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HHT: An Ontology to Represent Territorial Dynamics for Digital Humanities

William CHARLES [b] and Nathalie HERNANDEZ [a,b]
[a] *Université Toulouse 2 Jean Jaurès, Toulouse, France*
[b] *IRIT, CNRS, Université de Toulouse, Toulouse INP, Toulouse, France*
ORCiD ID: Nathalie Hernandez https://orcid.org/0000-0003-3845-3243

Abstract. The notion of territory plays a major role in human and social sciences as it allows to anchor in a spatio-temporal context the facts studied in humanities. Representation of territories as spatio-temporal entities has been tackled in various ways. However, approaches for an historical context are scarce, as most approaches are designed for either a contemporaneous or case specific use. Notably, most ontologies used to represent territories are focused on spatial representation and do not intend to ecompass the impact of actors over said space, which happens to be a defining dimension of territories in humanities. In order to represent historical territories, we proposed a new version of the previously conceived HHT ontology (Hierarchical Historical Territory) to represent hierarchical historical territories and include actors representation. The resulting ontology encompasses the description of evolving territories, territorial divisions, explicit change representation, the will of actors to change established characteristics of territories and allows to represent territories without having to know their geometry by relying on a notion of building blocks to replace polygonal geometry.

Keywords.
territory ontology, evolution representation, actor dynamics, digital humanities, hierarchical territories

1. Introduction

Digital Humanities are a field of studies putting forward the use of computing science to facilite humanities research [1]. In this context, representing territories as they once were is a keen issue, as it is mandatory to anchor facts in a contextualized geography.The notion of *territory* does not boil down to a mere space area, which could be characterized by its geometry. The notion of territory encompasses the entanglement of a geographical area and actors having an influence over it, whether this action be normalized by managing institutions or enacted by informal actors, such as individuals. The notion of territory includes that of *territorial unit*, which corresponds to a territory defined by a territorial division and often involved in a hierarchy. Ontologies have been used in digital humanities due to their ability to build representation models fitting the needs of humanity researchers and to favour reusability and interoperability of the knowledge they produce [2]. When it comes to representing territories, existing ontologies focus either on representing hierarchical units [3] without representing the institutions they involve, mostly for statistical purposes, or on dynamics in regard mostly of natural resources [4]. However, properly representing historical territories involves the representation of both the established territorial hierarchies as well as actors' claims to alter them. Furthermore, the geometrical representation of historical territories can be challenging [5] as it is missing from the available historical data. It is to be noted that the typical representation of a territory used to be a list of places [6]. Another dimension of historical territories is their layered structure within multiple hierarchies. While current territorial hierarchies rely on a single territorial division, labeled as a *nomenclature* (example: INSEE nomenclature), contexts such as the Modern Period in France call for several hierarchy layers depending on the power dimension considered (religious, administrative, etc.) with several attached institutions. To the best of our knowledge, there is no ontology which explicitly grasps all these dimensions of territory representation. Thus, this paper proposes the HHT (Historical Hierarchical Territories) ontology[1] which aims to represent both territorial divisions and power dynamics and was developped as part of the digital humanities ObARDI project[2]. This ontology was designed in interaction with historians to address their representation needs in order to support their research. We detail how the needs to be met by the ontology impact its content, and expose the methodology adopted to design it before presenting its content in detail. The version detailed in this paper is a new version which builds on a first which focused on units and hierarchies [7]. The previous paper also described the issue of geometries and the way HHT manages this issue. The remaining of this paper is structured as follows. Section 2 tackles the competency questions that our ontology addresses and a literature review in regard of each considered representation aspect. Section 3 presents the HHT ontology. Finally, section 4 briefly reports some uses of this ontology that validate the design choices, notably in regard of change computation and possibilities of knowledge graph management.

2. Competency questions and state of the art

The overall goal of our work is to design an ontology that would encompass the description of hierarchical historical territories and the dynamics they are involved in. As such, the developed ontology will have to account for several representation dimensions. This section presents the different representation goals we aim to achieve with our ontology as requirements, as well as the way such representations are carried out in related works. Table 1 summarizes how related work was used as a base to fulfill our requirements.

