Ontologies in CLARIAH: Towards Interoperability in History, Language and Media

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Abstract. One of the most important goals of digital humanities is to provide researchers with data and tools for new research questions, either by increasing the scale of scholarly studies, linking existing databases, or improving the accessibility of data. Here, the FAIR principles provide a useful framework as these state that data needs to be: Findable, as they are often scattered among various sources; Accessible, since some might be offline or behind paywalls; Interoperable, thus using standard knowledge representation formats and shared vocabularies; and Reusable, through adequate licensing and permissions. Integrating data from diverse humanities domains is not trivial, research questions such as “was economic wealth equally distributed in the 18th century?”, or “what are narratives constructed around disruptive media events?” and preparation phases (e.g. data collection, knowledge organisation, cleaning) of scholars need to be taken into account. In this chapter, we describe the ontologies and tools developed and integrated in the Dutch national project CLARIAH to address these issues across datasets from three fundamental domains or “pillars” of the humanities (linguistics, social and economic history, and media studies) that have paradigmatic data representations (textual corpora, structured data, and multimedia). We summarise the lessons learnt from using such ontologies and tools in these domains from a generalisation and reusability perspective.

1. Introduction

The digital humanities (DH) are a “movement and a push to apply the tools and methods of computing to the subject matter to the humanities” [25]. By increasing the availability of digital data and compute power, the DH, ultimately, strives to attain broader insights in settled debates and allow for the study of new questions [26]. This mimics the approach of “big data” that has been successful in other scientific fields over the past decades [27].

However, DH research is currently very challenging, as the reusability of DH datasets is limited due to their low fulfillment of the FAIR data principles for scientific data management [28]. Findability is problematic because DH datasets are typically scattered, small, and represented in non-machine readable ways (for example, scanned images), lack globally unique and persistent identifiers, rich metadata, and registration in search indexes. Accessibility is limited as data are often in possession of a handful of individual researchers; these datasets are, therefore, hard to access automatically through open protocols. Reusability, greatly empowered by releasing data under open access licenses (e.g. creative commons’), is hampered by a research culture that does not totally embrace open licensing yet. But, most importantly, interoperability among these datasets is severely compromised due to the scarce use of formal knowledge representation languages, shared vocabularies, and ontologies.

Linked Data and Semantic Web technologies have proven to be effective at addressing these issues in various domains. For example, Bioportal [44] is a comprehensive repository of ontologies to address interoperability in biomedicine. Similar successes have been observed in cross-domain, geographic, government, media and library datasets [17].

1 https://creativecommons.org/
In the Netherlands, we are taking up this interoperability mission in CLARIAH,² by developing a nation-wide, common data space for the Arts and the Humanities. The main objectives of CLARIAH are: (a) facilitating the publication and reuse of DH data following the FAIR principles and Linked Data standards. By doing so, we currently serve DH researchers with 114 datasets containing 865 billion RDF triples in 1,500 Knowledge Graphs; and (b) to do so by fostering the collaboration between different research disciplines (historians, social scientists, linguists, media studies, and computer scientists) that had rarely collaborated before at this scale.

CLARIAH consists of three pillars, each combining a domain with a technical challenge. The linguistic pillar (work package 3, WP3) aims to provide research infrastructure facilities for carrying out linguistic research. This includes tools, and resources to support the study of language as well as to support automatic text analysis tools for other domains.³ The economic and social history pillar (work package 4, WP4) deals with structured data. The field has a long tradition of creating tabular datasets and the challenge is to gather and integrate these datasets, both within and outside of the domain. The media studies pillar (work package 5, WP5) deals with audiovisual data, and aims to provide infrastructure for researchers that study and annotate mass media, newspapers, film, radio, television, and their contexts; and the central role these have played in the emergence of modern societies.

This publication of reusable DH datasets through interdisciplinary collaboration poses, however, a more important challenge: to find adequate social process and ontology engineering practices in order to reach agreement in what and how ontologies and vocabularies can be used to enable quantitative and comparative analyses in DH. An ontology is an “explicit specification of a conceptualization” [29] and formally describes the concepts and properties in a domain. The use of ontologies in AI and the Web has crystallised in a Semantic Web of Linked Data [17], a community effort to engineer, deploy and use ontologies to describe data in such a way that machines can process their meaning and address their interoperability.

In this chapter we address the question: how can ontologies and Semantic Web technologies enable quantitative analysis in the humanities? What ontology engineering practices are effective for enabling cooperation in research communities that have, traditionally, been distant? We do this through the lens of (a) Semantic Web ontologies that we have engineered in order to model key domains in DH; and (b) a set of tools that we have developed to leverage these ontologies as data interoperability enablers. Combined, these two insights help to streamline the fundamental phases of humanities data preparation (e.g. data collection, knowledge organisation, cleaning), which are typically the most time-consuming tasks in research projects [30]. Specifically, the contributions we describe in this chapter are:

- Related work on DH ontologies and ontology engineering (Section 2)
- A set of ontologies to model the domains of social and economic history, language, and media studies in DH (Section 3)
- A set of tools that leverage these ontologies to enable data interoperability and fulfill the FAIR data principles (Section 3)
- A description of our efforts to address a fragmented landscape of ontologies and increase their coupling and reusability, e.g. through workshops on linking these ontologies within CLARIAH (Section 3.4)

² [https://clariah.nl/](https://clariah.nl/)
³ In CLARIAH Plus, the successor of CLARIAH Core, language and automated text analysis tools are divided over two different work packages.
A discussion of future challenges, including new reuse methodologies such the adoption of more generic models of the world (e.g. schema.org) that can be extended with our proposed ontologies (Section 4)

2. Related work

In certain parts of Humanities, CIDOC-CRM⁴ and FRBR⁵ are the first ontologies that spring to mind when thinking of ontologies for humanities research. In other parts, working with ontologies is still new and the complexity of the carefully constructed is overwhelming. Moreover, despite the wide use of CIDOR-CRM and FRBR ontologies, they do not cover all relevant concepts that come into play in humanities research. As both these models stem from the archival world, their core strength is to describe objects, but, as the next few sections will show, people and language are also core objects of study in humanities research, and as such require different conceptual models. Various methodologies to strengthen the reuse and quality of these ontologies exist. Besides the aforementioned FAIR principles [28], Ontology Design Patterns [39] propose a directory⁶ of “small, task-oriented ontologies with explicit documentation of design rationales” that have shown to increase the quality in ontology design processes.

More recently, the workshops series on Humanities in the Semantic Web (WHiSe) have been organised as satellite events in Semantic Web conferences⁷. These are a relevant effort with strong ties to ontological modelling for humanities domains [10,11], especially regarding digital archives and libraries [12], historical records [13], musicology [14], and historical newspapers [15].

In a 2015 survey [1], authors analyse the joint work of historians and computer scientists in the use of Semantic Web methods and technologies in historical research, in particular ontologies modelling historical domains. They find and organise 13 ontologies and taxonomies in various areas of digital history such as genealogy, event modelling, geographical modelling, and support for representing change.

In [16], the authors survey the landscape of musical data on the Web. Their motivation is that despite the various possibilities of reusing musical data for analysis, combination, mixes, transformations, etc. of musical data, such reuses rarely happen. The survey aims at mitigating this by publishing its results as Linked Data⁸, finding in the process 12 ontologies and 2 schemas modelling musical data.

Here, we describe how in CLARIAH we contribute to this growing body of ontologies for the humanities, from the perspective of three basic pillars (structured data, linguistic data, and audiovisual data) and with a strong emphasis on reuse, collaboration, and sharing.

3. Ontologies in CLARIAH

In this section, we describe the ontologies developed in CLARIAH for the purpose of fulfilling the project goals regarding data interoperability. Our overview follows the “pillar” structure of the project, describing ontologies for structured data in Section 3.1 (in the domain of social economic history), unstructured data in Section 3.2 (in the domain of linguistics), and audiovisual data in

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⁴ http://www.cidoc-crm.org/
⁵ https://www.oclc.org/research/activities/frbr.html
⁶ http://ontologydesignpatterns.org/wiki/Main_Page
⁷ http://whise.cc/2020/
⁸ See https://github.com/enridaga/musow
Section 3.3 (in the domain of media studies). We conclude our description of the domain ontologies with a summary of our efforts to bridge these ontologies across domains in Section 3.4.

