OntoBelliniLetters: A Formal Ontology for a Corpus of Letters of Vincenzo Bellini

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Abstract. In this paper the formal OntoBelliniLetters ontology is described concerning the corpus of Vincenzo Bellini’s correspondence letters kept at the Belliniano Civic Museum of Catania. This ontology is part of a wider project - the BellinInRete project - one of whose aims is the development of a more general and complete ontology for the whole Vincenzo Bellini’s legacy preserved in the Museum.

The main concepts and relations building up the ontology knowledge base are described and discussed and hints for their implementation by means of the standard OWL-2 description language are presented. The ontology schema is inspired by the CIDOC Conceptual Reference Model (CIDOC CRM).

Keywords: Vincenzo Bellini · Correspondence letters · Ontology

1 Introduction

In this paper the formal OntoBelliniLetters ontology is described concerning the semantic organization of the corpus of Vincenzo Bellini’s correspondence letters kept at the Belliniano Civic Museum of Catania. OntoBelliniLetters partially stems from the TEI-encodings of Bellini letters developed as part of the BellinInRete project which aims at renewing and creating a lasting change in the exploitation and enhancement of the Belliniano Museum (see [2,3]); however, OntoBelliniLetters is not purely the result of a mapping grounded into the set of particular TEI constructs used for the letters: certain semantic specificities are involved that are not explicitly and directly undertaken within the TEI-encodings.

Conceptually, the OntoBelliniLetters ontology is made up of entities, provided with attributes, and relations (see Sect. 3). The ontology schema has been conceived with “CIDOC CRM mappability” in mind, with entities definable in terms of CIDOC CRM (sub)classes, and relations in terms of CIDOC CRM (sub)property chains. CIDOC CRM is the international standard for information integration and exchange in the cultural heritage domain. It consists of two main types of primitives, namely, the classes, identified by names E1, E2, . . . and the properties, named P1, P2, . . ., which serve to model objects and relationships underlying a

1 http://www.cidoc-crm.org/.
given reality. In fact, entities involved in the OntoBelliniLetters ontology which describe real-world instances (such as persons, places, dates, etc.) can be represented in terms of subclasses of corresponding CIDOC CRM \( E_n \) primitives, e.g., the classes \( E21 \) (Person), \( E53 \) (Place), \( E50 \) (Date), etc., whereas relationships between entities can be implemented by linking CIDOC CRM classes through chains of CIDOC CRM \( P_n \) properties, as in the case of the relationship “\( P \) has birth date \( D \)”, linking a person \( P \) to its date of birth \( D \), which can be modelled (e.g.) as the chain \( E21 \) (Person) → \( P98 \) (was born) → \( E76 \) (Birth) → \( P4 \) (has time-span) → \( E52 \) (Time-span) → \( P78 \) (is identified by) → \( E50 \) (Date).

In the literature, some proposals of manuscript digitisation, and digital data sharing and exploitation are presented that involve semantic organisation of letter corpora; see, for instance, [5], which presents a digital edition of a collection of letters of Vespasiano da Bisticci, and [7], where a linked data approach is described for the creation of a digital infrastructure for publishing, sharing and analysing correspondence based on EMLO.\(^2\) We mention also that, originally, an experimentation has been undertaken by the authors concerning the possibility of exploiting RDA (Resource Description and Access)\(^3\) framework for the development of an ontology of the whole Bellini’s legacy, including, in particular, the letter corpus (see [1]). However, due to data representation issues, which made things unnecessarily complicated, this task was abandoned in favour of the idea of exploiting CIDOC CRM instead.

The paper is organized as follows. Section 2 briefly reviews some notions and concepts used in the paper. Then, leading Sect. 3 provides a conceptual descriptions of the main ontology items (entities and relations) involved in OntoBelliniLetters; some domain specific axioms are even described as well, and their OWL-2 implementations are presented (cf. Sect. 3.4). Conclusions and future works are discussed in Sect. 4.

## 2 Background Notions and Concepts

The notion of an entity and other related ones are often used in this paper. For convenience we briefly review them below for future reference.

An entity (in the present context) is a formal representation of an homogeneous collection \( C \) of concrete or abstracts object within a given universe or domain of the discourse. Conceptually, an entity (for the collection \( C \)) consists just of a list (i.e., a finite ordered sequence) of features or properties shared by all objects in \( C \). Any particular tuple of values of these features is intended to uniquely identify a specific, well determined object of \( C \).