2.1. Territorial division representation

Describing a territory implies to represent the territorial division it takes part in. Territorial divisions are implemented in order to facilitate the management of large areas in regard of various key dimensions of a country's activity. Thus, those divisions are a key feature of power dynamics. In addition, while a territory does not boil down to its spatial extent, it still is a defining trait that ought to be represented. This subsection tackles the representation needs in regard of those two dimensions when describing historical territories.

[1] https://www.irit.fr/recherches/MELODI/ontologies/HHTv2
[2] https://obardi.hypotheses.org/

2.1.1. Territorial Units Hierarchy

In regard of territorial hierarchy representation, we aim to achieve two goals : (i) Propose a hierarchy representation usable for any country; (ii) Represent historical territorial divisions. As mentioned in the introduction, while nowadays, states define territorial hierarchies intended to be used for every dimension of a country's activity, history provides examples where several hierarchies, each attached to a different dimension, coexist, as during the modern period in France [8]. In addition, some hierarchical levels can take part in several hierarchies. Finally, these hierarchies may lack in uniformity at country-scale, with some levels being replaced by others (possibly several) in some regions. We thus formulate the following requirements to be satisfied by the ontology:

R1 - *A territory can be involved in one or several hierarchical divisions.*
Which can be further divided as follows:

- **R1.1 -** *A territory involved in a hierarchy has a hierarchical level attached to this hierarchy.*
- **R1.2 -** *A hierarchical level can be part of several hierarchies.*
- **R1.3 -** *A hierarchy depends on an explicit criterion which can be seen as a dimension of a country's activity or a power dimension (administration, justice, taxation...)*
- **R1.4 -** *A hierarchy can not necessarily be represented by a layered hierarchical pyramid with one level per layer. Some layer may contain several levels, and some levels may span over several layers.*
- **R1.5 -** *Hierarchical levels may vary in different times and countries.*

Several approaches exist to represent multi-level territorial divisions. First, several country-specific ontologies have been developed (`geofla`[3], `igeo` [4] for France, `postcode` [5], `osadm` [6] for the United Kingdom, `RAMON`[7] for the NUTS nomenclature). These ontologies are limited in their use, as the concepts they define are only sufficient to represent hierarchies of a particular country. For example, one cannot describe Spanish territorial hierarchies using `igeo` as is. Country specific ontologies can be extended to represent a different context, especially when their focus is very abstract, such as for [9]. Typically, these ontologies define several classes representing various hierarchical levels and generic hierarchical relations which can link any kind of level. It thus can be extended by adding new classes for each new level you want to take into account. However, this implies to extend the ontology for every new context which does not favour interoperability. In order to achieve genericity, other ontologies provide generic classes useful to represent any hierarchial territorial organization. `JUSO`[8] tries to achieve it by providing a very wide array of concepts, intending to cover every hierarchical level that could be found in any context. However, the drawback of this concept collection is that the semantic of a term may vary depending on the context. The definition of a town, for example, can vary. In the United States alone, the demographic upper threshold for towns

[3]http://data.ign.fr/def/geofla
[4]http://rdf.insee.fr/def/geo
[5]http://data.ordnancesurvey.co.uk/ontology/postcode/
[6]http://data.ordnancesurvey.co.uk/ontology/admingeo/
[7]http://ec.europa.eu/eurostat/ramon/ontologies/geographic.rdf
[8]http://rdfs.co/juso/

varies between 500 and 4 999 inhabitants depending on the considered state. GeoNames[9] provides a purely abstract hierarchical structure, which is only limited in its size by the properties defined. It is only possible to link a place to the first four upper places using the parent relationship this ontology defines. In addition, GeoNames focuses on places, not on territorial units, meaning the feature classes proposed in the ontology are not hierarchical levels (ex: Commune, Municipality) but common sense concepts (ex: City). GeoSPARQL[10] and the ontologies from the SAMPO project [10] achieve genericity by considering only spatial relations, whether they be mereological or geometrical. They do not properly describe a territorial hierarchy, as a hierarchical unit could be geometrically included inside another without being subordinated to the latest, typically in the case of multiple overlaying hierarchies. Finally TSN [11] provides a generic approach to represent territorial division nomenclatures by relying on high level classes while relegating context specificity regarding levels to named individuals. However all these approaches describe hierarchies covering a whole territory according to a single nomenclature, which is commonly accepted in the current country structures. They are not designed to manage several overlaying hierarchies. In order to achieve **R1**, we build on TSN's approach by adapting its structure to meet R1.2, R1.3, R1.4 and R1.5.

