HHT-Forest: A Module Based on HHT for Representing Temporally-Evolving Forests

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Abstract

Territory is a key concept across the human and social sciences. Capturing its spatial and temporal dimensions remains challenging. Existing methods for modeling territorial entities and their evolution rely on precise geometric descriptions—data that are generally absent from historical sources. To overcome this limitation, the HHT (Hierarchical Historical Territory) ontology has been developed, a framework that represents historical territorial structures and their hierarchies without relying on geometric information. In this article, we introduce an HHT module that provides a more precise representation of a specific type of territory: forests. HHT-Forest illustrates how the ontology can be extended to describe particular territories and explores how spatial, temporal and juridical data can be aggregated within the HHT framework. It was applied to a database compiled between 2010 and 2015 by historians to assess the impact on forests of the French reform of the Eaux et Forêts institution led by Louis de Froidour between 1665 and 1673 in Southwestern France.

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1. Introduction

The "Grande Réformation des Eaux et Forêts" (1661–1680) was a major administrative overhaul initiated by Jean-Baptiste Colbert, Louis XIV's Controller-General of Finances, to restore order to France's forest management. In their view, the forests had suffered from decades of mismanagement, illegal logging, and corruption. The reform aimed to reclaim royal authority, standardize forest management, to ensure the profitability of forests, to subdue the rural nobility, and secure timber supplies—particularly oak for the merchant fleets and royal navy, which was critical for France's military and economic power.

Louis de Froidour, a forestry expert and court officer, was appointed in 1666 as Commissaire réformateur for the vast Grande Maîtrise de Toulouse, which included the provinces of Languedoc, Guyenne and Béarn. His mission was to inventory forest properties, document abuses, and redefine territorial boundaries and usage rights. Froidour traveled extensively, producing maps and inventories that were sent to Colbert, revealing widespread corruption and usurpation of royal lands. An analysis of his reports also shows that the southern forest was not as degraded as the elites had thought.

From an administrative point of view, the reform reorganised the Eaux et Forêts in a more rational manner: a new territorial grid was drawn up in order to implement the ordinance of 1669 and the local regulations resulting from the reform. The reform is especially relevant for historical geography and territorial studies. The maps, inventories, and legal documents produced provide detailed snapshots of

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forest territories at a pivotal moment, enabling historians to track changes in land use, deforestation, reforestation, property rights, and administrative boundaries over time. The emphasis on sustainable logging and prioritizing oak for shipbuilding, commerce and industries reshaped forest landscapes, with lasting ecological and economic impacts. The uniformity of methods across regions allows comparative studies of how territories responded to monarchical centralization.

A database was established between 2010 and 2015 by Sébastien Poublanc as part of his PhD work [1], representing geolocated forests, the associated reform's trials, and related proposographical data about staff of the Eaux et Forêts deparment. The present paper presents an ontological module in order to enrich semantically this database, enabling queries that would not be possible otherwise. The new ontological module is based on HHT ontology [2], [3], which some of us developed. Thus, this work constituted also a use case for investigating how HHT could be used to analyze the evolution of territories and associated data. The HHT-Forest ontological module enables a more precise representation of a certain type of territory: forests.

Section 2 presents some work regarding historical territory representation and how HHT tackles it, as well as existing forest ontologies. Section 3 describes our methodology to develop HHT Forest. Section 4 presents the ontological module itself. Section 5 presents its alignment with BFO. Section 6 concludes.

2. Relevant former work

2.1. Representing historical territories and changes

Among the many issues arising when attempting to represent historical territories in digital humanities is their geometrical representation [4]. While it is common to use a vector geometry representation when tackling space-spanning entities [5], geometric data is often either missing or imprecise in historical data, which makes such approaches difficult to implement, whether it be for representation or reasoning about changes. Moreover, focusing on representing the geometry of territories might be considered as a representation bias: for example, back in the 18th century, the typical representation of a territory was a list of places [6].

