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AN ONTOLOGICAL INTERPRETATION OF THE ICCD RECOMMENDATION

1. Introduction

The rapid progress of the "information society" in the past decade has been made possible by the removal of many technical barriers. In this context, cultural heritage has received increasing attention and been recognized as an important aspect for social groups in order to preserve the identity of the human community. Many efforts have been devoted to deal with cultural heritage preservation, promotion, and economic exploitation problems. To a greater degree, technology is solving one of the most problematic issues concerning cultural heritage assets: their nondestructive public access. Never before, have there been greater opportunities to explore and discover in detail these marvels of the Earth and of humankind without fear of irreparable damage. Organizing large information repositories is a difficult problem. In fact, standard databases provide sophisticated technology for data organization and maintenance, heterogeneous repositories like data warehouses, federated databases, and especially the World Wide Web suffer from the problem of heterogeneity that requires sophisticated organization methods.

Standard databases are mostly homogeneous systems with well-defined query languages that can be used to access information available in the database. On the web, a user first of all has to find the information needed, before it can be used. Then the information may be present in different kinds of data formats and structures. Last but not least, information that seems to fit the user's need may be tailored for a completely different purpose and consequently hard to use.

Furthermore, information is only meaningful in the context of other information, but most mechanisms we have available for publishing, locating and retrieving information, deal with single, isolated instances of information, at the grain size of a document, a web page or a diagram, and do not help us at all in integrating this information into what we already know.

The problem of information contextualization together with its retrieval and integration is called the problem of information sharing. Currently, it is argued that one possible way to cope with this problem consists of giving the computer better access to the semantics of the information. Thus, for a document, we not only need to store obvious metadata such as author, title, creation date, etc., but, in a machine-accessible way, we must store and make available the important concepts that are discussed in the document, the relation of these concepts with those in other documents, relating these concepts to general background knowledge, etc.

A key technology for resolving the open problem of meaningful information sharing seems to be based on the ontological information approaches. Although most of them rely on the existence of well-established data structures that can be used to analyze and exchange information, this is not the case for the web. In fact, on the web we have no access to the conceptual model of an information source or to the resulting logical data model. Nor is it possible to clearly determine which information has to be taken into account, because the information sources are frequently added, removed or changed. To cope with these problems we need to investigate ontology based approaches for resolving semantic heterogeneity in weakly structured environments.

The ontological organization of information differs basically from the other representation modalities in that the former is based on the following unique principle: if a piece of information exists, it must refer to one or more entities that are modelled by classes well-founded in the ontology, and the piece of information must be codified by appropriate examples of attributes and/or relations that concern those classes.

The objectives of Cultural Heritage Information Systems should be established as a federated network of culture related information providers, where all contents should be available to the general public, professionals and market operators through cooperating information systems. For such systems, the cooperation process should be focused on the re-organization and unification process of the existing relevant information resources. The cooperation would account for heterogeneous, dynamically changing and autonomous services to be combined into a single logical service.

Many information systems and international initiatives were started up to collect and manage information about cultural heritage artifacts. Furthermore, to win a wider audience and to promote a standardization process, many efforts are on going[1]. With the wide acceptance of the World Wide Web metaphor, most systems were transformed to replace the notion of record with that of document as elementary information entity on the basis of which the information systems could be designed.

One promising approach which could be exploited in pursuing the above mentioned goals is given by the Semantic Web Initiative (Berners-Lee 1969). As the Semantic Web begins to fully take shape, the grid CMS implementation will enable agents to understand what is actually being processed, since all contents are modeled in machine understandable OWL/RDF.

[1] For example the BIBLINK Core Application Profile (http://www.schemas-forum.org/registry/biblink/BC-schema.html); CIMI: Consortium of Museum Intelligence (http://www.cimi.org/); the Dublin Core Metadata Initiative (http://www.purl.org/dc/); CIDOC Conceptual Reference Model (http://cidoc.ics.forth.gr/).

In this paper, we address the problem of making existing distributed document collection repositories mutually interoperable at a semantic level. We argue that emerging Semantic Web technologies offer a promising approach to facilitate semantic information retrieval based on heterogeneous document repositories distributed on the web. Therefore, in our approach, the information sharing problem is dealt with by developing an ontology that accounts for the meaning of one of the most widely used metatada sets of the Italian Ministry of Cultural Heritage, the ICCD (Istituto Centrale per il Catalogo e la Documentazione)[2] recommendations, together with an ontology information management framework. To cope with the semantic interoperability issues we developed a cultural heritage ontology that is empirical and descriptive. It formalizes the semantics necessary to express observations about the domain of the discourse of cultural heritage documentation.

Here, we also describe the authors' efforts to design and implement a test bed to verify on the field some of the emerging web technologies to be deployed in order to experiment the Semantic Web approach, on the cultural heritage promotion arena.

In any current ontological formalization, the entities of the universe of discourse are represented by instances of classes[3]. Classes may formalize more or less general concepts and, therefore, a subsumption relation comes out that defines a hierarchy over them. In mathematical terms, it can be said that the set of classes of an ontology has the algebraic structure of a lattice, but, an ontology is not just a lattice of labelled tokens. The classes of an ontology are formally described in terms of both the distinctive qualities of their instances and the relationships that are likely to be expected between the entities they represent.

The rest of the paper is organized as follows: in section 2, the "Museo Virtuale di Napoli" scenario and framework is described briefly in order to motivate the adoption of the ontological approach introduced in section 3. In section 4, the structure of the ICCD recommendation is described and some of the critical features are analyzed. In section 5, the ontological interpretation is described. In section 6, the experience acquired is summarized briefly.

2. The "Museo Virtuale di Napoli" testbed

On designing a Multimedia Information System to promote cultural community identity most systems were transformed so that the notion of record was replaced with that of document as elementary information entity on the

[2] http://www.iccd.beniculturali.it/.

[3] Here the notion of class is used in the sense of the *classification theory* and not the *programming language area*.

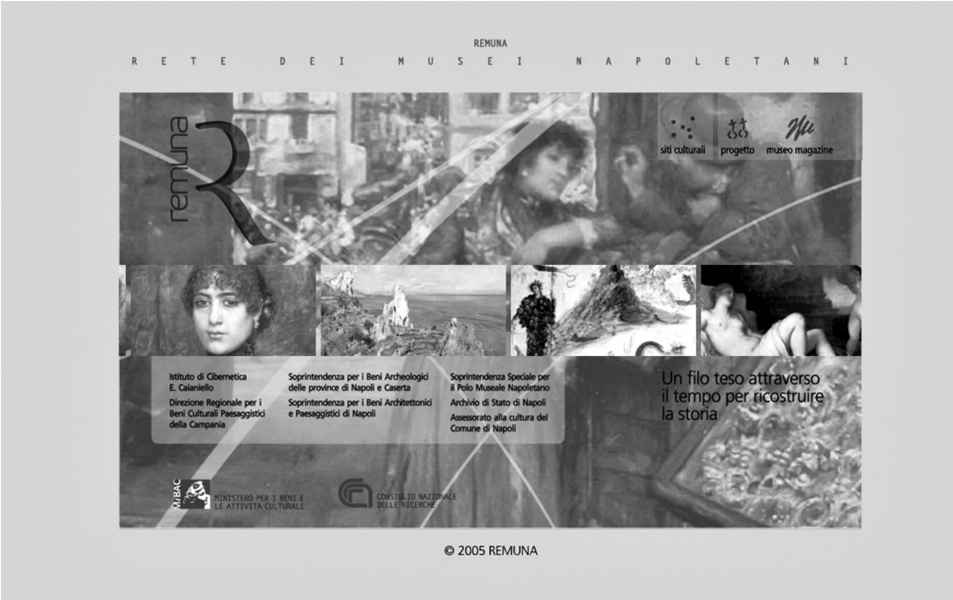

Fig. 1 – Home page of the ReMuNa web site.