2.2. *Territory evolution*

As our work aims to be used in a historical analysis context, it is mandatory to be able to represent territory evolution. The properties of a territory (name, spatial extent...) may change over time. Representation of change includes representing the successive states of a territory, identifying an identity criterion allowing to compare territories at different points in time, and explicitly representing the nature of the changes. These needs can be formulated as the following competency questions:

R2 - *The properties of a territory may vary in time.*

Which brings forward these subquestions:

- **R2.1 -** *A territory can have several states across time.*
- **R2.2 -** *Some changes induce a new territory, while others lead to a new state of the same entity.*
- **R2.3 -** *Several properties can evolve through a single change instance.*
- **R2.4 -** *Several changes can be part of a composite change.*

2.2.1. *Various states of a territory*

Following the intution that for example Paris in 1789 and Paris today both are the same entity despite its having changed across the years, we consider territories as perdurants [11] as defined in the DOLCE ontology [12]. DOLCE distinguishes perduring entities, whose temporal properties evolve, from endurants which retain the same properties during their whole existence. To represent such entities, [13] proposes a general conceptual framework distinguishing between SNAP (endurants) and SPAN (perdurants) ontologies in order to describe temporal entities. The 4D-Fluents approach [14] is also dedicated to represent perdurants [15], by representing entities as an ordered set of time slices. More precisely, while an instance p represents the entity itself, it is attached to several time

[9]http://www.geonames.org/ontology
[10]http://www.opengis.net/ont/geosparql

slices which represent its state at various points in time. This approach was recently extended to integrate statements in any contextual dimension [16]. TSN uses such an approach, which is legitimated by their representing territory nomenclatures defined by a central organism which seldom issues a new one [3]. TSN handles time-slicing by creating a new version of the whole hierarchy for every change occurring for any instance of this hierarchy. Note that the SAMPO approach [17], which uses ontology serialization, is similar in that it requires the replication of all knowledge whenever a change occurs in any territory. In an historical context, however, territories and their hierarchies tend to evolve without a centralized management. This is an issue, because as pointed out in [18], the main drawback of *Fluents* approaches is the multiplication of entities due to the multiple time-slices, which both increases the size of the dataset and makes reasoning more complex. Other approaches, such as Temporal RDF [19], rely on including time stamps directly on properties, which can be achieved using several techniques, including n-ary relations, named graphs, reification, or RDF-star [20]. However, these techniques retain the drawback of implying both a more complex representation and reasoning. To take into account R2.1, we adopt a fluents approach, which we use carefully to avoid over-slicing.

2.2.2. Territory Identity

Representing successive states of territories puts forward the need to be able to compare and match territories at various points in time, in order to be able to link several states as describing the same perduring entity. Comparing identities is complex in the case of spatio-temporal entities [21,22], as it involves to define *diachronic* criteria. When a synchronous criterion makes it possible to distinguish two entities at a fixed moment (simplistic example: two objects are identical if they occupy the same space), a diachronic criterion must, as for it, make it possible to distinguish two objects at different instants (example: two technical objects are identical if they have the same manufacturer and serial number). The definition of diachronic identity criteria, which are much more powerful than their synchronous counterparts (as a synchronous comparison is a particular case of a diachronic comparison where both compared object are existing simultaneously), is an extremely complex problem. Generally, identity criteria cannot be defined in an absolute way, and it is necessary to define them by trying to represent the available data as well as possible, adopting then an empirical approach (this is for example the case of the standard ontology for cultural heritage, CIDOC-CRM [2]). In the specific context of territories, the enunciation of a diachronic criterion is a particularly challenging task, which leads TSN to compare identities using metrics on names and geometries without formulating a semantic criterion [3]. The SAMPO project [17] proposes an evaluation of the identity of a territory on the basis of its name alone. If this choice is justified in the context of a purely geographical description of territories, historical research requires a refinement of this criterion (Constantinople and Istanbul are two different names, which designate the same city at two points in history). Recent works [22] focus on this notion of identity of a territory and put forward a difference between non-disruptive change (which does not affect the identity of a territory) and disruptive change (the new entity is a new territory). To satisfy **R2.2** we propose to take up the latter work to specify *a priori* the criteria that make it possible to differentiate these two types of change.

