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The LACRIMALit Ontology of Crisis: An Event-Centric Model for Digital History

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Abstract: The article presents the building of an event-centric model for the computational representation of crisis events using an ontology encoded in the Web Ontology Language (OWL). The work presented here is done in collaboration with the Leaders and Crisis Management in Ancient Literature. A Comparative Approach (LACRIMALit) project, (2022–2025) hosted at the Institute for Mediterranean Studies/Foundation for Research and Technology (IMS-FORTH). A key outcome of the project is the LACRIMALit ontology that aims principally at the semantic annotation of ancient Greek historiographical texts in open access via Perseus Digital Library. The ontology will facilitate reasoning on and across these documents and enable their semantic querying. The tagset of annotations, concepts, relations, and terms of the ontology will be both human and machine readable, extensible and reusable. The annotated corpus of texts to be produced will be available for sophisticated queries based on the concepts and relations, defined by the ontologies. This will considerably improve the string-based querying of the texts in their present digital format. This article presents the principles of conceptualization of the domain in the three dimensions: domain knowledge (mainly classes illustrated with some individuals), linguistic dimension (terms, proper names, definite descriptions), and references.

Keywords: ontology; semantic web technologies; digital humanities; standards; interoperability; linked data; open data

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1. Introduction

This paper introduces work-in-progress on the development of LACRIMALit ontology to describe crises in the span of Greek antiquity as structured descriptions of events taking into account different sources reporting crises in Greco-Roman antiquity. This work is done in collaboration with The Leaders and Crisis Management in Ancient Literature. A Comparative Approach-LACRIMALit project, aiming to offer a comprehensive study of crisis and leadership during crisis in Greco-Roman Antiquity (hosted at the Institute for Mediterranean Studies/Foundation for Research and Technology- IMS-FORTH).

In this contribution we aim to present the purpose of the ontology, its rationale, as well as some of the modelling choices required when representing historical knowledge, explicit or implicit, in the relevant texts by ancient historiographers spanning seven centuries (5th c. BCE-2nd c. CE). The present version of the ontology (Version 1.2) is based on semi-automatic curation of the texts of Herodotus, Thucydides, Xenophon, Dionysius of Halicarnassus, Plutarch and Arrian. To these theoretical texts on leadership in Antiquity (Xenophon's Hieron, Isocrates' Nicocles and To Nicocles, the first two books of Aristotle's Politics, the sixth book of Polybius' Histories and Cicero's De re publica) will be added in subsequent versions. Upon its completion, LACRIMALit ontology will be used for

the semantic annotation that will enable the semantic querying of ancient Greek historiographical texts in digital format drawn on Perseus Digital Library, a focused collection of digital objects, including text and image, along with methods for access and retrieval, and for selection, organization, and maintenance [1]. Our methodology focuses on user requirements for the explicit representation of relevant natural language terminology, i.e., terms in two languages (English and Greek, both ancient and modern).

Although still in an unsystematic and uncoordinated fashion, ontologies are more and more used in the Digital Humanities [2]. "Especially in the humanities, where textual data is often crucial, applications can be used which combine ontologies with text annotations or information retrieval." [3]. Even though digitizing historical documents in various forms has become widespread, semantic annotations are either missing or not marked up explicitly. LACRIMALit aims to narrow this existing gap. Also, the LACRIMALit structured vocabulary of crisis-related terms in Greek (in both its ancient and modern varieties) and English is usable by both humans (via an electronic dictionary interface) and machines (via the W3C standard languages). It thus supports consistency in the terms used, open and linked data discovery across multiple sources [4], automated reasoning upon the modelled data, and, finally, semantic annotation of the relevant textual sources with the terms linked to the ontology. The structured data to be created by the completion of the project will be of use to classical scholars as well as comparative politics experts. A machine-readable model of crisis-related shared terms in Linked Open Data formats, tagged in a consistent and interoperable manner increasing their findability and accessibility will be making at their disposal. The datasets to be produced fulfil all dimensions of data FAIRness, i.e., F (findability), A (accessibility), I (interoperability), and R (re-usability), as spelled out by [5].

The paper is structured as follows: Section 2 presents the state-of-the-art in event representation and modelling, the most important models for representing events useful to digital humanists working with historical texts. Section 3 presents the LACRIMALit ontology including the competency questions that the ontology is presently 'capable' to answer, as well as the representation of concepts, relations and terms. Section 4 presents the evaluation and validation of the ontology.

2. Related Work

The LACRIMALit model for crisis in ancient historiography is an event-centric model. Ref. [6] ask two central questions regarding the development of event-centric ontologies, the first on the metaphysics and the other on semantics of events: "What are events?" and "What is the referential mechanism that is in play when we describe an event?" The answer to the first question, is that events are qualitative changes cognitively constructed. The answer to the second question is that events are closely connected to their context: giving information not only on what happened, but also specifying how it happened, i.e., specifying details that often involve the context in which the event occurred.

A fundamental debate in Ontology as a philosophical discipline [7] regards the ontological status of events versus objects: a commonly held view is that objects continue to exist over time, hence they are also called "continuants", and events occur and/or unfold in time, hence they are also called "occurrents". The latter are sometimes further distinguished into events and processes [8–13]. Continuants are commonly thought of as primarily spatial, while occurrents as temporal par excellence. Different event models provide different definitions of events. In what follows, we present models whose definition of event is most relevant for and has inspired that of LACRIMALit ontology. Of the models included below, LACRIMALit is built as an extension of CIDOC-CRM. A first version of the ontology was presented at [14].

Ref. [15] provide a list of ontologies which include event concepts. Indicatively, the ABC Ontology for digital libraries, whose purpose was to facilitate interoperability between metadata vocabularies from different domains. Ref. [16]; the Event ontology [17] is an event-centric model for the domain of Music, which defines events as arbitrary classifications of space/time regions by a cognitive agent that may have participating agents, passive

factors, products, and a location in space/time. Event-Model-F [18] designed to facilitate interoperability in distributed event-based systems. The model is based on the foundational ontology DOLCE+DnS Ultralite (DUL) (DnS = Descriptions and Situations). It provides comprehensive support for the representation of time and space, objects and persons, as well as the mereological, causal and associative relations between events. Event-Model-F, developed at the University of Koblenz-Landau, provides a means to represent time and space, objects and persons as well as mereological and causal relationships between events, as well as representing different interpretations of the same event.

