Extending RiC-O to model historical architectural archives: The ITDT ontology

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Historical architectural archives enjoy attention from diverse audiences, acting as a primary source of information for architects, historians, public authorities, and common citizens alike. In Italy, the interest in architectural archives has grown slowly but steadily for the last 20 years. However, architectural archives do not generally follow the trend common for museums and galleries in publishing digitized materials and providing standard metadata for individual records. The information that is available online usually includes only an archival finding aid, instead of metadata about the individual records, or fully digital versions of the records. While cataloguing standards for archival descriptions of architectural records have existed at least since the 1980s, the rise of Linked Open Data as a framework for publishing cultural heritage data has allowed archivists to enhance these archival descriptions with richer contextual information and links to external knowledge bases. In this paper we present the ITDT ontology, an extension of the Records in Contexts Ontology that facilitates the representation of architectural records and of the context related to architectural projects, its process, and participating entities. We discuss the application of the ontology to the project files of Italian architect and engineer Dino Tamburini (1924–2011), and the creation of a digital archive offering multiple perspectives over the records.

CCS Concepts: • **Information systems → Digital libraries and archives**; *Web Ontology Language (OWL)*; • **Applied computing → Architecture (buildings)**.

Additional Key Words and Phrases: historical archives, ontology, semantic annotations

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1 INTRODUCTION

Historical architectural archives enjoy attention from diverse audiences. Practising architects explore them as a source of inspiration and reference while working on their own projects. Public authorities address archives for the restoration or restructuring of existing buildings. Architecture and urban development historians give preference to architectural records as a primary source with respect to interpretations, in particular for contemporary artefacts. Citizens may explore the history of their own homes and districts, or find information about planned interventions.

In Italy, in particular, the interest in architectural archives has grown slowly but steadily for the last 20 years, and there is some sound evidence about it. Since 2012, the National Archive System hosts the *Archivi degli Architetti* portal, a special point of access for architectural archives' finding aids and makes them searchable according to geographic

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location, type of architectural project and historical period [1]. Starting in 1999, a dedicated Association unites holders of modern and contemporary architectural records and promotes the discovery and communication of their fonds [2].

However, architectural archives generally do not follow the trend common for museums and galleries in publishing digitized materials and providing standard metadata for individual records. For example, among the 146 architects and engineers listed in *Archivi degli Architetti*, there are just over 1500 digital images, and they clearly have the goal of introducing those who search to the records prior to their visit to the physical archive, rather than give direct access to materials. In recent years, marked by the COVID-19 pandemic and restrictions to the free movement of citizens, this approach is limiting access to primary sources by researchers, forcing them to over-rely on the knowledge of professional archivists who act as intermediaries between the records and the people who want to access them.

The information that is available online usually includes only an archival finding aid — the *inventory* — that describes the tree-like structure of the fonds and indexing of records based on geographic locations and agents, without mentioning the specific type of relation. As architectural archives include many graphic materials, the annotation of individual records often follows the schemes proposed by The Central Institute for the Union Catalogue of Italian Libraries and Bibliographic Information, where they are treated as separate works and their annotations are focused on the medium and external characteristics such as execution and reproduction techniques, paper types, drawing tools.

However, this perspective applied to the archival materials is somewhat reductive, as architectural records are also reflections of the intellectual work of an architect, and by studying them as such, in the context of other documents, it is possible to reconstruct the knowledge process followed by the architect when developing each project. In our work, we adopt this wider perspective.

Our research aims to provide a data model for architectural archives that may help to prepare information in a way that enables answering questions such as the following: What design ideas were considered by an architect before developing the one that was realized? Are there any buildings of a specific type (e.g. religious buildings) that were designed by a particular architect? How has the approach to design of an architect changed over time?

To reach this goal, we have developed an ontology for architectural archives called ITDT.[1] The ontology has been built as an extension of the archival domain ontology Records in Contexts (RiC-O), that facilitates the representation of architectural records and creation of the context related to architectural projects, the process of their implementation, and participating entities. The ontology is suitable for representing typical architectural records such as drawings, written reports, bid documents and photographs, but also the different stages of an architectural project and their actors.

We have used the ontology to annotate and publish a subset of the records of Italian architect and engineer Dino Tamburini (1924–2011), and the resulting dataset has been published to a digital archive using the TiddlyWiki application [47], allowing for the exploration of the records from multiple perspectives by the users.

In Section 2, we describe the main related works. In Section 3, we present our ontology and how it has been designed. Section 4 describes how we applied the ontology to the case study of the Dino Tamburini archive. Finally, Section 5 reports our conclusions and future works.

2 RELATED WORKS

The benefits of a Linked Data approach for memory institutions have long been discussed in the literature [5], and several semantic data models have been developed specifically for the description of cultural heritage by GLAM (Galleries, Libraries, Archives, and Museums).

[1] ITDT stands for "Italy, Dino Tamburini," following ISAD(G) conventions [49])

The most well-known among these is the CIDOC Conceptual Reference Model [14], a high-level event-oriented ontology for the description of cultural heritage developed by the International Council of Museums (ICOM) that was first published in 1999 and standardised by ISO in 2006. The CIDOC CRM has been adopted in countless projects, and not only to represent data from museums. such as Europeana, the largest European digital library, represents data through the Europeana Data Model (EDM) [25], which is compatible with the CIDOC CRM.