2.2.3. Explicit Change representation

In order to support historians' disciplinary practices, we aim to provide further change representation by explicitly representing the changes occurring between successive versions of a territory. SAMPO [5] proposes the notion of *Change Bridge* to link two territory time slices (*input* and *output*) to characterize the differences between them. They are further described using a lightweight spatiotemporal vocabulary, which is composed of five classes (*Changepartof, Establishment, Merge, Namechange, Split*). Such a representation can be further developed by considering multiple levels of abstraction when considering changes. For example, [23] introduces three levels of change representation: changes involving only one entity (such as an expansion), functional relations between two units (such as replacements), and composite changes (such as split or merge). A similar representation is used by TSN-Change [3]. However, it only retains the single-entity and composite change categories. TSN-Change adds more categories in regard of identity, with the distinction between *Continuation* (identities are not impacted) changes from *Derivation* (identities are impacted) changes [24]. It also defines a notion of *lowerChange* and *upperChange* which allows to define multiple levels of change. While the taxonomy of TSN-Change is wide-ranged, the semantics of the relations between changes are not precise (for example, *lowerChange* is both used to link changes between various territories and between a territory and a nomenclature). **R2.3** and **R2.4** will be achieved by combining a *fluents* approach with a change representation that bases on both TSN and [23] approaches.

2.3. Actors and dynamics

In order to capture the notion of territory, one needs to represent the actors and their influence over it. In humanities, actor designates any individual or group of individuals who can carry out actions.More precisely, the interactions with historians allowed to identify the following competency questions:
R3 - *A territory is impacted by actors.*
Divided into :

- **R3.1 -** *Actors can be part of organisations, where they can have various roles.*
- **R3.2 -** *Organization members and roles may vary in time.*
- **R3.3 -** *A territory can be managed by an actor.*
- **R3.4 -** *Actors may try to cause a change in the current territory states.*

Representing persons, groups of persons and relations between persons is a problem that has been tackled by various ontologies. `foaf` is a well-known ontology to describe persons and their relations. It defines a notion of `Group` and `MembershipClass` allowing to represent groups and roles of actors in groups. However it does not provide any notion of temporality when describing roles and organisation. CIDOC-CRM [2] provides the notions of `Person` and `Group` but does not define the nature of memberships, and the membership property are not meant to explicitly describe temporal evolution, as they are to state a current or former member. However, CIDOC-CRM provides a range of events regarding changes of organizations, whether it be in regard of their existence (`Formation` and `Dissolution`) or of their membership. Finally, the Organization ontology is a W3C recommendation when representing organizations. It provides a notion a temporally-stamped membership allowing to combine a person and its role in an organisation, and comes with an alignment with foaf. However, though it provides a notion of ChangeEvent to describe organization changes, it does not further describe those changes, which CIDOC-CRM events achieve. When it comes to the impact of actor on territories, the current focus of our work is to represent the will of actors to cause changes in the territorial status quo. To the best of our knowledge, there are few works in that regard. [25] provides a very rich overview for the particular case of territorial disputes. However, the developed model cannot be found which makes reusability impossible. Some event approaches, such as FARO[26] introduce notions such as the intention to cause an event to causally link two events. However, they rely on events only and do not allow to explicitly represent the will of actors. Actor representation will be addressed using the Actor concept of CIDOC-CRM which we enrich using the Organisation Ontology. Claim representation was designed through interactions with historians, as no satisfying basis could be found.

