, as

demonstrated in the case of the Hangluo tradition [18]. Other efforts have focused on the simulation and virtual reconstruction of traditional clothing using neural networks and cloth physics algorithms. One such system enables the digital rendering and study of Chinese garments, facilitating both educational and heritage preservation purposes [19]. Additionally, KGs constructed through domain ontologies and natural language processing techniques have been proposed to organise and extract insights from large-scale textual resources concerning Chinese intangible cultural heritage [20]. While these approaches do not directly target Sardinian costumes, they exemplify the potential of combining artificial intelligence, visual computing, and semantic technologies to support cultural heritage documentation.

Against this background, BISTÌRIS contributes at both the ontological and the data levels: it provides a domain ontology specifically designed for modelling traditional Sardinian costumes, and a populated KG that instantiates this ontology using data gathered from literature, museum collections, and visual documentation.

3 Ontology Design & Development

The methodology adopted for the development of BISTÌRIS is articulated through a series of interrelated phases, which are described in the following subsections. Each phase contributes to addressing the research question: requirements and Competency Questions (CQs) elicit the relevant material, structural, and socio-symbolic dimensions; conceptualisation and implementation encode these dimensions in a formal model; and population prepares the ground for empirical validation through query execution.

3.1 Methodology

The methodology used to develop BISTÌRIS draws inspiration from established approaches for developing domain ontologies. Specifically, we adopt a combination of different approaches – such as Methontology [21] and Cyc [22] – to create BISTÌRIS. This process involves four main steps:

1. **Determining the domain and scope of the ontology**. In this phase, we focus on defining the specific domain of interest, which in our case is the intricate variations of the Sardinian traditional costume. We establish the scope of the ontology to ensure that it effectively captures all relevant aspects of the domain. This initial aim is to collect requirements and CQs from cultural stakeholders and domain experts.
2. **Conceptual model development**. Using the insights gained from the previous steps, we proceed to develop the conceptual model of BISTÌRIS. This involves defining the key concepts, relationships, and properties that characterise the variations of the Sardinian traditional costume. We employ formal ontology modelling techniques to ensure clarity, coherence, and interoperability of the ontology.
3. **Ontology reuse**. We explore existing ontologies and relevant resources to identify potential reusable components that can inform the development of BISTÌRIS. This step helps streamline the ontology development process and ensures compatibility with existing standards and practices.
4. **Ontology implementation**. This phase involves converting the conceptual model into a formal OWL ontology. Validation and testing are conducted to ensure the ontology's consistency, correctness, and alignment with the initial requirements.

By following this methodology, our goal is to create BISTÌRIS as a structured and comprehensive ontology that effectively captures the multi-dimensional characteristics and variations of the Sardinian traditional costumes.

3.2 Requirements Collection

The exploration of traditional Sardinian costumes poses unique challenges. These garments exhibit significant stylistic diversity, reflecting variations in geographical and cultural origins. Moreover, since the first half of the twentieth century, they have largely ceased to be in regular use, resulting in numerous deviations from traditional norms among the specimens available today [23]. BISTÌRIS aims to address these challenges by integrating heterogeneous requirements into a coherent semantic framework. From a modelling perspective, traditional costumes are inherently multidimensional, combining material, spatio-temporal, and cultural aspects. They express local identity and social meaning, shaped by geographic context, historical period, and technical composition. Accordingly, the requirements collection phase aimed to gather descriptive terms and to capture the interactions among these dimensions within a coherent semantic framework. These considerations guided the derivation of competency questions, each targeting a specific aspect of the artefact's structure, context, or variability. In this way, the CQs operationalise our research question by translating the costumes' multi-layered structure into concrete information needs that the ontology and the KG must be able to satisfy. Building on this perspective, the ontology was developed through a requirements collection process that mixed literature-based analysis and expert consultation. The derivation of these questions and other requirements followed a structured three-step process, consistent with the Ontology Requirements Specification Document (ORSD) approach proposed in [24].

- We first conducted a systematic review of ethnographic literature, costume catalogues, and archival inventories, focusing on descriptive sections that detailed garment parts, materials, decorations, and social or ritual contexts of use. Each text was annotated to identify recurring entities (e.g. *bodice*, *apron*, *embroidery*) and relations (e.g. *worn over*, *made of*) as well as spatial and temporal aspects (e.g. *used in local area*, *typical of specific period*). These annotations were collected in a preliminary vocabulary.
- The extracted data was then discussed with museum curators and cultural stakeholders. Experts were asked to validate the relevance of the identified entities and to suggest the kinds of questions they typically pose when describing, comparing, or cataloguing costumes. For instance, experts confirmed that distinguishing which garments are worn over others is a relevant information need. Similarly, they highlighted the importance of capturing variations in costume characteristics across different geographical areas and historical periods.
- Each validated information need was reformulated into a natural-language competency questions. The wording was kept as close as possible to the experts' phrasing and the terminology used in the sources, in order to preserve transparency and usability.

This process ensured that the conceptualisation was grounded in real ethnographic practices and could effectively support the information needs of domain experts.

While the literature provided an overarching understanding of traditional garments, detailed information was also gathered by examining photographs and illustrations from books, manuals, and institutional repositories to capture the internal structure and terminology of the costumes. Building on

1. Purpose
The purpose of the BISTÌRIS ontology is to serve as a structured framework for documenting and preserving the diverse variations of the Sardinian traditional costume.
2. Scope
The ontology focuses on capturing the intricate variations of the Sardinian traditional costume, encompassing geographical and temporal dimensions. It aims to index each asset based on descriptive parameters to facilitate comparative analysis and exploration of the cultural heritage embodied in these costumes.
3. Implementation Language
OWL2 DL
4. Intended End-Users
User 1. Cultural institutions (such as museums and archives) that have a detailed bibliography and collections about Sardinian costumes looking for a formal language to express it. User 2. Researchers and scholars with complex research questions or wanting to express the data they collected in a formal language.
5. Intended Uses
Use 1. Publish structured data about Sardinian traditional costumes online and integrate them with existing datasets to enhance the query potential of end users. Use 2. Support the conduct of specific analysis to address research questions within the domain research field.
6. Ontology Requirements
a. Non-Functional Requirements
NFR1. The ontology should be developed in accordance with international standards and schema, with a preference for direct reuse, to allow reusability. NFR2. The ontology should allow the addition of new costume types, materials, and decorative features without requiring major restructuring. NFR3. The ontology should be structured to facilitate updates as new ethnographic or archival information becomes available.
b. Functional Requirements: General Competency Questions
CQ1. How do costume and garment characteristics vary across different geographical areas of Sardinia? CQ2. How do costume and garment characteristics vary over time? CQ3. Do the costumes and garments share similar characteristics in nearby places? CQ4. Which specimens of a given garment are constructed using transparent materials? CQ5. Which garments are typically worn over others? For example, in which costumes is the bodice worn over the jacket? CQ6. What is the frequency with which two specific properties occur simultaneously among the garments?
7. Pre-Glossary of Terms (Term, Frequency in studied documents)
Festive (198), Colour (153), Skirt (92), Bodice (76), Embroideries (74), Shirt (73), Apron (47), Jacket (45), Trousers (38), Headwear (37)

Table 3. Ontology Requirements Specification Document.

this, we aimed to provide a comprehensive description of Sardinian costumes, categorising them into two primary types, male and female attire, which can be further refined according to their intended use, such as gala events, weddings, festive occasions, and daily wear. The ontological requirements collection primarily draws on the domain knowledge found in Franca Rosa Contu's essay [25]. This comprehensive study focuses on the description of traditional Sardinian costumes, including analysis of local variants, historical tracing, and abundant photographic examples. Additionally, references such as [26], [27] and [28] provided valuable insights necessary for making crucial comparisons regarding the composition of certain costumes. The terminology was primarily drawn from [25], whereas the conceptual requirements

derived from literature and expert consultation were formalised as CQs. Each CQ therefore represents an explicit and traceable information requirement grounded in ethnographic practice. A condensed version of the resulting requirements specification document is described in Table 3.

3.3 Conceptualisation

Based on the requirements identified in the previous phase, the ontology was conceptualised to reflect the material and structural composition of traditional costumes while maintaining explicit links to their temporal and cultural dimensions. This balance between descriptive accuracy and analytical expressivity directly aligns with the research question guiding this work. A *bottom-up* approach to designing the taxonomy of concepts, starting from individual garments and progressing to costumes, appeared promising. However, the extensive diversity of garment types uncovered in preliminary domain research prompted a shift to the *middle-out* approach [29]. We made a primary distinction between female and male costumes to reflect how ethnographic sources and museum catalogues consistently classify Sardinian traditional attire. In most archival and curatorial references, male and female costumes are described in separate sections and with gender-specific terminology, since clothing historically serves as a marker of gender identity and social role [30]. Reflecting this practice, the ontology is organised around seven core classes for describing female garments, grouped under the `:F-Garment` class:

- `F-Headwear`
- `F-Overgarment`
- `F-Jacket`
- `F-Bodice`
- `F-Shirt`
- `Apron`
- `F-Skirt`

Along with ten core classes for the description of male costumes, contained by the `:M-Garment` class:

- `M-Headwear`
- `Neckerchief`
- `M-Overgarment`
- `M-Jacket`
- `M-Bodice`
- `M-Shirt`
- `Belt`
- `M-Skirt`
- `Trousers`
- `Gaiters`

It should be emphasised that F- and M- prefixes are applied only to garments whose names are shared across genders (e.g. headwear, shirt, bodice). Items that are gender-specific by definition, such as *apron* or *belt*, do not carry the prefix, as their gender association is inherent in the garment type. These core classes further branch into 44 more specialised sub-classes, depicted in Figure 1. To preserve precision within the specific context, certain terms have been retained in their original language rather than translated into English; for instance, *manticello* refers to a small head mantle, while *giacchino* and *giubbetto* represent two variations of jackets, distinguished by the presence of buttons, fabric stiffness, and other defining characteristics. A glossary explaining these terms is available online [8]. When filling the ontology, the

[8] See the project repository for the glossary: `https://github.com/AIMet-Lab/BISTIRIS/blob/main/glossary.txt`