3.1. Social Economic History & Structured Data

CLARIAH’s work on structured data focuses on semantic interoperability of datasets in social and economic history. Within this field, quantitative analysis of registers and ledgers - among others - are extensively used to study the history of ordinary people [24]. Integrating and combining these datasets requires ontological representations of the domains they represent. Here, we describe the ontologies that we assembled to achieve this goal\(^9\) (Section 3.2.1), and present the tools that use these ontologies to solve data interoperability problems in the domain (Section 3.2.2)

3.2.1. Social and Economic History & Structured Data: Ontologies

Most historical quantitative datasets are indexes of official, institutional records of the past, such as national censuses, statistical national offices, and tax registers. Therefore, ontologies in social and economic history focus on modelling the concepts and properties of documents in such records, for example, occupations, vital events (birth, marriage, death, etc.), religious denominations, and so on. Nevertheless, a few crucial ontologies model aspects of the data that do not depend on the domain. The most common examples of these are the layout of the data, which allows historians to understand how the data was collected and ordered, as well as the organisation of the data in a general scheme.

**History of work.** Occupations are one of the key indicators in historical inequality research as it is commonly available for multiple centuries and in sources across the globe. To appreciate differences within occupations over time and across the globe international standards have been devised. The Historical International Standard Classification of Occupations (HISCO) categorises occupations by the activities of their incumbents, while the HISorical CAMbridge Scale (HISCAM) orders those categories based on the incumbents social interactions. In other words, HISCO allows for occupations over time and across the globe, while HISCAM orders the occupations within societies from ‘high’ to ‘low’. Currently, the community provides HISCO and HISCAM coded occupations in a lookup table as well as mapping files to code your own occupations.

In CLARIAH, WP4 created multiple versions of a vocabulary to use HISCO and HISCAM as Linked Data. The first version was very much oriented towards [SDMX Occupation ISCO-88 value list](https://github.com/CLARIAH/COW/blob/master/src/converter/util/namespaces.yaml), but this work appears to have been abandoned. This SKOS oriented version allowed for easy referencing towards multiple layers in HISCO and HISCAM using the skos:broader or even the skos:broaderTransitive relations and was attractive, because ISCO-88 could be seen as the contemporary equivalent of HISCO and thus modeling them in the same way made sense. Meanwhile there were discussions with the schema.org community on how to model occupational schema’s even generically, while allowing for occupational schema specificity\(^10\). This has led to the latest version of the HISCO and HISCAM schema (see Figure 1), which are fully represented via Schema.org. To describe the hierarchical structure of HISCO, we additionally borrowed from RDFS and OWL.

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\(^9\) Therefore, we limit ourselves to the ontologies and vocabularies that describe the domain; other ontologies are necessary to model technical aspects of the data, e.g. statistical dimensions, tabular structure, provenance, etc. For a complete list of vocabularies, see [https://github.com/CLARIAH/COW/blob/master/src/converter/util/namespaces.yaml](https://github.com/CLARIAH/COW/blob/master/src/converter/util/namespaces.yaml).

\(^10\) See e.g. [https://github.com/schemaorg/schemaorg/issues/2192](https://github.com/schemaorg/schemaorg/issues/2192) and [https://github.com/schemaorg/schemaorg/issues/2284](https://github.com/schemaorg/schemaorg/issues/2284)
Civil Registries. An important problem in social economic history deals with record linkage: finding the matching birth, marriage, and death certificates of individuals in historical civil registers. This is, in fact, a population reconstruction effort with many challenges, such as limited observational data, migration, spelling mistakes, acknowledgement of children, re-use of deceased sibling names, and so forth [7]. In WP4, we have taken up the efforts of the LINKS project to overcome these challenges, and link the appearance of the same person in 27.5 million birth (1812--1919), marriage (1812--1944) and death (1812--1969) certificates in the Dutch province of Zeeland [8]. Besides an effective, yet efficient, reconstruction of historical life courses and family connections, our contribution is an expressive model to universally represent civil registry data.

To model the civil registries data, we designed a simple ontology that reuses, whenever possible, existing vocabularies such as Schema.org and the Bio vocabulary. This model is presented in Figure 2 and has four main components:

1. **Civil registrations.** The first component (concepts coloured in brown) describes each civil registration (birth, marriage, or death certificate), listing its identifier, its sequential number, the location, and date of the registration.

2. **Life events.** The second component (in green) describes the actual life events (birth, marriage, or death event), listing the main individuals involved in this event, the location and the date of this event. In this model, a distinction is made between the civil registration and their associated life events, as certain civil registrations can be produced in different dates and locations from where the life event actually happened.

3. **Individuals.** The third component (in blue) describes each individual involved in these life events, listing their names, sex, civil status, and birth dates.

4. **Locations.** The final component (in orange) describes the location where each life event has happened and the location where it was registered. In this component, information regarding the municipality, the province, the region, and the country can be available.

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11 [https://iisg.amsterdam/en/hsn/projects/links](https://iisg.amsterdam/en/hsn/projects/links)
12 [http://schema.org](http://schema.org)
13 [http://vocab.org/bio](http://vocab.org/bio)
**Figure 2. Schema of the LINKS Knowledge Graph**

**Historical Religions.** Many historical records and registers, such as censuses,\(^\text{15}\), describe the religious affiliations of individuals and groups. Throughout the centuries, many different religious denominations have appeared. However, these denominations are represented in the original datasets in different ways and levels of detail, e.g. Confucianism and Ruism, or the various subcategories of Islam (Suni, Shia, etc.) or Christianity (Catholic, Protestant, Orthodox, etc.). These changing denominations pose a challenge to researchers in the field, who need unambiguous ways of defining religious denominations for comparative analyses.

To address this, we developed the Linked International Classification for Religions (LICR). This Classification Systems is a taxonomy that organises historical religious denominations into 131 categories and subcategories; and provides mappings to various other well known religious classification systems, such as IPUMS, NAPP, and HL7. These mappings are expert-made; an excerpt is shown in Figure 3. In addition, LICR is enriched with links to equivalent DBpedia resources, providing each of these categories with additional linked resources and machine-readable descriptions. LICR is built on top of (1) the unique religion identifiers of these systems, adding unique identifiers of its own; and (2) the Linked Data design principles [17], therefore producing a unique dereferenceable URI for each of these identifiers. The taxonomy itself and the relationship between taxonomic concepts is modelled through the SKOS vocabulary ([https://www.w3.org/2004/02/skos/](https://www.w3.org/2004/02/skos/)). LICR and all its mappings are available at [https://datasets.iisg.amsterdam/dataverse/LICR](https://datasets.iisg.amsterdam/dataverse/LICR) and as part of the Druid database.\(^\text{16}\)

\(^{14}\) For a higher resolution see [https://github.com/CLARIAH/wp4-civreg/blob/master/schema/LINKS-schema.png](https://github.com/CLARIAH/wp4-civreg/blob/master/schema/LINKS-schema.png)

\(^{15}\) [http://volkstellingen.nl/nl/index.html](http://volkstellingen.nl/nl/index.html)

\(^{16}\) See [https://druid.datalegend.net/dataLegend/LICR](https://druid.datalegend.net/dataLegend/LICR)
CEDAR and Tabular Layouts. Interpreting the layout of historical documents is an important mechanism historians use to assess their authenticity, and to interpret the knowledge they contain. A classic example of such documents, in the form of statistical tables, are the Dutch historical censuses (1795-1971). In these, the state counted the entire population of the Netherlands and aggregated various variables in three different census types: demography (age, gender, marital status, location, belief), occupations (occupation, occupation segment, position within the occupation), and housing (ships, private houses, government buildings, occupied status). This is a vital and singular dataset in Dutch history: it is based on counting the whole Dutch population, instead of sampling; it provides a great level of detail, hardly comparable to modern censuses due to privacy regulations; and little trace remains of the original survey microdata on which it is based. The dataset is available as a collection of 507 Excel spreadsheets, containing 2,288 census tables.\(^\text{17}\)