Another dimension of historical territories that makes their representation intricate is their layered structure within multiple hierarchies. While current territorial hierarchies typically rely on a single division, defined by a nomenclature (example: INSEE in France), historical contexts such as the modern period in France require several hierarchy layers, each reflecting a distinct dimension of power (religious, administrative, etc.). Although several approaches exist to represent multi-level territorial divisions, whether context-specific (e.g., RAMON[1] for NUTS) or generic (e.g., TSN [7]), they all model hierarchies that cover an entire territory according to a single nomenclature. It is, for example, impossible to simultaneously represent both an administrative and a religious territorial division in TSN [4].

Representing historical territories requires accounting for temporal evolution. Upper-level ontologies traditionally distinguish endurants (or continuants) from perdurants (or occurrents). Endurants are wholly present at any time they exist, persisting through time by changing; they include animals, buildings and rocks. Perdurants are temporally extended, with only a temporal part at most existing at any time; thus, they do not change - rather, they are changes. Perdurants include dinners, lectures and trips. For historical territories, one can represent either the territory itself across time (an endurant) or its evolution process (a perdurant).

Several approaches have been developed to represent such entities. The Basic Formal Ontology (BFO) structures ontologies around SNAP, which deals with continuants, and SPAN, which deals with occurrents [8]. Temporal evolution of continuants can be described using temporally qualified continuants, that is, intuitively, continuants considered from a limited temporal perspective [9]. For example, chair0@i1 is the restriction of chair0 to the temporal region i1. The 4D-Fluents approach represents perdurants as a series of time slices [10] [11] capturing the entity's state at each point.

[1] http://ec.europa.eu/eurostat/ramon/ontologies/geographic.rdf

However, as pointed out in [12], this approach leads to a proliferation of dataset size and reasoning complexity.

TSN and similar approaches [13] create a new hierarchy version for each change, regardless of actual territorial evolution. This results in a proliferation of time-related entities in most cases.

Other approaches, such as Temporal RDF [14] rely on time stamping properties. This can be achieved using several techniques, such as reification, named graphs, n-ary relations or RDF* [15]. However, temporally variable entities increase the complexity of representation and reasoning.

2.2. The HHT Ontology for historical territories

To sum up, the representation of historical territories requires an ontology that would allow representation of multiple overlaying hierarchies and their evolution, without knowledge of the territories' geometry. The HHT ontology was proposed, based on the TSN ontology [7], but focusing on territorial units that can be characterized by different criteria (religious, administrative, etc.). Another difference with TSN is that HHT temporally versions the territories, rather than the whole hierarchy. Moreover, the default representation of territories does not rely on polygons, and it supports an algorithm to detect territorial changes.

Figure 1a shows HHT's core classes and relations (with object properties represented as arrows going from their domain to their range classes): `hht:Unit` (territorial unit), `hht:Level` (hierarchy level, e.g. Department, State) , and `hht:HierarchicalCriterion` (organizational dimension that motivates a hierarchy and its levels, e.g. Administrative). This class is a key difference with TSN, as it enables the coexistence of multiple hierarchy layers over a single geographic space.

Successive territorial states are represented via `hht:UnitVersion` through the `hht:hasVersion` subproperty. Unit versions are hierarchized the same way as units. Each `hht:Version` has a validity period (via `hht:validityPeriod`), an *OWL-Time*'s time interval, another key difference with TSN.

To limit the fragmentation of the unit's time slices, it was decided that new versions would be created only when a change in lower territories induces a change in the parent territory's geometry; thus, if a change in a lower territory would leave its parent territory's geometry intact, no new version of the latter would be created. Hierarchical relations (`hht:hasSubUnit` and `hht:hasUpperUnit`) are thus valid only during the intersection of the validity intervals of the `hht:UnitVersion` it links.