basis of which the information systems could be designed. This change over is becoming more evident and is revealing the limitations of the browsing and portal approaches. In fact, the cultural identity of a community is only partially represented by the cultural heritage artifacts organized in museums. We think that a more comprehensive representation is better given by showing all the relationships that exist between museum artifacts and social-urban tissue.

As part of the research project "Museo Virtuale di Napoli: Rete dei Musei Napoletani" (ReMuNa)[4] (Fig. 1; Tav. Ia, b) and "Informatic System Applied to the Cultural Heritage" (SIABeC)[5] we built a community of Semantic Web-oriented Content Management System (CMS) for cultural heritage knowledge. We used the ontology methodology to implement and exploit a CMS grid,

[4] This research project, supported by Ministero dell'Università, Ricerca e Tecnologia, under contract C29/P12/M03 Law n. 488 initiative of Cluster, from here on denoted with ReMuNa, was carried out at the Istituto di Cibernetica "E. Caianiello" – CNR. The ReMuNa project (which stands for Network of Neapolitan Museums) is financed by the MIUR with the Law n. 488 initiative of Cluster.

[5] The project SIABeC is financed with the project Centro Regionale di Competenza per lo sviluppo ed il trasferimento della innovazione tecnologica applicata ai beni culturali ed ambientali (INNOVA) P.O.R. Campania misura 3.16.

where each system is used as a document repository that allows the museum manager to organize, as a whole, the cultural heritage and heterogeneous knowledge space scattered throughout many autonomous organizations.

One of the most important constraints that we took into account was the fact that the aim of any ordinary museum visitor is something quite different from just trying to find certain objects in the web document space. In fact, in physical exhibitions the cognitive museum experience is often based on the thematic combination of exhibits and their contextual knowledge. Furthermore, from the museum managers' perspective, each CMS should make the information relative to a given artifact available through the ReMuNa environment right after registering this information into the system. Knowledge is encapsulated into a digital object and no assumption about the schemata of the fixed attributes of names is made, so that the application builder can create new attributes as needed, by just modifying the associated ontology without changing the internal database schemata.

Using the framework that we developed, the knowledge provider[6] could also organize a set of related documents in document collections, according to some relationships that could be defined on top of the associated ontology. The notion of "collection" is a recursive one, in the sense that a collection could contain other collections. Each digital document is allowed to belong to multiple collections and may have multiple relationships with other documents. These nesting features allowed us to deliver more than one logical view of a given digital documents asset.

Clearly, the deployment of the notion of collection depends a great deal on the knowledge domain. Thus, it is necessary to guarantee an operational autonomy to the knowledge provider, without reducing the opportunities of cooperating with other knowledge providers. In other words, each content provider will publish a set of ontologies to collect metadata information organized and published through a contents knowledge authority.

From the point of view of content, the distributed system is built as a collection of document repository nodes glued together by an ontology server, where the *document* plays the role of elementary information and basic building block. The documents are represented as digital objects, together with the associated metadata information. The metadata is organized according to the associated domain ontologies where it takes values.

The CMS grid infrastructure was designed around the: *Document Repository System* (DRS), which stores and organizes the documents together with the associated metadata, appearing and behaving like a traditional web

[6] In this paper we assume that *museum manager* means the people in charge of the cultural heritage knowledge about the goods, inside the museum organization.

site; *Document Access System* (DAS), which creates friendly and flexible user interfaces to discover and access the contents; and *Contents Authority Management System* (CAMS), which stores and manages the ontologies used by each participating node to facilitate the DRS semantic interoperability. From a technological point of view, we adopted the multi-tiers web architecture, with the application server playing the central role of business logic driver. All the systems communicate among themselves by exchanging XML-encoded messages over http, according to well-defined protocols that represent the XML communication bus core (Aiello *et al*. 2006).

The documents are represented as digital objects together with the associated metadata information. Here, metadata are organized using domain ontology. The Data Store Module is composed of a document media repository, which stores the digital representations of the document contents according to a set of XML applications, and a metadata repository, that stores all the document annotations that are XML-encoded and organized according to RDF model[7]. This kind of document structuring and coding strategy makes it possible to separate the document layout implementation from its contents. The Sesame package (Broekstra, Kampman, van Harmelen 2002) is the main Data Store Module software component. It is an open source, platform-independent, RDF Schema-based repository, provided with querying facility written in Java. The low level persistent storage is achieved using Postgresql[8], one of most widely used public domain database environment. The Sesame environment offers three different levels of programing interfaces: the client API, for client-server programming; the server API; and the lower level Storage and Inference Layer (SAIL) API, for the RDF repositories.

The ontology server provides the Document Repository System with the basis for the semantic interoperability capabilities. Conceptually, it is the most important type of server since it manages the OWL/RDF (McGuinness, van Harmelen 2004) schema for the stored data, and determines the interactions with the other servers and/or modules, through the ontology exchange protocol. Each ontological feature is associated with a domain ontology; for example, ontologies for artifact, material and techniques have been defined according to the Italian Istituto Centrale per il Catalogo e la Documentazione (ICCD) standard, adopted by several museum mangers to archive art and craft data. The ontology descriptor is an RDF descriptor that summarizes the covered domain. It is used to annotate the documents, for each ontology component. The ontology RDF descriptor and the corresponding ontologies

[7] Resource Description Format: http://www.w3c.org/RDF; Lassila, Swick 1999.
[8] http://www.postgresql.org/.