The CEDAR project\(^\text{[34]}\) produced a Linked Data version of this dataset, publishing more than 6.8 million statistical observations using the RDF Data Cube vocabulary,\(^\text{18}\) Web Annotations,\(^\text{19}\) and PROV for provenance recording.\(^\text{20}\) In addition, we engineered the Tablinker vocabulary for the representation of table layout in RDF; this was needed in order to enable machines to interpret correctly the roles of table cells and produce a coherent knowledge graph. Figure 4 shows an example of usage of this vocabulary to mark cell roles. For example, tablink:DataCell (marked in white color in Figure 4) is used to indicate observation values. These values are linked to their corresponding column (tablink:ColHeader) and row (tablink:RowHeader) headers, enriching their descriptions. Additionally, we create resources that describe the column and row headers, their types, labels, cell positions in the spreadsheets (tablink:Metadata) and hierarchical parent/child relationships with other headers (tablink:HRowHeader).

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\(^{17}\) http://volkstellingen.nl/nl/index.html

\(^{18}\) https://www.w3.org/TR/vocab-data-cube/

\(^{19}\) https://www.w3.org/TR/annotation-vocab/

\(^{20}\) https://www.w3.org/TR/prov-primer/
3.2.2. Social Economic History & Structured Data: Tools

To use the ontologies described above for solving interoperability challenges, we integrate them in different tools for use in case studies from social and economic history. In this subsection, we provide descriptions of these tools and their use of the above ontologies in specific scenarios.

CLARIAH Data stories (https://stories.datalegend.net/). This tool aims to provide users with a means to narrate stories based on their Linked Data. Specifically, the tool combines text directly written by users, with visualisations resulting from SPARQL queries executed in real time against a Linked Data triplestore. In this way users can for example write an article about growth and inequality in economic history, providing figures and data plots directly generated from integrated linked datasets.21

CLARIAH Data stories use ontologies precisely as a means to integrate the underlying datasets directly via SPARQL. By clicking on the big up/down arrow, users can switch between seeing the data visualisation and the SPARQL query data produces it, as shown in Figure 5. In this SPARQL query, ontologies are directly used to combine datasets that use them to describe their data. In addition, the queries can be executed against various SPARQL endpoints, adding the possibility of combining not only datasets that were originally non-interoperable, but also datasets published elsewhere on the Web behind the same Linked Data principles.

21 See example at https://stories.datalegend.net/growthAndInequality/
Figure 5. Use of ontologies in queries of a CLARIAH Data story.

Druid ([https://druid.datalegend.net/](https://druid.datalegend.net/)). Druid is a state-of-the-art, highly scalable triplestore by Triply\(^{22}\) based on the HDT (header dictionary triples) technology [35]. The use cases and ontologies of WP4 served as an incubator for its design, which today powers the TriplyDB engine.

In Druid, the ontologies of the previous section play a primary role in diverse Linked Data browsing and interaction tasks. For example, Druid recognises certain classes, properties and values such as polygons and pictures, and adequately renders them in the browser. Figure 6 shows an example of this for the Almenum historical municipality, recognising the polygon shapes in the properties og:hasGeometry and og:AsWKT and appropriately rendering a map.

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\(^{22}\) Triply is a spin-off company from CLARIAH started up by former CLARIAH researchers from the Vrije Universiteit Amsterdam; see [https://triply.cc/](https://triply.cc/)
Druid’s browser recognises ontology classes and properties that require specific interaction and rendering components, like maps and images.

**Figure 6.**

COW ([https://pypi.org/project/cow-csvw/](https://pypi.org/project/cow-csvw/)) and cattle ([http://cattle.datalegend.net/](http://cattle.datalegend.net/)). Making Linked Data in RDF out of CSV files is one of the main objectives of WP4. CSV files, especially in social economic history, can be arbitrarily large and small and require a mapping to current ontologies and vocabularies to describe the data they contain. This is the purpose of COW (CSV on the Web), an efficient library and CLI for CSVW compliant CSV to RDF conversion, and its web service version cattle.

COW and cattle incorporate references to all ontologies surveyed in the previous subsection. Users can compose so-called CSVW schema files, where they can specify mappings between the headers and contents of their CSV files, and the classes and properties defined in these ontologies, among other options. The Linked Data that results from this process is therefore highly interoperable by means of reusing these ontologies across various datasets.

**grlc** ([https://github.com/CLARIAH/grlc](https://github.com/CLARIAH/grlc)). grlc leverages the social context of shared SPARQL queries, such as the endpoint they are directed to, their parameters, and their human-readable descriptions; to automatically generate Linked Data APIs. These APIs can be easily reused by humans and machines to access a large variety of Linked Data sources and Knowledge Graphs. A public instance of grlc is available at [http://grlc.io/](http://grlc.io/)

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23 [https://www.w3.org/TR/tabular-data-primer/](https://www.w3.org/TR/tabular-data-primer/)
grlc uses a variety of ontologies: internally, it uses PROV\(^24\) for provenance capture; externally, it processes every ontology used by SPARQL queries in their PREFIX clauses to augment the descriptions of queries. Furthermore, the APIs it generates provide a homogeneous access layer to Linked Data, enabling not just a semantic interoperable layer (through reuse of ontologies) but also an interoperable querying layer (through a common interface between SPARQL endpoints, RDF data dumps, Linked Data Fragments servers, RDFa/HTML pages etc.

**Directory of Humanities ontologies (“Awesome ontologies for DH”).** With a growing number of DH knowledge graphs, ontologies that are relevant for modelling DH concepts and relations tend to scatter and fragment. For example, the various domains that economic and social history deals with --as we have seen in the previous ontological efforts-- cover heterogeneous and disparate domains: history of work, demography, life events, religious beliefs, etc. The various ontologies and vocabularies that semantically describe these domains are difficult to track and manage. Therefore, finding adequate ontologies on the Web is hard; without structured ontology repositories, there is a risk DH scholars will write new ones for domains already covered; or stretch the use of existing ontologies out of their intended use.

For this reason, we started an initiative to build a sustainable repository of ontologies for Digital Humanities,\(^25\) utilising the distributed version control system git and the GitHub portal as underlying infrastructure. Git was chosen for four various reasons: (1) DH scholars typically work in the distributed collaboration networks for which git is specifically designed; (2) more DH researchers are acquiring programming skills, and therefore feel more comfortable with version control systems; (3) there is a growing trend to collate so-called ‘awesome’ lists, a principled way of collaboratively compiling topic lists using git tools; and (4) this is a relatively low cost solution compatible with the budget and funding limitations of DH projects. So far, four contributors have committed 23 links to ontologies and vocabularies in 5 categories.

### 3.2. Linguistics & Language Technology

Many sources relevant to humanities scholars are in textual form \([19]\). The linguistics work package in CLARIAH Core focused on developing tools for linguistic analysis. The different subprojects in this work package can be divided into two categories: technology for linguistics and computational linguistics for other humanities disciplines. The latter category includes for example tools to semantically analyse historical texts. In CLARIAH Core, both categories were addressed in one work package, in its successor, CLARIAH Plus, this was separated into two work packages.

Within linguistics research, many standards exist to express enrichments of texts. Even for a fairly standardised task such as part-of-speech tagging,\(^26\) dozens of tagsets exist \([18]\). Some of these tagsets only discern the base categories of words, others also include other grammatical information such as the case, number or tense. For other enrichment layers, such as named entities and semantic roles, also various standards exist. It is not the purpose of CLARIAH to reconcile all these standards, but to provide a shared means to work across these standards. The connection to core semantic web ontologies is less strongly developed than in the social and economic history & structured data work package, for two reasons: 1) the scope of this work package was broader, with more partners; and 2) more ‘legacy’ tools and resources that needed to be adapted.