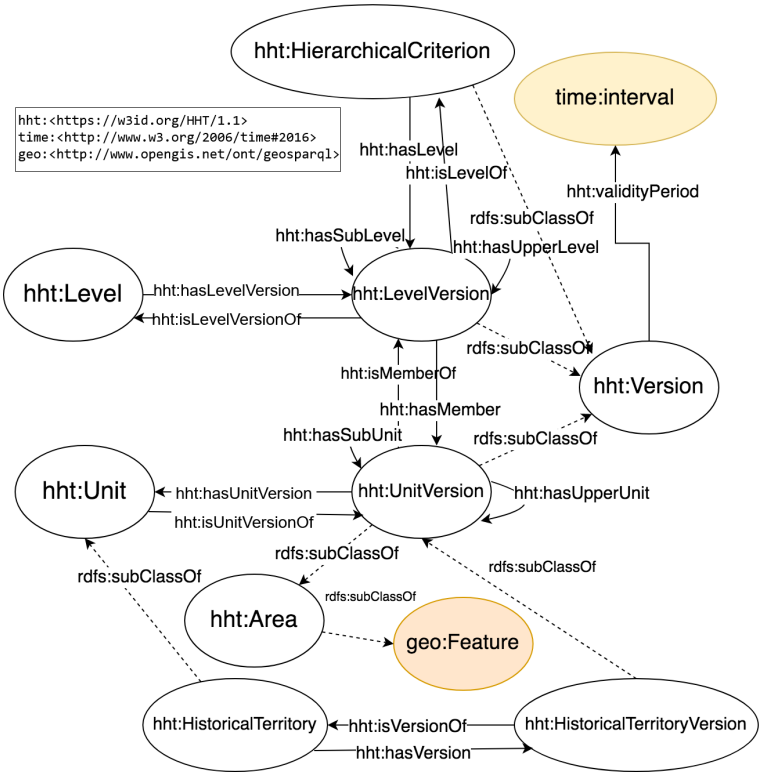
Figure 1b presents a multi-level description of territories using HHT, omitting validity periods (assumed identical across versions). Finally, the HHT framework includes HHT-Change and a rule-based algorithm for automatically detecting and qualifying changes between time slices in knowledge graphs using HHT.

2.3. Existing forest ontologies

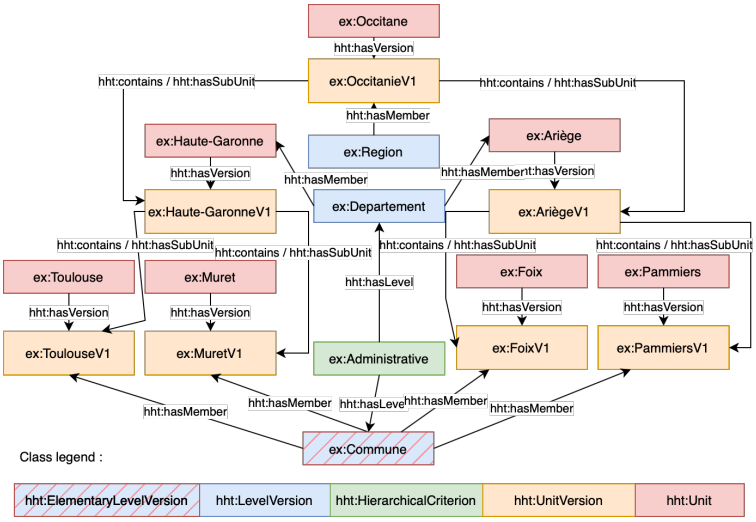
Some work has focused on the ontology of landscapes [16], analyzing them as space-time entities that evolve through interactions between human activities and the ecosystem. Several ontologies have addressed forests. In machine learning and computer vision, ontologies have been used to produce taxonomies of forests to complement purely-statistical approaches [17, 18], but are narrow-scoped and task-specific. Geographical ontologies, such as Ontomedia [19] and LinkedGeoData[20], include forests but do not describe their characteristics in detail. Recent work also includes sensor-based approaches to study ecosystems [21] or forecast forest fires [22]. However, the resulting models cannot be applied to human-observation based historical data.

Richer ontologies exist: an ontology encompassing plants, soil, and their interaction with human activities [23] and another focusing on how humans exploit the forest resources[24]. The Cross forest [25] ontology[2] and FEO [26] describe and represent forest environmental factors, with classes such as `LandManagement` or `PhysicalPhenomena`. Aligning with these concepts would favour knowledge reusability, but those ontologies view forests as either environmental entities or resource aggregates.