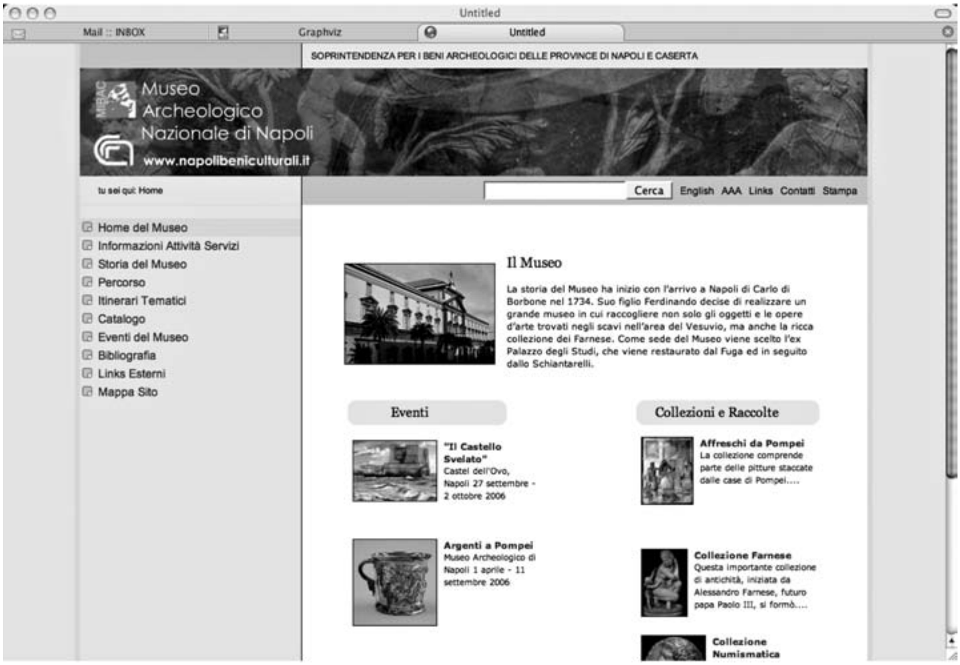

Fig. 2 – The screenshot of a generic ReMuNa CMS.

are stored into the metadata repository, and can be accessed through the ontology exchange protocol.

The Ontology Interface Server consists of a set of functionalities for walking through the ontology graph and the associated attributes. At runtime, these functionalities are used by the Document Access System to build the user interfaces, the browsing structures, the application services, and so forth. For example, to build the management user interface, it is necessary to create a set of dynamic forms, according to a classification schema, synthesized into the corresponding ontology. The Ontology Interface Server can be queried about the ontology class hierarchy, and/or the class properties, giving back an RDF document that could be transformed into HTML forms.

These methodologies were deployed and tested by setting up a prototype to connect about 20 museums in the city of Naples (Italy). The museums are equipped with multimedia knowledge systems and communication infrastructures. Those systems have different conceptual schemas and are physically located in different districts of Naples. The user will interact with the community of the Content Management Systems through a conventional browser (Fig. 2).

3. ReMuNaICCD ontology development

The main purpose of building an ontology is to capture the semantics of the documents describing a given knowledge domain, especially the conceptual aspects and interrelations. Essentially, our ontology model consists of 5 basic elements: *context*, is actually a grouping entity, it is used to group terms and lexicons in the ontology; *terms*, is an entity representing a lexical representation of a concept; *concepts*, is an entity representing some "thing", the actual entity in the real world; *roles* and *lexicons*, is a grouping element, it is a triple consisting of a starting term, a role (relation) and a second term. A lexicon always appears in a context, and describes certain relations which are valid in this context, but not necessarily in another context. In the full model there are some extra entities, such as *user* and *version*, mainly for administrative reasons.

The ontology contains a set of contexts, which form the ontology itself. As attributes, the ontology has a *name* (mandatory and unique in the ontology server); a *contributor*; an *owner*; a *status*, for example "under development", "finished", etc., and a *documentation*, i.e. an arbitrary string in which the contributor or the owner can specify relevant information.

How meaning in an ontology is represented varies greatly, and turns out to be an important factor in the success of applying ontologies. The simplest ontologies, in this regard, consist of a simple taxonomy of terms. The only meaning is supplied by a single relation which defines the taxonomy. The relation is usually the specialization relationship, but often it is a conglomeration of various relationships such as part-of, or similar-subject-matter.

The meaning captured in an ontology varies both in the amount being represented and the degree of formality of the representation. The amount of meaning (an attribute of the ontology itself) is directly related to restricting the possible interpretations which serves the primary purpose of reducing ambiguity. The greater is the amount of meaning, the fewer are the possible interpretations and the less is the ambiguity. Formality (an attribute of the ontology representation language) can vary from natural language to formal logic.

An ontology is typically built in approximately the following manner:

a) Assembling appropriate information resources and expertise that will define, with consensus and consistency, the terms used formally to describe things in the domain of interest. These definitions must be collected so that they can be expressed in a common language selected for the ontology.
b) Designing the overall conceptual structure of the domain, i.e. identifying the domain's principal concrete concepts and their properties, the relationships among the concepts, creating abstract concepts as organizing features, referencing or including supporting ontologies, distinguishing which concepts have instances.

c) Adding concepts, relations, and individuals to the level of detail necessary to satisfy the purposes of the ontology.

The ontologies can be classified according to their level of dependence on a particular task or point of view. GUARINO (1998) distinguished the following: *top-level* ontologies describe very general concepts and provides general notions under which all the root terms in existing ontologies should be linked; *task* ontologies describe the vocabulary related to a generic task or activity by specializing the terms in the top-level ontologies; *domain* ontologies are reusable in a given specific domain, since they provide vocabularies about concepts within a domain and their relationships, about the activities taking place in that domain, and about the theories and elementary principles governing that domain; and *application* ontologies are application-dependent, generally contain all the definition needed to model the knowledge required for a particular application.

4. THE CONCEPTUAL ANALYSIS OF THE ICCD RECOMMENDATION

In this context, our efforts were oriented to define an ontology for cultural heritage and based on the ICCD schema enriched with an "upper" ontology, embodying the topmost class and property hierarchies in the *TopLevelReMuNa* ontology, and the domain ontology (*ReMuNaICCD*). This approach was strongly influenced by works of Guarino on the formal ontologies foundation (GUARINO 1995, 1998; GUARINO, WELTY 2000), those of Gangemi on the *ontology patterns* (GANGEMI 2005), the guidelines proposed by RECTOR and ROGERS (2004) and the most recent OEP experiences available online[9]. Furthermore, it allows a more sophisticated use of the cultural heritage information available and, as it faces the crucial theme of re-contextualization, it also allows us to define formal historical reconstructions, thus permitting a more flexible and complete use of the available cultural heritage knowledge.

The developed ontology is composed of a hierarchy of classes, interlinked by named properties, and follows the object-oriented design principle: the classes in the subsumption relation hierarchy inherit properties from their parents. Property inheritance means that both classes and properties can be optionally sub-typed for a specific domain, making the ontology highly extensible without reducing the overall semantic coherence and integrity. It has been expressed according to the OWL semantic model[10]. More specifically, we used the subset

[9] OEP 2004-5, SemanticWeb Best Practices and DeploymentWorking Group, Task Force on Ontology Engineering Patterns. Description of work, archives, W3C Notes and recommendations available from http://www.w3.org/2001/sw/BestPractices/OEP/.

[10] OWL is the acronym of Web Ontology Language, a standardized language for the specification of formal ontologies, recommended by the W3C (MCGUINNES, VAN HARMELEN 2004).

of OWL called OWL Lite, introduced in DE BRUIJN *et al*. 2004, since it not only offers a sufficient expressivity, but also guarantees *a priori* a computational tractability of the final product (VOLZ 2004). In this paper we assume that the implied semantics is the OWL semantics introduced by PATEL-SCHNEIDER, HAYES and HORROCKS (2004). This choice yields a number of significant benefits; for example, the class hierarchy enables us to coherently integrate related knowledge from different sources at varying levels of detail. Many names of classes and properties were borrowed from well-known upper ontologies like DOLCE (MASOLO *et al*. 2003), and CIDOC CRM, but it also covers the cultural heritage taxonomy aspects and the specific issues of an upper ontology.