Event-centred modelling captures the dynamic aspects of a domain. In addition, events provide a natural way to explicate complicated relations between people, places, actions and objects [19]. Events are central elements in the representation of data from various fields such as history and cultural heritage. Ref. [20] propose to see events as meetings, that are, in turn, interactions of participants which bring about changes of state. Ref. [21] identify events in the domain of the history of science as situated occurrences incorporating complex and rich information about the subject of the event (who), the object (what), the time (when), the place (where), the cause(s) and effect(s) (why).

2.1. CIDOC-CRM

The most important model for the domain of cultural heritage is CIDOC-CRM. The CIDOC Conceptual Reference Model (CRM), also an ISO standard since 2006 [ISO 21127:2014, first edition ISO 21127:2006] is a high-level, event-centric, formal model of things and events happening in spacetime (a primitive whose instance may consist of one expression including temporal and spatial information). CIDOC's primary role is to enable information exchange and integration between heterogeneous sources of cultural heritage information.

In CIDOC base model Version 7.1.1 [22], the E5_Event class comprises "distinct, delimited and coherent processes and interactions of a material nature, in cultural, social or physical systems, involving and affecting instances of E77_Persistent Item in a way characteristic of the kind of process. Typical examples are meetings, births, deaths, actions of decision taking, making or inventing things, but also more complex and extended ones such as conferences, elections, building of a castle, or battles". Among the different subclasses of E5_Event, E7_Activity comprises actions intentionally carried out by instances of E39_Actor that result in changes of state in the cultural, social, or physical systems documented, including both complex, composite and long-lasting actions, such as the building of a settlement or a war, and simple, short-lived actions such as the opening of a door. LACRIMALit ontology is an extension of CIDOC-CRM E7_Activity, a subclass of E5_Event.

2.2. ArCo

ArCo, the Italian Cultural Heritage knowledge graph, consisting of a network of seven vocabularies, 169 million triples, and circa 820 thousand cultural entities, represents recurrent events as "a series of conceptually unified situations" [23]. ArCo collects and validates the catalogue records of Italian cultural heritage institutions, save for those of Italian libraries and archives. Its construction methodology is test-driven and combines the Ontology of Design Patterns (ODP) as part of eXtreme Design (XD) methodology. The list of Competency Questions (CQs) that ArCo is competent to answer was based on user stories (i.e., use-case scenarios).

2.3. LODE (Linking Open Descriptions of Events)

LODE (Linking Open Descriptions of Events) [24] is an ontology for publishing descriptions of historical events as Linked Data, and for mapping between other event-related vocabularies on the basis of what happened, where something happened, when it happened, and who was involved. These "factual" relations within and among events are constructed to generate representations of "intersubjective consensus of reality" not necessarily associated with a particular perspective or interpretation of one principal class

(Event) and six properties that refer to the happening of the event, six spatiotemporal properties (two properties for location, i.e., atPlace for a named or relatively specified place and inSpace for an abstract region of space, two properties of time, i.e., atTime for abstract instants or intervals of time and circa property for precise intervals of time, and two properties for an agent (involvedAgent) or an object (involved) involved in an event.

The class of Events of the LODE model describes an event as something that happened as might be reported in a news article or explained by a historian. In the LODE -as in the LACRIMALit- ontology, events have temporal and spatial boundaries, thus enabling statements correlated to people, places or things. By this definition, events are not differentiated from processes or states.

2.4. SEM (Simple Event Model)

The Simple Event Model (SEM) was created to model events in various domains, without making assumptions about the domain-specific vocabularies used. It is presented by virtue of two use cases: historic events and events in the maritime safety domain [19]. Events, according to SEM, describe everything that happens, including fictional events. SEM classes are divided into three categories: Core classes, Types, and Constraints. There are four core classes: sem:Event (what happens), sem:Actor (who or what participated), sem:Place (where), sem:Time (when). The SEM Type class contains all types of Core instances. These can be either individuals or classes themselves. This class is meant to be extended for each application domain. There are three kinds of Constraints: Role, Temporary and View. sem:Role describes the role that an individual of a class is playing in the context of a specific event. Roles can be specified for all Core individuals. The SEM Constraint class contains instances of properties that have a constrained (i.e., not universal) validity. This includes time-dependent validity (Temporary), validity in the guise of a specific role (Role), or validity according to a given Authority (View). Each core class has an associated sem:Type class, which contains resources that indicate the type of a core individual. Individuals and their types are usually borrowed from other vocabularies, e.g., Getty Thesaurus of Geographical Names (TGN).

SEM's properties are divided in three kinds: sem:eventProperty, sem:type properties and a few other properties like sem:accordingTo and sem:hasTimeStamp's subproperties. The sem:eventProperty relates sem:Events to other individuals. A sem:type relates individuals of the sem:Core class to individuals of sem:Type. There are subproperties of sem:type for each of the separate core classes to facilitate querying. To represent opinions sem:accordingTo relates a sem:View to a sem:Authority. Both these modeling choices are potentially useful for the domain of LACRIMALit, but have not been implemented in the present version.

SEM represents Time with the sem:hasTimeStamp property for single time values, while for time intervals SEM has two properties (sem:hasBeginTimeStamp and sem:hasEndTimeStamp), and for uncertain time intervals, SEM has four properties (sem:hasEarliestBeginTimeStamp, sem:hasLatestBeginTimeStamp, sem:hasEarliestEndTimeStamp, and sem:hasLatestEndTimeStamp).

2.5. REO/RED (Rich Event Model/Rich Event Description)

The Rich Event Ontology (REO) [25] aims at a unified representation of events with a rich structure of event concepts with varying levels of specificity. By unifying NLP resources, such as the FrameNet, VerbNet. REO bridges ontology with lexical resources (corpora) and serves as a shared hub for different annotation schemas. REO supports mapping between specific event types of different resources and enables the merging of associated annotated corpora. By relating events to their key objects and participants and by encoding the temporal and causal relationships between events that do not exist in these resources, REO facilitates reasoning on and across documents, revealing relationships between events that come together in temporal and causal chains [26].

REO extends the Richer Event Description (RED) project [27,28] with temporal and causal relations such as the hasPrecondition, hasCause, hasResult, and hasSubevent relations so as to enable users to expand, refine, or alter their queries. The RED project aims to annotate text with mentions of events and entities, so as to represent the temporal and causal relationships that hold between those events in so that an accurate timeline of events could be automatically constructed.