For the purposes of this book chapter, we focus on two main aspects of interoperability that are explicitly implemented in the CLARIAH linguistics and linguistic technology work package: 1) diachronic linked data lexicons (ontologies); and 2) linguistic annotation formats (tools).

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\(^{24}\) [https://www.w3.org/TR/prov-primer/](https://www.w3.org/TR/prov-primer/)

\(^{25}\) [https://github.com/CLARIAH/awesome-humanities-ontologies](https://github.com/CLARIAH/awesome-humanities-ontologies)

\(^{26}\) Part-of-speech tagging is task concerned with assigning types such as noun or verb to words
3.2.1 Linguistics & Language Technology: Ontologies

Within CLARIAH Core, the researchers in the linguistics work package have started modelling diachronic lexicons as linked data to further their interoperability and use in different projects. Diachronic lexicons are dictionaries that describe how the meaning of certain terms has changed over time. Various CLARIAH partners, such as Meertens Institute and the Dutch Language Institute, have a long history of creating and maintaining such dictionaries, but these did not always find users outside linguistics. By adopting a linked data approach, terminological knowledge can be connected more easily to non-terminological resources, adding context from a linguistic perspective.

As a starting point for modelling diachronic linked data, six lexicons were converted [31]. These lexicons cover various topics such as plant names (Pland) and embodied emotions, but through evolution in meaning of concepts described in these lexicons shared contexts can be identified. Furthermore, the aim of this exercise was also to show that these different lexicons could be described using a shared data model.

The model uses Lemon - Lexicon Model for Ontologies [33] where possible and extended with concepts necessary to describe the temporal scope of a word sense. Figure 7 represents the CLARIAH diachronic lexicon model.

![Figure 7. The CLARIAH diachronic lexicon model](image)

[32] further developed diachronic LOD lexicons by the conversion of DiaMaNT, a digital historical language infrastructure. Where in [31] lexical senses were assigned to time periods, this work aggregates senses through attestations, or observed use of the language. This provides an additional etymological provenance trail for the linguistic context of terms.

3.2.2 Linguistics & Language Technology: Tools

Text enrichments are typically encoded through some form of XML annotation [23]. Many different formats are used among different research initiatives in computational linguistics, and some efforts have focused on aligning or mapping between different formats (cf. [20]).

Within the CLARIAH project, two linguistic annotation formats are used. These formats were developed in the context of prior research projects and were adopted into the CLARIAH infrastructure because they are the predominant formats in the text analysis tools adopted and further developed in
CLARIAH. The main reason to discuss linguistic standards here, is that they provide the bridge between the raw data (text) and semantic layers that connect these data to other (LOD) resources.

The **NAF format** is a stand-off XML annotation format that combines strengths of the Linguistic Annotation Framework (LAF) and the NLP Interchange Format [21]. It was developed at the Vrije Universiteit Amsterdam in the BiographyNet and the NewsReader projects (in collaboration with Fondazione Bruno Kessler in Italy and the University of the Basque Country in Spain). It was developed from a need to connect semantic annotation layers to linguistic annotation layers, and has a serialisation to RDF for ingestion into a knowledge graph.

Figure 8 shows a sample of a NAF annotation for an entity in a text. The entity id indicates that it is the 24th entity that is identified by the named entity recogniser. The header of the NAF file provides a reference to which named entity recogniser was used, which version and when it was run. The span indicates that terms 437 to 439 in the text correspond to this entity. The term layer is defined further up in the document. The comment on line 14830 provides a human readable reference, in this case ‘City of London’. Through an entity linker, references to external resources that provide more information about this entity can be encoded. NAF allows multiple references to be defined, even coming from different entity linkers. In this example, DBpedia spotlight v1 is used, and the confidence the tool had in its reference is provided too. Further processing can use the information ‘as is’ or it can be reused and additional layers can be specified that for example aim to encode the best proposed reference.

```xml
<entity id="24" type="06">
  <references>
    <reference>
      <span>City of London</span>
    </reference>
    <reference>
      <target id="437"/>
    </reference>
    <reference>
      <target id="438"/>
    </reference>
    <reference>
      <target id="439"/>
    </reference>
  </references>
  <externalReferences>
    <externalRef confidence="3.807143E-39" reference="http://dbpedia.org/resource/City_of_London_School" resource="en" source="spotlight_v1"/>
    <externalRef confidence="9.45119E-38" reference="http://dbpedia.org/resource/City_of_London_Elections_to_the_Parliament_of_England" resource="en" source="spotlight_v1"/>
    <externalRef confidence="4.389597E-28" reference="http://dbpedia.org/resource/Flag_of_the_City_of_London" resource="en" source="spotlight_v1"/>
    <externalRef confidence="1.905465E-27" reference="http://dbpedia.org/resource/City_of_London_UK_Parliament_constituency" resource="en" source="NAF"/>
    <externalRef confidence="4.842958E-26" reference="http://dbpedia.org/resource/City_of_London_Policce" resource="en" source="spotlight_v1"/>
    <externalRef confidence="5.916195E-23" reference="http://dbpedia.org/resource/Royal_Exchange_London" resource="en" source="spotlight_v1"/>
    <externalRef confidence="1.29019E-13" reference="http://dbpedia.org/resource/London_Delphia" resource="en" source="spotlight_v1"/>
    <externalRef confidence="1.138233E-8" reference="http://dbpedia.org/resource/City_of_London_Corporation" resource="en" source="spotlight_v1"/>
    <externalRef confidence="8.021894E-4" reference="http://dbpedia.org/resource/London" resource="en" source="spotlight_v1"/>
    <externalRef confidence="8.321909E-4" reference="http://dbpedia.org/resource/London_police" resource="en" source="NAF"/>
    <externalRef confidence="5.021909E-4" reference="http://dbpedia.org/resource/London_police" resource="en" source="NAF"/>
    <externalRef confidence="8.089835E-4" reference="http://dbpedia.org/resource/City_of_London" resource="en" source="wikipedia-db-nlEn"/>
    <externalRef confidence="8.978039E-4" reference="http://dbpedia.org/resource/City_of_London" resource="en" source="wikipedia-db-nlEn"/>
  </externalReferences>
</entity>
```

*Figure 8. Example of NAF annotation*

The **FoLiA format** is a mixture of an inline and stand-off XML annotation format. It was first and foremost developed with the focus of storing and exchanging textual resources (including large corpora) in mind [22]. Its development started in the context of CLARIN-NL, DutchSemCor and OpenSoNAR at Tilburg University and was continued at Radboud University. Figure 9 provides an overview of the FoLiA architecture.

Within the CLARIAH project, a **conversion tool** between NAF and FoLiA was created. However, as new features are still added to each of these formats, the formats are sometimes out of sync in what they can encode, and subsequently the tool cannot always convert all layers of one format into the other.
It should be noted that NAF and FoLiA are less focused on describing the form of a text, as TEI is, but rather the linguistic and semantic characteristics of the words. However, both NAF and FoLiA encode some text shape characteristics such as paragraph, sentence and word boundaries. Mappings and tools exist to convert a subset of TEI to FoLiA.

![FoLiA Architecture Diagram](https://proycon.github.io/folia/)

**Figure 9.** FoLiA architecture (source: https://proycon.github.io/folia/)

### 3.3. Multimedia & Media Studies

Media Scholars typically are interested in heterogeneous multimedia data sets and that they want to investigate the various sources together [2]. These include radio, and television broadcasts as well as amateur and professional film material. Next to this, contextual sources such as newspapers, broadcasting guides, historical data and even social media content are explored and analysed to investigate a wide variety of research questions about media and how it has shaped and still shapes society. As a lot of these sources are time-based media combining images and sound, to make these sources findable and accessible, they need to be enriched with textual and structured metadata. This is done either by hand (through professional annotation or crowdsourcing) or through automated methods such as speech or image recognition.