At the same time, a standard model has been developed by the International Federation of Library Associations (IFLA) for use in the library field. This model is called Functional Requirements for Bibliographic Records (FRBR) [50], and its more recent successor is the Library Reference Model (LRM) [54]. An ontology based on Semantic Web standards, called FRBRoo [31] (later LRMoo [45]), has been developed on top of FRBR, and has seen wide adoption in the library and information science field.

Such standardization efforts based on Semantic Web technologies have long eluded the archival field, where despite the existence of internationally recognised archival standards such as ISAD(G) [49], until recently there was no widely adopted standard ontology.

In 2016, the International Council for Archives (ICA) published the initial version of the Records in Contexts Conceptual Model (RiC-CM), which was later expressed in a formal way through the Records in Contexts Ontology (RiC-O) [11, 12]. This ontology focuses on the semantic links between records, their creators, and their function and is intended to produce more context-oriented descriptions for single documents, rather than structure-oriented descriptions for files as previous standards. The ontology has recently started to be applied in practice ([13, 18, 48]), in particular at the *Archives nationales de France* ([8–10]), but it has not yet received a wide adoption.

Independently of the efforts of ICA, alternative ontologies for archival description have recently been proposed, often within the scope of representation of a specific archive. ArDO is an ontology designed for describing the hierarchical nature of archival data and the dynamics of adopted classification, first used for description of records about the Weimar Republic [52]. ARKIVO is an ontology designed around the concepts of Collection and Historical Event that were used to describe holdings of Jozef Pilsudski Institute of America [37]. ArchOnto is an ontology for Portuguese archives, based on the CIDOC-CRM [30].

The Italian National Archive System uses for fonds and files level description its own ontology SAN [26] and a controlled vocabulary based on SKOS [34]

Architectural archives relied on guidelines for the description of architectural records which were published by the international community of archivists, social scientists and architects since the 1980s [22]. The International Council on Archives had published a dedicated guide, that described the document typologies and the development of architectural project according to French legislation [7]. The analysis of architectural project's phases and concrete examples soon followed, in particular [40] mapped different types of records to their respective phases and [16] proposed to create separate entries for projects and its documents.

In Italy, significant work for preservation and dissemination of architectural archives was made by *Archivio Progetti IUAV Venezia*, *Associazione Nazionale Archivi di Architettura*, *Museo MAXXI* [6, 15, 19, 20, 51]. Specialized guidelines for the description of architectural records do not exist, as archivists often use models proposed for cataloguing specific types of cultural heritage objects (photographs [27], drawings [28]) independently of the type of institution that holds them (library, archive, museum) and of the reason they were created for.

We would consider [21], part of [4] as first guidelines for descriptions of architectural records, that were taking in account their digital representation. The guide advised for separate descriptions for the architectural built works, their depictions (images, models) and current and previous states for alternated buildings.

To the best of our knowledge, there is no mapping of existing archival guidelines for architectural records to Semantic Web technologies, however, the Post-War Queensland Architecture Digital Archive developed a functional upper ontology for describing their records [23].

3 ONTOLOGY DESIGN

In this section, we propose an extension of RiC-O for the semantic annotation of architectural archives, the ITDT ontology[2] The ontology focuses on the reconstruction of the knowledge process behind an architectural project through document testimonies, thus providing a way to describe the phases and stages of development of a project, their participants, and the documents that are produced as an outcome of this process.

3.1 Scope

The ITDT ontology was created to support the publishing of the architectural archive of Italian architect and engineer Dino Tamburini (1924-2011), therefore the development had the practical goal of modelling and sharing archival descriptions as Linked Open Data. The resulting dataset, together with digital copies of the documents, were published to a digital archive. The publication tool, that operates as a document-based database, influenced some of our design decision, for example we avoided extensive use of non-binary and complex chain relations.[3]

3.2 Methodology

As the final goal of the project was the publication of the digital archive, the modelling were driven both by analysis of requirements for knowledge representation and by actual records to describe, therefore we didn't aim for universal ontology nor to satisfy all existing national standards and data exchange schemes. Instead, we focused on the context in which the documents were created and paid attention to the intellectual content of the records. This led us to explore the concept of *architectural project*.

The (architectural) project is a polysemous expression, that is, it has more than one sense and these senses are related to each other (these types of words are also commonly referred to as complex semantic types or dot objects [42]). The architects consider a project as a knowledge process, public authorities and archivists as a set of documents and public as a final result of both, a building. In the ontology, we aimed to cover aspects of all senses of the Project. For each sense we used an existing RiC-O class, if matching, or extended them to accommodate a meaning and provided specific properties to express information related to the senses and to link these classes back to Project itself. This approach helped us to provide as much context about architectural projects as possible, without interfering with the basic principle of non-ambiguity of ontology concepts.

For instance, the class `Architectural project` in ITDT ontology describes an intellectual process that leads to the creation of an architectural artefact, a conceptual intangible work. All properties having as domain `Architectural project` describe the characteristics that emerge during this process and guide it, also including those that in natural language would be attributed to the building itself, such as its function or formal type. We leave out "a posteriori" critical considerations such as architectural style or influences.