3. Modelling Crisis Events: The LACRIMALIT Ontology

The LACRIMALit project focuses on the following three basic categories of (political) crises are included in the typology and analysis:

(a) emergency crisis incidents in times of war or peace, such as dispute (Gr. διαφωνία, διαφωνέω), military threat (Gr. άπειλ-ή, -απειλέω), etc., which usually require the undertaking of immediate measures;
(b) breach of trust between leaders and their followers; as well as the means (e.g., harangues, Gr. δημηγορία, λόγος) by which leaders attempt to restore order;
(c) conspiracy (Gr. συνωμοσία), treason (Gr. προδοσία), revolt (Gr. στάσις), political confusion, tumult (Gr. ταραχή).

3.1. Crisis Types

The definition of what a crisis is, the forms it can take and the language of crisis can be fuzzy [29,30] (p. 18), in fact, suggests that "there is no one, universally accepted definition of crisis". Crises are sometimes defined as decisive points in a sequence of events: they require serious decision-making and can determine the events to follow. Defining a crisis is quite complex because of the interdisciplinary nature of the concept. According to the [31], it is defined as a point in time: 1. A time of intense difficulty or danger. 1.1 A time when a difficult or important decision must be made. 1.2 The turning point of a disease when an important change takes place, indicating either recovery or death. Originally from Greek krisis 'decision', krinō 'to decide' [32].

Historically, increasing numbers of crises/disasters, natural and human-made, have demonstrated the importance of crisis management. The success of crisis management largely depends on finding, assembling, and successfully integrating related information in order to inform both the decision-making/response stage, as well as and planning the preparedness/planning stage. Also, the degree of predictability of a crisis event is crucial: a crisis is predictable, if place, time or in particular the manner of its occurrence is knowable to at least one concerned party and if the probability of occurrence is not negligible.

Despite extensive relevant work on the importance of building a typology of crises in recent decades [33–39], no such satisfactory typology exists. According to [35], a classification of crises is the first step to keeping them under control and allows for analysis and planning of crisis management actions. He defines four conditions for a good typology: (1) mutually exclusive classes, (2) exhaustive, covering also future events, (3) practicable, i.e., covering measures of prevention and (4) pragmatic, thus manageable.

Ref. [35] (p. 110) distinguishes crisis events depending their degree of predictability, hence manageability into conventional (+predicable, +manageable), unexpected (-predictable-manageable), intractable (+predictable-manageable), fundamental (-predictable-manageable). The most predictable and manageable are conventional crises, whereby the occurrence of the event is known and probable, thus predictable and easy to prevent with proper quality controls and planning. An example of a conventional crisis is the Peloponnesian War, especially as explained by Thucydides, i.e., as an inevitable event owing to the fact that Athens was on the rise and on a colliding course with Sparta, the most iconic military power among Greek city-states. Unexpected crises are neither easy to predict nor easy to manage. Once an unexpected and dangerous process has been triggered, it is almost impossible to stop it within a reasonable timeframe. An emergency response can combat the crisis successfully, but its surprising occurrence can hinder the solution. To illustrate this type of crisis, we cite the regime of the Thirty tyrants in classical Athens, the fragile pro-Spartan oligarchy installed in

Athens after its defeat in the Peloponnesian War in 404 BCE. The third type is the intractable crisis that can have precedents in the past and be easy to predict, but is difficult to manage, as countermeasures are difficult due to the complexity of the systems involved, e.g., the exile of Alcibiades, while being the leader of the Athenian fleet during the campaign in Sicily. Last, fundamental crises are both unpredictable and difficult to manage because they give rise to chaotic, unprecedented circumstances. Examples of the fourth type are contagious illnesses, such as the plague in Athens in 430 BCE that led to a series of socio-political traumas. All four types of this typology of crises are included in LACRIMALit.

LACRIMALit ontology types crises of the Graeco-Roman period as subtypes of the class Event, further distinguished into six categories of crisis depending on the sphere they affect, namely environmental crisis (deforestation, drought, earthquake, famine, inundation and tsunami), financial crisis (economic, financial mismanagement of public money, monetary), migrant crisis (expulsion), military crisis (battle, blockade, campaign, capture of city or fortress, dispatch of troops, insurrections, invasion, piratical attack, sack, siege, war, war declaration), political crisis (assassination, civil war, conspiracy, coup, defection, demonstration, end of alliance, murder, oligarchy, ostracism, perceived threat to power, reform, refusal to prostrate, revolt, riot, secession, sedition, succession crisis, treason), and public health crisis (epidemic, pandemic).

3.2. Competency Questions

Competency Questions [40] play an important role in the lifecycle of engineering an ontology. Competency questions represent the requirements that an ontology has to fulfil.

In the present version, LACRIMALit is "competent" to answer the following competency questions (CQ).

- CQ 1: What are the different types of political crises?
- CQ 2: Where did a crisis take place?
- CQ 3: Who are the protagonists of a crisis (e.g., the sedition of Corfu)?
- CQ 4: What are the relevant terms denoting crises (military, political etc.)?
- CQ 5: What are the events that refer to the term "Athenians" in their Perseus reference?
- CQ 6: Who served the function of Prytan at the trial of the generals of the Arginusae battle?

The first three CQs aim to identify the types of crises we need to represent in the ontology (CQ1) as well as their parameters such location (CQ2) and protagonists (CQ3). The fourth is about the linguistic dimension, i.e., the terms denoting crises when the two last competency questions illustrate what we can ask to the ontology.

The translation of the CQs into SPARQL and the answers the system returns are provided in Section 4 of this paper.

3.3. Building the Ontology

3.3.1. Methodology

In computer science and information science, a computer-readable conceptualization of a domain is an ontology. There are different definitions of ontology [41]. All of them rely on a formal knowledge model for the comprehensive description of a domain of knowledge that encompasses the set of concepts in the domain, their properties, and the relations that hold between concepts. Ontologies are used in practice for the representation of knowledge in a way that can be calculated by the computer, for the standardization, semantic interoperability, knowledge discovery, complex question answering and automation of the inference process. In particular, the description of the properties of the objects of the world and their classification into categories (concepts), together with the description of the relations between these categories (concepts), enables further classifications of the objects, and the extraction of further associations between the concepts.

Ontologies are software artefacts whose purpose is to inject semantics into the data available on the Web, attention has turned toward the use of ontologies [41–46] for the representation of knowledge and for applications of automatic knowledge discovery. Through

the incorporation of formal definitions, they also allow the application of basic inference mechanisms when interpreting data exploiting taxonomic and other relations built into the ontology.

There are several methods for building ontologies depending on the criteria established [47–54].