Within Clarih WP5 Media, the main product is the MediaSuite [3], which bundles multiple forms of search and browsing. A selection of the possibilities: searching in collections, collection inspection, putting together interesting facets on the collections, defining your own projects and making annotations. One of the largest data sources is the catalogue of the Netherlands Institute for Sound and Vision (NISV). In addition to the NISV catalog, the MediaSuite includes the KB’s newspaper collection, the DANS oral history collections and several Open Images collections. All data in the MediaSuite is indexed as a full text document, with one or more suitable types selected for each field. After the collections were imported, normalization was carried out where necessary, for example when personal names fields contained other information or when date fields contained other free text.
The current development aims at least to make the NISV collections available in RDF, so that the collection can be better connected and cross-collection and domain questions can be asked.

3.3.1. Multimedia & Media Studies: Ontologies

**Simple Event Model (SEM)** As media scholars often look at (media) events, we needed a model that is able to express a variety of events. SEM allows for the representation of events, actors, locations and temporal descriptions [6]. One of its features is that it is a very basic event-centric model, but more complex relations between, for example, events and persons (such as the role that a person plays in an event) can also be expressed. Its mappings to CIDOC-CRM or LODE increase the usability of this ontology.

**SKOS**[^27] is used to represent concepts from structured vocabularies, including the GTAA (Common Thesaurus for AudioVisual Heritage),[^28] which is a core vocabulary in our tool, as it is one specifically to describe (Dutch) audiovisual material and is shared by a number of AV archives in the Netherlands.

**Dublin Core**[^29] is used for the descriptive metadata of the objects.

**W3C Web Annotation Model** We use this Model[^30] to model user annotations, both from expert users, and resulting from crowdsourcing initiatives.

**NISV ontology** From 2006 to 2018, a catalog management system (CMS) was developed within the NISV that ties in with the main processes of registration, digitization and access to a large number of audiovisual items. The system, iMMix, had a data model derived from FRBR, a model widely used in the library world that distinguishes works, manifestations and realizations in a hierarchy. The iMMix data model has adopted this hierarchical form in a modified version with work, series, season, program and segment. In mid-2018, the NISV switched to a new catalog management system, called DAAN, which is an adapted version of the VizOne product from VizRT. All metadata hierarchies in Viz One use metadata fields based upon the Dublin Core Metadata Initiative (DCMI). Where iMMix was built roughly around the programs, the DAAN model is built around the physical carriers, called items, that can be part of a program, which can be part of a season, a series. The work level has been dropped. The DAAN model also contains the notion of log track items that describe additional, mostly time-coded metadata such as annotations and transcriptions.

The existing NISV data models are modelled in an RDFS scheme. Another approach could be re-using a widely used ontology and expressing the NISV data in that model. The benefit of the current approach is that the RDFS scheme for the NISV data is as close to the original data as possible, while the option remains open to express the classes in a different ontology by using rdfs:subClassOf and the properties using rdfs:subPropertyOf. The NISV thesaurus is already described using the SKOS ontology and therefore the classes that are tied to the controlled vocabularies of the thesaurus are defined as SKOS concepts using the rdfs:subClassOf relation. Further mappings to other desired target models (including schema.org, ebuCore[^31] / pbCore[^32] or Europeana Data Model [45]) are planned for.

[^27]: https://www.w3.org/2004/02/skos/
[^28]: https://old.datahub.io/dataset/gemeenschappelijke-thesaurus-audiovisuele-archieven
[^29]: http://dublincore.org/documents/dcmi-terms/
[^30]: https://www.w3.org/TR/annotation-model/
[^31]: https://www.ebu.ch/metadata/ontologies/ebucore/
[^32]: https://pbcore.org/
Part of the DAAN model are the subtitles, that are provided by the broadcaster for the deaf and hearing impaired. An additional source of metadata are the transcriptions provided by the automatic speech recognition. These have proven to be very useful for researchers when indexed for search. Partly due to the fact that loading the 'core' metadata initially brought with it some serious problems, this type of ‘additional’ time-based metadata was left out of the initial knowledge graph. Transcriptions and annotations are comprehensive across the entire catalog and would therefore be of an order of magnitude too large to manage directly. For most of the problems solutions are engineered, so future plans definitely include loading additional enrichment datasets.

One thing that needs a little further elaboration is the introduction in the NISV schema of an rdfs:Class that defines both an acting entity and a role in which it acts. Existing models include classes such as Agent or Role, which do not provide exactly the structure needed to express the NISV data properly. For example, an audiovisual item has a maker, a specific person. Here, the person is the ‘acting entity’ within the role of ‘creator’. Also, the organisation responsible for the production is the

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**Figure 10.** Partition table of the NISV Ontology (image produced with Ontospy)

| Concept | Acting entity | Organisation |
|---------|---------------|--------------|
|         | Broadcast station | Person |
|         | Broadcaster | |
|         | Genre | |
|         | Language | |
|         | Location | |
|         | Music style | |
|         | Subject | |

| Entity in a role | Cast | Programme commissioner |
|------------------|------|-------------------------|
|                  | Creator | |
|                  | Funder | |
|                  | Original Artist | |
|                  | Producer | |
|                  | Guest | |
|                  | Sponsor | |

| audiovisual object | Playable audiovisual object | Programme |
|--------------------|----------------------------|-----------|
|                    | Season | Programme section |
|                    | Series | |

| Entity with duration | Programme | Programme section |
|----------------------|-----------|-------------------|
|                      | Publication | |
|                      | Programme section | |

| Distributable Entity | Publication | |
|----------------------|-------------| |
|                      | Series | |

| Recording or Publication | Publication | |
|--------------------------|-------------| |
|                          | Recording | |

| Sequence Member | Carrier | Programme section |
|-----------------|---------|--------------------|

| Context | Language usage | Nationality | Rights | Target group | Title |
|---------|----------------|-------------|--------|--------------|-------|

**Figure 11.** The 39 classes in the initial NISV data model (the 140 properties are not shown)
‘acting entity’ in the role ‘producer’. The rdfs:subClassOf the nisv:EntityInRole can be, for example, an nisv:Speaker. This class can have a blank node instance that is linked to the audiovisual item using the nisv:hasSpeaker property that has the nisv:Speaker as rdfs:domain.

This way, an overload of roles within the person record can be avoided and it is easier to replace or sub-class the nisv:Person with schema.org/Person later. A person can be an editor in one program and also a speaker in the next show. Using an entity-in-a-role we get a unique combination of a person (or organisation) and a specific role in the context of the program or item.

**Figure 12. The EntityInRole class in the new NISV RDFS scheme.** (Documentation generated with Ontopsy)

### 3.3.2. Multimedia & Media Studies: Tools

**CLARIAH MediaSuite.** The CLARIAH Media Suite is a research environment and core facility provided by this work package. It brings together data and tools in a virtual workspace for researchers interested in (Dutch) media. It facilitates access to key Dutch audio-visual and contextual collections with advanced mixed media search and analysis tools. The Media Suite includes tooling to

a) Inspect data using critical methods and various views on collection metadata

b) Provide faceted search options for distant reading, corpus selection and close reading and
c) Provides an exploratory browser, to facilitate serendipitous discovery

**Exploratory linked media browser** The above mentioned exploratory browser is based on the DIVE tool, where items from various collections are linked through shared vocabularies and ontologies [4]. To make an interconnected knowledge graph which can be used for exploratory search, we employ various strategies for enrichment: We establish mappings from collection-specific metadata to generic terms for each of the collections. This ensures that queries on this generic level (such as retrieving a textual description for an item) return relevant results from each of these collections. Using alignment services such as Cultuurlink ([http://cultuurlink.beeldengeluid.nl/](http://cultuurlink.beeldengeluid.nl/)), we establish correspondences between the persons, places and events found in our enrichments and structured vocabularies [5].
3.4. Intra-WP Interoperability

To investigate how the developed ontologies and tools would perform in practice, CLARIAH invited researchers from outside the consortium to propose pilot projects in which CLARIAH technology could be put to the test. This resulted in 16 CLARIAH research pilot projects of €60k and a runtime of at most 1 year, and 4 Accelerating Scientific Discovery in the Arts and Humanities (ADAH) projects, a collaboration between CLARIAH and the Netherlands eScience center, in which CLARIAH technology was tested in projects totalling an investment of €100k + 1.5 full time equivalent expertise from one or more eScience center research engineers over the course of 18 months. In addition, the Amsterdam Time Machine project was funded as an accelerator project that spanned all work packages in connection to the European Time Machine project.