[2] https://github.com/Cross-Forest/Ontologies



(a) Schema of the HHT Ontology



(b) Simplified instance example using ex as an arbitrary prefix

Figure 1: HHT Ontology: classes and instanciation

They rely on detailed patterns reflecting current understanding, which may not match past actors' perspectives.

Additionally, the notion of territoriality, which is essential in the context of HHT, is absent from these ontologies. Specifically, forests are not understood as human-defined spaces with rights for managing human activities. Forest integration within other territories is scarcely addressed, although the Cross-forest ontology has been used to aggregate forest data to territories [27].

3. Methodology

3.1. The initial knowledge structure

The database of interest consists of three interconnected tables: “Forests”, “Trials”, “Prosopography”, with respectively 166, 54 and 66 fields for each record. A forest record (e.g. Comte forest) is associated with the lawsuits involving local residents (e.g. the inhabitants of Mantious, Boussens and Frechetas) and with the attached forestry personnel. The Forests table contains information about each forest, from surface area to wood type. The Prosopography table describes individual careers. The Trials table documents forest management trials, particularly cases of reformers judged for embezzlement. In the studied database, records are partially connected to sources: each entry references the archives and secondary sources used to establish its facts, but unfortunately without specifying which source supports each piece of information.

The database structure resulted from an iterative process spanning months of research, with the model extended as new significant information fields were identified. This process was facilitated by the reformation’s methodology: clerks systematically provided a common core of information. The database was populated by analyzing over 300 archival references, each containing hundreds of pages across multiple documents. The resulting database indexes 1,742 forests, 2,200 trials, a prosopography of 448 people, and 439 records on forestry institution history.

3.2. Ontology design methodology

The main challenge was balancing ontological considerations with pragmatism regarding what would be represented. The following methodology was used. First, the database was assessed to list involved entities. Then, through interactions with the historian, the most relevant entities were identified and competency questions were established. Entities were integrated with the existing HHT ontology. To strengthen the ontology’s foundations, terms were aligned with BFO (see section 5). The previous steps were carried out in an iterative fashion, with concepts discussed with the historian and validated against the database content at each step to reach the final iteration. The established competency questions are:

1. Which forests were surveyed by the Rey brothers between 1668 and 1669?
2. What is the total area of forest surveyed by Gabriel Rey?
3. Which tree species are most common, and where can they be found?
4. What are the most common forestry treatments?
5. Which woodlands had their Maîtrise Judiciaire changed during the reformation?

4. The HHT-Forest ontological module

4.1. Characteristics of a forest

HHT-Forest focuses on a specific type of territory, forests, with afforestation as the central notion: an area legally defined as a forest, regardless of whether it contains trees or shrubs. Figure 2 presents an overview of HHT-Forest, with object properties represented as arrows going from their domain to their range classes. Creating a new instance of hht:Level `afforestationLevel` would be sufficient to describe the inclusion of the forests within territorial hierarchies. However, to document forest-specific information (e.g., wood types), new classes were created: `hhtF:Afforestation` is introduced as a subclass of Unit, and `hhtF:AfforestationVersion` represents the evolution of afforestations.

Formally, a `hhtF:AfforestationVersion` is a UnitVersion whose level is a version of `hhtF:AfforestationLevel`. As a subclass of UnitVersion, it still can be included in territorial hierarchies, notably to describe which territory whose level is `Maîtrise Judiciaire` has dominion over it. Regarding the identity of afforestation through time, we retain the generic diachronic identity criterion of territories proposed for HHT [28].