The LACRIMALit ontology follows the ontoterminological approach which combines the semasiological and onomasiological approaches, while taking into account the way of thinking of Humanists [55,56]. Both the semasiological and onomasiological approaches seek to untangle the problem of meaning expressed by means of natural language: while the former takes the concept (i.e., the meaning denoted by the word) as a starting point, the latter takes the term as a starting point. An ontoterminology is a terminology (list of terms in natural language terms) whose conceptual system of the domain of interest is a formal ontology [57]. In LACRIMALit these two dimensions, the conceptual dimension, encompassing the concepts in the domain of crisis and the linguistic dimension, comprising the terms found in the relevant textual excerpts have been created as separated classes (LACRIMALit and Lexical_Unit).

The LACRIMALit ontology was built using Protégé 3.3.1 [58], a free, open-source ontology editor of Stanford University. The present version of the ontology is made up by circa 4500 triples, 1500 declaration axioms, 110 classes, 44 object properties, 16 data properties, and 460 individuals. It is openly accessibly online at this address: http://ontologia.fr/OTB/lac.owl (accessed on 2 May 2022) The ontology documentation is also available online using the LODE Live OWL Documentation Environment (LODE) service: http://ontologia.fr/OTB/LACRIMALit-Ontology.htm (accessed on 14 August 2022).

LACRIMALit has been designed, engineered and semi-manually curated by two knowledge engineers (one of whom is also a domain expert), with the assistance of five more domain experts whose task was to identify the terms and relevant passages in the texts and feed them into spreadsheets that were, in turn, imported in Protégé using the Cellfie plugin, a Protégé Desktop plugin for importing spreadsheet data into OWL ontologies (see Figure 1) [59]. (Note: Ancient Greek fonts do not appear correctly in some of Protégé editors and the same holds for the Cellfie Excel. Once they are entered into the Ontology, however, they appear correctly again).

A	B	C	D	E	
instance Event	Class	begin date	end date	location	rdfs:comment
evt-Peloponnese_war	War	-431	-404	loc-Peloponnesus	[2] But the Argives, Athenians, Boeotians, a
evt-Battle_of_Cyzicus	Naval_Battle	-410	-410	loc-Cyzicus	Meanwhile the Athenians at Sestus, learnir
evt-Aetolian_campaign	Campaign	-426	-426	loc-Aetolia	Thuc. 3.105.1-3.114.3Thucydides. Historia
evt-battle_Olpae	Battle	-426	-426	loc-Olpae	το□ δ□ α□το□ χειμ□νος □μπρακι□ται, □στ
evt-battle_of_Abydos	Battle	-411	-411	loc-Abydos	After this, not many days later, Thymochare
evt-battle_of_Aigos_Potamoi	Naval_Battle	-405	-405	loc-Aigos Potami	
evt-siege_Cedreiae_by_Lysander	Capture_of_City_or_Fortress	-405	-405	loc-Cedreiae	[15] Now Lysander, when Cyrus had thus ç
evt-battle_of_Amphipolis	Land_Battle	-422	-422	loc-Amphipolis	

Figure 1. Excel spreadsheet featuring the crisis events "Peloponnese war" and "sedition of Corfu".

After importing the datasheet in Protégé, the Cellfie window appears showing the rules defined by means of MappingMaster, a domain-specific language that defines mappings from spreadsheet content to OWL ontologies [60]. The first following rule allows to create automatically individuals representing events (column A) as instances of Event Classes (column B):

Individual:@A*
Types: @B*

The second one allows to link events (column A) to their beginDate (column C):

Individual:@A*
Facts: beginDate @C*

In this way, a minimal degree of automation is ensured as, by means of transformation rules, spreadsheet data become graph data. As the LACRIMALit ontology is expected to grow tenfold in the next version, we look into more efficient ways of populating.

3.3.2. Classes and Relations

LACRIMALit is conceptualised by means of three components to accommodate the needs of domain experts (see Figure 2):

- the domain knowledge regarding crises and related information (agents, locations etc.) is encoded using standardised properties such as rdfs:subclassOf for subclasses, rdfs:type for instances and properties defined in the LACRIMALit ontology to represent, e.g., agents (lac:agent) and locations (lac:location) of the LACRIMALit events.
- the linguistic dimension encoding the relevant language used to communicate this knowledge in the texts by means of terms, definite descriptions and proper names represented as subclasses of the class Lexical_Unit. The instances of each of these classes are linked to the conceptual dimension by means of the relation lac:designates.
- the network of references, i.e., the bits of text, mainly from Perseus Digital Library, represented by means of the class Reference and linked through the property lac:linkedReference. The references are linked to events with the lac:refersTo property that allows to semantically structuring the references based on the domain ontology.