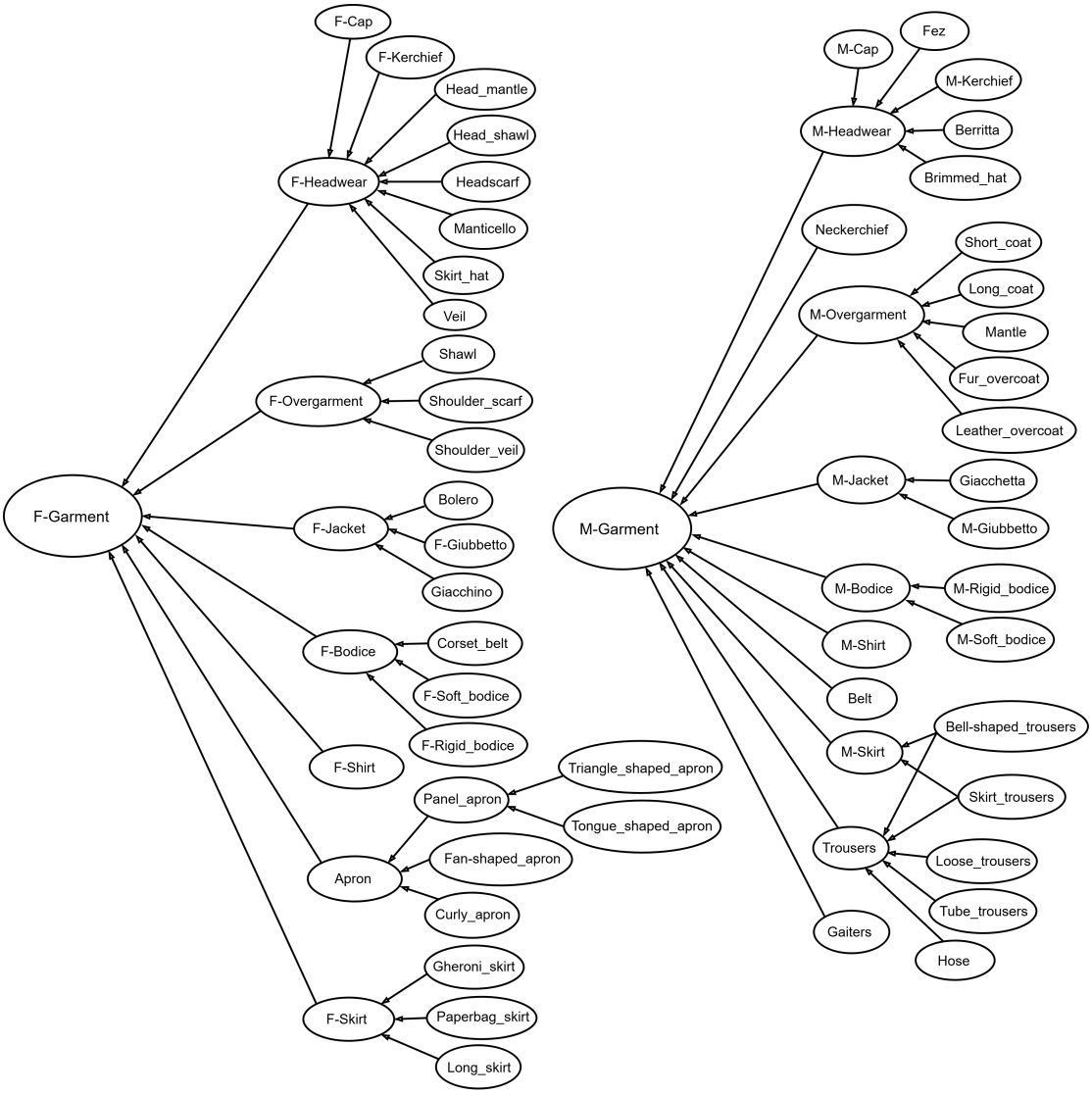

Figure 1. Graphical representation of the `:F-Garment` and `:M-Garment` classes along with their subclasses, with arrows denoting the `rdfs:subClassOf` property.

key decision lies in accurately determining the appropriate subclass for each garment being catalogued. Similarly, when establishing the ontology's parameters, the initial focus is on thoroughly examining the distinctions among different garment types.

Within BISTÌRIS, garments categorised into the aforementioned classes are detailed using specific properties highlighting their colours, fashions, and the order in which they are worn when assembling the costume. Additionally, two significant classes are the `:F-Costume` and the `:M-Costume` classes, which serve as aggregators of constituent garments and as linking elements among them, their places of origin, the referenced bibliographic sources and the time periods they represent, as illustrated in subsection 3.5.

3.4 Ontology Reuse

Before detailing the specific classes and relationships implemented in BISTÌRIS, we first outline the external ontologies and vocabularies that have been reused and aligned with our model. This approach enhances both the interoperability and reusability, establishing explicit connections with external ontologies through direct reuse strategies, in accordance with best practices identified in the state of the art [31]. BISTÌRIS followed these approaches by seamlessly integrating ontology terms from two prominent sources: DBpedia [9] and Schema.org [10]. From the ArCo ontologies network, concepts and properties for the description of costumes were imported, such as `a-dd:TechnicalCharacteristic`, along with the property `a-lite:hasColour`. Classes and properties from Dublin Core [11], SPAR ontologies [12], and ARKIVO [32, 33] [13] were imported to represent sources. Additionally, properties from the GEO vocabulary [14] were used for annotating geographical latitude and longitude. Geographic data and colour standardization were further enriched through the integration of DBpedia and YAGO [15]. Furthermore, alignments with CIDOC CRM were established to ensure conceptual interoperability with cultural heritage reference models, and correspondences with the Art & Architecture Thesaurus (AAT) [16] were introduced specifically for colour concepts, promoting terminological consistency and multilingual integration.

Table 5 shows the direct reuse of external classes and properties in BISTÌRIS, including their specific usage. The direct reuse has been achieved by incorporating selected ontology terms into BISTÌRIS through the use of `rdfs:isDefinedBy` axioms. This approach delegates the semantics of reused terms to the external ontologies identified, with the aim of promoting virtuous reuse that facilitates integration between different schemas and enables access to the vast amount of data available in the Linked Open Data. In the remainder of this paper, when the prefix is omitted, it is assumed to be '`bst:`', indicating that it refers to a BISTÌRIS prefix. As part of the reuse strategy, several classes of the ontology have been conceptually aligned with entities defined in CIDOC CRM. Specifically, the class `:Costume` is defined as a subclass of `crm:E22_Human-Made_Object`, as it represents complete traditional outfits that are intentionally created artefacts and therefore consistent with the CIDOC CRM notion. Similarly, `:Garment`, which refers to individual clothing components, is also aligned as a subclass of `crm:E22_Human-Made_Object`, sharing the same ontological grounding while allowing

[9] https://www.dbpedia.org/
[10] https://schema.org/
[11] https://www.dublincore.org/
[12] http://www.sparontologies.net/ontologies
[13] https://github.com/ArkivoTeam/ARKIVO
[14] https://www.w3.org/2003/01/geo/wgs84_pos#
[15] https://yago-knowledge.org/
[16] https://vocab.getty.edu/aat/

Ontology	Prefix Name	Expansion
Arco Lite	a-lite:	https://w3id.org/arco/ontology/arco-lite/
arkivo	arkivo:	http://purl.org/arkivo/ontology#
AAT	aat:	http://vocab.getty.edu/aat/
BIBO	bibo:	http://purl.org/ontology/bibo/
CIDOC CRM	crm:	http://www.cidoc-crm.org/cidoc-crm/
DBpedia	dbo:	http://dbpedia.org/ontology/
	dbp:	http://dbpedia.org/property/
	dbr:	http://dbpedia.org/resource/
DCMI	dcterms:	http://purl.org/dc/terms/
Denotative Description	a-dd:	https://w3id.org/arco/ontology/denotative-description/
Document Components	doco:	http://purl.org/spar/doco/
GEO	geo:	http://www.w3.org/2003/01/geo/wgs84_pos#
Pattern	po:	http://www.essepuntato.it/2008/12/pattern#
Schema	schema:	https://schema.org/
YAGO	yago:	http://yago-knowledge.org/resource/

Table 4. Details on the re-used ontologies in the data model. It includes the ontology name, the corresponding prefix used, and the expansion of each prefix into its full *Internationalized Resource Identifier* (IRI).

finer distinctions within the costumes domain. The class `:TechnicalCharacteristic` is aligned with `crm:E26_Physical_Feature`, since it captures measurable or observable physical aspects of garments, such as weaving patterns or embroidery details. Further conceptual alignments have been established to strengthen semantic interoperability, as also discussed in recent studies [34]. Finally, colours are mapped to their corresponding entries in the AAT through the property `skos:exactMatch` while Wikidata serves as an effective intermediary between DBpedia and AAT, aligning with DBpedia via `owl:sameAs` and with AAT through `skos:exactMatch`.

3.5 Implementation

We implemented BISTÌRIS using Protégé [35] editor for designing and visualising the ontology structure, and Owlready2[17] for manipulating and reasoning over the ontology within a Python environment. The ontology presents a moderate size with a relatively rich class hierarchy and balanced properties. The `SRIQ(D)` expressivity indicates a high level of formal complexity, conforming to OWL2 DL language [36, 37]. Table 6 summarises the main metrics of the `TBox`. Both the full and the simplified *Lite* versions of the ontology are publicly available and documented[18]. The *Lite* version removes region-specific constructs while retaining the core conceptual structure, ensuring easier reuse and adaptation to other cultural heritage contexts. In the following subsections, we describe in detail the implementation of the classes and properties.