Requirement(s)	Elected Solution
R1	TSN structure adapted to fit our needs (cf 3.1)
R2.1-2	Adapted Fluents model with careful handling of slicing (cf 3.1)
R2.3-4	Change model and taxonomy derived from TSN and [23] (cf 3.2)
R3.1-2	Organization ontology aligned with CIDOC-CRM (cf 3.3.1)
R3.3-4	Original Design (cf 3.3.2)

Table 1. Requirements and solutions elected to fulfill them

3. The HHT Ontology for historical territories

3.1. Representing the territorial hierarchical division as a temporal entity

To sum up, historical territories require an ontology that would allow representation of multiple overlaying hierarchies and their evolution, without knowledge of the territories' geometry and would allow to grasp the various power dynamics impacting territories. In order to take into account all these particularities of historical territory representation, the HHT ontology was proposed. To properly address the various representation aspects we aim to achieve, this ontology was split into three modules: HHT (core of the ontology), HHT-Change to describe changes and HHT-Claim to represent claims. Figure 1 presents the territorial hierarchy representation proposed by HHT, which constitutes the core of the ontology. The notion of territory is declined through three classes and subclasses. hht:Territory qualifies geographical areas which are meaningful in a humanities context as they both encompass the notion of spatial extent and of interaction with actors. hht:Unit represents a territorial unit as defined in a territoral division and is a subclass of hht:Territory. Its subtype hht:ManagedUnit adds the notion of control by an actor which will be detailed in section 2.4. In order to address **R1.1-3** HHT defines hht:Level which categorizes a hierarchical level, and hht:HierarchicalCriterion which corresponds to the criterion related to a level (example: Religious) along with a hierarchy architecture inspired from TSN. The ontology does not include an explicit concept of hierarchy. The hierarchical criterion implicitly encompasses this concept, as we consider that a hierarchical criterion defines a

Figure 1. Schema of the HHT Ontology

single hierarchy in order to have a less verbose representation. **R2.1** and **R2.2** are tackled by applying a *fluents* approach. Instances of `hht:Territory` and `hht:Level` are bearers of the identity of the real world entities they represent. In order to represent their successive states, they are provided respectively with `hht:TerritoryVersion` and `hht:LevelVersion` through the dedicated `hht:hasVersion` subproperty. Each of these `hht:Version` has a `hht:validityPeriod` providing the time stamp of the described state relying on *OWL-Time*'s interval concept. A `hht:UnitVersion` (subclass of `hht:TerritoryVersion`) is a member of a level version which materializes its level in the hierarchy. Unit versions on a given level can be linked to its directly inferior/superior units that are members of the direct Sub/Upper level through the `hht:hasSubUnit` and `hht:hasUpperUnit` properties. This structure, along with `hht:EquivalentLevelTo`, allows to achieve **R1**. Note the existence of a super property for `hht:hasSubUnit`, `hht:contains` which merely denotes a geometric inclusion, and is thus transitive. This property is notably used to access the building blocks of a version, which are a feature we use to reason on geometry without any polygonal representation. This formalism is further discussed in [7]. Figure 2 presents a multi-level description of territories using HHT, and the `hht:contains` property. It omits validity periods, which are considered to be the same.

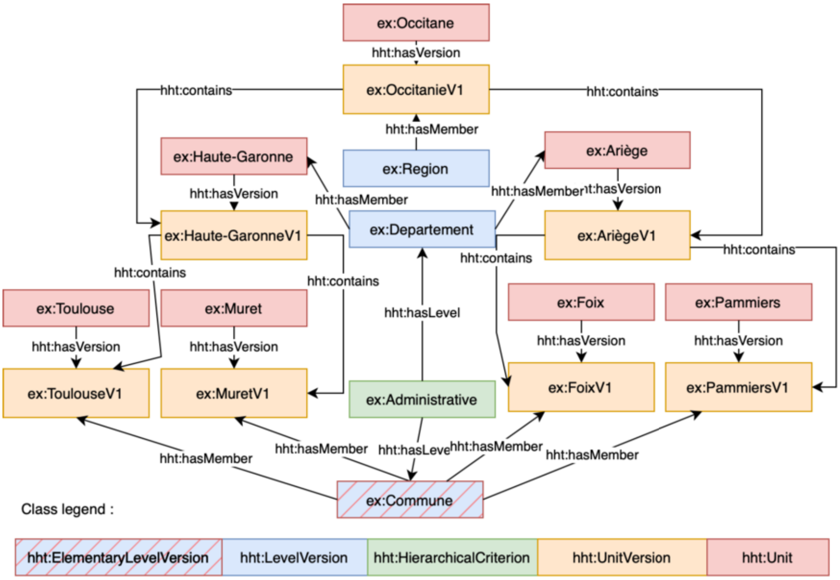
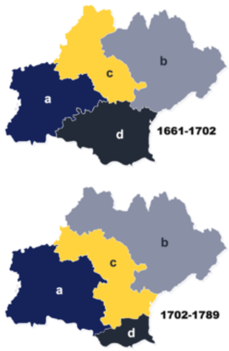