These projects have proven to be very beneficial to CLARIAH as they provide insights into the strengths and limitations of the developed ontologies and tools. They have the additional benefit of involving humanities researchers outside the consortium as first adopters of the technology and the potential for a broader CLARIAH community.

3.4.1 Ontologies

In the CLARIAH Amsterdam Time Machine, three use cases focusing on Amsterdam from each of the CLARIAH work packages were connected through a historical geographical infrastructure. The core idea of the project was to answer a research question on inequality is to connect each piece of

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33 [https://clariah.nl/en/projects/research-pilots/the-call-for-proposals/the-call/research-pilots-the-call](https://clariah.nl/en/projects/research-pilots/the-call-for-proposals/the-call/research-pilots-the-call)
34 [https://clariah.nl/en/projects/adah-projects](https://clariah.nl/en/projects/adah-projects)
35 [https://www.timemachine.eu/](https://www.timemachine.eu/)
36 [https://amsterdamtimemachine.nl/hisgis-clariah/](https://amsterdamtimemachine.nl/hisgis-clariah/)
information from the different use cases to a specific place and time. This generates multiple information layers on a map, allowing scholars investigating for example sociolects to easily take into account tax information as an additional indicator of status.

Figure 14 provides a schematic overview of how different information sources are grounded in space and time. The difficulty in this and any other historical urban project, is the fact that addresses change over time. Streets appear and vanish, just as house numbers are extended or remunerated.

The space-time integration was made possible via the space-time-prism model [41], in their paper exemplified via CO2 measurements. Just as in the CO2-case, where there is a certain ‘ping’ indicating the time, location and value of the measurement, the HISGIS\(^{37}\) project specified ‘pings’ via a fixed set of location points (that can be expanded on by others)\(^{46}\). The location points have a geographical representation, a time indication (year), and the address as value. Hence, sources mentioning this value can be directly linked to the location point, allowing for multiple datasets to be combined. For example, in the linguistics use case, Amsterdam dialects were investigated, for which the diachronic lexicon model described in subsection 3.2.1 was used [31]. Through the space-time-prism model, we were able to study to what extent there was overlap in the social and economic position of individuals (modeled via HISCO and HISCAM) and the social economic prestige of Amsterdam dialects [40]. In addition to a geographic representation, the lexicon allowed us to link words to a particular dialect, and next linked these to interviews of elderly persons having lived in Amsterdam, to get a feel for what a particular dialect sounded like.

\(^{37}\) https://hisgis.nl
The basis for the CLARIAH diachronic lexicon model [32] was also reused in the Diamonds in Borneo project [38]. In this project, the causes and consequences of the circulation of people, commodities and ideas in a globalising world are investigated through the automatic analysis of large historical newspaper corpus from the Dutch National Library.38

3.4.2 Tools

Various research pilots and ADAH projects revolve around text, for which the tools from the linguistics work package were put to the test. In the EviDENce project, historians wanted to analyse oral history records and ego documents (e.g. letters, diaries) to trace how the concept of violence changed over time. The project made use of various tools, such as the CLARIAH WP3 Robust Semantic Parsing pipeline, which for example outputs NAF text annotations and SEM events, in combination with prior processed data from Nederlab which is formatted in FoLiA. Over the course of the project, the team found that the fine-grained level of linguistic analysis was too detailed for the research questions [37] and text analysis at paragraph level was investigated and finally evaluated with users. These results confirm that adapting ontologies and tools across domains is difficult and further support the splitting of linguistic analysis in CLARIAH Plus into two work packages.

38 https://delpher.nl
4. Future challenges

At the start of the CLARIAH project, WP4 technical lead Rinke Hoekstra coined some practices in economic history research as throw-away-science [43]. A message that hit home and we subsequently used to advocate Linked Data to our colleagues. Just like the disposable cameras from the 1990s, datasets would only be used once, and sit on someone’s hard drive forever, even after paper publication. The core of this chapter shows that within CLARIAH, just as in other DH projects across the globe, a lot of effort is put in making data reusable, either by re-using ontologies of others or by creating explicit vocabularies to describe one’s own data and allow others to contribute similar data.

Despite the advance in the use of ontologies, the obvious challenge of negotiating alternative ontologies to describe similar entities remains. In CLARIAH, we organized two community workshops regarding the use of vocabularies to describe data on persons.39, 40 One aim of the first workshop was to highlight and appreciate different use cases (and choices for ontologies) to describe persons (e.g. FOAF, DBpedia ontology, schema.org, etc.). The other aim was, as a community, to decide on one particular vocabulary, to always describe just the fact that someone was a person, in addition to any vocabulary that one would ordinarily use. The community was not ready for such a decision. Nevertheless, it appears as if there is ground to reach such a decision, as a year after, people were asking for a follow-up of the workshop, as they had thought of the first one as useful.

A second future challenge that we want to underline, although implicitly part of an ontology, is the lack of common data models being reused. Sometimes there are alternative ways to describe data, for example, whether to use SKOS, RDFS or OWL to describe hierarchical data39, or different approaches to model geographical data over time [42]. Just as with ontologies, common use and reuse of data models is an important aspect to further the degree by which DH exchanges data.

To tackle both these issues, we advocate both grassroots and a top-down approach. A first initiative that we recommend to people in DH is to add the ontologies they use to the ‘Awesome Humanities Ontologies’42, which is part of the awesome-list-initiative on GitHub43 (see Section 3.2.2 for a detailed description). While repositories such as Linked Open Vocabularies44 provide alternative ontologies and even an indicator of generic use, the Awesome Humanities Ontologies could provide a domain-friendly alternative. Moreover, if the initiative would extend by allowing for mentions of projects using those vocabularies, it would grow into a ‘reputation system’ showing the more and less popular ways to describe data over time.

A second grass root initiative that we advocate is the way Menno den Engelse and Leon van Wissen have created (and present) their Reconstructions and Observations in Archival Resources (ROAR) ontology.45 ROAR explicitly borrows (imports) terms from existing, general purpose ontologies, such as SEM, PROV and schema.org. However, in cases where ‘general purpose’ is too broad a brush to describe content (e.g. trailing patronyms as part of a name), domain specific vocabularies are used, such as the PNV vocabulary46 for historical names.

39 Workshop notes, courtesy of Ivo Zandhuis, July 31st, 2018, http://tiny.cc/u47emz
40 Workshop slide deck, courtesy of Ivo Zandhuis, June 24, 2019, http://tiny.cc/lb8emz
41 https://www.w3.org/TR/vocab-data-cube/
42 See https://github.com/CLARIAH/awesome-humanities-ontologies
43 See https://github.com/sindresorhus/awesome
44 http://lov.linkeddata.es
45 https://leonvanwissen.nl/vocab/roar/docs/
46 https://www.lodewijkpetram.nl/vocab/pnv/doc/#
Our third recommendation is top-down. For some the choice for a data model or ontology is a deliberate process. However, based on our community sessions, we believe that some people have no preference for one vocabulary over the other and simply would like to have a recommendation. CLARIAH, or any other project for that matter, could therefore advocate the use of specific ontologies and data models to support inter-work package coherence. If we were to make such a recommendation\(^\text{47}\), it would be along the lines of:

- use schema.org where possible;
- use vocabularies from awesome-humanities-ontologies for specifics;
- use Linked Open Vocabularies for all else.