4.1 *TopLevelReMuNa*

Now, before going into the classes that translate the segments the ICCD schema are made of, we will delineate the conformation of the upper ontology *TopLevelReMuNa*, i.e. the backbone of the domain ontology *ReMuNaICCD*.

4.1.1 The hierarchy of classes

The only root of the TopLevelReMuNa hierarchy of classes is the class Entity. It represents the most generic entity of the universe which we are interested in. We suppose that a universe is worth being represented formally if and only if it is populated by entities that can be talked about for the following minimal reasons:

– The entities have a system of identity, which can be given by: **name** and/or **identifier** and/or **description**.
– The entities are interconnected by a network of relations.

In TopLevlReMuNa, these minimal distinctive specifications of the instances of `Entity` have been formalized as the following:

– `Entity` is domain of the *dataTypeProperties* `name`, `identifier` and `description`. These properties are grouped under the superproperty `identity_annotation` meaning that, working together, they must enable the identification of whatever instance of `Entity`.
– `Entity` is the domain and the range of the symmetric and transitive *objectProperty* `relation`, which is superproperty of all the other *objectProperty* defined inside the ontology. This allows us to formally represent the "any kind of otherwise hidden connections" between entities that can be gathered from the network of the explicitly declared relations.

`Entity` is structured in two subclasses that are radically different from each other (Fig. 3):

– `Concrete` that could be intended as the world of the observable things,

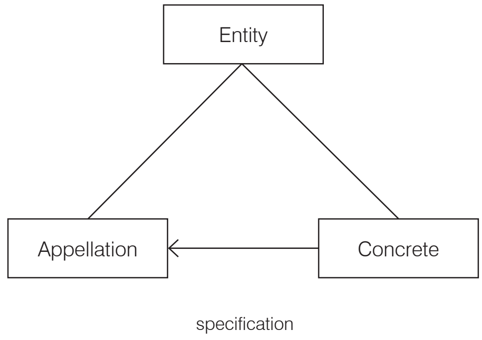

Fig. 3 – Entity classes.

the most general class that comprises all of the entities in the domain that we have to analyse and model.
– `Appellation` is the root class of all the linguistic entities involved in the lexicon relevant to the domain. Actually, it formalizes a vocabulary created and controlled by a third party, whose semantics is foreign to whatever ontology.

In ReMuNaICCD, every *objectProperty* is considered to be a "specification" if it connects a `Concrete` with an `Appellation`. Formally, we introduce an *objectProperty* named `specification` and define it as superproperty of any *objectProperty* having the domain in `Concrete` and the range in `Appellation`.

The hierarchy of the `Appellation` subclasses was built starting from the range of the subproperties of `specification` and, in a sense, it reflects the hierarchy of those subproperties. Direct subclasses of `Appellation` are the classes:

– `Conventional` = conventional annotations.
– `Prescribed` = the prescribed terms for the fields that correspond to the classes.
– `Controlled-Term` = the lexis used to respect the restraints of the ICCD on the valorization of certain attributes. This class is defined as the domain and range of the binary relations that usually build the lexical taxonomy in a thesaurus: *lexical relation* (symmetric, transitive); *synonym* (symmetric, transitive); *antonym* (symmetric); *iponym* (transitive); and *iperonym* (transitive).

`Controlled-Term` is the root of a family of classes, like `Type`, `Role`, `Phase`, `Motive`, etc., that are ideal to collect, as own instances, standard terms like those in the DCMI Type Vocabulary, the elements in the DCMI Metadata Terms, as well as their element refiniments and extensions. For example, those proposed by Merlitti (2005) for the CulturaItalia portal conceptual scheme.

4.1.2 The Concrete Pattern

The subclasses of `Concrete` come from the following considerations: the World of the Observables presents *observable entitities* (`Endurant`) which repeatedly appear in different *observations* (`Perdurant`) and therefore fill the theatre, otherwise empty, of the *SpaceTime* (`Space-Time_Region`).

One of the most ambitious objectives of TopLevelReMuNa is to formalize the analysis and the synthesis of the Observations in terms of the entities that can be detected (the Observables) inside them. The main structure of the *Concrete Pattern* is illustrated in Fig. 4.

Fundamental transitive binary relations of all the kind of `Concrete` are: `comprises` (`comprised_in`) and its direct subproperty `has_part` (`part_of`). These properties formalize the basic relations for the analysis of the `Concrete` entities. Stating that an Observable *B* is `comprised_in` an Observable *A*, we formalize the idea that, besides the actual modalities of the occurrence, it is possible to assert the presence of *B* in *A*.

The function of the *objectProperty* `has_part` (`part_of`) is more specific with respect to that of `comprises`. In fact, if an Observable *B* is `comprised_in` an Observable *A* this fact does not necessarily mean that *B* is part of *A*, instead if *B* is `part_of` *A*, it is commonly accepted that *B* is `comprised_in` *A*.

The `Space-Time_Region` is the direct subclass of `Concrete` which points out the Observable representing the "where and when" of an observation. By definition, it is the range of the relation `space-time_localization` defined on `Perdurant`.

The perdurants (also known as "occurrents") are defined in the literature as the entities whose parts are distributed along time and, therefore, in different intervals of time, they manifest different segments of themselves. In TopLevelReMuNa, `Perdurant` is the direct subclass of `Concrete` (the Observables) that formalizes the concept of observation seen as an observable. Since `Perdurant` is the class of all the entities that are spread over the space and time, it was defined as the domain of the property `space-time_localization`. This means that each instance of `Perdurant` does fill the own relative instance of `Space-Time_Region` and the latter is linked to the former by an instance of `space-time_localization`.

What is peculiar about the Observations is that, at times, it is possible to identify a relation of cause-effect among them. In TopLevelReMuNa, this aspect was formalized by introducing the *objectProperty*, `caused_by`, transitive together with its inverse (`has_caused`), having the class `Perdurant` as either domain and range.

The endurants (also said "continuants") are defined in the literature as those entities whose parts are not distributed in time, but demonstrate themselves all together, instant by instant, during the whole existence of the entity.

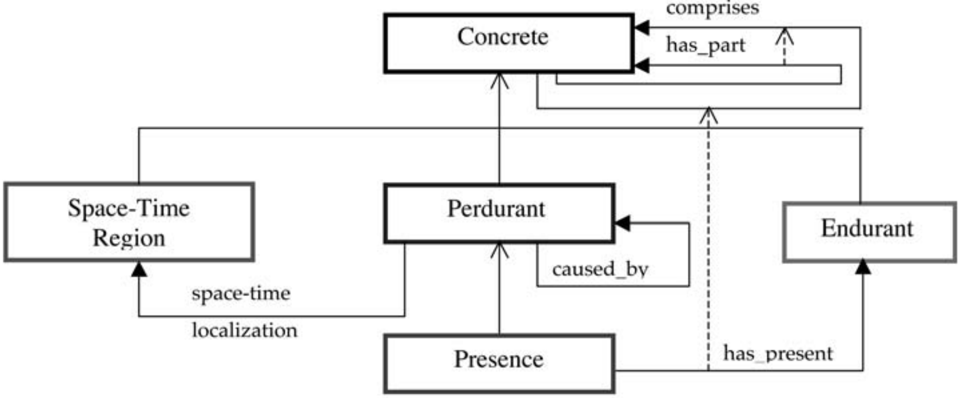

Fig. 4 – Concrete Pattern.