A feature is conceptually represented by the set of its values, called an (entity) attribute. So, an entity has the form \((\text{att}_1, \text{att}_2, \ldots, \text{att}_n)\) where \(\text{att}_1, \text{att}_2, \ldots, \text{att}_n\) are the attributes carrying out the information about the object features. A sequence of values \((v_1, v_2, \ldots, v_n)\), where \(v_i \in \text{att}_i\), for \(i = 1, 2, \ldots, n\), is called an

\(^2\) EMLO (Early Modern Letters Online) is a collaborative, open source union catalogue of early modern correspondence (http://emlo.bodleian.ox.ac.uk/).

\(^3\) http://www.rda-rsc.org/.
(entity) instance which is thus meant to represent a specific object of the collection $C$. Note that, the role of an attribute $\text{att}_i$, i.e., the particular feature it represents, is determined by just its position $i$ in the sequence $\text{att}_1, \text{att}_2, \ldots, \text{att}_n$; however, usually, specific names are associated to attributes that exemplify their roles. Entity attributes can be basically divided into two main classes: atomic attributes and non-atomic attributes. Atomic attributes carry out a unique, unstructured type of information, whereas non-atomic attributes are defined in terms of atomic ones and correspond by themselves to entities; i.e., each of them is in fact the instance set of some entity.

A more formal definition of an entity can be provided recursively as follows. Note that below we denote with $\langle \langle E \rangle \rangle$ the instance set of an entity $E$. Let $A_1, A_2, \ldots, A_m$ data item sets representing atomic attributes.\footnote{Formally, the data items referred to here correspond to strings over some fixed alphabet.} Then:

1. Each 1-tuple $E = \text{Def}(A_j)$, where $1 \leq j \leq m$, is an entity (a primitive entity), and we put $\langle \langle E \rangle \rangle = \text{Def} A_j$;
2. If $E_1, E_2, \ldots, E_k$ are any $k$ entities, where $k \geq 2$, then the $k$-tuple $E = \text{Def}(\langle \langle E_1 \rangle \rangle, \langle \langle E_2 \rangle \rangle, \ldots, \langle \langle E_k \rangle \rangle)$ is an entity, and we put \[
\langle \langle E \rangle \rangle = \text{Def} \langle \langle E_1 \rangle \rangle \times \langle \langle E_2 \rangle \rangle \times \cdots \times \langle \langle E_k \rangle \rangle,
\]
   (i.e., the cartesian product of the instance sets $\langle \langle E_1 \rangle \rangle, \langle \langle E_2 \rangle \rangle, \ldots, \langle \langle E_k \rangle \rangle$);
3. Nothing else is an entity.

Note that the representation provided by an entity is essentially conceptual: in particular, in the case an entity $E$ is used to represent a collection $C$ of concrete objects of the real world, not all possible combinations of attribute values (i.e., not all entity instances) necessarily correspond to objects actually existing within the collection $C$.

For example, the collection $C$ of the letters sent by Vincenzo Bellini to its father Rosario Bellini or to its uncle Vincenzo Ferlito, with each letter being characterized by its own written text content, can be conceptualized in terms of an entity and, specifically, represented as the triple $E = \text{Def}(\text{sender}, \text{recipient}, \text{text})$, where: (i) the attribute $\text{sender}$ is used to represent the property that someone (i.e., some person) is the sender of a letter, with its values identifying letter senders; (ii) the attribute $\text{recipient}$ similarly concerns letter recipients; and, finally, (iii) the attribute $\text{text}$ carries out information about letter texts. If there are altogether $n$ different letters, and we stipulate to represent the text of the $i$-th letter by means of a string $T_i$, we may put $\text{text} = \text{Def}\{\{T_1, \ldots, T_n\}\}$, with text thus being a primitive entity composed of only the atomic attribute $\{T_1, \ldots, T_n\}$. Next, if we assume that a person is determined solely by just its first and last names, we may represent the collection of all of the involved persons (i.e., letter senders/recipients) by the entity $(\text{firstName}, \text{lastName})$, where the two (atomic) attributes $\text{firstName}$ and $\text{lastName}$ provide in fact the information about persons’ first and last names, respectively; formally, we may put:

\[
\text{firstName} = \text{Def}\{\text{Vincenzo, Rosario}\} \quad \text{and} \quad \text{lastName} = \text{Def}\{\text{Bellini, Ferlito}\}.
\]
Summing up we may write
\[ \mathcal{E} = ( \{ \text{Vincenzo, Rosario} \} \times \{ \text{Bellini, Ferlito} \}, \{ \text{Vincenzo, Rosario} \} \times \{ \text{Bellini, Ferlito} \}, \{ T_1, ..., T_n \} ) . \]

Note that (e.g.) the entity instance

\[ ((\text{Vincenzo, Ferlito}), (\text{Rosario, Bellini}), T_i) , \]

where \( i \in \{1, \ldots, n\} \), does not correspond to any letter of the collection \( C \) as it would represent a letter whose sender is Vincenzo Ferlito (and hence not included in \( C \)).