Figure 2. Simplified instance example, without validity period and using `hht:contains`

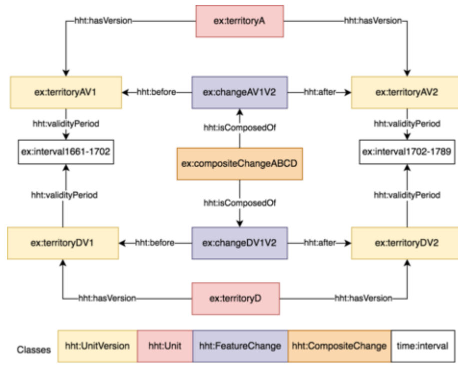
3.2. HHT-Change : Representing and qualifying changes

To tackle **R2.3-4** the HHT-Change module allows to explicitly represent changes that occur between versions. Change representation shares most of TSN change taxonomy [11]. However, the change description structure is quite different. While TSN-Change relies on a multi-level change genealogy, we distinguish between feature changes, which describe a change regarding a single change, and composite changes which are linked together using a mereology approach. A third subclass, `hht:UpdateKnowledge` allows to represent changes regarding the knowledge graph itself, as detailed in section 4.1. Figure 3 displays an arbitrary composite change, and figure 3b presents a simplified subgraph for territories A and D.

`hht:FeatureChange` represents a change involving two `hht:TerritoryVersion` of the same `hht:Unit`. The nature of the change can be further qualified using subclasses. These classes include attribute changes (`hht:NameChange`), geometry changes (`hht:GeometryChange`), which can further be qualified with subclasses, and life cycle related changes (`hht:Appearance`, `hht:Disappearance`). A `hht:FeatureChange` is linked to the two versions of the `hht:Territory` it involves through the relations `hht:before` and `hht:after`, as seen in figure 3b. As opposed to a `hht:FeatureChange`, a `hht:CompositeChange` is meant to represent a change that involves unit versions related to several `hht:Territory`. More accurately, the goal of the `hht:CompositeChange` class is to assemble several feature changes in order to make sense of those changes on a broader level. A subclass is defined for geometry alterations (`hht:GeometryRestructuring`). It is divided in three categories (split, merge, redistribution) which are further separated depending on their preserving the territories identity (continuation change) or not (derivation change). Figure 4 presents examples of these categories.



(a) Map representation of the composite change



(b) Subgraph for A and D

Figure 3. An arbitrary composite change

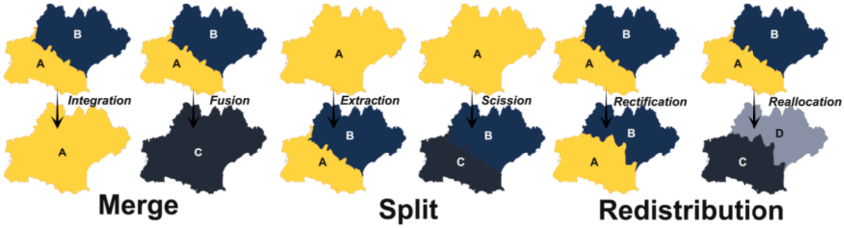


Figure 4. The various types of `hht:GeometryRestructuration`

3.3. Territories and actors

3.3.1. Institutions and other actors of territories

In order to fit our needs regarding **R3.1-2**, the Organization Ontology was selected as it fits most of our representation needs and is a semantic web recommendation. However, in a digital humanities context, it was necessary to align this ontology with CIDOC-CRM to favor interoperability. This notably improves the Organization Ontology base representation by adding the Group change taxonomy provided by CIDOC-CRM. While aligning, a choice was made regarding the organization themselves. While these may evolve through time, their most common changes revolve around membership changes, which can be represented using the time-stamped membership class of the Organization Ontology. It was thus elected to consider that Organization remained the same entity so long as their only changing feature was their member, and were transformed into a new organization whenever they go through another change, which appears to be the modeling choice of the Organization Ontology.**R3** is further addressed by adding the `hht:attachedTo` property which denotes a territory impacted by an actor. A subproperty, `hht:managedBy` is also defined to achieve **R3.3** and denotes an official management capability of an actor over a territory.