In TopLevelReMuNa, `Endurant` is the class of the objects/subjects "present", with different title, in the "Observations". Endurant entities can be conceived without any need of spacetime references and therefore are represented categorically ignoring the spacetime contexts (scenarios of the "Observations") as well as the specific roles they exhibit during their "participation" in whatever may occur and put them in the forefront.

The classes `Perdurant` and `Endurant` are structurally linked to each other by the primitive relation `has_present` (subproperty of `comprises_in`) and its inverse `present_in`. Actually, the recontextualization of the endurants into the SpaceTime is modelled through the subclass `Presence` of `Perdurant`. In fact, the domain of `has_present` is `Presence` which is the most elementary perdurant, made just to represent the bservation of one and only one endurant in a determined region of space and time. More precisely, the Observation O_1 of the instance E_1 of `Endurant` in the instance ST_1 of `Space-Time_Region`, is represented by an instance P_1 of `Presence` whose value of the property `has_present` is the instance E_1 and whose value of the property `space-time_localization` is ST_1. To be coherent with the former representation, P_1 must be added to the other values, if any, that the property `present_in` assumes on the instance E_1.

4.1.3 The Historicity Pattern

In ReMuNaICCD, the endurants (i.e. the subject/object abstractly considered) are seen in their becoming historical, through the modality they become related to the family of the `Perdurant`'s subclasses. The architecture offered by ReMuNaICCD in order to place the endurants in historical contexts is illustrated in the *Pattern of Historicity* (Fig. 5). The basic component is the class Participation and the constructors are the relations has_participation, has_report and characterized_by. All these relations are defined to be non-transitive subproperties of comprises: this formalizes the concept of "comprehension" of an Endurant in a Perdurant. In this research, the endurants are abstractions which have neither intrinsic role nor spacetime localizations. In fact, these qualities refer to the contextual observation in which the presence of the endurants are detected and they can assume different values for the same Endurant instance in different observation instances.

The association of the endurant to a spacetime context was resolved with the introduction of the perdurant Presence. As we have already said, Presence formalizes the description of the circumstance that a given space-time region is occupied by a given endurant. Before passing to the formalization of the contextualization of endurants in more complex sceneries than those modelled by Presence, we will demonstrate how TopLevelReMuNa resolves, with the introduction of some other subclasses of Perdurant, the problem of the association of "phases" or "roles" to the endurants.

The class Presence has the following two subclasses representing its main specializations:

– Phased_Sortal is the domain of the property phase that assumes value in Phase, subclass of Controlled_Term. It is the kind of Presence characterized by the "phase" that the endurant (value of the property has_present) goes through while it is in the space-time context indicated by the spatial_localization and the temporal_localization.
– Material_Role is domain of the property role which assumes values in Role, subclass of Controlled_Term. It is the kind of Presence characterized by the "role" that the endurant, value of the property has_present, executes while it is in the spacetime context indicated by the spatial_localization and the temporal_localization.

An important step towards the inserting of the endurants in the flow of history is the introduction of the class Participation (subclass of Material_Role), which formalizes the observation of an Endurant, in the execution of a "role", which makes it a "participant" in the elementary "interaction" expressed by the class Fragment_of_History. In fact, in ReMuNaICCD the classes Participation and Fragment_of_History are respectively domain and range of the *objectProperty* participates_in (has_participation), property through which it is possible to associate amongst them all the participations that, in a symbiotic way result in the Observation of a Fragment_of_History.

Through the Fragment_of_History, the elementary interactions existing among participating endurants are modelled; mainly, like all of the subclasses of Perdurant, Fragment_of_History inherits the properties

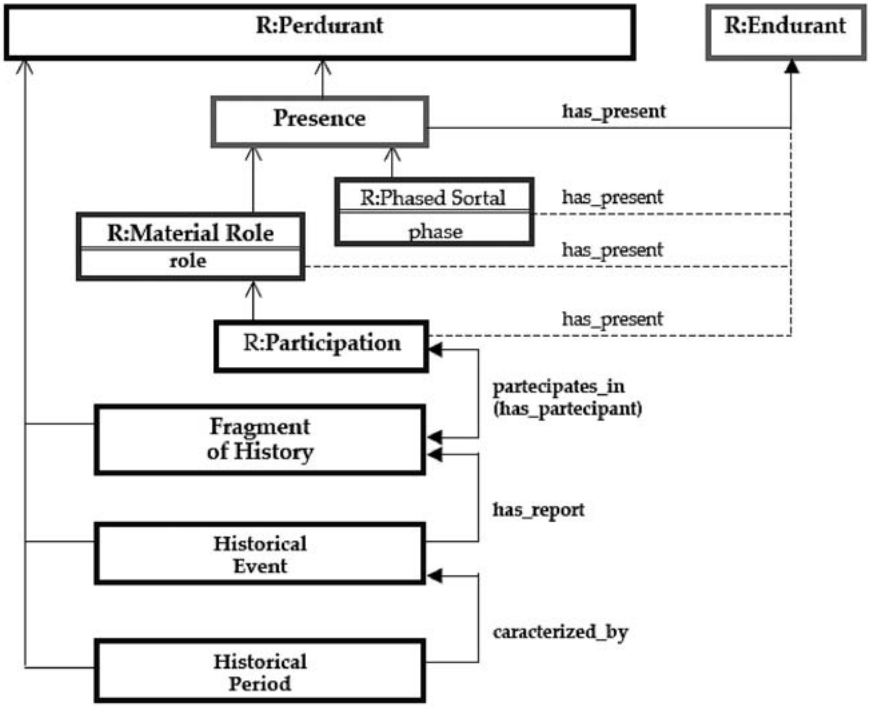

Fig. 5 – Historicity Pattern.

spatial_localization, Fragment_of_History (both subproperties of spacetime_localization) and has_caused, basic relations for the historical reconstructions. Furthermore, Participation is the domain of the specifications participation_type and participation_gender, which respectively allow us to:

– qualify the istances of Participation and its subclasses without introducing other subclasses;
– distinguish if the endurant participates actively or passively.