### 3 Conceptualizing Bellini’s Correspondence

We conceptually represent the whole collection of Bellini’s letters kept at the Belliniano Museum as an entity (the letter-entity).

As dictated by the examination and analysis of this letter collection, the letter-entity involves various groups of attributes determined by the consideration of different aspects of the letters. A group of standard attributes identify who wrote a letter and to whom the letter is addressed to, and carry information about postal shipping/delivery of letters, such as:

- **author** (person(s) that wrote a letter);
- **addresse** (person(s) a letter content (i.e., meaning) is addressed to);
- **sender** (sender of a letter);
- **recipient** (recipient of a letter).

Similarly there are even attributes about letter preservation and archiving, e.g., the organization keeping a letter and how and where it is archived there; these include:

- **repository** (organization keeping the letter);
- **inventory** (inventory number);
- **collocation** (physical collocation of the letter);
- **title** (letter title).

Besides the letter-entity, the OntoBelliniLetters ontology involves several other entities and relations concerning such aspects as physical letter structure, letter texts arrangement and letter text contents, as well as other types of entities and relations, as described in the following sections.

Note that, in the OWL-2 formalization of the ontology, all these entities and relations correspond to OWL-2-(sub)classes and OWL-2-(sub)properties, respectively, with the role of an attribute att of an entity \( \mathcal{E} \) implemented by means of a specific property linking the class corresponding to \( \mathcal{E} \) to the class corresponding to att.
Fig. 1. Glued letter-sheets.

3.1 Physical Letter Structure

Letter texts are written on sheets of paper (letter-sheets): certain texts spread across two or more letter-sheets (possibly glued along edges, as shown in Fig. 1) and/or lie on opposite sides of the same sheet (say, the front side and the back side).

Each letter-sheet is conceptualized as a rectangle with its own width and height dimensions; is made up of a certain material (e.g., the type of paper with its thickness) and has a given condition state. Opposite sides of letter-sheets – the (letter-)pages - are the elementary physical support units bearing letter texts. Thus each letter-sheet is composed of two (opposite) pages and a letter (text) may spans one or more pages. Each page acquires the dimensions and the material of the letter-sheet it is a side of, and two opposite pages have thus the same dimensions and the same material; however, condition state of opposite pages may be different (e.g., due to stains, abrasions, discolorations, etc.). A page thus corresponds to an entity provided of (at least) the following attributes: dimension, conditionState and material; moreover, two page-entities $P_1$ and $P_2$ may be related by the hasOpposite relation meaning that $P_1$ and $P_2$ are opposite sides of the same letter-sheet. A letter $L$ is related to a page $P$ bearing
(part) of $L$’s text by means of the relationship $L$ hasSupport $P$. Note that the hasOpposite relation is symmetric, since sides of a paper sheet are opposite each other; moreover any page cannot have more than one opposite (see Sect. 3.4).

### 3.2 Letter Text Arrangement

A peculiar property of Bellini’s correspondence is the presence, within the same letter page, of written text parts that follow different writing orientations and/or that partially overlap each other. See for instance Fig. 2. These peculiarities represent useful information about writing modalities and preferences in Bellini’s letters. We take care of them by conceptually wrapping the written text parts into 2-dimensional rectangular boxes - the wboxes - that virtually lie within letter pages, and to each wbox $D$ we associate the cartesian coordinate system $(x_D, y_D)$ where the positive direction of the $x_D$-axis follows the writing direction of the text within $D$, and the positive direction of the $y_D$-axis goes from the baseline.
Fig. 3. The \((x, y)\) cartesian coordinate system associated to a wbox.

Fig. 4. Graphical representations of the relationships \(A \text{ hasRight } B\) (1), \(A \text{ hasLeft } B\) (2), \(A \text{ hasTop } B\) (3) and \(A \text{ hasBottom } B\) (4), where \(A\) and \(B\) denotes wboxes.

to the top of the written characters (see Fig. 3). Then, we consider the following 5 kind of relationships between two wboxes \(A\) and \(B\):

1. \(A \text{ hasRight } B\): axes \(x_A\) and \(x_B\) have the same positive directions;
2. \(A \text{ hasLeft } B\): axes \(x_A\) and \(x_B\) have opposite positive directions;
3. \(A \text{ hasTop } B\): axes \(y_A\) and \(x_B\) have the same positive directions;
4. \(A \text{ hasBottom } B\): axes \(y_A\) and \(x_B\) have opposite positive directions;
5. \(A \text{ hasOverlap } B\): a portion of \(A\) overlaps over a portion of \(B\).