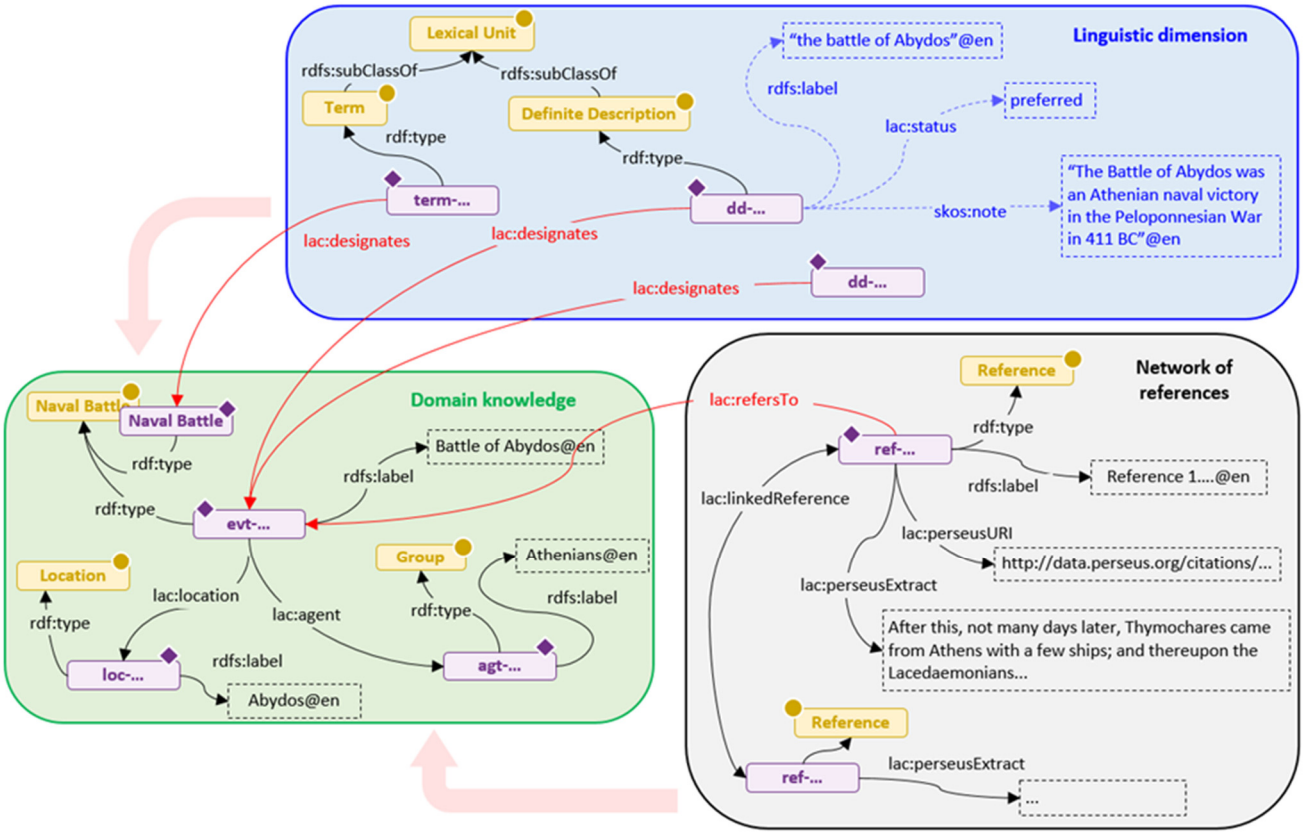

Figure 2. Overview of the LACRIMALit Ontology.

The last two components will be fully implemented in the next version of LACRIMALit. Currently the rds:label is mainly used to represent terms and proper names as labels attached to classes and individuals.

The core of the model is the representation of Event as a type of action carried out by one or several LACRIMALit Agents that leads to changes of states in cultural, social or physical systems. It is made up of one or several LACRIMALit subevents, can have one or more causes and consequences as well as predecessors and successors, is located in a

geographical space (Location), has a date of beginning and a date of ending. LACRIMALit crises are subclasses of the LACRIMALit Event class. LACRIMALit Events have agents that are Humans (Persons or Groups) and Natural agents, such as an earthquake, or a flood.

The LACRIMALit Ontology is defined as a domain extension of some CIDOC classes, as shown in Figure 3. The domain classes are organized into four main categories: Agent (including Group and Person), Event (Crisis), Location and Function, each of them defined as subclasses (rdfs:subClassOf) of respectively E39_Actor, E7_Activity, and E53_Place. The object properties cause and consequence, which are not supported by CIDOC, have been introduced, in order to represent the causes and the consequences of an event.

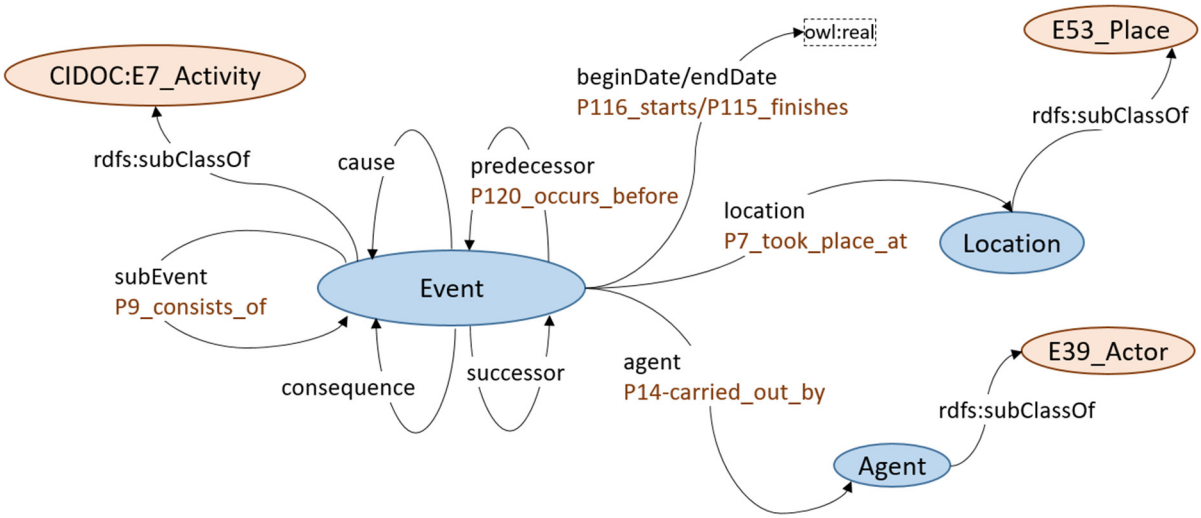

Figure 3. LACRIMALit model as an CIDOC-CRM extension.

The formal definition of classes is done directly in Protégé: property restrictions, e.g., the Event class, disjointness, e.g., the Group class and the Person class, domain and range of relations, e.g., the agent object property whose domain is the Event class and the range is the Agent class. The following DL definition of the Event class:

Event $\geq$1agent.Agent $\sqcap$ $\geq$1location.Location $\sqcap$ $\geq$0causedBy.Event $\sqcap$ $\geq$0consequence.Event $\sqcap$ $\geq$0subEvent.Event

corresponds to the following defined class in Protégé:

(agent min 1 Agent) and (location min 1 Location) and (causedBy min 0 Event) and (consequence min 0 Event) and (subEvent min 0 Event)

The different types of Events complete the definition of the class Event with new object properties restrictions, when necessary, e.g.,

Crisis $\sqsubseteq$ Event

Military_Crisis $\sqsubseteq$ Crisis

Battle $\sqsubseteq$ Military_Crisis

Naval_Battle $\equiv$ Battle $\sqcap$ =1location.Sea_Location

An event can take place in different locations ($\geq$1location.Location), such as the Peloponnesian War, whereas a battle takes place in only one location (=1location. Location), for example the battle of Abydos.

Groups are represented as individuals of the class Group and members of a group (instances of the class Person) are linked to the group (individual) via the memberOf object relation. We have decided to represent groups as individuals of the class Groups for two reasons: the first reason is to align with CIDOC where Group and Person are different concepts–indeed a group is not a type of Person even though the extension of a group is a subset of the extension of Person. The second one is because groups are individuals representing protagonists linked with the agent property to individuals representing events (object properties link only individuals). For example, the individual

'evt-war-of-Peloponnese' is linked to the individual 'Athenians', an instance of the Group class, and to the individual 'Alcibiades, an instance of the Person class.