We advocate schema.org because of its wide range and its ability to adapt to community requests as shown in the HISCO case. However, it will not cover domain specific needs. Awesome-humanities-ontologies is an open list where anybody can learn and advocate such domain-specific vocabularies. If neither of those options would work, Linked Open Vocabularies provides many vocabularies and ontologies outside of the domain, including a recommender system based on common use of the vocabularies.

5. Conclusion

In this chapter, we have summarized the efforts within the CLARIAH project to engineer ontologies and tools for DH using Semantic Web technologies. These tools were developed to achieve interoperability and enable broadly quantitative research in linguistics, social and economic history, media studies, and DH as a whole. In the light of some major milestones, such as the models, tools and use cases described in Section 3.4; queries that can now gather and provide data across multiple datasets from various domains; and initiatives such as the “awesome ontologies for DH”; we can conclude that our decentralized, yet controlled Knowledge Graph development practices have contributed to increase interoperability in DH.

In total, we have used 26 different ontologies, taxonomies, classification systems and lexicons. Of these, 6 were engineered from scratch to model new DH domains, while 20 were reused or converted. Many such reused ontologies and vocabularies, like RDFS, OWL, PROV, SKOS and schema.org, apply not just to DH but to broader contexts; while others, such as BIO, IPUMS, HISCO and HL7 are more strictly related with DH domains. But, despite this reuse, our ecosystem is still highly fragmented, which signals the difficult challenge of collaborative ontology engineering even in highly controlled environments. At least, 26 ontologies are currently used for DH research in the Netherlands. A large number of ontologies can be both a strength and a weakness; on the one hand, they are all needed to model their specific domains, but, on the other hand, more ontologies also imply larger integration costs. In other words, a huge degree of standardisation and, concomitantly, interoperability without loss of information is possible with ontologies and vocabularies; but at the cost of relying on a large number of different ontologies.

To increase interoperability further, our current challenge is to find a solution to working with these different ontologies. In order to address this fragmentation and increase coupling, integration, and reuse, we have applied a number of methodologies. For example, including ontology linking workshops. These workshops have also given us input on another important aspect of projects dealing with Semantic Web technology and Knowledge Graphs: usability. In general, we observe that users without Semantic Web knowledge find these technologies hard to use, and find high value in tools like Data Stories (see Section 3.1) that enable their engagement. Consequently, we can only emphasize the importance and need of more and more usable tools that specifically target the goals of

\(^{47}\) [https://twitter.com/rlzijdem/status/1189825493811519488]
concrete communities --in our case, the analytical and quantitative answering of DH research questions for DH scholars. In this sense, usability is not just important in a tool context, but also in a modelling context. General schemas like schema.org might be a powerful tool for ontological cooperation due to a number of reasons: (a) such general schemas have a higher chance of being picked and used by large search indexes, enabling their appearance --and therefore larger chances of findability and reuse-- in global tools like e.g. Google Dataset Search; (b) one central vocabulary that covers a large portion --e.g. 80%-- of a community’s modelling needs feels more convenient to users; and (c) even if that coverage is not perfect, such vocabularies might add the required little semantics to go a long way [36]; and (d) these vocabularies can be extended with our ontology ecosystem to reach a satisfactory specialization level. Therefore, prioritising vocabularies seems to be the best solution to the necessity of the different ontologies. Given the community interaction and collaboration in workshops and projects, such as exemplified by the CLARIAH pilots and ROAR vocabulary, we believe that the domain as a whole will move towards a more homogeneous use of ontologies and vocabularies.

References

1. Albert Meroño-Peñuela, Ashkan Ashkpour, Marieke van Erp, Kees Mandemakers, Leen Breure, Andrea Scharnhorst, Stefan Schlobach, Frank van Harmelen. “Semantic Technologies for Historical Research: A Survey”. Semantic Web — Interoperability, Usability, Applicability, 6(6), pp. 539–564. IOS Press (2015)
2. Bron, M., Van Gorp, J., & De Rijke, M. (2016). Media studies research in the data-driven age: How research questions evolve. Journal of the Association for Information Science and Technology, 67(7), 1535-1554.
3. Carlos Martinez-Ortiz, Roeland Ordelman, Marijn Koonen, Julia Noordegraaf, Liliana Melgar, Lora Aroyo, Jaap Blom, Victor de Boer, Willem Melder, Jasmijn Van Gorp, Eva Baaren, Kaspar Beelen, Norah Karrouche, Oana Inel, Rosita Kiewik, Themis Karavellas and Thomas Poell. "From tools to “Recipes”: Building a media suite within the Dutch digital humanities infrastructure CLARIAH." 2017.
4. De Boer, V., Oomen, J., Inel, O., Aroyo, L., Van Staveren, E., Helmich, W., & De Beurs, D. (2015). DIVE into the event-based browsing of linked historical media. Journal of Web Semantics, 35, 152-158.
5. Victor de Boer, Liliana Melgar, Oana Inel, Carlos Martinez Ortiz, Lora Aroyo and Johan Oomen. Enriching Media Collections for Event-based Exploration. In: Garoufaliou E., Virkus S., Siatri R., Koutsoniha D. (eds) Metadata and Semantic Research. MTSR 2017. Communications in Computer and Information Science, vol 755. Springer, Cham
6. van Hage, W.R., Malais, V., Segers, R., Hollink, L., Schreiber, G.: Design and use of the Simple Event Model (SEM). Web Semantics: Science, Services and Agents on the World Wide Web 9(2), 128-136 (2011)
7. Mandemakers, K., Laan, F. “LINKS dataset Genes Germs and Resources, WieWasWie Zeeland, Civil Certificates, version 2017.01. International Institute of Social History, Amsterdam (2017)
8. Joe Raad, Rick Mourits, Auke Rijpma, Ruben Schalk, Richard Zijdeman, and Albert Meroño-Peñuela. “Linking Dutch Civil Certificates”. In: 3rd Workshop on Humanities in the Semantic Web (WHiSe), ESWC 2020 (under review) (2020).
9. Maks, E., van Erp, M. G. J., Vossen, P. T. J. M., Hock- stra, R. J. and van der Sijs, N. (2016). Integrating Diachronous Conceptual Lexicons through Linked Open Data (pp. 1–2).
10. Alessandro Adamou, Enrico Daga, Leif Isaksen (eds.). WHiSe 2016, Humanities in the Semantic Web. Proceedings of the 1st Workshop on Humanities in the Semantic
Web, co-located with 13th ESWC Conference 2016 (ESWC 2016). Anissaras, Greece, May 29th, 2016. CEUR-WS.org, online http://ceur-ws.org/Vol-1608/

e11. Alessandro Adamou, Enrico Daga, Leif Isaksen (eds.). WHiSe 2017, Workshop on Humanities in the Semantic Web. Proceedings of the Second Workshop on Humanities in the Semantic Web (WHiSe II), co-located with 16th International Semantic Web Conference (ISWC 2017). Vienna, Austria, October 22, 2017. CEUR-WS.org, online http://ceur-ws.org/Vol-2014/ 

12. Tommaso Di Noia, Azzurra Ragone, Andrea Maurino, Marina Mongiello, Maria Paola Marzoza, Giuseppe Cultrera, Mauro Paolo Bruno. Linking data in digital libraries: the case of Puglia Digital Library. In: Proceedings of the 1st Workshop on Humanities in the Semantic Web (WHiSe), ESWC 2016, pp. 27--38 http://ceur-ws.org/Vol-1608/#paper-05

13. Esko Ikkala, Mikko Koho, Erkki Heino, Petri Leskinen, Eero Hyvönen, Tomi Ahoranta. Prosopographical Views to Finnish WW2 Casualties Through Cemeteries and Linked Open Data. In: Proceedings of the Second Workshop on Humanities in the Semantic Web (WHiSe II), ISWC 2017, pp. 45--56 http://ceur-ws.org/Vol-2014/#paper-06