[17] https://owlready2.readthedocs.io/en/v0.47/
[18] https://github.com/AIMet-Lab/BISTIRIS

Element	Type	Ontology	Usage
`author`	Property	Schema.org	The author of a source.
`Book`	Class	BIBO	A book used as a source for cataloguing a costume.
`Colour`	Class	DBpedia	Colour of a garment or costume.
`dateCreated`	Property	Schema.org	The date or period when a particular garment or costume was created.
`datePublished`	Property	Schema.org	Date of publication of a source.
`E73_Information_Object`	Class	CIDOC CRM	An immaterial source of information documenting a costume or garment.
`elevation`	Property	DBpedia	Average elevation above the sea level.
`Figure`	Class	BIBO	An image of a costume or garment from a source, eg. from a book.
`fromLocation`	Property	Schema.org	The geographical origin or location associated with a particular garment or costume.
`GlamThing`	Class	arkivo	Any entity that is or can be stored in an Gallery, Library, Archive or Musem (GLAM) institution
`hasColour`	Property	Arco Lite	This property links costumes or garments to a colour.
`isContainedBy`	Property	Pattern	A property that links a figure to the source from which it was taken, e.g. a book.
`lat`	Property	GEO	Geographical latitude of a place of origin of a costume.
`long`	Property	GEO	Geographical longitude of a place of origin of a costume.
`name`	Property	DBpedia	The toponymy of a place of origin of a costume.
`neighboringMunicipality`	Property	DBpedia	This property connects the neighbouring towns.
`Periodical`	Class	BIBO	Documents issued at regular intervals.
`Place`	Class	Schema	Town or city from which a costume originates.
`Provinces_of_Italy`	Class	Yago	Administrative district of Italy.
`publisher`	Property	Schema.org	The publisher of a source.
`P46_is_composed_of`	Property	CIDOC CRM	A costume comprises or includes specific garments as its parts.
`P46i_forms_part_of`	Property	CIDOC CRM	A particular garment is part of or belongs to a costume.
`P62i_is_depicted_by`	Property	CIDOC CRM	This property links an object to what it depicts.
`P89_falls_within`	Property	CIDOC CRM	This property indicates that a place is spatially contained within another place (e.g. a town to a province).
`SocialMediaPosting`	Class	Schema.org	A post to a social media platform.
`TechnicalCharacteristic`	Class	Denotative Description	Technical characteristic related to a cultural item.
`title`	Property	Dublin Core	A name given to the resource.

Table 5. Direct reuse of classes and properties in BISTÌRIS.

3.5.1 Classes. Class axioms were used to model the concepts of male and female costumes, along with the peculiar patterns of wear of specific garments, as shown in the following definitions and

Metric	Value
Total Axioms	616
Logical Axioms	303
Declaration Axioms	156
DL Expressivity	SRIQ(D)
Classes	101
Object Properties	17
Data Properties	35

Table 6. Summary of BISTÌRIS ontology metrics.

restrictions expressed in DL syntax [38]. This approach enhances the informative content of the ontology while preventing the entry of inconsistent data into the KG. Beyond their formal function, these restrictions reflect how Sardinian traditional costume is structured and described in ethnographic sources. The definitions of `:M-Costume` and `:F-Costume` capture stable composition rules (such as the coexistence of specific headwear, jackets, and aprons) that are documented across several archives and catalogues.

To illustrate, the following expression defines the `:F-Costume` class, which represents a specific type of costume with several constraints on its components. The class is required to consist of only female garments (`:F-Garment`), and it imposes specific limits on the number and types of items that can be part of the costume. For example, the costume must have at least 1 but no more than 3 pieces of female headwear, exactly 1 jacket, 1 bodice and 1 shirt, ensuring that each of these garments is included. Additionally, the costume must have at least one and at most two skirts. It is also limited to having a single outer garment. These constraints ensure that the `:F-Costume` class is precisely defined, restricting the structure and composition of the costume.

$$
\begin{aligned}
\texttt{F-Costume} \sqsubseteq\ & \forall \texttt{P46\_is\_composed\_of.F-Garment} \\
& \sqcap\ (\geq 1\ \texttt{P46\_is\_composed\_of.F-Headwear}) \\
& \sqcap\ (\leq 3\ \texttt{P46\_is\_composed\_of.F-Headwear}) \\
& \sqcap\ (\leq 1\ \texttt{P46\_is\_composed\_of.F-Overgarment}) \\
& \sqcap\ (= 1\ \texttt{P46\_is\_composed\_of.F-Jacket}) \\
& \sqcap\ (= 1\ \texttt{P46\_is\_composed\_of.F-Bodice}) \\
& \sqcap\ (= 1\ \texttt{P46\_is\_composed\_of.F-Shirt}) \\
& \sqcap\ (\leq 1\ \texttt{P46\_is\_composed\_of.Apron}) \\
& \sqcap\ (\geq 1\ \texttt{P46\_is\_composed\_of.Skirt}) \\
& \sqcap\ (\leq 2\ \texttt{P46\_is\_composed\_of.Skirt})
\end{aligned}
$$

The shoulder veil is defined as a garment that always transparently covers the garments underneath. It is white and can only be part of one female costume. The formal definition of the shoulder veil is as follows:

$$\begin{aligned}\texttt{Shoulder\_veil} \sqsubseteq\ & (\exists\, \texttt{coversWithTransparency.F-Garment}) \\ & \sqcap\ (\forall\, \texttt{coversWithTransparency.F-Garment}) \\ & \sqcap\ (\texttt{hasColour} = \texttt{White}) \\ & \sqcap\ (= 1\, \texttt{P46i\_forms\_part\_of.F-Costume})\end{aligned}$$

The following constraints define the structure and composition of the `:M-Costume` class, ensuring that the male costume includes a specific set of items. The class is constrained to only include male garments as its parts. The costume must have between 1 and 2 pieces of male headwear, at most 1 neckerchief, and no more than 2 male overgarments. Additionally, it must include exactly 1 male jacket, 1 male shirt, and at most 1 male bodice. The costume may also have at most 1 belt. Regarding lower garments, it must include either exactly 1 skirt and 1 pair of loose trousers, or exactly 1 pair of tube trousers.

$$\begin{aligned}\texttt{M-Costume} \sqsubseteq\ & \forall\, \texttt{P46\_is\_composed\_of.M-Garment} \\ & \sqcap\ (\geq 1\, \texttt{P46\_is\_composed\_of.M-Headwear}) \\ & \sqcap\ (\leq 2\, \texttt{P46\_is\_composed\_of.M-Headwear}) \\ & \sqcap\ (\leq 1\, \texttt{P46\_is\_composed\_of.Neckerchief}) \\ & \sqcap\ (\leq 2\, \texttt{P46\_is\_composed\_of.M-Overgarment}) \\ & \sqcap\ (= 1\, \texttt{P46\_is\_composed\_of.M-Jacket}) \\ & \sqcap\ (\leq 1\, \texttt{P46\_is\_composed\_of.M-Bodice}) \\ & \sqcap\ (= 1\, \texttt{P46\_is\_composed\_of.M-Shirt}) \\ & \sqcap\ (\leq 1\, \texttt{P46\_is\_composed\_of.Belt}) \\ & \sqcap\ \big(((\leq 1\, \texttt{P46\_is\_composed\_of.M-Skirt}) \\ & \sqcap (= 1\, \texttt{P46\_is\_composed\_of.Loose\_trousers})) \\ & \sqcup (= 1\, \texttt{P46\_is\_composed\_of.Tube\_trousers})\big)\end{aligned}$$

As illustrated above, BISTÌRIS provides two types of men's skirts that are also considered trousers by tradition. It is worth noting that the loose trousers are the only pair compatible with these two types of skirts, namely skirt trousers and bell-shaped trousers. Loose trousers are white and are worn with a man's skirt and gaiters, as stated below.

$$\begin{aligned}\texttt{Loose\_trousers} \sqsubseteq\ & (= 1\, \texttt{coveredBy.M-Skirt}) \\ & \sqcap\ (= 1\, \texttt{coveredBy.Gaiters}) \\ & \sqcap\ (\texttt{hasColour} = \texttt{White}) \\ & \sqcap\ (= 1\, \texttt{P46i\_forms\_part\_of.M-Costume})\end{aligned}$$

The two core classes :F-Costume and :M-Costume are contained within the :Costume class, from which they inherit three important axioms:

$$\texttt{dateCreated} \equiv (= 1\ \texttt{dateCreated})$$
$$\texttt{P62i\_is\_depicted\_by} \equiv (= 1\ \texttt{P62i\_is\_depicted\_by})$$
$$\texttt{fromLocation} \equiv (= 1\ \texttt{fromLocation})$$

These axioms ensure that each costume has one and only one place of origin (the city or town where it is traditional), a single date and a single reference source.

The Semantic Web Rule Language (SWRL) rules presented hereinafter facilitate the consistent application of this information to each individual garment that composes the costume.

```
  DatingRule

crm:P46_is_composed_of(?costume, ?garment) ^
schema:dateCreated(?costume, ?date) ->
schema:dateCreated(?garment, ?date)

  LocationRule

crm:P46_is_composed_of(?costume, ?garment) ^
schema:fromLocation(?costume, ?place) ->
schema:fromLocation(?garment, ?place)

  SourceRule

crm:P46_is_composed_of(?costume, ?garment) ^
crm:P62i_is_depicted_by(?costume, ?source) ->
crm:P62i_is_depicted_by(?garment, ?source)
```

In particular, colours are represented in the ontology as individuals contained in one or more subclasses of the class dbo:Colour. The colour classification into 12 categories enables a search for garments or costumes by colour without the need for precise shade specification. For example, one can query the entire :Red_category to include garments of various shades of red, or the :Brown_category to include both brown and bronze garments or costumes, without specifying exact colours.

Other two important classes of BISTÌRIS are also crm:E73_Information_Object and schema:Place. The former contains a set of subclasses to catalogue the sources from which the images were taken to describe the costumes: these can be books, periodicals, private collections, social networks, GLAM items. The latter contains entities representing the places of origin of the costumes and interfaces with the sub-class yago:Provinces_of_Italy, which contains entities representing the administrative provinces to which they belong.

These modelling choices are central to our research work, as they allow BISTÌRIS to jointly capture the material components of costumes, their structural layering, and selected socio-symbolic aspects such as intended use and geographical origin.

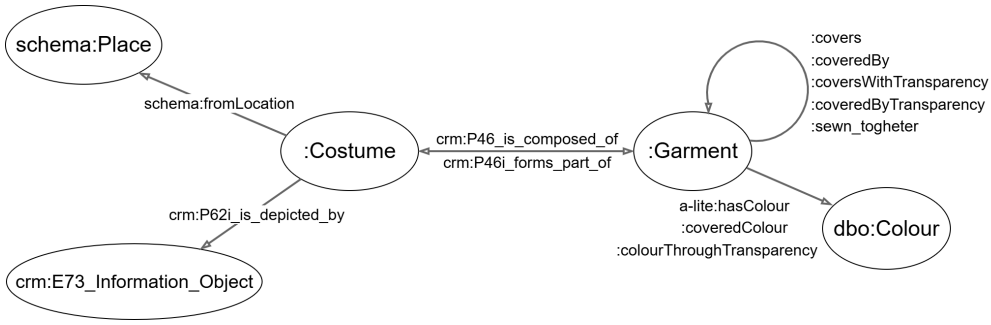

Figure 2. Main classes and object properties in the ontology.

3.5.2 Object Properties. The properties `schema:fromLocation` and `crm:P62i_is_depicted_by` are used to link costumes and garments to their geographical origins and sources. The property `dbo:neighboringMunicipality` relates each location to neighbouring towns. Additionally, the `crm:P46_is_composed_of` (and its inverse `crmP46i_forms_part_of`) property establishes the connection between costumes and their component garments.