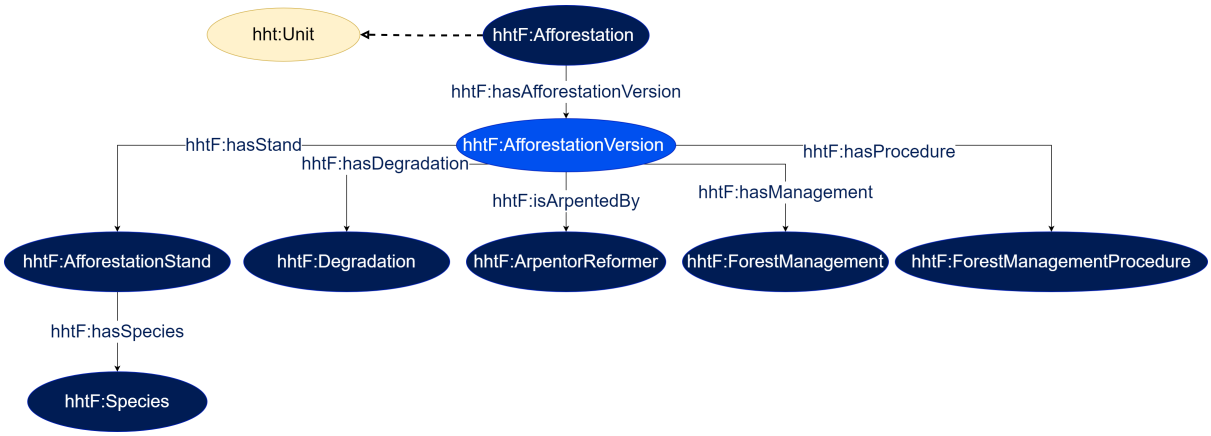


Figure 2: The key elements of HHT-Forest

The goal of this module is to describe forest characteristics. HHT-Forest can be used to describe forests, their states, the damage they undergo, and the forest management procedures in place. We define the following classes as follows:

- `hhtF:ForestManagement`: a collection of actions implemented to transform the `hhtF:AfforestationVersion` to achieve objectives such as wood production. Its characteristics are described using subclasses following the taxonomy established by [1]. For instance, a forest for which the clearing of an area was decided will be linked to an instance of `hhtF:EmptyPlaceManagement`. Data properties further document the management by detailing the ages of the considered trees.
- `hhtF:Degradation`: a process of change characterized by a negative alteration in the condition or quality of a woodland, such as a fire in the woodland, or overuse of the woodland by surrounding communities. A `hhtF:Degradation` is attached to the `hhtF:AfforestationVersion` it affects. Though it is a change, it is not a `hhtC:Change` as the latter are reserved for changes leading to a new territorial structure and thus to a new `hhtF:AfforestationVersion` being created.
- `hhtF:AfforestationStand`: a quality of an `hhtF:AfforestationVersion` characterizing one of its tree or shrub species, and for one of the stand, we can describe the number of trees, their age or their spatial arrangement.
- `hhtF:ForestManagementProcedure`: a procedure characterized by an ordered set of steps or principles, to specify the cutting or seeding rules applied within the afforestation. These procedures differ from the `hhtF:ForestManagement` in that they are directive informational entities rather than their actual realizations.

These classes enable an inventory of a forest state, providing information on its condition, usefulness, the species produced and harvested, and the procedures followed by the actors operating on it.

4.2. Connection to other ontological modules

HHT-Forest reuses classes and relations from the two previous ontological modules. The notion of actors is central in the context of forests. HHT-Forest allows to represent the owners of the afforestation and tracks the evolution of forests' ownership. For example, it can represent the attachment of forests to the royal domain or changes in the number of forests owned by private individuals or ecclesiastics. It also provides a representation of actors involved in woodland management. Based on CIDOC-CRM's E39_Actor class, it represents both persons and communities of inhabitants. Actors may have offices and occupations related to certain woodlands, describing their role in forest management. Similarly to HHT-core, the notion of role is implemented by aligning with the Organization ontology.[3] Using