We also, for now, do not represent in the ontology the physical artefacts as separate entities, as, for example, it is suggested in [21]. These guidelines prescribe the use of *built work* entities for the buildings and *movable work* for

[2]The ontology is available in human-readable form at: https://dmikhaylova.github.io/itdt_ontology/,
and as an OWL document (using the Turtle syntax) at: https://dmikhaylova.github.io/itdt_ontology/itdt.ttl.
[3]A sample dataset, licensed under CC BY-SA 4.0, is available at: https://github.com/dmikhaylova/dt_archive/blob/main/dt.ttl.

drawings and other architectural records. However, this method works well only if the architectural records correspond to an existing building (there persists a relation between a building and a project, for example the drawing was preparatory for the building) or if the record is related to a building that was never built (there is a relation between the drawing and non-existent thing similar to the first case). Instead, the description is more problematic if the building in question exists but has no relation to the records: it was designed and built by another architect or following another project or was modified. In this case, relating a building as *built work* to a project or records would create confusion.

To develop the ontology, we adopted an iterative design methodology, inspired by [38], that requires three steps: creation of motivating scenario and competency questions, formal ontology modelling and data and query testing. This method allowed us to test the model on real data early in the development process and verify its compliance with project tasks.

3.3 RiC-O

RiC-O [11] is the OWL implementation of the International Council on Archives's most recent standard on archival description — the Conceptual Model Records in Context (RiC-CM) [24] which incorporates the previous standards, in particular the widely used ISAD(G), and aims to replace them. It "focuses on intellectually identifying and describing records, the agents that created, used, or are documented in them, and the activities pursued by the agents that the records both facilitate and document" [36]. RiC-CM introduces the idea of semantic description of records independent of the final product (differently from previous standards that were designed exclusively for finding aids), making it easily adoptable for designing digital archives comparing to other standards.

Among the ontologies for archival description described in Section 2, we chose RiC-O as a basis for our project ontology because it clearly incorporates the multitude of views and approaches to description, and it is inclusive by design, i.e., it supports different types of archives and different needs. Moreover, RiC-O is the only ontology that has a strong focus on context of the archival material and allows the description not only the context of conservation or archival practices, but also of the creation of records and even their information content. It provides sufficiently generic classes such as Event or Function that can be extended to describe knowledge processes, such as architectural projects. It also covers a broad range of precisely defined relations between entities, that we found directly applicable to our data, and the clear ontological organisation guided us in defining more specific relations necessary for the description.

The core RiC-O entities are the classes `rico:Record Resource`, `rico:Event` (with its subclass `rico:Activity`), and `rico:Agent`. `Record Resource` and its subclasses are designed for describing records, parts of records and aggregation of records. The `Event` class describes events or activities that are reported in the records, while `Agent` allows the representation of the creator of the archive and any other agent that is mentioned in the records.

RiC-O additionally defines the `rico:Instantiation` class — "the inscription of information made by an Agent on a physical carrier in any persistent, recoverable form as a means of communicating information through time and space" [11]. RiC-O distinguishes the intellectual content of `Record` from physical `Instantiation` and permits multiple physical instances for the same record.

The design of RiC-O provides different possibilities for the description of specific types of records. Firstly, the types could be designed as subclasses of the `rico:Record` class, and this would make it possible to arrange and represent them as a natural hierarchy [35, 18]. Alternatively, the record types could be implemented as instances of the class `rico:Type` and its subclasses. The `Content Type` may be used for the intellectual purpose of the record, `Representation Type` or the `Carrier Type` - for the physical characteristics. The broader and narrow terms could be implemented via the appropriate properties from SKOS. [33].