Beyond these, we have defined several important properties to characterise the relationships between garments. These include the properties `:covers` and `:coversWithTransparency`, as well as their inverse counterparts, `:coveredBy` and `:coveredByTransparency`. Furthermore, the property `:sewn_together` captures instances where garments, such as skirts and bodices, are physically joined together. These relationships facilitate the identification of garments that are fully visible when the costume is worn in its entirety, those partially or nearly completely covered, and those overlaid with transparent fabrics (e.g. a sheer veil).

In BISTÌRIS, object properties are also employed to describe the colours of garments. The `a-lite:hasColour` property indicates the visible colours of a garment when the costume is fully worn, while `:colourThroughTransparency` specifies when the colour of a garment is visible through another garment that covers it transparently. The `:coveredColour` property denotes colours that remain hidden when a garment is worn, such as those on the inside of jackets or bodices. Figure 2 provides an overview of how the main classes in the ontology are interconnected through the object properties described above. Regarding the dating, source, and provenance of costumes, SWRL rules are employed to propagate information from costumes to garments. Specifically, two rules are implemented to make the information about the colours of garments transitive, ensuring that the colours of the garment are reflected in the overall costume when worn. The following rules enable the transitive propagation of the `a-lite:hasColour` and `:colourThroughTransparency` properties.

```
  ColourRule
crm:P46_is_composed_of(?costume, ?garment) ^
a-lite:hasColour(?garment, ?colour) ->
a-lite:hasColour(?costume, ?colour)
```

```
  TransparencyRule
:colourThroughTransparency(?garment, ?colour) ^
crm:P46_is_composed_of(?costume, ?garment) ->
:colourThroughTransparency(?costume, ?colour)
```

3.5.3 Data Properties. Data properties are used in the BISTÌRIS ontology to record information of interest regarding garments and costumes. This includes information on the pictures depicting them, their bibliographic sources and geographical data related to the provenance of the costumes. The majority of properties used for describing garments accept a datatype `xsd:boolean` as their range. These include pleating, curliness, open sleeves, buttons, tassels, fringes and similar features. In the description of garments, the use of `rdfs:Literal` values is limited to the indication of colours in relation to bows, embroidery and sleeve ribbons. Among the most interesting properties is the `:intended_use` property, which has been implemented to indicate the traditional use of the costumes, e.g. wedding, festive, gala, daily. These categories represent the main traditional distinctions among Sardinian costumes, as there are no separate garments associated with different ages or specific community roles. It is also worth noting that the dating of costumes is often uncertain and scholars can only estimate whether a costume dates back to the mid-19th, late 19th or early 20th century. For this reason, BISTÌRIS adopts the Extended Date/Time Format (EDTF)[19], a standard proposed by the US Library of Congress for the annotation of uncertain or approximate dates in the field of cultural property. Additional data properties provide bibliographic data and information regarding reference sources and further details about the analysed image – e.g. whether the image is a drawing or photograph, and whether it is black-and-white (`:BW`) or not – while geographical data provides details about the geographical origin of the exhibited customs, including longitude, latitude and height above sea level.

3.6 Population

The ontology was populated using multiple sources, including historical documents, social media posts, and images provided by photographers and private individuals. Additionally, images from Gallery, Library, Archive or Musem (GLAM) initiatives were also incorporated. Entities imported from external KGs, such as ArCo, are linked to the corresponding individuals within BISTÌRIS through the `owl:sameAs` property.

Given the challenge of retrieving bibliographic material that provides systematic and accurate descriptions of costumes at the individual garment level, populating the BISTÌRIS KG required considerable effort and meticulous observation of photographic materials. Collaborations with local associations dedicated to cultural heritage preservation, along with engagement with museum institutions housing Sardinian costume collections, were essential. We describe the population process as follows, while Figure 3 presents a simplified graphical representation of it:

1. **Image collection and digitisation**. This phase actively engaged domain experts in the collection of photographs and drawings of traditional Sardinian costumes. These sources included historical books, magazines, and other printed materials, all of which were first digitised through scanning before being annotated.

[19] `https://www.loc.gov/standards/datetime/index.html`

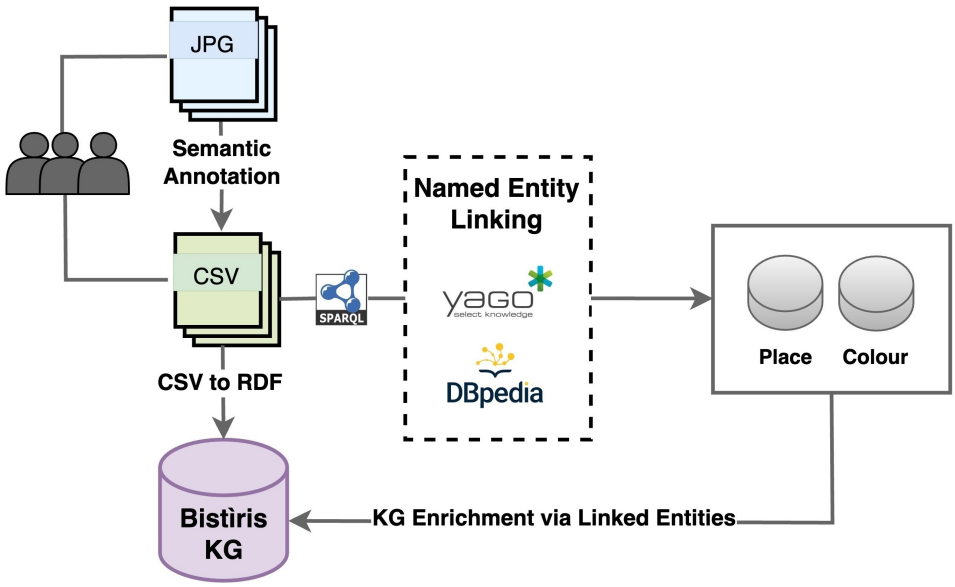

Figure 3. The figure illustrates the population process. Domain experts manually annotate images, and the resulting annotations are initially collected in CSV format. These are then transformed into RDF triples to populate the BISTÌRIS KG. Selected RDF data – such as places and colours – undergo enrichment through named entity linking with external knowledge bases like DBpedia and YAGO. The enriched data are used to populate specific ontology classes, including Places and Colours, and are subsequently integrated into the KG.

2. **Semantic annotation**. To annotate the images, the online tool *MakeSense AI*[20] was employed. This tool was selected for its flexibility in enabling the labelling of images according to predefined conceptual schema. Through *MakeSense AI*, domain experts could identify and classify garments visible in the photographs, with the ability to match each garment to categories within the BISTÌRIS model. The tool supports a user-friendly interface that allows annotators to label different objects in an image, making it easy to associate visual elements with the correct class of garment (e.g. headwear, overgarment, etc.).
3. **Data enrichment & transformation to RDF**. Once annotated, data was exported in CSV format and then enriched with supplementary information, including but not limited to the source of the image, the specific garment type depicted, and its contextual relation to the broader costume structure. Using automated Python scripts, the enriched CSV data were transformed into RDF triples, aligned with the BISTÌRIS ontology.
4. **Knowledge graph population**. The RDF triples were ingested into the BISTÌRIS KG, forming the initial graph structure.
5. **Named Entity Linking (NEL)**. This step processes mapped costume provenance information and other attributes to entities in external knowledge bases such as DBpedia and YAGO:

[20] `https://github.com/SkalskiP/make-sense`

- Geographical entities were linked to the `schema:Place` class.
- Italian provinces were associated with the `yago:Provinces_of_Italy` sub-class.
- Colour terms were mapped to corresponding entities in DBpedia and AAT to ensure consistency, disambiguation, and standardisation across the dataset.

6. **Knowledge graph enrichment**. The results of the NEL phase are fed back into the BISTÌRIS KG, enhancing its completeness, contextual richness, and interoperability.

The BISTÌRIS KG is publicly available [39] and can be queried via a dedicated SPARQL endpoint[21].

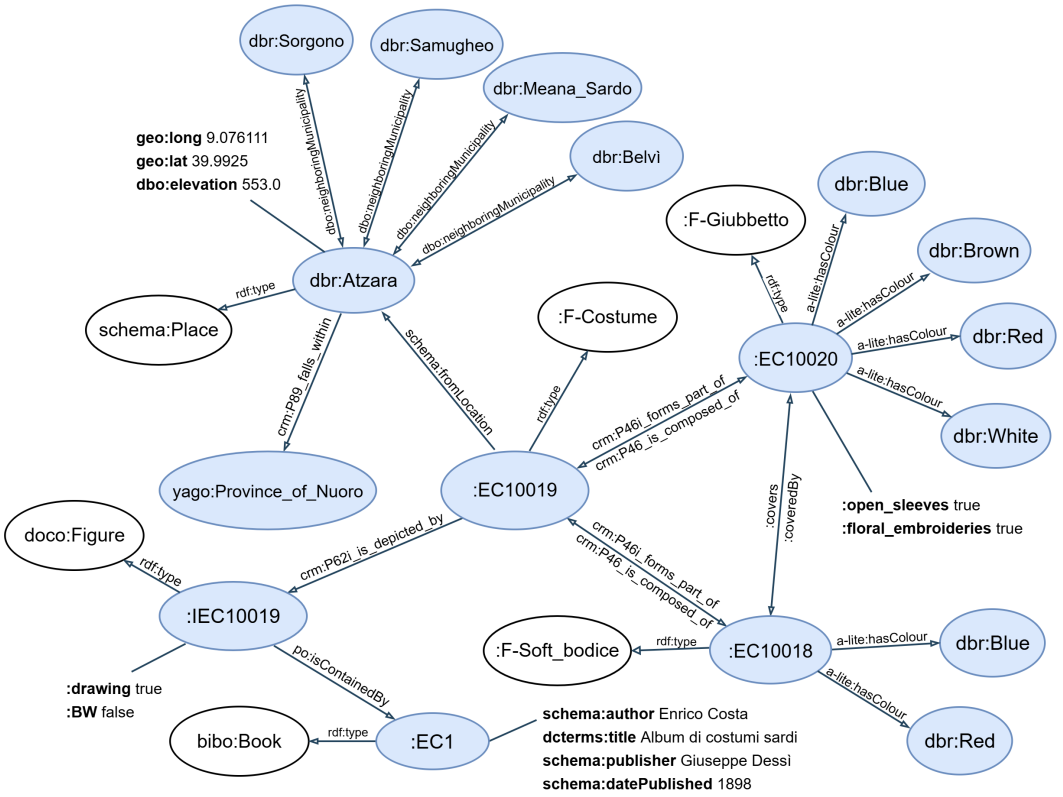

Figure 4. Example of individuals of the class `:Costume` and their relationships with other individuals and data values.