Finally, Historical_Event and Historical_Period let us represent the historical vicissitudes with a wider view. Although it is described exclusively in terms of Fragment_of_History instances, a Historical_Event instance evidences a more complex observation. The building element of the Historical_Event entity is the *objectProperty* has_ report (report_of), a non transitive subproperty of comprises (comprised_in). Every entity which comprises a Historical_Event is a Historical_Period. Formally:

Historical_Event ⊆ ∀comprised_in.Historical_Period

4.2 *ReMuNaICCD*

The space-temporal perspective offered by the Historicity Pattern is completely foreign to the ICCD schema. For example, if a subject "X" carries out:

a) the function of the scientific director in a survey which enabled the finding of a good "α", or
b) the function of the official director of the compilation of an ICCD card of a good "β",

then according to the ICCD recommendation, its name will simply be repeated in the fields, which refer to:

– the Scientific Director (RCGA) responsible for the Survey (RCG), which have enabled the finding of a cultural heritage site or good, for the case a),
– the Official Director (FUR) responsible for the compilation of the ICCD form (CM) for the case b).

In our ontological interpretation, instead, the subject "X"

– in the case a), is the instance of `Person` value of `present_in` for an instance of `Participation` in which the property role is set to `Scientific_Director`; that instance of `Participation` is related by `participates_in` to an instance of `Fragment_of_History` which is `report_of` an instance of `Survey` (subclass of `Historical_Event`);
– in the case b), is the instance of `Person` that, `present_in` a `Participation` with the role of Official, `participates_in` an instance of `Fragment_of_History` of the type `Compilation_of_ICCD_card`.

In the same way, if "Y" is

c) the author of a cultural heritage "γ" or
d) the customer of a cultural heritage property "δ"

then in the ICCD schema, its name will simply be repeated in the corresponding fields, which refer to:

– the chosen name (AUTN) of the author of a cultural heritage property, for the case c);
– the name (CMMN) of the customer of a cultural heritage property, for the case d).

By contrast, in ReMuNaICCD the subject "Y"

– in the case c), is the instance of `Author` (subclass of `Person`), in the role of `Cultural_Heritage_Author`, who `participates_in` an instance of `Fragment_of_History` which is a `report_of_a_Realization` (subclass of `Historical_Event`). Obviously, the same instance of `Fragment_of_History` `has_participant` the instance of `Participation` which `has_present` the

cultural heritage property "γ" (expressed as an instance of the class `Human_Production`) in the role of `Accomplished_Cultural_Heritage_Property`.
– In the case d), is a `Person` in the role of `Customer` who `participates_in` a `Fragment_of_History` which is `report_of` a `Realization` (subclass of `Historical_Event`). Of course, also in this case, the cultural heritage property "γ" (expressed in a subclass of "`Human_Production`"), in the role of `Accomplished_Cultural_Heritage_Property`, `participates_in` the same `Fragment_of_History`.

5. The ontological interpretation of the ICCD schema

The starting points of our analysis are based on the following considerations:

– Each card "X" relates to a specific subject "S" (it is implied from the card that it is unique, even if it can also be a composed element), which is a separate entity from "X".
– Each card "X" through its fields indicates:
 – The codes used to spot the card "X" and the subject "S" as well
 – The relationships that link "S" with other cultural heritage entities
 – The state and the typological, technical, analytical characteristic of "S"
 – The "history" of "S", with a particular view to:
  – its present and past location
  – its creation
  – how it was found
  – the type of intervention, how it was re-used, its restoration and analysis
  – its juridical and patrimonial condition
 – The "history" of "X", codified according to three key events:
  – its creation
  – its revision
  – its informatization

On the base of the foregoing considerations, given an ICCD card "X", we have had to create in our ontology:

– a class C_1 for the subject "S" the card "X" deals with
– a class C_2 for the card "X"
– *dataTypeProperty* and *objectProperty* having the class "C_1"as domain, which express the pieces of the text of the card "X", which refer to the subject "S" directly
– further classes C_3, C_4, C_5, …, that express pieces of text of the card "X", through their attributes (dataTypeProperty and objectProperty), and that refer to the subject "S" indirectly.

5.1 *The object of the present ontological analysis*

We have taken into consideration the ICCD schema[11]. The ICCD recommendation suggests two different organizational criteria. The first one is built around a classification taxonomy construed according to the cultural heritage type, such as an archaeological artifact, an archaeological site, a historical building, and so on. Furthermore, the cultural heritage artifacts are also classified according to their structure, i.e. it could be a *simple* artifact, like a statue, a *compound* artifact, like an altar, and finally an *aggregate* artifact, like ceramic cups.

The adopted data model is record oriented, structured according to the following schema:

```
scheda
    paragraph_1
        field_1
        ...
        field_n
            subfield_1
            ...
            subfield_n
...
    paragraph_m
        field_1
        ...
```

The ICCD fragment considered includes 27 fields of the Bibliography card, to the nearly 300 fields of the Architectural card, with an average of 200 fields per card. We elaborated ReMuNaICCD.v2.0, an ontology of 381 classes (199 are Appellation subclasses), 473 objectProperties, 458 dataTypeProperties and c.a. 750 instances (nearly all of them have been taken from the ICCD vocabulary).

The main ICCD schema paragraphs considered are shown in Table 1. Furthermore, considering their importance in a precise description of archaeological excavations, archaeological sample and archaeological survey, we have studied and given an ontological interpretation to the schema shown in Table 2.

Moreover, we have introduced some simple classes, without defining their properties, seeing as we do not have the up to date related schema, in order to represent the concepts of *Real Estate* and *Urban and Territorial Resources*.

The decision to involve such a wide domain was motivated by the wish to deal as thoroughly as possible with the spatial and temporal environments an archaeological find happens to belong to during its entire existence. In par-

[11] The recommendation analyzed refers to the ICCD version 3.0.

Object type	Paragraph name	ICCD code
Moveable	Numismatic Finds and Coins	NU
	Drawing	D
	Photo	F
	Table of Archaeological Material	TMA
	Engraving	MI
	Works and Art Objects	OA
	Archaeological Finds	RA
	Printing	S
Real Estate	Architecture	A
	Archaeological Monuments and Archaeological Complexes	MA-CA
	Parks and Gardens	PG
	Stratigraphic sample	AS
Urban and Territorial Resources	Archaeological Sites	
Archives	Authority File	AU
	Bibliography	BIB
	Archaeological Survey	RCG
	Archaeological Excavation	DSC
Multimedia	Photographic Documents	IMR
	Graphic Documents	IMV
	Video Documents	VID
	Audio Documents	AUD
	Archives or Bibliographical Resource	DOC
	Other Multi-medial Documentation	ADM

Table 1 – Fragment of ICCD version 3.0.

Object type	Paragraph name	ICCD code
Stratigraphic Unities		US
	Wall Stratigraphic Unities	USM
	Covering Stratigraphic Unities	USR
	Funerary Depositions Stratigraphic Unities	USD

Table 2 – Studied ICCD version 3.0 cards.

ticular, we have highlighted its *documentation*, its *location* and its *finding*. In fact, we have defined an interpretation of relevant ICCD pieces of information into our ontology according to the following modalities:

– A class `Documentation` and its subclasses model the information coming from those schema more strictly related to the Finds, like *Author* (`AUT`), *Bibliography* (`BIB`), *Photography* (`F`), *Print* (`P`), *Drawing* (`D`), but also the data recorded in the schema which are linked to the multimedia card types (`IMR`, `IMV`, `VID`, `AUD`, `DOC`, `ADM`) that nevertheless refer to the Finds.