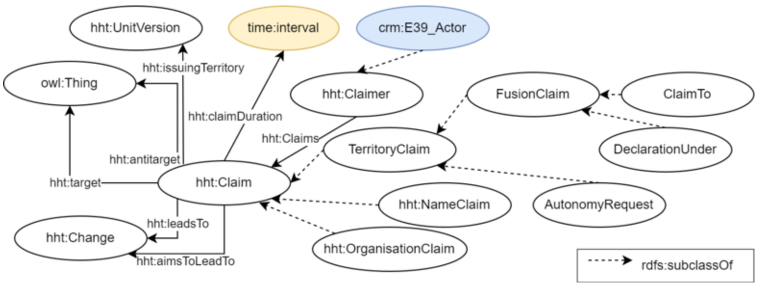


Figure 5. Scheme of the ontological module HHT-Claim

3.3.2. The concept of Claim

The humanities researchers wish to be able to capture the desire of territorial actors to enact changes (**R3.4**). This need is fulfilled by a module of the HHT ontology, dubbed HHT-Claim, the structure of which is given in figure 5. It focuses on the notion of *claim* (`hht:Claim`), which constitutes the will of an actor to upset the established order. These claims are accompanied by a temporal interval that indicates the period when this claim exists and are initiated by an Actor of a Territory (`hht:ClaimedBy`, `hht:issuingTerritory`). HHT provides two complementary and compatible ways to describe claims, one defining a claim taxonomy while the other allows to extend the range of claim representation. The first one relies on subclasses of Claim and generic properties. As it is a will to change a dimension of the territory, we provide a `hht:target` property that allows to define the object (different from the issuing territory) that is the finality of the claim. Note the existence of `hht:antiTarget` which allows to define claims that wish to oppose an aspect of the territory without putting forward a replacement solution. The exact semantics of the target (and anti-target) properties vary depending on the Claim class considered:

- `hht:ManagementClaim`: The will of an actor to change the managing actor of the issuing territory. The `hht:target` property denotes the actor that is to manage the territory.
- `hht:NameClaim`: The will of an actor to change the name of a territory. `hht:target` points to the intended name.
- `hht:FusionClaim`: a type of `hht:TerritoryClaim` which describes the case where actors from a territory wish to see it merged with another, denoted by `hht:target`.
- `hht:DeclarationUnder`: a type of `hht:FusionClaim` which describes the case where actors from a lower-level unit aim to become subordinate to a new upper unit, denoted by `hht:target`.
- `hht:ClaimTo`: a type of `hht:FusionClaim` which describes the will of actors from a higher-level unit to get dominion over another unit, denoted by `hht:target`.
- Autonomy Request (`hht:AutonomyRequest`): a claim by a lower territory position itself as a higher level territory. `hht:target` describes the intended level in the hierarchy.

A second model of Claim allows to attach a Claim to a `hht:Change` that will describe the change a Claim intends to cause. However, these `hht:Change` should be treated differently from the actually happening changes. We need to distinguish between entities that have an actual existence in the world and those that are only the result of thought experiments, which is tackled through the `hht:FactualObject` and `hht:DiscourseObject` classes. Note another property, `hht:leadsTo` which links to changes that are caused by a Claim. As the changes induced by the Claim may differ from the intended ones (in the case of a compromise typically), `hht:leadsTo` is not a subproperty of `hht:aimsToLeadTo`.

4. Practical use in the context of the ObARDI project

As mentionned in the introduction, the HHT ontology was designed as part of a digital humanities project, which focused on the French period of ”Ancien Régime” (1661-1789). As part of this project, the HHT ontology is being put to use in order to create a geographical knowledge graph. The graph is built incrementally, with a base knowledge graph being created by converting CSV files provided by humanity researches (using code resources available on our GitHub[11] and expanded by adding new versions that will correct the first rough description [7]). Though the HHT ontology has a wide expressivity, its practical use in a humanity project raises several issues. This section will present the challenges that were detected through the use of the HHT ontology in the ObARDI project.