The process of populating the BISTÌRIS KG also involved the practical application of the ontology to real-world data, demonstrating how entities from historical sources can be accurately represented and linked. Figure 4 provides a graphical representation of individuals belonging to the class `:Costume` and

[21] `https://triplydb.com/aimetlab/bistiris/sparql`

their interrelationships within the knowledge graph. Individuals are represented by sky-blue ellipses, with their corresponding membership classes depicted as white ellipses. Data property values are displayed as free-standing bold text, while object properties linking individuals are illustrated as labelled edges, providing a clear visualisation of the relational structure. The example illustrates the relationships between two garments from the traditional costume of Atzara[22], including the costume itself, its place of origin and the drawing that depicts it. Garments belong to the `:F-Giubbetto` and `:F-Soft_bodice` classes. They are linked to the entity representing the costume to which they relate through the inverse properties `crm:P46i_forms_part_of` and `crm:P46_is_composed_of`. They are also linked to each other by the inverse properties `:covers` and `:coveredBy`. In addition, connections to their source (`crm:E73_Information_Object`) and geographic origins (`schema:Place`) are illustrated through relevant object properties. The entity representing the place of origin is then related to neighbouring towns and the province in which it is located, using the properties `dbo:neighboringMunicipality` and `crm:P89_falls_within`.

4 Evaluation

To assess whether BISTÌRIS effectively addresses our research question, we conducted a multi-faceted evaluation of the ontology and its associated knowledge graph, encompassing four complementary dimensions: *(i)* ontology validation, focusing on the formal soundness of the representation; *(ii)* analysis of knowledge graph metrics, assessing the coverage and structural richness required by the domain's multi-layered nature; *(iii)* querying the KG through the competency questions formulated during the requirements specification phase, testing whether the model can satisfy the information needs derived from the research question; and *(iv)* an expert-based evaluation, gathering feedback from potential users to assess the perceived relevance and interpretability of the answers.

4.1 Ontology Validation

The evaluation of the BISTÌRIS ontology was carried out through a systematic approach, employing a set of well-established criteria for ontology quality assessment, outlined by [40]. The evaluation was based on a set of five key metrics: Consistency, Completeness, Conciseness, Expandability, and Sensitivity. The evaluation process consisted of both automated reasoning and manual analysis, aimed at assessing the ontology's ability to meet the defined requirements.

Consistency. It is a critical quality criterion, referring to the absence of contradictions or conflicting information within the ontology. To assess the consistency of the BISTÌRIS ontology, we used Pellet [41] as a reasoner to perform reasoning tasks and check the coherence of the ontology's axioms. Specifically, we aimed to ensure that no class or individual in the ontology conflicts with the others and that all property assertions are logically consistent with the defined classes and relations.

[22] Atzara is a small town located in the central part of Sardinia, Italy. It is known for its rich cultural heritage, particularly in the preservation of traditional Sardinian costumes. The town has a long history of local craftsmanship and folklore, which is reflected in the distinctive garments worn during its festivals and celebrations.

Completeness. It evaluates whether the ontology fully represents the relevant concepts and relationships required to model the Sardinian traditional costume domain. This criterion was measured by performing a set of SPARQL queries against the ontology to verify whether it can correctly answer the defined competency questions. Further details regarding this step can be found in subsection 4.3.

Conciseness. It ensures that the ontology contains the minimal number of classes, properties, and relations required to accurately represent the domain, without unnecessary redundancy. To evaluate conciseness, a redundancy check was conducted to identify duplicated triples or unnecessary assertions within the KG. No redundant triples were detected, indicating a clean and efficient structure without superfluous repetitions.

Expandability. It measures the ontology's ability to incorporate new concepts, relationships, and data without requiring major structural changes. To assess expandability, the ontology was designed to be modular, allowing for the seamless integration of new subclasses and properties. Moreover, the ontology's alignment with external ontologies was tested to ensure that the addition of new concepts or external resources would not disrupt the existing structure.

Sensitivity. It refers to how changes in the ontology's core structure affect its overall integrity. Sensitivity was assessed through modifying some key elements, such as the main class `:Costume`, to determine how these changes impacted related classes and properties. During this tests, experts' feedback was solicited to validate that such changes did not destabilise critical aspects of the ontology.

4.2 Knowledge Graph Metrics

To gain a deeper understanding of the structure, population, and complexity of the BISTÌRIS KG, we computed some key metrics. These metrics provide insights into the KG's ability to represent the intended domain knowledge, the richness of its schema, and how the data is distributed across different entities and properties. We first computed the overall size and basic characteristics of the KG. Table 7 summarises these key metrics.

Metric	Value
Number of individuals	5,321
Number of object property assertions	141,015
Number of data property assertions	4,553
Total number of triples	60,695

Table 7. Overview of key metrics for the BISTÌRIS KG.

The BISTÌRIS KG comprises a total of 5,321 individuals, interconnected through 141,015 object property assertions and described by 4,553 data property assertions, resulting in an overall size of 60,695 triples. The significantly higher number of object property assertions compared to data property assertions indicates a strong focus on representing relationships between entities rather than merely describing their attributes. This structural richness suggests a modelling approach oriented towards capturing complex inter-entity connections, which is particularly suitable for the domain addressed by BISTÌRIS. Moreover, the moderate overall size of the KG reflects the specialised nature of the domain.

A more detailed analysis of individuals across different classes is shown in Figure 5, where we highlight the most populated classes. The bar chart provides an overview of the distribution of these entity types, with each bar representing the number of individuals associated with a particular class. The `:Garment` class stands out as the largest category, containing 3,386 individuals, followed by its

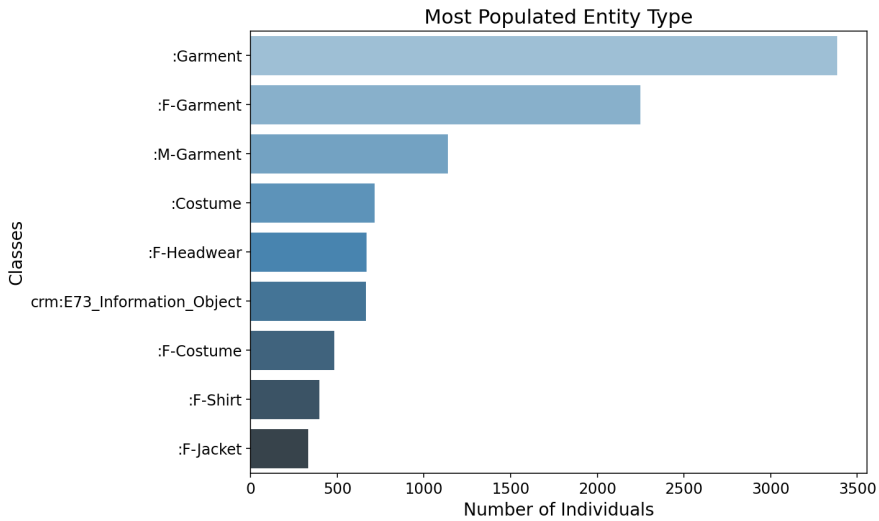

Figure 5. Overview of the most populated entity types within the KG.

subclasses, `:F-Garment` and `:M-Garment`, which include 2,248 and 1,138 individuals, respectively. Other notable classes include `:Costume` with 716 individuals and `:F-Costume` with 482 individuals. On the other hand, the class `:F-Jacket` has the fewest representations, with only 332 individuals. It is relevant to note that the chart only includes the most populated classes, meaning less frequent classes are not shown here. The clusterisation of entities clearly reveals a concentration around a few core classes, while many others remain sparsely populated. In this regard, we conducted a qualitative inspection of the least populated classes, which together represent a small fraction of the total instances in the KG. Several of these, such as `:Fez` (9 instances), `:Shoulder_veil` (9), `:M-Cap` (10), `:Triangle_shaped_apron` (10), or `:Mantle` (6), correspond to garments that appear only occasionally in ethnographic catalogues or are restricted to specific local dress traditions. Their scarcity reflects both the fragmentary documentation of certain costume types and the high regional variability of Sardinian attire.

Figure 6 illustrates the top 10 most frequent relationships in the KG. The property `a-lite:hasColour` leads with 7,577 triples, followed by `schema:fromLocation` with 4,102 triples , indicating a strong focus on visual and geographical attributes. Other prominent properties, such as `crm:P62i_is_depicted_by` and `crm:P46_is_composed_of`, feature over 3,400 triples each, suggesting that the dataset contains rich information regarding sources and part-whole relationships. The distribution is clearly skewed, with a small set of predicates dominating the dataset, while more specialised properties like `:technical_details` and `:drawing` appear less frequently.

In addition to these, several low-frequency relationships such as `:fringes`, `:embroideries`, `:floral_embroideries`, and `:coversWithTransparency` capture refined decorative or material characteristics that are mentioned only sporadically in documentation or visible in a limited number of photographic sources. The degree distribution of the nodes, shown in Figure 7, offers insight

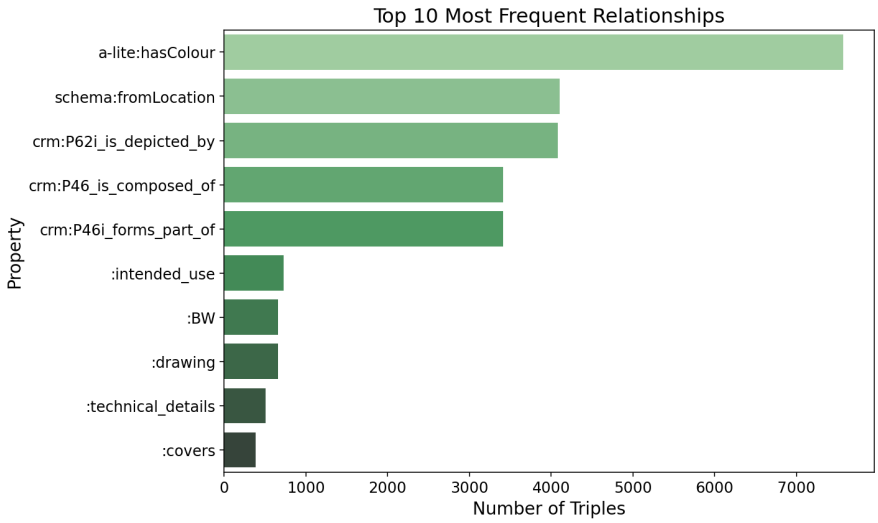

Figure 6. Bar chart of the top 10 most frequent relationships in the KG.

into the connectivity of the KG. The histogram reveals that most nodes exhibit low degrees, with a concentration around degrees 9-10, indicating that most entities are moderately connected to other nodes. However, there are a few highly connected nodes, with degrees reaching up to 20, suggesting the presence of central hubs within the KG. This long-tail distribution, where a small number of nodes are highly connected and the majority are sparsely connected, is characteristic of scale-free or small-world networks. The average node degree is approximately 9.26, meaning each node is connected to an average of 9 other nodes.