To predicate about times, we represent relations between the begin and the end of event entities via six (6) object properties following CIDOC-CRM (Version 7.1.1). Also, two (2) data properties allow to express the begin date and end date of event entities with xsd:integer. Example: the sedition at Mallus before the battle of Issus (see Figure 4):

:evt-sedition-at-Mallus-before-Issus
rdf:type :Sedition;
:agent :agt-Alexander_the_Great;
:agent :agt-Mallotes;
:location :loc-Mallus;
:startsBeforeTheStartOf :evt-battle_Issus;
:beginDate -333;
:endDate -333.

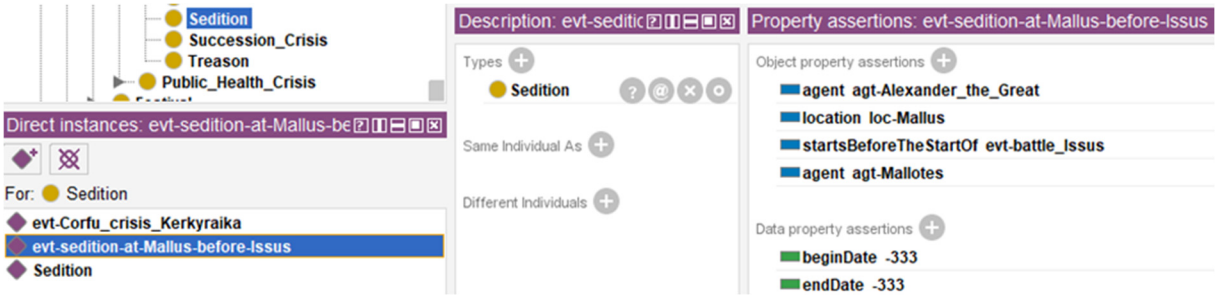

Figure 4. *Property* assertions of the event "sedition at Mallus" taking place just before the battle of Issus.

3.3.3. Populating the Ontology

Populating the ontology consists in defining individuals corresponding to natural (e.g., earthquake) and human agents (groups, e.g., Athenians, or persons, e.g., Alcibiades), locations, (e.g., Peloponnesus), and events (e.g., the Peloponnesian war or the sedition of Corcyra).

The representation of events consists of linking individuals through the relationships (object properties) which define the events: agents, location, start and end dates, sub-events, etc. For example, the protagonists of the Peloponnesian war, i.e., the Athenians, Alcibiades, the Andrians, Lysander, and the Laconians, must be linked to the individual representing the Peloponnesian war (see Figure 5).

3.3.4. Linguistic Dimension

The linguistic dimension plays a central role in the LACRIMALit project, whose main objective remains the semantic annotation of texts. The LACRIMALit methodology takes terms to be verbal designations of concepts, i.e., specific words that designate concepts, in compliance with the ISO principles on Terminology [61,62]. This allows for extralinguistic modelling (conceptualisation) of crises independently of the different ways of talking about them in natural languages.

The terms were not extracted automatically from texts but provided by experts and illustrated by excerpts from the corpus. Terms are organized according to the denoted information: people, places, and events corresponding to as many corresponding concepts of the ontology: "The Peloponnesian war is the conflict between the league of Delos, managed by Athens, and the league of Peloponnesus, under the hegemony of Sparta".

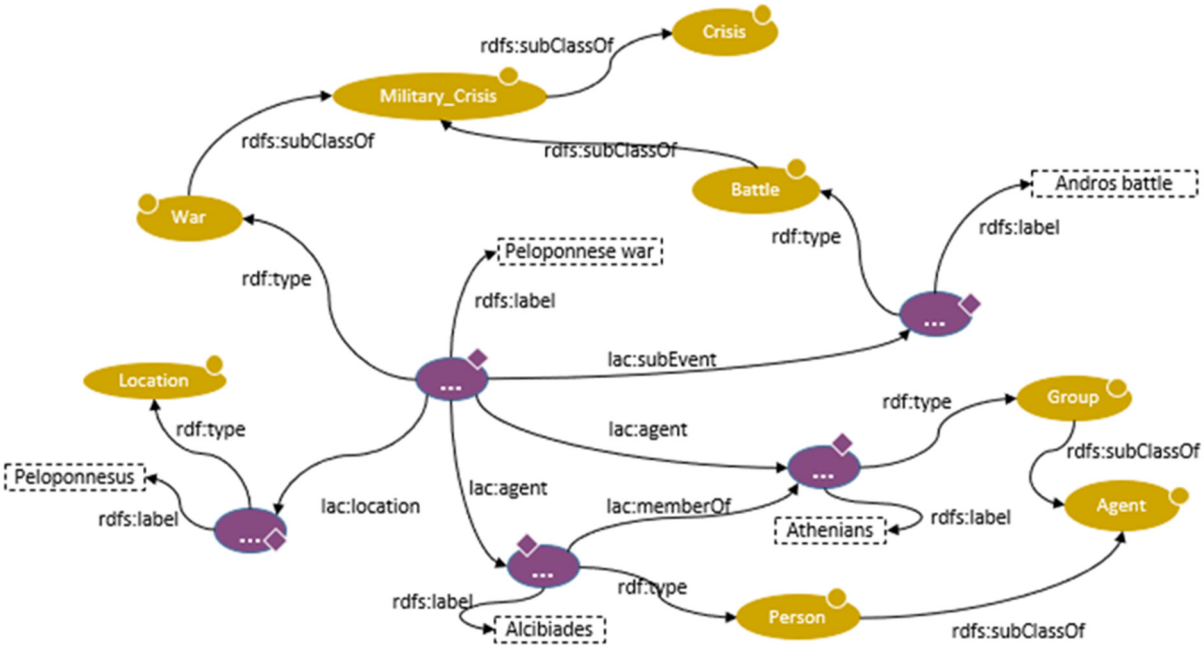

Figure 5. Representing the individual "Peloponnesian war".

3.3.5. Linking Terms and Concepts

In a first version of LACRIMALit, terms are represented as labels on classes, which not allows to explicitly attach information to a term. As a matter of fact, terms cannot be reduced to labels attached to classes since they bear a lot of information, e.g., notes, contexts, references as well as linguistic relationships between them such as synonymy. That requires an explicit representation of terms as individuals of a class Term.