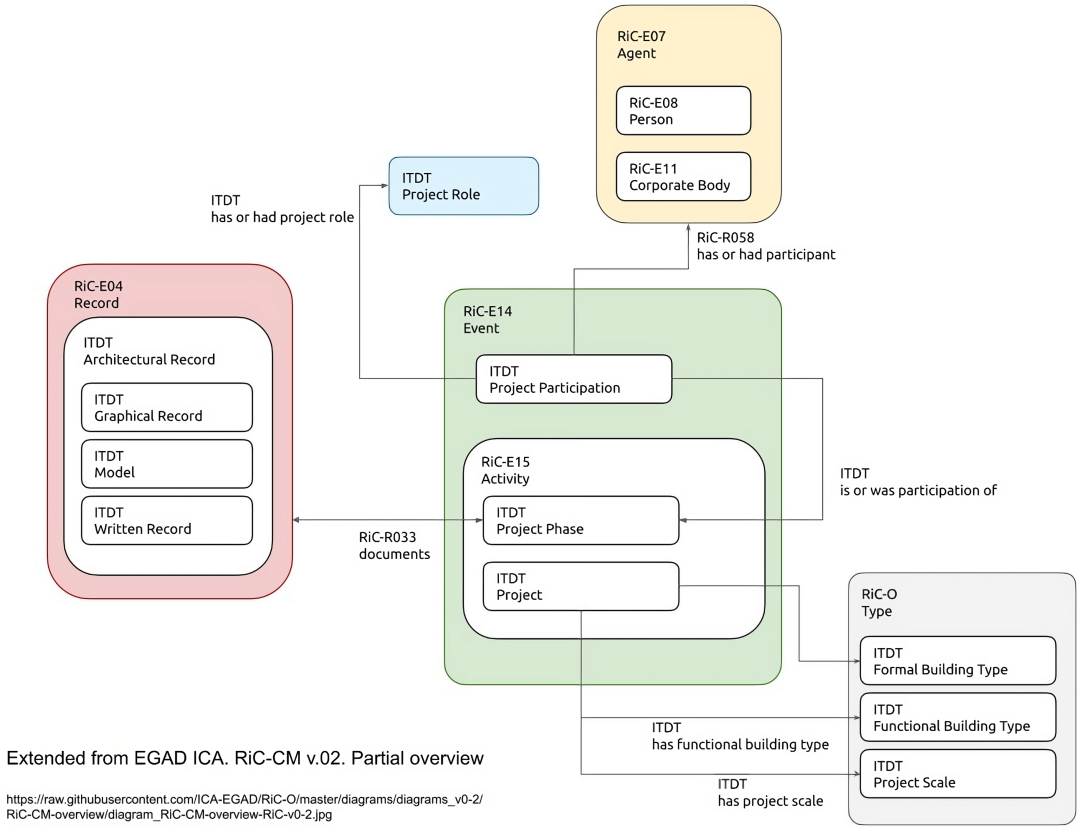

Fig. 1. Schematic representation of the RiC-O extension by ITDT Ontology. Original diagram of RiC-CM partial overview by EGAD ICA (CC BY 4.0) https://tinyurl.com/yb67xwzf.

In our ontology, we opted to represent types of architectural records as subclasses, because the type, such as working drawing or model, is an essential concept for the architectural archive. Indeed, these records differ in purpose, content and carrier, and their own properties are singular. We believe that the classification we created is suitable for reuse and extension by other architectural archives, as the record types are similar for all of them. However, we have also implemented other classifications, discussed in Sections 3.2 and 3.3, through the use of `rico:Type`. The context of records creation is represented by subclasses of `rico:Event` and a newly defined class `Project Role`, further described below. The overall extension is schematically shown in Fig. 1.

In addition to RiC-O, our ontology builds on SKOS [33], FOAF [17] and OWL [53]. The main concept of the ontology is the Architectural Project, which is seen from three different perspectives, that of archival file, that of knowledge process and that of potential built work. The following sections describe the sections of the ontology dedicated to each of the perspective.

3.4 Knowledge Process Description

Architects generally see the architectural project as "a process tool for knowledge acquisition that helps to gradually construct a solution to a problem that they are faced with" [46] and the drawings as "fundamental thought-form of an architect" [41] in this process. In the traditional archival finding aids, projects are listed in a project index, the entries of which are then referred in the files' description in a manner of controlled vocabulary.

To represent architectural projects semantically, we have extended the class `rico:Activity` with a subclass `itdt:ArchitecturalProject`. As mentioned above, it describes an intellectual process that leads to creation of an architectural artefact.

As is common for processes, an architectural project may be divided in several phases and stages. Different sources propose five to seven phases, including Analysis, Design, Execution, Acceptance and Follow-Up [7, 40]. Each phase results in particular types of drawings and documents. For example, during the Execution phase, engineers draft the construction drawings. However, the overlap is not full, as, for example, elevations may be created at different phases with different level of detail. Providing independent annotations for both documentary type and the associated phase give richer context for an architectural record.

Historians of architecture are particularly interested in the analysis and design phases, as the documents related to these phases provide a clue for understanding the creative process of an architect.

The ontology provides classes for the five phases described above, but also for the more granular stages of the design phase and executive phase. The stages of the design phase were adapted from [46], a work dedicated to the creative process relevant for the architecture of the second half of XX century, and are expressed as (`itdt:SetupStage`, `itdt:ConciseIdeaStage`, `itdt:DevelopmentStage`). The executive phase is composed of `itdt:PermitStage`, `itdt:BidStage`, `itdt:ConstructionStage`. The object property `itdt:hasOrHadProjectPhase` relates an architectural project to its phases and stages.

The records are connected to the stage or phase by object property `rico:documents`, as the super-class `itdt:ArchitecturalProjectPhase` is defined as a subclass of `rico:Activity`. In the annotation of the Tamburini archive, for each project we have listed all phases that applied (e.g. the never-built design would end with the creative phase), even if they are not documented at all. This rule provides a way to note lack of records for a particular project.

The quantity and duration of phases depend, among other factors, on what is known as *project scale* [15], i.e. a common way to classify an architect's work by describing the magnitude of the intervention. The scale of a project is described by the class `itdt:ProjectScale`, that extends `rico:Type` and is linked to the project by the object property `itdt:hasProjectScale`, the sub-property of the `rico:hasOrHadCategory`. For example, for the Tamburini archive we implemented the classification proposed by [15]: "general planning", "implementation planning", "architectural design", "restoration", "interior and industrial design". A graphical representation of the ontology classes related to the architectural project is shown in Fig. 2.