(Figure 4 provides graphical representations of the relationships (1), (2), (3) and (4) above.) In fact, from an examination of Bellini’s correspondence, it turns out that the five relations above cover all possible cases of mutual arrangement of the various text parts in terms of writing orientation and overlapping.
Fig. 5. The use of diminutives within Bellini’s letter texts: “Carluccio” refers to the person Carlo Pepoli, the librettist of Bellini’s Opera I Puritani.

For a wbox $D$ and a page $P$ we define the relationship $D$ hasPage $P$ meaning that $D$ lies within $P$. Note that we intend a wbox as being uniquely identified by the particular text part it wraps and the letter page it lies within. Thus, each wbox $D$ has associated a unique text part $T$ and lies within one and only one page $P$; hence in particular, if $P_1$ and $P_2$ are pages such that $D$ hasPage $P_1$ and $D$ hasPage $P_2$ both hold, then $P_1$ and $P_2$ are identical. Below we will discuss other properties relating pages and wboxes (cf. Sect. 3.4).

3.3 Letter Text Contents

The text of a letter expresses concepts and describes situations and facts about everyday life. Certain single words, or, more generally, word sequences $W$ occurring within the written texts of Bellini’s letters are interpreted as referring to relevant entities $E$ of which it is useful to keep track of the information about their involvement into the various text parts and how they are in fact referred to (i.e., the word sequences $W$); such information is relevant to the museum context and for education purposes. We call these entities $E$ the named-entities, and the word sequences $W$ above that refer to them, their respective internal-names. Named-entities corresponds to persons, places, organizations, (manifestations and types of) musical works, etc. For example, in its letters, Bellini sometimes uses diminutives for naming persons, such as for instance the word “Carluccio” with which he refers to Carlo Pepoli, the librettist of its Opera I Puritani (see Fig. 5). Also, mentions to musical works (such as Puritani or Capuletì) frequently occur within the text of Bellini’s letters, as well as the use of specific terms related to the musical domain (such as aria, atto, cantata, cavatina, coro, duetto, opera, sortita, etc.); even specific places and/or organizations are referred to in various parts of the letters, such as cities and theatres. Note that the correlation between a named-entity $E$ and an internal-name $W$ of it, does not always follow “by per se” from solely the information contained within $W$ (e.g., as in the case above of the diminutive “Carluccio” correlated to the person Carlo Pepoli), but is sometimes the result of a contextual analysis of the various text parts of the letter(s) where $W$ occurs and/or other information available on the life of Vincenzo Bellini.
Named-entities have their own attributes. Note that certain specific attributes provide external linkings of these entities to corresponding authority file entries, and similar informative resources and repertories, such as VIAF, Geonames, Wikipedia, Treccani encyclopedia, RISM, and LesMU. Besides these link-attributes, owned by all named-entities, other characterizing attributes are specific to the particular type of named-entity they are involved in. For instance, in the case of a person-entity, there are the attributes foreName, surName and addName carrying out information about the forename, the surname and aliases (or nicknames) of persons, respectively, as well as the attributes birthDate (resp. deathDate) and birthPlace (resp. deathPlace) holding the date and the place of birth (resp. of death). Also, attributes concerning social role and status of persons are involved. In the case of the place-entity, the attributes settlement, district and country are involved which correspond to the urban-type settlement, urban district and belonging country of geographic places, respectively.

3.4 Domain Axioms

Besides entities and relations described above, for a fruitful modelling of our domain of interest, i.e., the Bellini’s correspondence, certain (domain) specific axioms are to be introduced ruling the way entities are related each other. Below we present and describe some of these axioms. Note that for notational convenience we use First Order Logic (FOL) to formally state the axioms. However, we point out that the full machinery of FOL is not actually required for this purpose; in fact, the Description Logic (DL) underlying OWL-2 (i.e., SROIQ, see [4]) suffices. We use FOL notation as it is more easy and intuitive than DL (at least to our opinion), and allows to express a deeper level of detail.