[3]https://www.w3.org/TR/vocab-org/

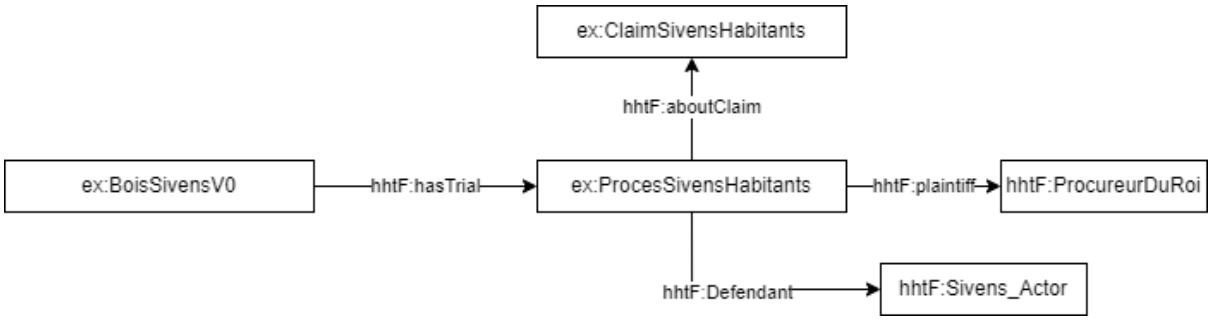


Figure 3: An example of trial regarding a forest

the HHT-Right module, HHT-Forest represents the fact that actors may have specific rights to certain woodlands, enabling them to carry out certain actions in that woodland such as hunting, harvesting or selling timber, or grazing animals. These rights are defined as `hhtF:UsageRight`, a subclass of `hhtR:Right`, with a total of 30 subclasses to describe the various rights.

Finally, HHT-Forest is used to describe lawsuits concerning afforestations and their consequences. Based on the `hhtCl:Claim` class from the module HHT-Claim, it defines the parties involved in the lawsuit, the reason for the lawsuit, its sentence, and the afforestation affected by the proceedings. Lawsuits are characterized as events revolving around a specific `hhtCl:Claim`. They have various consequences for the parties involved, whose use rights may be modified, retained or withdrawn, or who may be dismissed from their positions. Trials also lead to changes in forestry personnel and management procedures, with further adjustments possibly requested at the end of the proceedings. For example, during the Froidour reformation, the number of Maîtrises Judiciaires governing the southern woodlands doubled, leading to numerous changes in the mastery of existing woodlands. Figure 3 presents an example of trial revolving around the Sivens wood, with the plaintiff being the Procureur du Roi, and the defendant the moral actor of Sivens. The trial's topic is represented using the claim entity `ex:ClaimSivensHabitants`, which is not detailed in this figure.

4.3. Afforestation temporal representation

As many characterizations are time-dependent, they are attached to an `hhtF:AfforestationVersion`:

- `hhtF:AfforestationStand` instances represent tree species, number, ages and locations in their attached `hhtF:AfforestationVersion`. They condition the identity of the version: a change in an AfforestationStand (e.g., a forest layout change) would lead to a new AfforestationVersion.
- As they both affect `hhtF:AfforestationStand` instances, `hhtF:ForestManagement` and `hhtF:Degradation` link one version of an afforestation to the next.
- the realization of a `hhtF:ForestManagementProcedure` may affect attributes (instances of AfforestationStand) of an `hhtF:AfforestationVersion`, and a change in this attribute leads to a new AfforestationVersion.

Note that the available information is sporadic. Indeed, the exploited database relies on the analysis of documents called "arpenting reports", which provide punctual snapshots of forest state, providing knowledge regarding instances of `hhtF:ForestManagement` and `hhtF:Degradation`. Forest evolution between arpenting reports cannot be directly traced. In a realist spirit, the ontological module represents the real world, of which we have only partial knowledge via the data. Represented territory versions are chosen based on arpentor observations. In an open-world spirit, many other territory versions, degradations or attributes of the forest exist, but we only represent those we have knowledge of. In particular, a new AfforestationVersion is created only when an actor's testimony recognizes a change. Represented `hhtF:ForestManagement` or `hhtF:Degradation` are causally linked to testified afforestation changes. Thus, these entities can be directly attached to the version preceding the

arpenting report that established them. Other territory characteristics can be assigned directly to the version existing during the arpentor's observations.