Architectural projects of the second half of the XX century are rarely the work of a single individual, or even of a single entity. Complex documentation submitted for competitions and building permits requires collaboration of different professionals or companies. The ontology provides a class `itdt:ProjectParticipation`, whose instances represent the ternary relation between a project or a project phase/stage, an agent and a project role, that are expressed through the object properties `itdt:isOrWasProjectParticipationOf`, `rico:hasOrHadParticipant`, `itdt:hasOrHadProjectRole`.

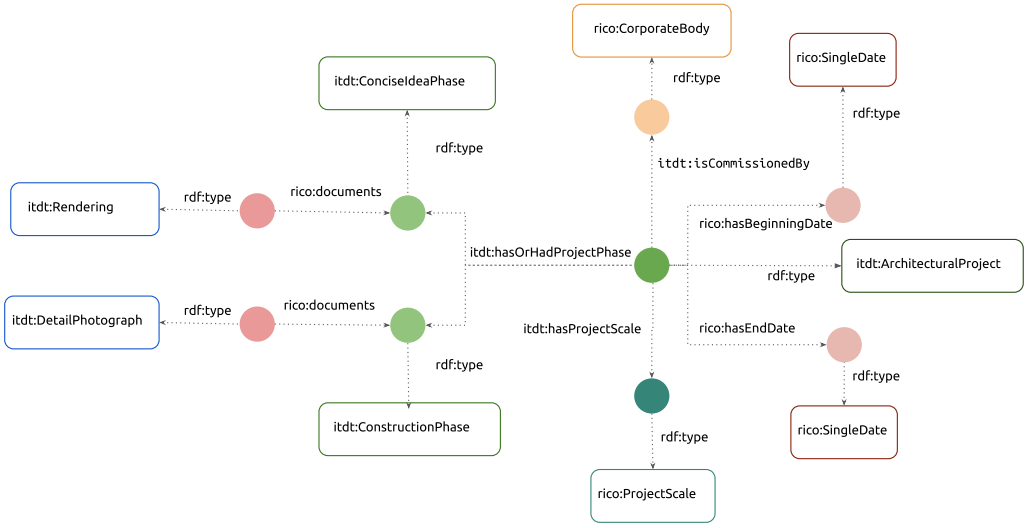

Fig. 2. Two records documenting two phases of the same project and the entities implemented for the architectural project description. Circles stand for individuals, rectangles for classes.

The role of the architect in the project reflects the degree of involvement, responsibilities, and a set of competencies provided by a professional towards the project. For the Tamburini's archive we used among others "project architect", "construction manager" and "consultant". A particular role in the project is reserved for the commissioner of the building, for which we define a subproperty `itdt:isCommissionedBy`.

We also introduce in the ontology the notion of *functional* and *formal types* of building [3, 32]. The functional type describes the intended use of a future building (e.g. residential, commercial), instead a formal type is an idea of building that is recognisable by others but can be interpreted by an architect in many ways (e.g. Roman theatre, courtyard house). Building types are implemented as individuals of `FormalBuildingType` or `FunctionalBuildingType`, subclasses of `rico:Type`.

Architectural archives usually contain the project records that do not relate to any existing built work, either because the project was never carried out or because the building was demolished or altered. To provide means for transmitting this information, we implemented the datatype properties `itdt:wasCarriedOut` and `itdt:exists`.

3.5 Project File Description

In architectural archives, the typical unit of description is the project file — a set of documents related to one architectural project. Each project file may be further divided into sub-files, often mirroring administrative procedures for architectural competitions, building permissions and public procurement. In particular, in Italy the requirements for the set of documents required for presenting projects for public buildings was gradually defined by different laws starting from 1895 (see [43], [44], [29]). In the contemporary practice, the sets are named according to the level of development of project documentation – *progetto preliminare*, *progetto finale*, *progetto esecutivo* and roughly correspond to the end of creative phase and executive phase of the project, although they include only a small subset of officially submitted documents.

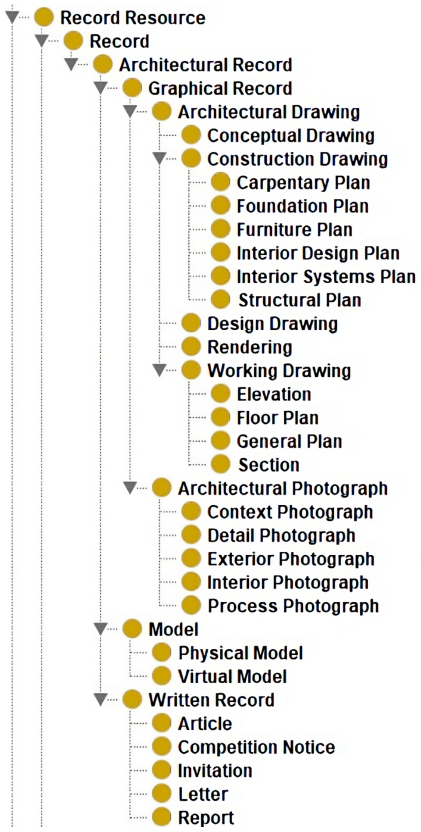

Fig. 3. Subclasses of rico:Record class represented in Protégé

RiC-O provides entities for multilevel archival description of the project file: the class `rico:RecordSet` represents the project file itself, the class `rico:Record` represents an individual document, and the property `rico:isOrWasIncludedIn` annotates the tree structure of an archive. To reflect the particular nature of architectural records, we extended class `Record` with subclass `itdt:ArchitecturalRecord`, and this one with further subclasses that represent graphical records, written documents and architectural models. In particular, subclasses for common types of drawings were defined based on descriptions provided in [7], [40], Art and Architecture Thesaurus [39] and actual archival records. The hierarchy of subclasses is presented in Fig. 3.