– Patterns of classes and properties are designed to formalize the concept of space-time localization and collect many pieces of information coming from the schema which regard the *Real Estate* and the *Urban and Territorial Resources* (`A`, `MA`, `CA`, `SAS`, `PG`, `SI`).

– The findings are modelled by ontology patterns that re-contextualize the pieces of information codified into the schema of the *Archaeological Excavation* (DSC) and *Archaeological Survey* (RCG).

5.1.1 The specificity of paragraphs and fields

To determine what other classes were to be arranged, the essential point was to distinguish between *paragraphs* and *fields*, those which are found without any variations in all the cards ICCD, from those which are specific and destined to give account of a precise type of historical goods and sites. Concerning the localization, we were able to evidence that in almost all of the cards describing the:

– *Moveable Cultural Heritage* we have the following relevant paragraphs:
LC Administrative Geographical Localisation
LA Other Administrative Geographical Localizations
CS Cadastral Localization
GP Georeferentiation by Point
UB Site, Patrimonial Data
– *Cultural Heritage Estates* we have the following paragraphs:
LC Administrative Geographical Localization
LS Historical Localization
CS Cadastral (Land Registry Office) Localization
GP Georeferentiation by Point
GA Georeferentiation by through Area
GL Georeferentiation by through Line

The reference documentation is expressed in the paragraph *Fonts* and *Documentation of Reference* (DO), whose fields, which always have the same subfields, could either be or not be present in the different schema, according to the characteristic of the cultural heritage.

The chronology is, instead, expressed in all of the schema describing the cultural heritage in the paragraph *Chronology* (CD), with the exception of the subject cards *Architecture* (A) and *Gardens and Parks* (PG), for which the *Chronology* is dealt with in the paragraph *Historical News* (RE).

The information connected to the realization of the cultural heritage property/object are found in the paragraph *Cultural Definition* (AU), which occurs in all of the schema in which it is possible to talk about the cultural environment which a cultural heritage property arouse from. The *Table of Archaeological Material* (TMA), and the *Stratigraphic sample* (SAS), remain excluded.

Finally, all of the schema which regard the cultural heritage properties, whose finding can be connected to the archaeological activities (*Archaeological Finds*, *Numismatic Finds and Coins*, *Table of Archaeological Material*, *Work of Art*, *Archaeological Monument and Complex*, *Stratigraphic sample*, *Archaeological Site*), present the paragraph *Modalities of Finding* (RE), which does not show a variation from one tracing to another.

All the other paragraphs and fields present in the ICCD cards, either occur on a small number of different type of cards or are just specific to unique schema specifically oriented to deal with the peculiar characteristics of certain cultural heritage subject.

5.1.2 Indirect and direct references

The analysis of the ICCD schema illustrated in the previous paragraph has helped us to understand the type of information contained in each *paragraph* and in each *field* and to establish if they were referred indirectly or directly to the subject of the cards. For example, the DES field (occurring in numerous cards), dedicated to the description of the subject "S" of the card, was considered a direct reference of "S", so the class "C_1" which "S" belongs to, has become the domain of the properties indications_on_the_object and indications_on_the_subject that translate the subfields DESO and DESS and the structured field DES into ontological elements. In this way, the segments of the text "T_1" and "T_2" in DESO e DESS, turn into the values "T_1" and "T_2" of the properties indications_on_the_object and indications_on_the_subject of the instance which represents "S".

On the other hand, a field like the ATB one, which, also, occurs in different cards and refers to the cultural field in which "S" was realized, was considered an indirect reference to "S", so a class Realization was created, having among its properties the *dataTypeProperty* denomination_of_the_cultural_field which is the ontological translation of the simple field ATBD.

A more complex case is that of a field like DSC, which occurs in different cards, and allows a synthetic reference to the excavation, which allowed the finding of "S". This field, which is considered an indirect reference of "S", was translated in the class Excavation. This class is defined as the domain of the properties:

– that bring in the ontology the subfields of DSC and those
– which derive from the paragraphs and fields of the authority file Excavation that were a direct reference to the DSC and would give further information if compared to those given by the subfields of DSC.

Furthermore, the subfields of DSC, like DSCU and DSCS, which indicate the stratigrafic unity number and the tomb number in which the subject could have been found, have become *dataTypeProperty* not of the class Excavation, but of other classes, namely Stratigrafic_Unity and Tomb.

Of course, instances of these classes are created only in the case there is a tomb or another stratigrafic unity correlated to the finding of the culture heritage.

5.1.3 The Endurants codified in the ICCD cards

As we were saying, the fields which were considered a direct reference to "*S*", have become properties having the class representing "S" as domain. However, fields like those which refer to "the modalities of finding", were considered indirect references to "S" and have given rise to separate classes.

According to their characteristics the classes created on the basis of the ICCD schema, have become subclasses of `Endurant` or `Perdurant`, while the expressions of the closed or open terms which determined fields refer to have become instances of the `Appellation` subclasses.

The upper hierarchy of the `Perdurant` was already introduced in the paragraph on the Historicism Pattern. Now, we will briefly introduce the following part of the uppermost hierarchy of the `Endurant` subclasses:

```
Human_Production
    Documentary_Material
        Immaterial_Elaboration
        Cultural_Heritage
            Object
            Real_Estate
            Composed
            Component
Actor
    Physical_Person
    Juridical_Person
```

Currently the different types of cultural heritage estates or objects taken into consideration in the ICCD schema (`A`, `RA`, `CA`, `MA`, etc.) have been put in the `Human_Production` area (subclass of `Endurant`). In particular, the `Cultural_Heritage` subclass was introduced in order to model them in a specific way. In this class, the estates and objects have respectively been distinguished by the subclasses `Objects` and `Real_Estate`. Furthemore, since several goods (for example, archaeological finds, architectures, etc.) are described by the ICCD schema in terms of a series of possible components (*stairs*, *elevations*, as also *inscriptions*, *tomb stones*, *bearings*, etc.) we provided `Cultural_Heritage` with the subclasses `Composed` and `Component` which were related to each other by the `has_component` (`component_of`) subproperty of `has_part`.

All of the following estates and objects, that in the ICCD schema were considered structured in possible components, were classified as a subclass of `Composed`:

```
Architecture
Archaeological Monuments and Archaeological Complexes
```

```
Photo
Engraving
Works of art and Art Objects
Parks and Gardens
Archaeological Finds
Stratigraphic sample
Archaeological Sites
Printing
```

While the following entities, that emerged from the ontological analysis, were classified as subclasses of `Component`:

```
Sample
Covering
Drawing
Building_handcraft
Decorating_Element
Fountain_Element
Primary_Green_Area_Element
Elevation
Green_Area_Relief_Sample
Foundation
Plumbing_Water_Irrigation_System
Inscription-Tomb Stone
Work_of_Art
Pavement-Paving
Fencing_Gate
Archaeological_Finds
Covering
Stair
Mark_Armorial_Bearing
Mark_of_Quarry_and_Firm
Ceiling_and_Pavement_Structure
Vertical_Structure
```

The subfields that are useful to indicate the location of the component according to the reference good, are denominated:

– **location** (`FNSU`, `SVCU`, `SOU`, `CPU`, etc.), in the Architecture (`A`) tracing and refer to an open vocabulary,

– **position** (`OGTP`, `ISRP`, `STMP`, `CMP`, `FNSP`, `SOLP`, etc.) in all of the other schema and are intended for a free text content.