The most connected nodes within the KG reflect key domain concepts. Entities such as `:Garment` (3,407 connections) and `:F-Garment` (2,270 connections) emerged as central hubs, alongside external resources such as `dbr:White` (1,866 connections) and `dbr:Black` (1,626 connections).

Overall, the BISTÌRIS KG presents a foundation for representing domain-specific knowledge, but there are opportunities for further expansion. By diversifying under-represented classes and relationships, and by enhancing the connectivity between less central nodes, the KG could be made even more comprehensive and reflective of the domain's full complexity.

4.3 Using Competency Questions to Query the Knowledge Graph

In this subsection, we present the evaluation of the BISTÌRIS KG to answer the predefined competency questions. For transparency and reproducibility, all SPARQL queries, developed to address the CQs, are

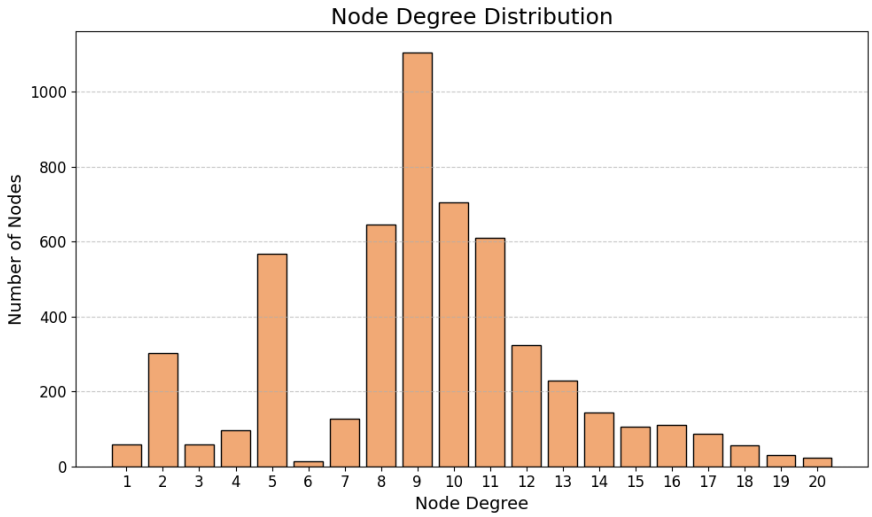

Figure 7. Node degree distribution in the KG, showing the frequency of nodes with various degrees of connectivity.

available in the project repository [23]. To clarify the rationale behind the translation from natural-language questions to their SPARQL implementations, we adopted a competency-driven validation strategy. Each SPARQL query represents the executable counterpart of a CQ, allowing us to empirically verify whether the ontology can retrieve the information required to answer the question it was designed for. This translation transforms the abstract information needs identified during the requirement collection phase into operational tests of the ontology's expressivity and data coverage. The translation process followed three main steps. First, the entities and relations mentioned in each CQ were mapped to the corresponding ontology classes and properties. Second, constraints (such as spatial, temporal, or material conditions) were formalised using SPARQL filters and logical patterns. Third, the resulting queries were tested against the KG to confirm that they returned complete and accurate results.

Answering these questions is especially important for researchers in fields such as anthropology, history, and ethnography, as it allows them to retrieve complex and structured information about traditional practices, temporal changes, and symbolic meanings encoded in the data.

CQ1. How do costume and garment characteristics vary across different geographical areas of Sardinia?

To address this competency question, a SPARQL query was designed to retrieve instances of headwear garments (`:M-Headwear`), categorised by their specific type and the elevation of their place of origin. As specified in sub-section 3.5.3, the geographical information used to answer this query is retrieved

[23] `https://github.com/AIMet-Lab/BISTIRIS/tree/main/query`

through dedicated data properties that encode the provenance of each costume specimen, including its latitude, longitude, and elevation.

In particular, elevation data, retrieved via the `dbo:elevation` property from DBpedia, enabled classification into two altitude-based categories: 'Elevation $>$ 600 m' and 'Elevation $\leq$ 600 m', using a `BIND` operation. Generic types such as `owl:NamedIndividual` were excluded through `FILTER` clauses, and a `FILTER NOT EXISTS` condition ensured that only the most specific garment classes (those without subclasses) were considered. The resulting data was grouped and ordered by elevation category and garment class.

The query results revealed that `:Berritta` is the most prevalent headwear type across both elevation ranges, while specific types such as `:Brimmed_hat`, `:M-Kerchief`, `:Fez`, and `:M-Cap` appear exclusively in areas below 600 meters. These findings suggest a degree of geographical differentiation in headwear traditions.

CQ2. How do costume and garment characteristics vary over time?
In this case, the SPARQL query aimed to assess colour usage across different historical periods. Garments were associated with their respective colours through the `a-lite:hasColour` property, excluding shirts (`:F-Shirt` and `:M-Shirt`), which would have introduced bias due to their exclusively white colouration. The garments were divided into two temporal categories based on the value of `schema:dateCreated`: the 19th century (dates beginning with "18") and the 20th century (dates beginning with "19"), using a BIND operation with `IF-STRSTARTS`.

The results showed that in the 19th century, the dominant colour categories were `:Blue_category` and `:Red_category`, followed by `:White_category`. By contrast, in the 20th century, alongside `:Red_category`, the `:Black_category`, `:Yellow_category`, and `:Purple_category` became more prevalent. These findings highlight a temporal evolution in colour preferences, with `:Red_category` demonstrating continuity across both centuries and an increased prominence of darker and warmer tones in the 20th century.

CQ3. Do the costumes and garments share similar characteristics in nearby places?
This query investigates the similarity of traditional garment features between the town of Galtellì and its neighbouring municipalities. Garments classified under `:F-Garment` were selected based on their place of origin, retrieved via the `schema:fromLocation` property. To ensure specificity, general classes and named individuals were excluded. For each garment, the query extracted its type, colour, and technical characteristics, the latter identified through `:technical_details`) property. The analysis then compared these features with those of garments from neighbouring municipalities (linked to Galtellì through `dbo:neighboringMunicipality`), counting how many distinct neighbouring locations share garments of the same type, colour, and technical characteristics. The results reveal clear patterns of regional stylistic continuity. Head shawls in black and purple with decorative fringes are common in Dorgali, Irgoli, and Orosei, while light aprons with gathers and flared skirts in brown or red, featuring pleating, further demonstrate shared aesthetic traditions and local variations in garment design across neighbouring communities.

CQ4. Which specimens of a given garment are constructed using transparent materials?
This competency question focused on identifying garments that incorporate transparent overlays. The

SPARQL query selected garments involved in a `:coversWithTransparency` relationship, where one garment partially covers another in a way that transparency plays a visual or functional role.

The resulting list predominantly included veils and shoulder veils, but also identified some curly aprons, providing evidence of the use of transparency as a deliberate stylistic feature in specific types of traditional garments.

CQ5. Which specimens of a given garment are constructed using transparent materials?
Here, the SPARQL query targeted garments of type `:F-Bodice` that cover garments of type `:F-Jacket`, linked through the `:covers` property. The place of origin was identified using `schema:fromLocation`.

The query results indicated four municipalities where traditional women's costumes feature the bodice worn externally over the jacket, suggesting a distinctive stylistic or functional layering convention within these communities.

CQ6. What is the frequency with which two specific properties occur simultaneously among the garments?
To explore the co-occurrence of garment features, the SPARQL query computed the proportion of `:Curly_apron` garments that participate in a `:coversWithTransparency` relation. The query first counted the number of curly aprons involved in such a relation and then calculated the total number of curly aprons.

The analysis showed that 6 curly aprons exhibited this transparency relationship, corresponding to a relative frequency of approximately 3.4%. This quantitative measure underscores how transparency use is present but not widespread within this garment type.

Table 8 provides a concise overview of the main aspects of each competency question. For every CQ, it summarises the retrieved information, the query structure (including key filtering and grouping criteria) and the principal findings.

CQ	Query Strategy	Summary of Results
CQ1	Group headwear garments by type and elevation (`dbo:elevation`)	`:Berritta` prevalent at all elevations; other types like `:M-Kerchief`, `:Fez` found only below 600m
CQ2	Count garment colours by century (19th vs. 20th, using `schema:dateCreated`)	19th century: blue and red are dominant; 20th century: black became more frequent
CQ3	Compare garments and technical traits between Galtellì and neighbouring municipalities	Head shawls (black/purple, with fringes) common in three neighbouring towns; Curly aprons (white, gathered) and gheroni skirts (brown/red, pleated or with *màsculas*) show local technical variations
CQ4	Retrieve garments involved in `:coversWithTransparency` relation	Veils and curly aprons identified as garments using transparent overlays
CQ5	Identify cases where bodice covers jacket using `:covers` property	Found in four towns where the bodice is worn over the jacket
CQ6	Compute frequency of curly aprons involved in transparency relations	6 curly aprons involved; relative frequency 3.4%

Table 8. Summary of the SPARQL queries designed to address the competency questions.

The six competency questions suggest that BISTÌRIS is capable of representing and retrieving information spanning material features, structural relations, and socio-cultural patterns, providing initial empirical support that the ontology-based model can capture different aspects of the multi-layered structure of traditional costumes outlined in our research question.

4.4 External Experts-Based Evaluation

To complement and extend the validation performed through SPARQL queries in sub-section 4.3, we conducted an external evaluation of the six competency questions with professionals and researchers in the fields of arts, cultural heritage, and tourism. The aim was to assess the perceived *relevance*, *completeness*, and *understandability* of the CQs and their corresponding results, as interpreted by potential end-users of the BISTÌRIS KG.