4.4. Population and query

A knowledge graph following the HHT-Forest ontological module was produced from the initial database. The database was exported as Excel tables and converted using SPARQLAnything[4]. The resulting knowledge graph contains 158,133 triples, describing 1,703 `hhtF:Afforestation`, with 3,529 `hhtF:AfforestationVersion`, as well as 1,082 trials and 360 actors. The proposed pipeline, the dataset considered and the resulting knowledge graph are available online[5]. This dataset was used to verify that the ontological module answers the historian's competency questions. Each question was translated into SPARQL queries and executed over the populated graph. All five queries returned non-empty, consistent results. For instance, the Rey brothers were found to have surveyed 210 distinct forests (Listing 1), and coppice management is the most frequent forest management in the dataset (Listing 4). This confirms both the ontological module's expressivity and the conformance of the generated knowledge graph.

Listing 1: CQ 1: Which forests were surveyed by the Rey brothers between 1668 and 1669?

```
SELECT (COUNT(DISTINCT ?forest) AS ?nb) WHERE {
  VALUES ?rey { ex:Gabriel_Rey ex:Francois_Rey }
  ?forest hht:hasVersion ?v .
  ?v hhtF:isArpentedBy ?rey ;
     hhtF:arpentDate ?date .
  FILTER(REGEX(?date, "/166[89]$"))
}
```

Listing 2: CQ 2: What is the total area of forest surveyed by Gabriel Rey?

```
SELECT (SUM(?area) AS ?total) WHERE {
  SELECT ?forest (SAMPLE(?a) AS ?area) WHERE {
    ?forest hht:hasVersion ?v .
    ?v hhtF:isArpentedBy ex:Gabriel_Rey ;
       hhtF:forestTotalArea ?a .
  } GROUP BY ?forest
}
```

Listing 3: CQ 3: Which tree species are most common, and where can they be found?

```
SELECT ?species (COUNT(DISTINCT ?forest) AS ?nb) WHERE {
  ?forest hht:hasVersion ?v .
  ?v hhtF:hasStand/hhtF:containsSpecies ?species .
}
GROUP BY ?species
ORDER BY DESC(?nb)
```

Listing 4: CQ 4: What are the most common forestry treatments?

```
SELECT ?type (COUNT(DISTINCT ?forest) AS ?nb) WHERE {
  ?forest hht:hasVersion ?v .
  ?v hhtF:hasManagement ?forestManagement .
  ?forestManagement a ?type .
```

[4]https://github.com/SPARQL-Anything
[5]https://github.com/Brainchain09/HHT/tree/main/HHT-Forest

```
}
GROUP BY ?type
ORDER BY DESC(?nb)
```

Listing 5: CQ 5: Which woodlands had their Maîtrise Judiciaire changed during the reformation?

```
SELECT ?forest ?m0 ?m1 WHERE {
  ?forest hht:hasVersion ?v0, ?v1 .
  ?v0 hht:isMemberOf ?m0 .
  ?v1 hht:isMemberOf ?m1 .
  FILTER(CONTAINS(STR(?v0),"V0") && CONTAINS(STR(?v1),"V1"))
  FILTER(CONTAINS(STR(?m0),"MaitriseParticuliere") &&
         CONTAINS(STR(?m1),"MaitriseParticuliere"))
  FILTER(REPLACE(STR(?m0),"V0$","") != REPLACE(STR(?m1),"V1$",""))
}
```

5. Alignment of HHT-Forest with BFO

To enhance interoperability with other ontologies, we aim to align HHT-Forest with the Basic Formal Ontology [29]. However, since this alignment may increase the number of triples in the final base, without certainty that it would improve the ontological module's expressivity for our specific use case, we did not prioritize it. However, for long-term interoperability with BFO-based ontology, such alignment remains important. The following paragraphs outline the steps already taken, future work required, and open questions that BFO must address to enable full integration.

A forest, in one of its senses, could be understood as a BFO:Object aggregate composed of trees, bushes, shrubs, etc. Exactly which entities belong to a forest is an ontologically difficult question: It remains an open question whether animals, given their mobility and independence, should be counted as parts of this object aggregate or merely as entities that occupy a forest site at a given time. Similarly, the status of a dead leaf on the ground is unclear: it may be a part of the forest aggregate, or it may be an entity that merely occupies the forest site without being a constituent of it, if for example the forest is considered to be composed of only living entities.