The class `itdt:ConceptualDrawing` aggregates small scale freehand drawing that gives a preliminary, symbolic idea of the design; `itdt:DesignDrawing` represents the refined version of conceptual drawings made with instruments; `itdt:Rendering` stands for detailed free-hand or instrument-aided drawings that features entire project, but also people, vegetation, vehicles and is made with shading, colour and perspective.

To translate three-dimensional design of a future building to two-dimensional medium such as paper, architects use four types of technical drawings: *elevations* (projections on vertical plane), *sections* (traversal or longitudinal cut), *floor plans* (horizontal cut through the building made above the floor) and *general plans* (depiction of the area for construction).

These drawings are aggregated by class `itdt:WorkingDrawing` and its subclasses. Large scale, detailed drawings used directly on construction sites are represented by the class `itdt:ConstructionDrawings` and its subclasses.

Architectural photographs are often found in archives and used as a medium for study of urban context and to document construction works and final design of buildings and their decorative details. Photographs are aggregated by subclasses of `itdt:GraphicalRecord`: `itdt:ExteriorPhotograph`, `itdt:InteriorPhotograph`, `itdt:ProcessPhotograph` and `itdt:DetailPhotograph`.

Written documents are described by subclasses of `itdt:WrittenRecord`: `itdt:CompetitionNotice`, `itdt:Report`, `itdt:Article`, `itdt:Invitation`, `itdt:Letter`. Finally, we have created a class `itdt:Model` with two subclasses `itdt:PhysicalModel` and `itdt:VirtualModel`. In the annotation of the Tamburini archive, we use the class `rico:Instantiation` to describe simple photographs of architectural models and connect them with their digital copies through the property `rico:hasDerivedInstantiation`.

3.6 Architectural Artefact

The concept of Architectural project carries also a sense of would-be built work, however we found that from archival point of view RiC-O provides enough means for describing some intrinsic aspects of the future buildings, for example the class `rico:Place` connected with an instance of an architectural project may be used to convey geographical information.

4 CASE STUDY: PROJECT FILES OF DINO TAMBURINI

As a case study, the ontology presented in this paper has been applied to the description of the private archive of Dino Tamburini (1924–2011). Tamburini, an Italian engineer and architect, was an important figure during the post-war reconstruction of Trieste. A representative of the Modern movement and organic architecture, he participated in more than 100 architectural projects and designed public and private residential buildings, transport infrastructures, educational complexes, churches, and theatres. Tamburini is best known for the restoration of Trieste's *Teatro Verdi*, the Church dedicated to Saint Aloysius Gonzaga, and the city's first skyscrapers in Conti street. Tamburini's papers were recognised as historical heritage by the Italian state in December 2022.

The annotation with the ontology was applied to the "Architecture" series of the archive that contains documents created by Tamburini during his career (1948–2011) and existence of his architectural studio (1952–2007). The series contains files consisting of entire project documentation (mostly for later works) and so-called portfolios: photocopies of selected sketches, drawings, photographs and written documents arranged in chronological order by the creator in photo albums.

The creation of the ontology was one of the goals within a larger project of digitization and publishing of the archive. Before this work started, the archive was not arranged and no finding aids existed. At the moment, the arrangement of the archive exists only "on data" and applies to the digital documents. We divided the annotation process by two stages: firstly, we described the record sets with RiC-O classes and properties editing the analytical inventory. The inventory gave us the first understanding of the archive's structure and documentary typologies. Next we chose a subset of records for the publication and approached their annotation on single document level. The development of the ontology was carried out iteratively in parallel with the description of the archive. All implemented classes were used to represent documents of the archive or aggregate them for easy search and visualization. An example of annotation is shown in Fig. 4.