4.1. Managing identities

As we use a *Fluents* approach, it is mandatory to be able to determine which version should be attached to which entity. For example, is it possible to consider that Istambul and Constantinople are two versions of the same territory? We thus needed to define a criterion allowing to state that two `hht:TerritoryVersion` describe the same entity. Building on the notion of disruptive change used in [22], we formulated a working criterion: *A new entity is created whenever the name changes alongside another property*. As such whenever a new version is added to the knowledge graph, this criterion will be used to determine whether this new knowledge should lead to a new entity being created or not. To manage exceptions to this criterion, historians should however be able to have the final word when it comes to identity, which leads this criterion to be defined outside the scope of the ontology.

4.2. Maintaining an incremental state of knowledge

In the ObARDI project, we develop an incrementally built knowledge graph. Indeed, historical knowledge is bound to be updated along with the progress of historical research. We thus propose the lifeline mechanism to maintain such knowledge graphs. The logic that presides the implementation of the lifeline is to consider that the last added information is necessarily the most valid. Therefore, as illustrated in figure 6, whenever a new version is added, if it contradicts one or more existing versions, we

[11] https://github.com/Brainchain09/HHT-SHACL

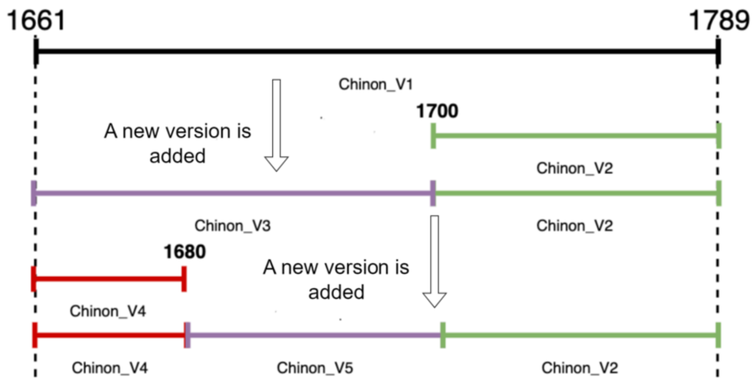


Figure 6. Different states taken by the life trajectory of a unit as the knowledge graph populates

fragment them in order to reconstitute a new timeline consistent with the last addition. Thus, when adding `Chinon_V2`, we create `Chinon_V3` which carries the same information as `Chinon_V1` but whose validity period is compatible with `Chinon_V2`. Note that to avoid over-slicing timelines, fragmentation is reported on upper territories only if it leads to a change of geometry. Moreover, the version mechanism that has been presented is, in order to keep track of knowledge evolution, enhanced by a notion of deprecation (`hht:isDeprecated`) which makes it possible to mark versions as obsolete while keeping them in the graph. Moreover, a subclass of change, `hht:UpdateKnowledge` can be used to link the previous state of knowledge to the one that leads it to be deprecated.

4.3. Computing and analyzing changes

Manually populating a knowledge graph with both the various versions of territories and the changes occuring between them is found to be an exhausting task. In order to make HHT more useful, we developed an algorithm that computes changes. An implementation using SHACLRules was carried out. This implementation, alongside several datasets described using HHT and a Python script to convert data from `.csv` tables to HHT-based knowledge graphs can be found on the GitHub resource. Note that these resources use the version of the ontology detailed in [7], and slight differences are to be expected.

5. Conclusion

The HHT ontology was developed to support the integration of geographical data in a digital humanities context. Not only does it allow to represent territories and territorial units involved in hierarchies without having any exact geometry representation, it also provides a representation of actors attached to territories and their will to impact it. In addition, it includes temporal representation, which allows to represent change implicitly and explicitly. This ontology is being used in the ObARDI project, as part of which tools were developed to allow humanities researchers to manipulate the ontology. In order to improve the current representation, further works will tackle the representation of the source of the represented knowledge, which is a key practice in social sciences. In addition, the current representation of claims does not explicitly encompass the legitimacy of actors to induce the underlying change, which could further improve the expressivity of the ontology.

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