As explained above, we opted for another definition of forest, less materially-based and more juridically-based, that was more in agreement with the forest as defined by Froidour, and does not raise this kind of issues. Indeed, we defined an afforestation ("boisement") as a BFO:Site, more precisely a site whose boundaries are juridically rather than ecologically determined. This definition follows the sense introduced by Froidour, under which an area can be legally designated as forest independently of whether it currently contains trees or any other plants. This means that a full ontology of forest should accommodate socio-legal entities alongside material ones.

We represented rights associated with forested areas, including rights to cut wood, to use land for goat grazing, to rent land, and to fish, as continuants. Their precise classification as BFO:Generically dependent continuants of a socio-legal kind remains a matter of ongoing discussion in the BFO community [30], and thus we did not take position on this. This is one of the reasons why a full alignment with BFO still appears premature.

Persons involved in the historical forest reform (lawyer reformers, carpenter reformers, soldier reformers…) are humans and thus classified as material objects. Nevertheless, each professional category could ultimately be defined through an equivalent class axiom relating the individual to a role, e.g., in Manchester syntax:

ReformerLawyer EquivalentTo (Human **and** bearerOf ReformerLawyerRole)

where ReformerLawyerRole is a subclass of BFO:Role.

A variety of entities are classified under BFO:Process. Among them, one can find Forest management ("aménagement forestier") and its subclasses: several management types are distinguished by the

target age that the trees of the resulting forest are intended to reach. For instance, young high forest management (“aménagement jeune haute futaie”) aims at obtaining a forest whose trees have the potential to reach an age between 61 and 120 years, whereas old high forest management (“aménagement vieille haute futaie”) targets an age between 121 and 200 years. Those properties could themselves be represented as dispositional properties, e.g. the disposition to reach an age between 61 and 120 years.

Processes also include the taxonomy of degradations, for example, snow degradation, clearing degradation, and browsing degradation, the latter being caused by animals browsing on young trees and shrubs and thereby impairing their development. Ultimately, the ontological module could represent participants (related by BFO:participatesIn) of such processes, e.g. animals or meteorologically related material entities such as amounts of snow or amounts of water.

Finally, forest management procedures are classified under IAO:Directive information content entity [31], which are information content entities that can direct processes.

On the basis of those classifications, we wrote Aristotelian definitions [32] wherever possible, following the template: "An S is a G that D", where S is the term to define, G is the genus and D the differentia. For example, we define "snow degradation" as a "Degradation due to snow damage" and "secretarial reformer" as "A reformer with a secretarial profession".

6. Conclusion

The HHT-Forest ontological module extends the HHT framework to model forests as juridically-defined, temporally-evolving entities. While existing ontologies often model forests as environmental or resource aggregates, HHT-Forest captures their socio-legal and administrative dimensions, aligning with the historical context of the Grande Réformation des Eaux et Forêts. By integrating spatial, temporal, and juridical data, the module enables richer analyses of forest management, ownership, and ecological changes, without relying on precise geometric descriptions, which are frequently absent in historical sources.

This work demonstrates the flexibility and extensibility of HHT, showing how domain-specific modules can refine the representation of particular territories while maintaining interoperability with broader ontological frameworks. The partial alignment with BFO underscores the potential for future integration and the need to clarify the status of socio-legal entities. Applying HHT-Forest to the original database validates its practical utility and provides a reusable model for historians and digital humanities scholars studying territorial dynamics. A prototype mapping interface over the knowledge graph also provided the historian with a spatial perspective on his data that was not available from the original tables, such as visualizing the itineraries of individual surveyors.

Future work may include expanding the ontological module to accommodate additional historical datasets, deepening the alignment with BFO and other upper-level ontologies and exploring interoperability with other domain-specific ontologies to enable cross-disciplinary research.

This approach enriches historical research and paves the way for more sophisticated digital humanities methodologies, where ontologies bridge fragmented archival data to support coherent, queryable knowledge.

Acknowledgments

Declaration on Generative AI

During the preparation of this work, the author used Le Chat by Mistral to help with peer review simulation as well as to improve English writing in combination with DeepL. After using these tools, the author reviewed and edited the content as needed and take full responsibility for the publication’s content.

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