To begin with, we recall from Sect. 3.1 that the supports for text letters are the pages which correspond to the sides of the sheets of paper where the texts are actually written. As noted, if two pages $A$ and $B$ are opposite, then they must have (I) the same material and (II) the same dimensions; moreover, (III) for each page $P$ there can be at most a unique page $Q$ which is the opposite of $P$; i.e., the relation hasOpposite must be functional. Formally, we can readily state conditions (I) and (II) within FOL, respectively, as follows:

$$\forall A \forall B \forall M (A \text{ hasOpposite } B \land B \text{ hasMaterial } M \Rightarrow A \text{ hasMaterial } M) \quad (A1)$$

and

$$\forall A \forall B \forall D (A \text{ hasOpposite } B \land B \text{ hasDimension } D \Rightarrow A \text{ hasDimension } D), \quad (A2)$$

\[5\] http://viaf.org/
\[6\] https://www.geonames.org/
\[7\] https://www.wikipedia.org/
\[8\] http://www.treccani.it/enciclopedia/
\[9\] http://www.rism.info/home.html.
whereas conditions (III) states as:

\[(\forall A)(\forall B)(\forall C)(A \text{ hasOpposite } B \land A \text{ hasOpposite } C \Rightarrow B = C)\]. \hspace{1cm} (A3)

Observe further, that if a page \( A \) has a page \( B \) as its opposite then the converse should even hold true, i.e., \( B \) has \( A \) as its opposite; thus, the relation \text{hasOpposite} is symmetric:

\[(\forall A)(\forall B)(A \text{ hasOpposite } B \Rightarrow B \text{ hasOpposite } A)\]. \hspace{1cm} (A4)

Additionally, it is quite reasonable to assume that \text{hasOpposite} is an \textit{irreflexive} relation, namely, no page can be the opposite of itself:

\[(\forall A)(\neg(A \text{ hasOpposite } A))\]. \hspace{1cm} (A5)

Also, since a page conceptually identifies a side of a paper sheet bearing some letter text, one should postulate that any page is the support of some letter:

\[(\forall P)(\exists L)(L \text{ hasSupport } P)\]. \hspace{1cm} (A6)

Further axioms involve (e.g.) wboxes. Recall that wboxes are conceptualized as specific parts of letter texts wrapped into rectangular containers that are intended to be matched against writing directions and/or overlapping. Thus, any wbox \( D \) must lie within exactly one page \( P \); a condition which corresponds to the (conjunction of the) following two statements, the second of which expresses \textit{functionality} of the relation \text{hasPage}:

\[(\forall D)(\exists P)(D \text{ hasPage } P)\] \hspace{1cm} (A7)

and

\[(\forall D)(\forall P)(\forall Q)(D \text{ hasPage } P \land D \text{ hasPage } Q \Rightarrow P = Q)\]. \hspace{1cm} (A8)

Also, relation \text{hasOverlap} (cf. Sect. 3.2) could be postulated as \textit{irreflexive} (i.e., no wbox \( D \) overlaps with itself):

\[(\forall D)(\neg(D \text{ hasOverlap } D))\], \hspace{1cm} (A9)

and, since any wboxes agrees with itself in terms of text writing direction, we further have that \text{hasRight} relation is \textit{reflexive}:

\[(\forall D)(D \text{ hasRight } D)\]. \hspace{1cm} (A10)

Furthermore, given that writing directions within two wboxes \( X \) and \( Y \) can mutually arrange \( X \) and \( Y \) in one and only one way, the relations \text{hasRight}, \text{hasLeft}, \text{hasTop} and \text{hasBottom} should be pairwise \textit{disjoint}; formally, this can be stated as an \textit{axiom-schemata} as follows:

\[(\forall X)(\forall Y)(X \text{ rela } Y \Rightarrow \neg(X \text{ relb } Y))\], \hspace{1cm} (A11)

where

\[\text{rela} \in \{\text{hasRight, hasLeft, hasTop, hasBottom}\}\]
Fig. 6. OWL-2 Functional-Style representation of the domain axioms (A1)–(A11).

As remarked above, axioms (A1)–(A11) are expressed by means of FOL syntax. For completeness we report in the table represented in Fig. 6 the corresponding translations into OWL-2 Functional-Style Syntax, where LETTER, PAGE and WBOX represent the OWL-2-classes corresponding to the letter-entity, the page-entity and the wbox-entity, respectively.

4 Conclusions and Future Work

In this paper, the OntoBelliniLetters ontology has been described concerning the corpus of Vincenzo Bellini’s correspondence letters kept at the Belliniano Civic Museum of Catania. The ontology schema has been devised and formalized
within the logical apparatus provided by the OWL-2 description language for semantic knowledge representation; however, it is currently under refinement, and the ontology has not been fully populated yet, as a subset of letters is being processed for the purposes of the formal extraction and analysis of the relevant information to be inserted into the ontology. Completion of the ontology is planned for the near future.

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