It is the reason why, the Lexical Unit class was introduced in order to explicit represent terms, references attached to terms, etc. as well as proper names, such as 'Alcibiades', and definite descriptions such as "the Peloponnese war". As shown in Figure 6, the linguistic dimension will be represented by explicit subclasses of the Lexical_Unit class corresponding to terms, proper names and definite descriptions, e.g., Κερκυραϊκά is a definite description designating the event sedition of Corfu. A new object property between Lexical_Unit (domain) and LACRIMALit classes (range) is introduced in order to link terms to their denoted classes as well as proper names and definite descriptions to the corresponding individuals.

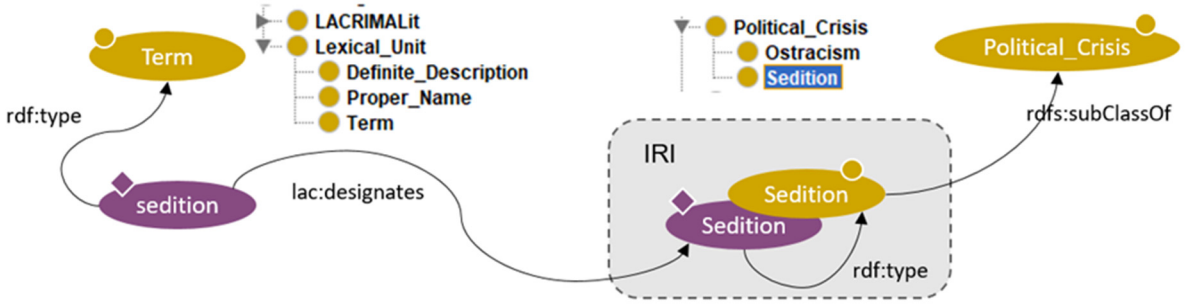

Figure 6. The linguistic dimension of LACRIMALit.

However, terms corresponding to common nouns cannot be directly linked to classes since object properties are defined only between individuals. Classes can be treated as individuals—a class can be an instance of itself—as it is allowed in OWL Full, using the same IRI identifying both a Class (owl:Class) and an individual (owl:NamedIndividual).

This practice is allowed in OWL as well as OWL 2; however, it is not always recommended [63] (p. 441).

In the next version of the LACRIMALit ontology linking with the OntoLex Lemon W3C standard [64] will be investigated.

4. Evaluation & Validation

Ontology evaluation is the task of measuring the quality of an ontology. There are different evaluation methods whose goal is "to assess the quality and correctness of the obtained ontology" [65]. Criteria [66] allow to calculate the "richness" of an ontology such as the attribute richness (defined as the average number of attributes (slots) per class and computed as the number attributes for all classes divided by the number of classes) or relationship richness. Nevertheless, evaluation of criteria strongly depends on the aims of the ontology and the choices made for its implementation: "a good ontology does not perform equally well with regards to all criteria" [67]. LACRIMALit aims to be available for querying by domain experts.

To check the logical consistency of the ontology, we ran the Protégé built-in DL reasoners Hermit and Pellet. For the validation of the RDF syntax, we used the W3C RDF validator [68].

Ontology validation refers to the competency of the ontology to answer queries defined by the users at earlier stages of the ontology building. The ontology must allow users to retrieve the right answers to the competency questions. The LACRIMALit ontology competency questions presented have been translated into SPARQL [69] to query the OWL version of the LACRIMALit ontology built with Protégé. All of them are satisfied.

In what follows (Table 1) we present the competency questions that LACRIMALit ontology is competent to answer translated in SPARQL as well as the answers returned.

Table 1. Competency Questions.

SPARQL Query	Variable Values

# CQ1: What are the different types of political crises? 	
 	
PREFIX rdf:
<http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs:
<http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX skos:
<http://www.w3.org/2004/02/skos/core#>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX lac: <http://ontologia.fr/OTB/lac#>
SELECT DISTINCT ?crisisName
WHERE {
?crisis rdfs:subClassOf* lac:Political_Crisis.
?crisis rdfs:label ?crisisName.
FILTER (lang(?crisisName)='en')
}
ORDER BY ?crisisName
	"civil war"@en
	"conspiracy"@en
	"coup-d-etat"@en
	"defection"@en
	"demonstration"@en
	"end of alliance"@en
	"exile"@en
	"murder"@en
	"ostracism"@en
	"perceived threat to power"@en
	"plot"@en
	"political crisis"@en
	"reform"@en
	"refusal to prostrate"@en
	"revolt"@en
	"riot"@en
	"sedition"@en

Table 1. *Cont.*

SPARQL Query	Variable Values

# CQ2: Where did the sedition of Corfu take place? 	
 	
PREFIX rdf:
<http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs:
<http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX skos:
<http://www.w3.org/2004/02/skos/core#>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX lac: <http://ontologia.fr/OTB/lac#>
SELECT DISTINCT ?locationName
WHERE {
?sedition rdf:type lac:Sedition.
?sedition rdfs:label 'sedition of Corfu'@en.
?sedition lac:location ?location.
?location rdfs:label ?locationName
FILTER (lang(?locationName)='en')
}
	"Corfu"@en

#CQ3 Who are the protagonists of the sedition of Corfu? PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> PREFIX owl: <http://www.w3.org/2002/07/owl#> PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#> PREFIX xsd: <http://www.w3.org/2001/XMLSchema#> PREFIX skos: <http://www.w3.org/2004/02/skos/core#> PREFIX foaf: <http://xmlns.com/foaf/0.1/> PREFIX lac: <http://ontologia.fr/OTB/lac#> SELECT DISTINCT ?protagonistName WHERE { ?sedition rdf:type lac:Sedition. ?sedition rdfs:label 'sedition of Corfu'@en. ?sedition lac:agent ?protagonist. ?protagonist rdfs:label ?protagonistName FILTER (lang(?protagonistName)='en') } ORDER BY ?protagonistName	"Alcidas"@en "Brasidas"@en "Peithias"@en "Peloponnesians"@en

Table 1. *Cont.*

SPARQL Query	Variable Values

#CQ4: What are the relevant terms denoting crises (military, political etc.)?
 	