In ReMuNaICCD, the previous fields are respectively represented by the following properties, both with domain in `Component`:

– the *objectProperty* location with range Object-Real_Estate_Location_Reference (subclass of Controlled_Term)
– the *dataTypeProperty* position with range xsd.string.

5.1.4 The documentation

The assumption that the Concrete are documentable, linked to the study of the paragraph Fonts and Documents (DO), that establishes the terms according to which, in the ICCD schema there is documentation that gives information on a specific estate or object, has determined the creation of the class Documentary_Material (subclass of Human_Production), and its relative subclasses:

```
Documentary_Material
Multimedial_Object
Text
Bibliography
    Font-Document
    Inventory
    Form
        Cassette_Form
        ICCD_Form
        Epigraphic_Insert_Form
        Restoration_Form
        US_Form
    Videocinematografic_Reproduction
    Audio_Registration
    Photography
    Graphic_Object
        Drawing
        Print
```

Documentary_Material was related to the Concrete through the documentation *objectProperty* and, more precisely, each of its subclasses is associated to the Concrete by one specific subproperty of documentation:

Concrete	documentation	Documentary_Material
Concrete	bibliographic_documentation	Bibliography
Concrete	font_document	Font_Document
Concrete	documentation_form	Form
Concrete	videocinematographic_documentation	Videocinematographic_Reproduction
Concrete	audio_documentation	Audio_Recording
Concrete	photographic_documentation	Photography
Concrete	graphic_documentation	Graphic_Object
Concrete	inventory_documentation	Inventory

The classes `Photography` and `Graphic_Object`, already subclasses of `Moveable`, occur, also as subclasses of `Documentary_Material`, so it is possible to catalogue these classes as cultural heritage properties and objects and like documents.

In the same way, the classes `Architecture` and `Sector`, which analyze elements which can be taken into consideration because they are cultural sites and places of findings, deposits, expositions etc. of other objects, are subclasses both of `Cultural_Heritage` and `Human_Production`. In both cases we have to distinguish the role in which the elements are taken into consideration however, the desire to go nearer to the common perception in respect to these topics induced us adopt this solution. Always inside `Documentary_Material`, a family of subclass with root `Multimedial_Object` and an appropriate family of `documentation` model the schema regarding the multimedia documentation (`ADM`, `IMV`, `IMR`, `VID`, `DOC`, `AUD`).

5.1.5 The Perdurants coded in the ICCD cards

Considering that in ReMuNaICCD the time and space localizations pertain only to the `Perdurant`, the classes deriving from the structured paragraphs and field that need reference of localization type have become subclasses of `Perdurant`. The following criteria were used:

– The events (like the “deposit of goods” or the “display of goods”) which are reported in the schema through the fields which merely indicate the space-time location and the participating subjects, have become `Historical_Fragments` qualified by appropriate specification of the type (for example, by putting the property `type_specification` equal to `Deposit` or to `Exposition`).

– The events described in the schema by fields which refer not only to space time location and to the participating subjects, but also by fields reporting peculiar characteristics (for example, in the case of `Restorations`, `Exhibitions`, etc.) are modelled by specific subclasses of either `Fragment_of_History` or `Historical_Event`.

In particular, all of those events that, due to their complexity, can be fragmented in single chronicles are inserted in `Historical_Event`:

```
Analysis
Survey
Finding
Excavation
Exhibition
Digitalization_Process
Production_and_Diffusion
Trust_Measure
Publication
```

```
Realization
Re-use
Restoration
Film_shooting
Photographic-reportage_Photo
```

Instead, those events that, according to their characteristics and/or how they were treated in the ICCD, need to be considered a minimal report, have been considered `Fragments_of_History`:

```
Acquisition
Exportation
Intervention
News
Evaluation
Use-Re-Use
Ground-Use
```

Lastly, the `Juridical State` of an element analyzed singularly, evidenced in the schema, has been modelled by using specific sub classes of `Presence`:

```
Juridical_Condition
Reproduction_Rights
```

6. Conclusions

The ReMuNaICCD ontology has modelled a "natural" infrastructure for the re-contextualization of the information contained in the catalographic cards produced according to the ICCD recommendations. A first arrangement was determined by the taxonomy of the classes and the properties, but the true logic of the model is contained in the pattern of the classes and properties that express the role of the different entities in their entirety. First of all, we realized that certain fields were restricted to contain character strings that could not remain within the limits of our ontological analysis. Those fields were, however, represented in ReMuNaICCD and organised in a taxonomy of classes, which have the root `Appellation`, a taxonomy of *dataTypeProperty*, which has the root `Annotation` and a taxonomy of *objectProperty* which has the root `Specification`. The other fields have allowed us to identify the entities of the ontology domain: the `Concrete` i.e. the Observables.

The most relevant objective in our ontological analysis was to structure the `Concrete` in only three distinct separate subclasses: the `Endurant` (i.e. the continuants), the `Perdurant` (i.e. the occurrents) and the `Space-Time_Region` (i.e. the Space and the Time). The potential of an ontology built on this basis are expressed by the *Concrete Pattern*, that illustrates the contextualization of the `Endurant` in the `Space-Time_Region`, by the formalization of the concept of `Presence`, a `Perdurant`. Moreover, the *Historicity Pattern* illustrates how ReMuNaICCD models the interactions between the `Endurant`. Basic is the path: `Participation`, `has_present` an `Endurant` endowed with a `role` (since `Participation` is a subclass of `Material_Role`), and `participates_in` a `Fragment_of_History`.

In this paper, we have dedicated space to the illustration of the ontological analysis of the various paragraphs fields and subfields of the ICCD schema but we acknowledge the fact that we have just outlined the modalities according to which the data are translated in instances of objects of ReMuNaICCD. On the basis of these encouraging results we are planning to actively pursue some of the goals set by the Semantic Web Initiative (Berners-Lee 1996; Horrocks, Tessaris 2002; HP Labs Semantic Web Research, "Jena-A Semantic Web Framework for Java", 2004: http://www.hpl.hp.com/semweb/).

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ABSTRACT

This paper outlines some results which have come out from the analysis of the Cultural Heritage domain, an analysis supported by the Virtual Museum of Naples project ReMuNa and SIABeC; both of these initiatives have the objective of promoting the artistic cultural inheritance of Naples. In this context, a domain ontology was developed which allows a more articulate use of the cultural heritage data available and, as it faces the crucial theme of re-contextualization, it also allows to define formal historical reconstructions.

In this paper, the "upper "ontology TopLevelReMuNa, i.e. the topmost classes and properties hierarchies embodied in ReMuNaICCD v2.0, is described. According to the Authors, the most remarkable features of TopLevelReMuNa are illustrated by the three ontology patterns that are reported here.