14. Terhi Nurminko-Fuller, Kevin R. Page. A linked research network that is Transforming Musicology. In: Proceedings of the 1st Workshop on Humanities in the Semantic Web (WHiSe), ESWC 2016, pp. 73--78 http://ceur-ws.org/Vol-1608/#paper-09

15. Marieke Van Erp, Thomas van Goethem, Katrien Depuydt, Jesse de Does. Towards Semantic Enrichment of Newspapers: A Historical Ecology Use Case. In: Proceedings of the Second Workshop on Humanities in the Semantic Web (WHiSe II), ISWC 2017, pp. 39--44 http://ceur-ws.org/Vol-2014/#paper-05

16. Marilena Daquino, Enrico Daga, Mathieu d'Aquin, Aldo Gangemi, Simon Holland, Robin Laney, Albert Meroño-Péñuela, Paul Mulholland. Characterizing the Landscape of Musical Data on the Web: state of the art and challenges. In: Proceedings of the Second Workshop on Humanities in the Semantic Web (WHiSe II), ISWC 2017, pp. 57--68 http://ceur-ws.org/Vol-2014/#paper-07

17. Tom Heath and Christian Bizer (2011) Linked Data: Evolving the Web into a Global Data Space (1st edition). Synthesis Lectures on the Semantic Web: Theory and Technology, 1:1, 1-136. Morgan & Claypool.

18. Petrov S, Das D, McDonald R (2011) A universal part-of-speech tagset. arXiv:1104.2086v1

19. Jockers, Matthew L., and Ted Underwood. "Text-mining the humanities." A New companion to digital humanities (2015): 291-306.

20. Sebastian Hellmann, Jens Lehmann, Sören Auer, and Martin Brümmer. (2013) Integrating NLP using Linked Data. 12th International Semantic Web Conference, 21-25 October 2013, Sydney, Australia.

21. Antske Fokkens, Aitor Soroa, Zuhaitz Beloki, Niels Ockeloen, German Rigau, Willem Robert van Hage and Piek Vossen. 2014. NAF and GAF: Linking Linguistic Annotations. In: Proceedings 10th Joint ISO-ACL SIGSEM Workshop on Interoperable Semantic Annotation. Reykjavik, Iceland.

22. Maarten van Gompel, Ko van der Sloat, Martin Reynaert, Antal van den Bosch (2017). FoLiA in Practice: The Infrastructure of a Linguistic Annotation Format. In: CLARIN in the Low Countries. Eds: Jan Odijk and Arjan van Hessen. Pp. 71-81.

23. Wilcock, Graham. "Introduction to linguistic annotation and text analytics." Synthesis Lectures on Human Language Technologies 2, no. 1 (2009): 1-159.

24. Ruggles, S., & Magnuson, D. L. (2019). The History of Quantification in History: The JIH as a Case Study. Journal of Interdisciplinary History, 50(3), 363-381.

25. Haigh, Thomas. "We have never been digital." Communications of the ACM 57, no. 9 (2014): 24-28.

26. Renckens, Erica. "Digital humanities verfrissen onze blik op bestaande data." E-Data & Research 10 (2016).
27. Collins, Francis S., Michael Morgan, and Aristides Patrinos. "The Human Genome Project: lessons from large-scale biology." Science 300, no. 5617 (2003): 286-290.
28. Wilkinson, Mark D., Michel Dumontier, JIlsbrand Jan Aalbersberg, Gabrielle Appleton, Myles Axton, Arie Baak, Niklas Blomberg et al. "The FAIR Guiding Principles for scientific data management and stewardship." Scientific data 3 (2016).
29. Gruber, Thomas R. "Toward principles for the design of ontologies used for knowledge sharing?." International journal of human-computer studies 43, no. 5-6 (1995): 907-928.
30. Garijo, Daniel, Pinar Alper, Khalid Belhajjame, Oscar Corcho, Yolanda Gil, and Carole Goble. "Common motifs in scientific workflows: An empirical analysis." Future Generation Computer Systems 36 (2014): 338-351.
31. Maks, E., van Erp, MGI, Vossen, PTJM, Hoekstra, RJ & van der Sijs, N 2016, 'Integrating Diachronous Conceptual Lexicons through Linked Open Data'. In: DHBenelux 2016. Belval, Luxembourg.
32. Katrien Depuydt and Jesse De Does (2018) The Diachronic Semantic Lexicon of Dutch as Linked Open Data. In: Globalex 2018 Workshop: Lexicography and Wordnets. 7-12 May. Miyazaki, Japan.
33. John P. McCrae, Julia Bosque-Gil, Jorge Gracia, Paul Buitelaar and Philipp Cimiano (2017) The OntoLex-Lemon Model: development and applications, Proceedings of eLex 2017, pp 587-597.
34. Meroño-Peñuela, Albert, Ashkan Ashkpour, Christophe Guéret, and Stefan Schlobach. "CEDAR: the Dutch historical censuses as linked open data." Semantic Web 8, no. 2 (2017): 297-310.
35. Fernández, Javier D., Miguel A. Martinez-Prieto, Claudio Gutiérrez, Axel Polleres, and Mario Arias. "Binary RDF representation for publication and exchange (HDT)." Journal of Web Semantics 19 (2013): 22-41.
36. Hendler, J. (2013). A little semantics goes a long way. URL: http://www.cs.rpi.edu/~hendler/LittleSemanticsWeb.html [November 24, 2014].
37. Hogervorst, S., Brugman, H., Buitinck, L., van Erp, M., Klijn, E., Kouw, W., de Vos, M. and Willemsen, J. (2018). The Event-Detection GAP: Manual vs. automatic event detection in historical research.
38. Karin Hofmeester, Ashkan Ashkpour, Katrien Depuydt, and Jesse de Does (2019) Diamonds in Borneo: Commodities as Concepts in Context. In Proceedings of the 3rd International Conference on Digital Access to Textual Cultural Heritage (DAteCH2019). Association for Computing Machinery, New York, NY, USA, 45–50. DOI:https://doi.org/10.1145/3322905.3322924
39. Gangemi, Aldo, and Valentina Presutti. "Ontology design patterns." In Handbook on ontologies, pp. 221-243. Springer, Berlin, Heidelberg, 2009.
40. Nederlandse Dialectenbank. https://www.meertens.knaw.nl/ndb/ Date of last Access: April 3, 2020.
41. Kesßler, C., C.J.Q. Farmer. 2015. Querying and integrating spatial-temporal information on the Web of Data via time geography. Journal of Web Semantics, 35 part 1, 25-34.
42. Beek, W., & Zijdeman, R.L. (2018). nGis: A use case in linked historic geodata. In PSW4CH 2018 Semantic Web for Cultural Heritage 2018: Proceedings of the Third International Workshop on Semantic Web for Cultural Heritage (Vol. 2094). (CEUR Workshop Proceedings).
43. Hoekstra, Rinke, Albert Meroño-Peñuela, Auke Rijpma, Richard Zijdeman, Ashkan Ashkpour, Kathrin Dentler, Ivo Zandhuis, and Laurens Rietveld. "The dataLegend ecosystem for historical statistics." Journal of Web Semantics 50 (2018): 49-61.
44. Noy, Natalya F., Nigam H. Shah, Patricia L. Whetzel, Benjamin Dai, Michael Dorf, Nicholas Griffith, Clement Jonquet et al. "BioPortal: ontologies and integrated data resources at the click of a mouse." Nucleic acids research 37, no. suppl_2 (2009): W170-W173.

45. Doerr, Martin, Stefan Gradmann, Steffen Hennicke, Antoine Isaac, Carlo Meghini, and Herbert Van de Sompel. "The europeana data model (edm)." In World Library and Information Congress: 76th IFLA general conference and assembly, pp. 10-15. 2010.

46. Raat, Mark and R.L. Zijdeman. 2019. “HISGIS Amsterdam Location Points”, https://hdl.handle.net/10622/FHJJYK, IISH Data Collection, V3, UNF:6:P+a9TgaaGvAIA7T2K8NpCyQ==[fileUNF].