The online questionnaire[24] was drafted in Italian and was distributed to a selected group of museum curators, academic researchers, students, and professionals working in Sardinian and Italian institutions related to cultural heritage, art history, ethnography, and tourism studies. Respondents were asked to indicate their role (e.g. researcher, curator, student, other) and area of expertise. The questionnaire was anonymous to encourage free feedback. Overall, the sample included 32 respondents: 19 researchers (59%), 7 curators (22%), and 6 students (19%). The declared domains of expertise covered mainly cultural heritage and archaeology (34,38%) and art history and museology (31,25%), followed by tourism studies (12,50%), geography (6,25%), history and philology (6,25%), and computer science/digital humanities (6,25%), with a small share of respondents indicating other or unspecified fields (3,12%).

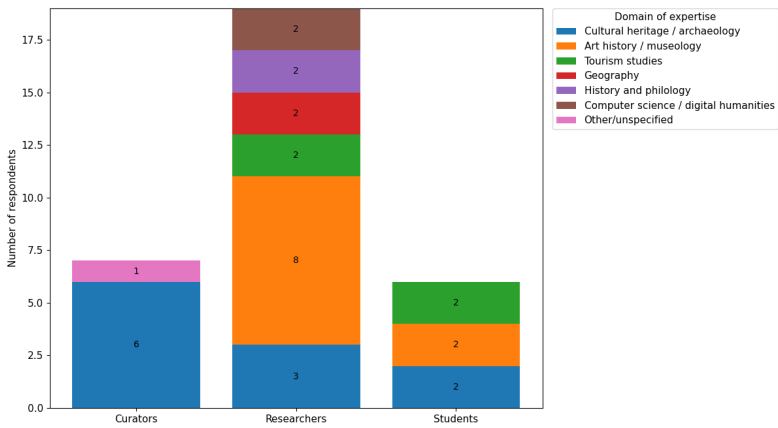

Figure 8. Number of respondents by role and domain of expertise. Each bar represents a role, and different colours indicate the respondents' domains of expertise.

[24] The questionnaire is available at: `https://aimet-lab.github.io/BISTIRIS/questionnaire/index.html`.

Each CQ was presented in natural language together with its SPARQL-derived tabular result and a short explanatory note clarifying its meaning and possible interpretation. Participants rated each CQ on a five-point Likert scale [42] (1 = very low, 5 = very high) according to: (*i*) relevance to their professional domain, (*ii*) completeness of the retrieved information, and (*iii*) understandability of the question and its results. An optional free-text field allowed qualitative comments and suggestions.

CQ	Relevance	Completeness	Understandability	Notes Summary
CQ1	3.88	4.00	3.97	Suggestion to use historical regions instead of altitude ranges; distinguish differences between communities
CQ2	4.22	4.00	4.38	Interest in finer temporal division; before/after WWII comparisons
CQ3	4.06	3.91	3.97	Clarify municipality grouping; compare with other garment types
CQ4	4.41	4.31	4.31	Notes on frequent head veils and light aprons; transparency of materials
CQ5	4.28	4.25	4.22	One respondent surprised by results; need for more examples
CQ6	4.09	4.41	4.25	Suggestion to include more examples; overall clarity appreciated

Table 9. Mean scores from expert evaluation of the predefined competency questions in terms of perceived relevance, completeness, and understandability, along with a summary of qualitative feedback from participants.

The evaluation indicates that the CQs were generally perceived as highly relevant and understandable (*mean relevance* = 4.15; *mean understandability* = 4.18), while completeness received slightly lower but still clearly positive scores (*mean completeness* = 4.14). A closer inspection of Table 9 shows that the lowest scores for relevance and understandability are associated with CQ1 and CQ3, which both focus on spatial patterns across Sardinian communities. This is consistent with the qualitative feedback, where experts stressed the need for a finer-grained and historically grounded geographical classification (e.g. using historical regions instead of altitude ranges) and for clearer grouping of municipalities. In other words, the spatial dimension of the KG is considered useful but also perceived as the area where modelling choices have the greatest impact on interpretability. By contrast, CQ2 and CQ4, which address

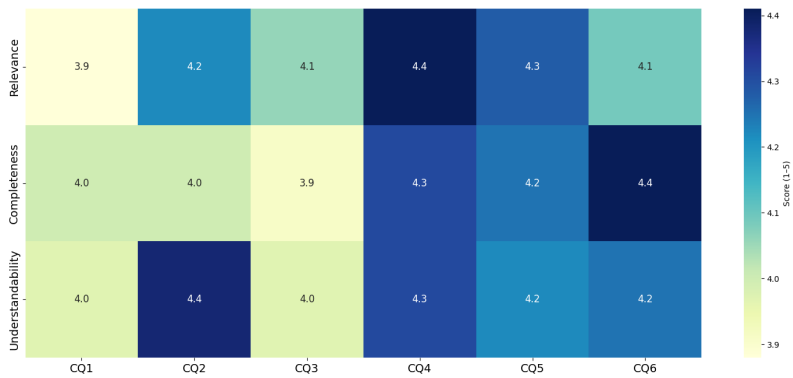

Figure 9. Average expert ratings across the six competency questions. Each axis represents a CQ, while the three lines correspond to the evaluation dimensions: relevance, completeness, and understandability.

temporal variation and material properties respectively, display some of the highest ratings across all three dimensions. CQ2 benefits from the fact that temporal change is a core concern for historians and curators, even though several respondents requested a finer temporal granularity (for instance, distinguishing pre- and post-World War II periods). However, this limitation largely stems from the available sources, which often do not provide precise dates but rather broad temporal ranges. This constraint also underscores the need to model temporal information using EDTF, which is specifically designed to accommodate uncertain or interval-based dating. CQ4, which targets the use of transparent materials, is particularly appreciated by curators, as it directly supports questions related to conservation, display strategies, and visitor experience. The high scores for CQ5 and CQ6 further suggest that BISTÌRIS is effective in capturing relational and co-occurrence patterns (e.g. garment layering and joint occurrence of specific properties), even when the resulting distributions occasionally challenge experts' expectations, prompting them to revisit their prior assumptions about traditional costume practices.

Figure 9 summarises these trends by visualising the mean expert ratings across the six CQs. The overall pattern confirms that all questions are rated well above the midpoint of the scale, with limited variation in perceived relevance and understandability. Completeness shows slightly greater variability, especially for CQ1 and CQ3, which experts associated with opportunities for deeper contextualisation, additional examples, or alternative spatial aggregations. This suggests that the underlying KG is already able to support meaningful exploration of the data, but that some queries could benefit from richer contextual information or more flexible filtering options.

5 Applications and Usage Scenarios

The BISTÌRIS ontology and its associated knowledge graph provide a structured framework for documenting and analysing traditional Sardinian costumes. Rather than pursuing exhaustiveness, BISTÌRIS adopts a formal and adaptable model designed to support comparative and diachronic analyses at both local and regional scales.

In the field of cultural heritage, the detailed semantic modelling of traditional costumes addresses a real need for tools that can capture the subtle variations between garments originating from different geographical areas or historical periods. In Sardinia, where traditional attire plays a prominent role in the preservation of local identities, such a structured approach is particularly valuable.

For example, cultural institutions such as the *Costume Museum* located in Nuoro, which houses one of the most important Sardinian collections of clothes, jewellery, textiles and wooden artefacts and masks, can benefit from BISTÌRIS to semantically enrich their catalogues. Using the ontology, curators and researchers can formally describe individual costume elements, trace their provenance, and compare stylistic variations across different communities.

Beyond the Galleries, Libraries, Archives, and Museums (GLAM) context, events such as the *Cavalcata Sarda* in Sassari or the *Sant'Efisio procession* in Cagliari, which involve public parades showcasing hundreds of costumes from diverse Sardinian villages, highlight the ongoing significance of traditional attire in contemporary cultural practices. While BISTÌRIS is not designed for real-time event management, its KG could be used to support educational or curatorial initiatives, for instance by enabling interactive digital exhibits or by providing structured background information on the costumes displayed during such events.

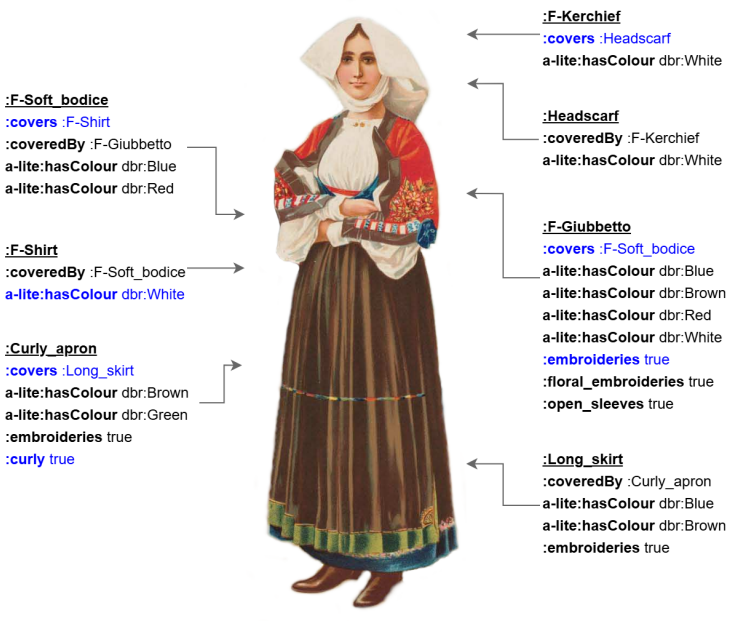

Figure 10. Traditional costume of the town of Atzara accompanied by data extracted from the BISTÌRIS KG. Blue text denotes insights inferred by the reasoner.

Moreover, by integrating BISTÌRIS with external Linked Open Data resources, such as geographical information, it becomes possible to develop richer, interconnected narratives. For instance, a researcher could analyse how certain garment features are distributed geographically, or explore correlations between specific decorative elements and historical trade routes affecting different Sardinian areas.

To further clarify how BISTÌRIS captures the detailed structure of traditional costumes and their associated metadata, we provide an illustrative example from the KG. Figure 10 illustrates the costume of Atzara - which was partially described in Figure 4 – alongside the pertinent data sourced from the BISTÌRIS knowledge base. Each garment, highlighted in bold and underlined, is associated with a complete set of property values. Values shown in blue are inferred through reasoning. As we can see from this Figure, BISTÌRIS can be a very valuable support to highlight recurrences with respect to the colours, fashions and dressing of the garments in the catalogue. The image is taken from an 1898 illustrated book by the Sardinian writer and historian Enrico Costa [43] and shows details of the costume which changed over time. For example, Atzara's costumes from the 20th century to the present day show a more colourful and embroidered apron, with pleating and differences in colouring (black replacing brown, and a more pronounced use of the colour green). Such changes in Sardinian attire highlight the relevance of a KG like BISTÌRIS, which can effectively document and trace these evolving cultural expressions over time.