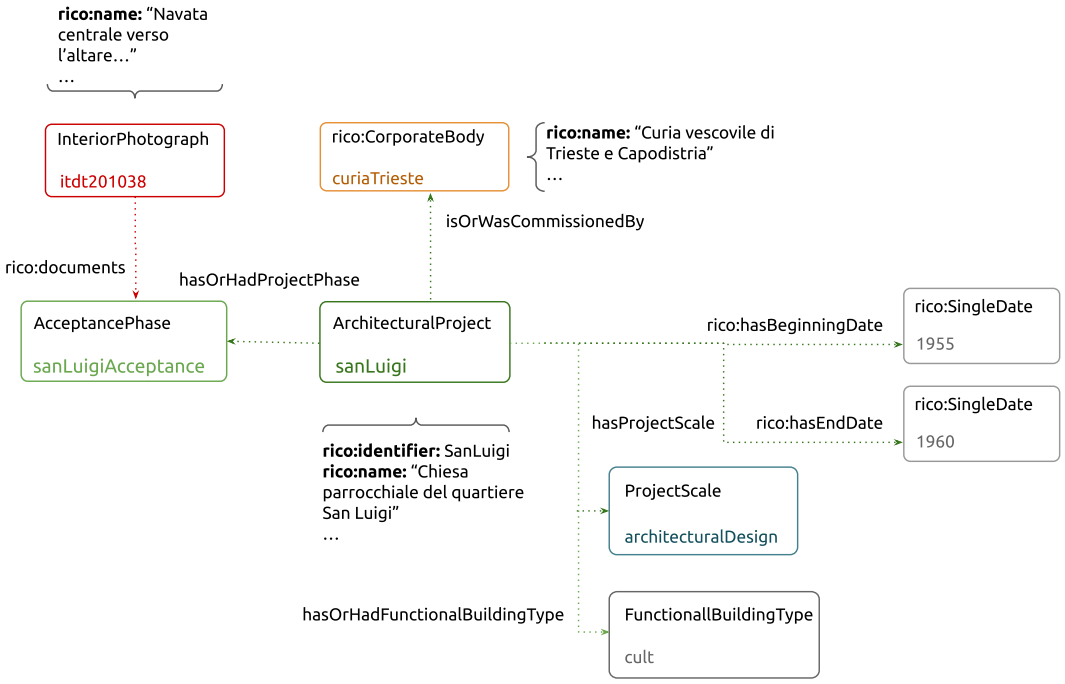

Fig. 4. An example of annotation: a photograph from the Tamburini archive and the architectural project it documents. Rectangles stand for individuals with class name at the top and individual name at the bottom, arrows stand for relations, datatype properties are delimited by curly brackets.

During the annotation, we had to decide whether to apply the RiC-O principles to the letter or adapt the ontology for our purposes. For example, in RiC-O each `rico:Record` represents the information content of a document and it "does not exist until it is represented in at least one instantiation, that is, its information content is inscribed on a carrier in a persistent, recoverable form" [24, p. 21] (either analogue or digital), described by `rico:Instantiation`. However, in our case the description of the physical instantiation in many cases would have resulted in a one-to-one mapping with significant duplication of data, because, as it is common for personal archives, the Tamburini one contains mostly unique paper documents in one copy. Therefore, while fully understanding the limitations of such choice in terms of unambiguous machine-readability, for the first phase of our project we decided to simply create an instance of `rico:Record` corresponding to each physical document, and use `rico:Instantiation` only for the digital copy.

The distinction between the conceptual and the material is naturally present in architectural archives, as their arrangement is almost always only conceptual: for example, a large format drawing is often not stored in the same folder with other project documents. In this case, the drawing's record would belong to the conceptual record set, and its instantiation to the optional physical record set. The distinction between intellectual content and its instantiation would add to this pre-existing complexity.

Moreover, for most essential archival information, RiC-O provides a possibility to fall back to a simpler, flat annotation using datatype properties instead of classes and object properties. This proved useful in many cases, for example, for annotating archival identifiers and titles. While there are designated classes and properties to handle them, in case the

sets and records have only one instance of name or identifier (the arrangement is recent) their use can be avoided, as it is improbable that their values would correspond to some other entities in the LOD network.

Among the other modelling issues that we had to consider, there were the important choice between classification through subclasses and categorization through types (see Section 3), and the representation of temporal information. For example, the uncertainty of dating is modelled in RiC-O through a datatype property `rico:certainty`. In our annotation, the same year is often represented by two individuals of `rico:SingleDate`, certain and uncertain.

The resulting graph contains 5433 triples describing 78 files of the "Architecture" series and the subset of 25 architectural project Tamburini worked on, and 153 records that document half of those described.

4.1 Digital archive

The results of the annotation with ITDT ontology dataset and the digital copies of the documents were published as the digital archive of Tamburini's records using a TiddlyWiki, an interactive wiki application written in JavaScript[4].

TiddlyWiki, which primary utilisation is stated as a "non-linear personal notebook" [47], can be used as a single HTML file from a browser, without the need of any additional software, or as a Node.js application. This permits to publish a read-only version of the digital archive on the web or indeed share it as a stand-alone enhanced finding aid that can be downloaded and used locally.

TiddlyWiki uses the JSON data structure to store information. Each JSON data entry corresponds to a *tiddler*, the basic fundamental unit of information. It can be said that a tiddler corresponds to an item, a record, a node, an entry in other types of applications, and it is a list of fields and corresponding values. The main fields are `title`, `text`, `modified` and `tags`, but any number of fields with unique names may be defined for a tiddler. TiddlyWiki, which uses WikiText, a markup language similar to Markdown, can be considered a programming environment and document-oriented database that permits to store, query and visualize data with its own high-level programming language. It works directly with documents of different structure and media, without the need to create a rigidly structured relational database. As historical archives, and even more so architectural archives, deal with heterogeneous documents, it is very important to be able to keep a unit of information as closer to a document as possible and have a dynamic structure.

As TiddlyWiki uses a JSON structure and at the moment of writing does not support JSON-LD, the triples of the dataset were mapped to JSON. For each individual we created a tiddler, and the last part of the IRI was mapped to the value of the title field. The predicates were represented as fields and the corresponding objects as their values. The class of an individual was mapped to its tag.