PREFIX rdf:
<http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs:
<http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX skos:
<http://www.w3.org/2004/02/skos/core#>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX lac: <http://ontologia.fr/OTB/lac#>
SELECT DISTINCT ?term
WHERE {
?subClassOfCrisis rdfs:subClassOf* lac:Crisis.
?subClassOfCrisis rdfs:label ?term.
FILTER (lang(?term)='en')
}
ORDER BY ?term
	"battle"@en
	"campaign"@en
	"capture of city or fortress"@en
	"civil war"@en
	"conspiracy"@en
	"coup-d-etat"@en
	"crisis"@en
	"defection"@en
	"demonstration"@en
	"dispatch of troops"@en
	"drought"@en
	"earthquake"@en
	"economic crisis"@en
	"end of alliance"@en
	"environmental crisis"@en
	"epidemic"@en
	"exile"@en
	"expedition"@en
	"expulsion"@en
	"financial crisis"@en
	"financial mismanagement"@en
	"insurrection"@en
	"inundation"@en
	"invasion"@en
	"land battle"@en
	"migrant crisis"@en
	"military crisis"@en
	"monetary crisis"@en
	"murder"@en
	"naval battle"@en
	"ostracism"@en
	"pandemic"@en
	"perceived threat to power"@en
	"piratical attack"@en
	"plot"@en
	"political crisis"@en
	"public health crisis"@en
	"reform"@en
	"refusal to prostrate"@en
	"revolt"@en
	"riot"@en
	"sack"@en
	"sedition"@en
	"siege"@en
	"treason"@en
	"war"@en
	"war declaration"@en

Table 1. *Cont.*

SPARQL Query	Variable Values

#CQ5: What are the events that refer to the term "Athenians" in their Perseus reference?
PREFIX rdf:
<http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs:
<http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX skos:
<http://www.w3.org/2004/02/skos/core#>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX lac: <http://ontologia.fr/OTB/lac#>
SELECT DISTINCT ?eventName
WHERE {
?eventClass rdfs:subClassOf* lac:Event.
?event rdf:type ?eventClass.
?event rdfs:label ?eventName.
?event lac:perseus_reference ?reference.
FILTER regex (?reference, "Athenians")
FILTER (lang(?eventName)='en')
FILTER (lang(?reference)='en')
}
ORDER BY ?eventName
	"Naval Battle of Cyzicus"@en
	"Peace of Nicias"@en
	"Plague of Athens"@en
	"epidemic at Athens in 430 BC"@en
	"Λοιμός των Αθηνών"@en

#CQ6: Who served the function of Prytan at the trial of the generals of the Arginusae battle? PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> PREFIX owl: <http://www.w3.org/2002/07/owl#> PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#> PREFIX xsd: <http://www.w3.org/2001/XMLSchema#> PREFIX skos: <http://www.w3.org/2004/02/skos/core#> PREFIX foaf: <http://xmlns.com/foaf/0.1/> PREFIX lac: <http://ontologia.fr/OTB/lac#> SELECT DISTINCT ?whoName WHERE { ?evtTrial rdf:type lac:Trial. ?evtTrial rdfs:label "trial of generals after the battle of Arginusae"@en. ?evtTrial lac:beginDate ?beginDateTrial. ?evtTrial lac:beginDate ?endDateTrial. ?function rdf:type lac:Political_Function. ?function rdfs:label "prytan"@en. ?evtPerfFct rdf:type lac:Performed_Function. ?evtPerfFct lac:function ?function. ?who rdf:type lac:Person. ?evtPerfFct lac:agent ?who. ?who foaf:name ?whoName. ?evtPerfFct lac:beginDate ?beginDateFunction. ?evtPerfFct lac:beginDate ?endDateFunction. FILTER ((?beginDateTrial >= ?beginDateFunction) && (?endDateTrial <= ?endDateFunction)) } ORDER BY ?whoName	"Socrates"@en

5. Conclusions

This paper presents ongoing work on the LACRIMALit project for the construction of a model of crises for Ancient Greek historiography and a terminology of crises in Greek (Ancient and Modern) and English. The alignment of the three terminologies, Ancient Greek, Modern Greek and English, is based on a common conceptualisation of crises.

Thanks to the modelling of crisis events and their temporal and causal relationships, it becomes possible to link the various historiographic resources, thus facilitating their exploration and reasoning in order to answer complex questions. The LACRIMALit model aims to organize historical knowledge about crises in the Graeco-Roman world and provide access to and understanding of these historical narratives.

We have illustrated how the LACRIMALit ontology conceptualizes crises in ancient Greek historiography and allows to answer the competency questions. We put particular emphasis on those essential terms that ancient historians use to present and discuss crises on the political scene, affecting the life of many and the course of subsequent events. We envision that populating the ontology with the crisis events from the whole corpus of ancient authors will provide a useful resource for digital historians: it can help historians to compare and contrast factual information about events.

The LACRIMALit ontology is a domain ontology defined as an extension of the CIDOC-CRM classes dedicated to the description of events involving one or more actors (E7 Activity). The ontology was built using the Protégé environment, which allows the construction of ontologies in W3C format. If this environment is particularly well adapted to the organization of individuals into classes, it is much less so with regard to the modelling of the linguistic dimension, i.e., terms. The explicit representation of terms as individuals raises problems whose solutions are less than satisfactory.

In addition to the modelling issues necessitated by the theory underlying Protégé and the learning curve it presents for domain experts [70], the problem of knowledge and terminology modelling in digital humanities for the purposes of semantic annotation and knowledge retrieval remain open issues.

For digital humanities' data to fit into the framework of the semantic web of fully interoperable, linked and open data taking into account the way of thinking of domain experts, the following tasks are typically required: selecting a corpus of texts to study, defining the domain of knowledge one is interested in, create or choose an ontology for that knowledge domain, and formally annotate the relevant text passages using the ontology. LACRIMALit is work-in-progress towards the semantic annotation that will enable the semantic querying of a vast number of ancient Greek texts via a SPARQL API and a friendly interface for end-users. As such, it brings to the fore central common problems faced by digital humanists, especially those working with texts.

As a final note, achieving efficient knowledge management in the field of history and historical knowledge, the question "What comes after the digitization?" Ref. [71] is still valid, even after over two decades of a host of mass digitization projects. Users need to access the digitized documents easily in order to study their content, search them not just based on strings but also on things, and enrich them with annotations. Knowledge management systems are needed to store, visualize, organize, search and annotate these documents. Our future work in the context of the LACRIMALIT project is to complete populating the ontology, while contributing to international, interdisciplinary initiatives, such as those of the Data for History consortium, founded in 2017, with the aim of establishing a common method for modelling, curating and managing semantically robust data in historical research.

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