5.1 Cross-Cultural Application of BISTÌRIS

To promote the reusability and adaptability of the proposed model, we developed a lightweight version of the ontology, named BISTÌRIS *Lite* [25], designed to preserve the conceptual backbone of BISTÌRIS while removing region-specific classes, constraints, and instances. This version maintains the high-level garment taxonomy, the main object and datatype properties, and the modular separation between structural, material, and decorative dimensions of the garments.

The *Lite* model was conceived to test the generalisation potential of the ontology across different cultural contexts. While the full version of BISTÌRIS encodes detailed ethnographic knowledge specific to Sardinian tradition, this *Lite* version abstracts from local classifications, retaining only the universal conceptual relations that underpin traditional attire across cultures. This distinction enables the reuse of the same ontology schema for representing other Mediterranean or European traditions without the need for extensive restructuring. From a methodological perspective, the cross-cultural application was

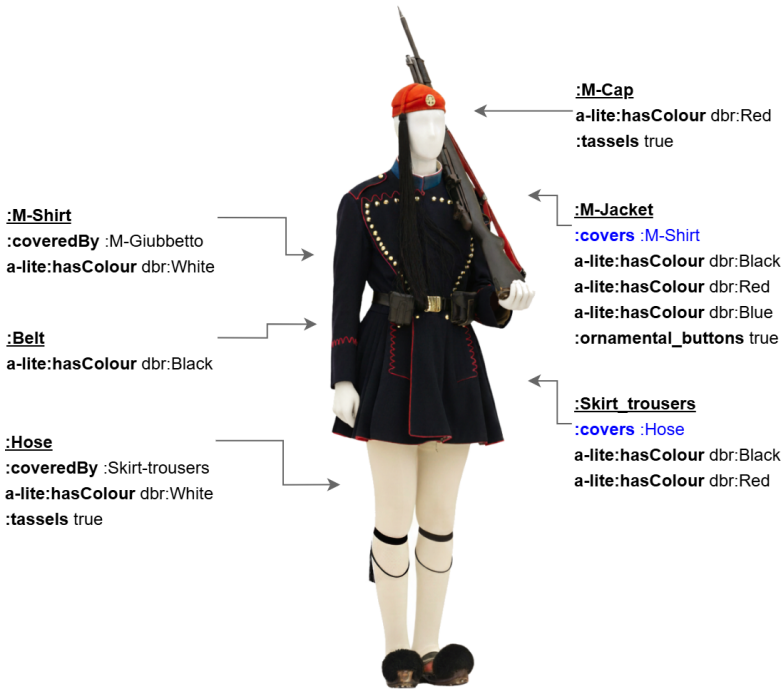

Figure 11. Traditional uniform of the Greek Presidential Guard, annotated with BISTÌRIS *Lite*.

guided by two hypotheses: (*i*) that the hierarchical and compositional structure of BISTÌRIS which organises garments according to function, body area, and layering, captures a pattern that is common to many traditional dress systems; and (*ii*) that the ontology can be reused across different cultural

[25] Available at: `https://aimet-lab.github.io/BISTIRIS/bistiris_lite.owl`

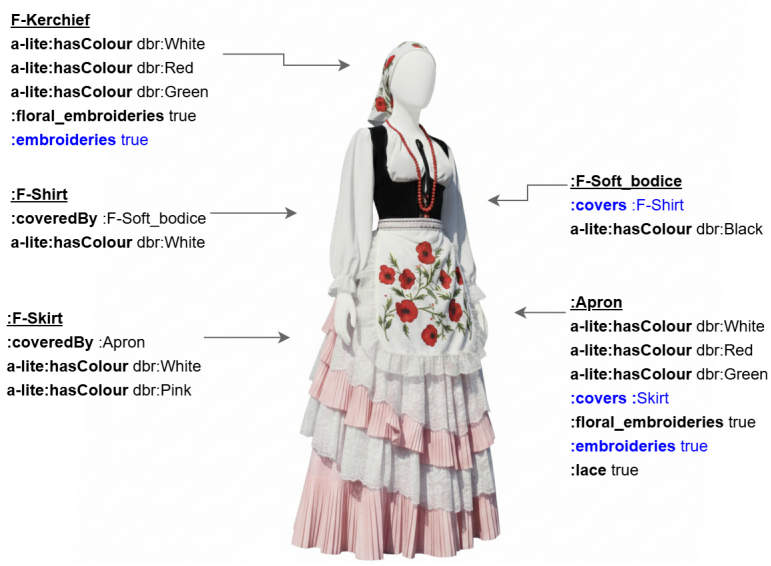

Figure 12. Sicilian traditional costume, annotated with BISTÌRIS *Lite*.

contexts without requiring structural modification, thus preserving its logical consistency. To verify these hypotheses, we applied BISTÌRIS *Lite* to two test cases: the traditional uniform of the Greek Presidential Guard and a Sicilian traditional costume. The mapping was performed manually by aligning each garment and decorative element with the most appropriate class from the lightweight ontology version. No structural changes or additions were introduced; instead, we evaluated how far the existing conceptual framework could capture the relevant features of each costume. Logical consistency was verified with reasoner, confirming that all class assertions were satisfiable within the original model, which can also be extended with specific classes or properties when needed.

As shown in Figure 11, the jacket of the Greek Presidential Guard corresponds to the class `:M-Jacket`, and the trousers are described by the class `:Hose`. Traditional knee elements (*Kaltsodétes*), currently generalised as tassels, could be further refined by defining a dedicated property, thus extending the expressiveness of the model for military or ceremonial attire. New features, such as *epaulettes* and *stand-up collar*, could be introduced to model specific characteristics of the military uniforms.

In the Sicilian case (Figure 12), BISTÌRIS *Lite* effectively captured common structural components, such as the kerchief and apron, while additional refinements (e.g. a subclass for pleated skirts, or a property for shirts fastened with a string) could be introduced to encode local stylistic nuances.

The results of this cross-cultural application indicate that the conceptual organisation of BISTÌRIS appears to provide a flexible basis for representing traditional attire in different contexts. Although these findings are preliminary, they suggest that the core ontology can be effectively reused without structural modifications and that it could support the extension with additional culturally specific classes and properties, enabling intercultural applications.

6 Discussion and Future Work

The present work introduces a semantic-driven approach for Sardinian traditional costume analysis, grounded on structured ontologies and knowledge graph methodologies. Our work *(i)* formalises a domain ontology for Sardinian costumes and garments; *(ii)* instantiates it in a populated KG; *(iii)* evaluates it through reasoning-based validation, KG metrics, competency-questions' execution, and an external experts-based questionnaire; and *(iv)* explores cross-cultural reuse via a BISTÌRIS *Lite* application. The results collectively show that a competency-driven modelling workflow can effectively support the representation of cultural artefacts characterised by overlapping material, structural, and temporal dimensions. The ontology–KG combination proved expressive enough to capture the internal composition of garments as well as their geographical and historical variability. The CQ execution offered a concrete means of validating modelling choices against domain-relevant information needs, while the expert evaluation provided additional feedback and highlighted points requiring refinement, including geographical granularity and the need for more contextual annotations. Overall, the work illustrates how a structured modelling pipeline can support the representation and exploration of complex heritage objects, and lays the foundation for future extensions and comparative applications.

While the results demonstrate promising avenues for integrating historical and material culture knowledge into a computable form, several limitations and challenges persist. In particular, the annotation process of cultural artefacts – especially clothing – remains a labour-intensive and highly specialised task, requiring domain expertise and meticulous visual scrutiny. From a practical standpoint, and given the manual and expert-intensive nature of the current annotation workflow outlined above, future research will aim to integrate machine learning techniques to augment and partially automate the annotation process. At the time of writing, we have manually annotated approximately five thousand images of Sardinian costumes. This dataset, while relatively modest in scale, opens up the possibility for applying transfer learning or fine-tuning approaches, particularly given the lack of large-scale, high-quality training data in the domain of historical and cultural fashion. In the best-case scenario, this could enable object detection systems capable of identifying specific garments within an image and localising them through bounding boxes –providing valuable spatial and semantic metadata. In more constrained settings, object classification approaches may suffice, determining only the presence or absence of specific types of clothing. Comparative baselines such as Fashion-MNIST [44], although relevant, offer only low-resolution images of garments in isolation (i.e. not worn), which limits their applicability to our context where garments are often partially occluded, stylised, or worn in complex compositions.

From a knowledge representation perspective, the current work also lays the foundation for answering competency questions via SPARQL queries over the BISTÌRIS KG. One such question (CQ1: "How do costume and garment characteristics vary across different geographical areas of Sardinia?") highlights a key avenue of future development. Historical regions represent culturally significant subdivisions of Sardinia and provide a meaningful axis for comparative analysis[26]. We have already initiated the development of a dedicated geo-module within the ontology to model these historical regions and to link each costume instance to its town of origin. Feedback from the external expert-based evaluation

[26]The historical regions of Sardinia are 35 traditional subdivisions of the island's territory, rooted in ancient origins and still present in its cultural identity.

confirmed the relevance of this refinement, as multiple respondents explicitly requested a shift from altitude-based groupings toward historically grounded regional distinctions.

Furthermore, future iterations of the BISTÌRIS ontology could benefit from the integration of additional contextual dimensions, such as rituals, festivals, or oral traditions associated with specific garments. Linking material culture to intangible heritage could greatly enrich the semantic depth of the KG, supporting interdisciplinary research in ethnography, anthropology, and digital humanities. This also opens avenues for aligning BISTÌRIS with broader cultural heritage ontologies and initiatives, such as Europeana or Wikidata, facilitating data reuse and multilingual access.

A further direction concerns real-world deployment through collaboration with local stakeholders, using participatory design to ensure usability and support applications such as digital exhibitions and educational platforms. Building on the network established through *e.INS - Spoke 2* project (which includes cultural enterprises, municipalities, institutions, museums, and foundations), we will continue gathering expert feedback and integrate BISTÌRIS into the broader *e.INS* platform to support cultural institutions and enterprises across Sardinia.

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