Our main goal while designing the digital archive was to provide multiple views and representations of the Tamburini records, to support different types of users. Firstly, following the archival standards, we created an interactive analytical inventory, that aggregates record sets according to their position in the tree-like structure of the archive. The description of a file represents, when available in the digital archive, the documents contained in the file in their original order and with links to their dedicated pages.

The second view is that of a project, shown in Fig. 5. Each project has a dedicated page that presents all metadata in the form of a natural language sentence and as a list of fields and values. The project view aggregates documents, that may come from different project files and portfolios, and sort them according to the phase of the project they document. Fig. 5 illustrates an example of a project page, where the annotation, shown in the Fig. 4, is represented by TiddlyWiki. Projects of Tamburini in the archive are aggregated in dynamic lists, organised by the scale, intended use, start date or

[4]The first version of the archive is available at http://dinotamburini.it

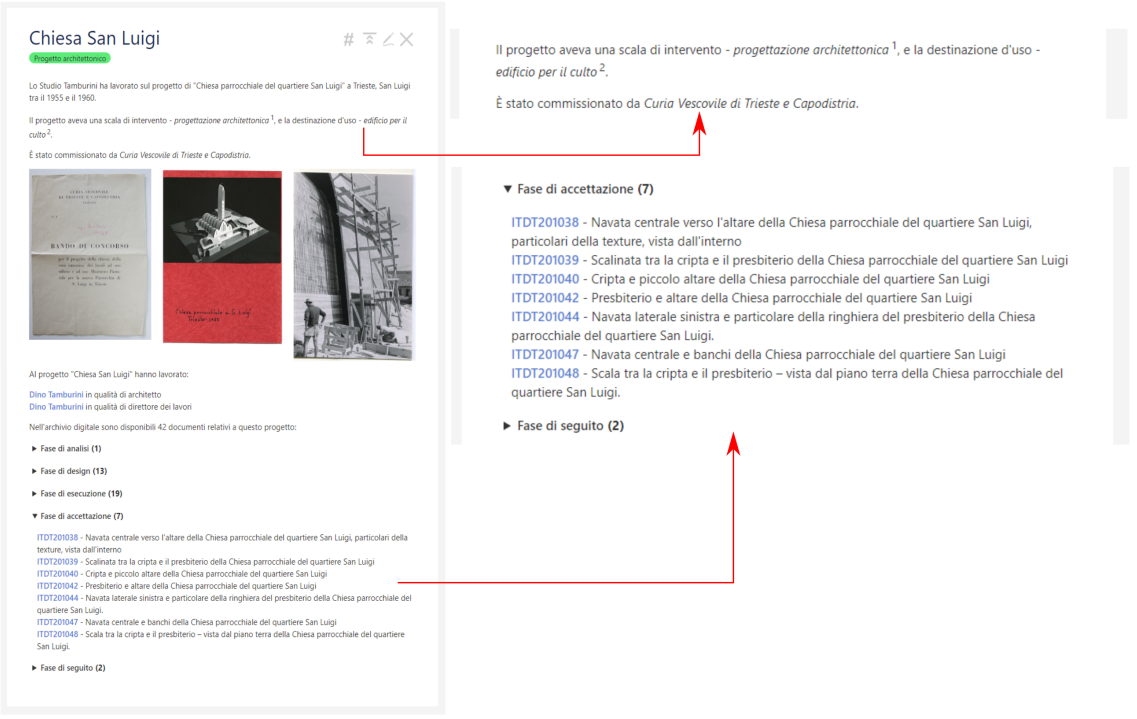

Fig. 5. The page about the project of the Church dedicated to Saint Aloysius Gonzaga, Trieste. The entire page on the left and the zoom-ins on the right: the natural language description of the project created from the annotations and the dynamic list of the records related to the project, divided by phases.

geographical location. As all projects are related to a `Place`, where they were intended to be built, it is also possible to locate them on the map.

Finally, the third implemented view is a free-form narrative that uses a simple hypertext to create associations between records and other entities, or cite records and their metadata as historical sources or include the digital images as illustrations, providing a link for further information. Examples of such texts may be seen in the published archive.

5 CONCLUSIONS AND FUTURE WORKS

In this paper, we have presented the ITDT ontology, an extension of Records in Contexts Ontology (RiC-O) that allows a structured and formal representation of data about architectural archives. The ontology extends RiC-O by modelling the architectural project, its different phases, and the specific types of record that are found in an architectural archive.

The ITDT ontology makes it possible to represent architectural archives in a structured and formal way, compatible with the Linked Open Data framework and existing standards, thereby improving information search and exploration in this archival domain. The ontology has been published online.

We have validated the ontology by applying it to a concrete case study — the archive of Italian architect Dino Tamburini (1924–2011). The results of the annotation with ITDT ontology and the digital copies of the documents have been published as a digital archive using the TiddlyWiki application.

The application to the Tamburini archive has shown that the ontology is capable of supporting a rich representation of an architectural archive, allowing for multiple perspectives over the records (inventory, project view, timeline view) that may be of interest to different types of users.

As future work, we plan to share the data we collected from the Tamburini archive through the Archives Portal Europe and Europeana digital library, and to investigate the application of the ontology to other architectural archives, allowing for a wider evaluation of the model. To facilitate the access and direct querying of the dataset, we will also consider implementing a SPARQL endpoint.

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