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AnnoMAD: A Semantic Framework for the Management and the Integration of Full-text Excavation Data and Geographic Information

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Abstract

This paper describes the advances in the development of the AnnoMAD System, a modular framework created by PIN and The Cyprus Institute for the management and the integration of free-text archaeological data and geographic information related to excavations. The system provides a free-text encoding tool able to annotate textual documentation using semantic features and a GIS integrated framework to capture the spatial descriptions and make them available in a geographical context. AnnoMAD is built using Open Source software. It leverages on the flexibility of CIDOC-CRM and RDF to create a layer of semantic metadata to be linked to the original documents, in order to preserve their integrity. Integration of the GML standard geographic language with CIDOC-CRM guarantees data interoperability and demonstrates that CIDOC-CRM can offer a valid schema that may be easily extended to incorporate geographic features and relations. AnnoMAD has been applied to a case-study concerning a Bronze Age excavation in Cyprus, the Hala Sultan Tekke archaeological site.

Categories and Subject Descriptors (according to ACM CCS): Information Storage and Retrieval [H.3.5]: Web—based Services

1. Introduction

The present paper describes a documentation system developed for the management of free text information produced or used by archaeologists during their activities [NFHN09] [NFS*10]. This class of information comprises a wide range of documents, from the texts of the ancient sources to the diaries and notes collected during the excavation activity, usually very difficult to process using the traditional forms and relational databases [CDN02] [JHOO09].

Our system tries to approach this problem from a totally different point of view, putting the main focus on the text and its meaning, rather than on the structure of its "container" (e.g. the tables of a database or the fields of a form). This document-centric approach provides a way of preserving the integrity of the original documents without sacrificing efficiency during information retrieval. Performance and usability of the system is guaranteed by state-of-the-art tools and technologies, while data interoperability and integration is ensured by the use of well known standards, like CIDOC-CRM and RDF for data encoding [HU] [D'A06] [DMZ06].

This management system is the fruit of the collaboration between the computer experts of PIN (Italy), STARC at the Cyprus Institute, and the archaeologists of the Mediterranean Archaeological Research Institute (MARI) of the Vrije Universiteit Brussel (Belgium). The framework will also be released as part of the 3D-COFORM European project [3DC]. The final application will be released for a general purpose use. At present, it is applied to a case-study regarding a 35 year-long Late Bronze Age excavation in Cyprus (the Hala Sultan Tekke excavation documentation). Furthermore, it will also be used in another project on medieval archaeology and architecture in the Aegean Islands.

2. System Overview

The AnnoMAD System is made up of 3 different components combined together to create an archive of anno-

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tated textual documents and geographic data bound together through semantics. The components are:

1. **AnnoMAD Text**, a free-text annotation tool for the editing and the semantic annotation of textual documents using the classes and the relationships provided by different ontologies.

2. **AnnoMAD GIS**, a tool derived from different open source GIS projects providing a complete multiplatform GUI and many features for geographic data integration and sharing.

3. **AnnoMAD DB**, a featured container for the semantic textual and spatial information combining the semantic capabilities of the SAD framework, a Semantic Archive built on top of the MAD technology developed during the EPOCH project [Fel06] [MAD]. The new version of SAD It has been now designed to contain the digital version of all the documents edited and annotated with the AnnoMAD tool and the related annotations in a semantic format.with the flexibility of the most common communication protocols to guarantee efficient data storage and retrieval andÊeasy data exchange.

A detailed description of the architecture and features of each component is provided in the following sections.

2.1. The AnnoMAD Text

The AnnoMAD Text application was developed for the annotation and the semantic enrichment of archaeological texts (printed or type-written sources and manuscripts) and for the creation of semantic archives using the annotation paradigm [NFHN09]. The tool comes with a complete and user friendly web interface written using the Adobe Flex Framework [FLE]. The latest release of the tool (v0.9) also provides multilingual features enabling to change the language of the interface on-the-fly (at present it is possible to switch between 4 languages: English, Italian, German and French), to translate the name of the defined annotations and to switch the language of the entities and properties of the underlying ontologies. In the current version this function is only available for the CIDOC-CRM ontology.

The multilingual framework we are currently using is under development at the University of Brighton for the 3D-COFORM european project and, although still in beta version (current release is 0.8beta), it is already able to implement interface localization and language-sensitive access to metadata, entities and relations, and to support multilingual querying and annotation.

The framework is not directly embedded into the AnnoMAD Text tool, but it is just connectedÊto its interface via the Java API provided by the framework itself. Therefore it will be possible in the future to take advantage of the stable releases of the Brighton tool (or to connect a different framework the our system) without touching the AnnoMAD code.

A similar client/server mechanism has been used to connect different thesauri to the AnnoMAD Text interface. Thesauri are very useful during the operations of name assignment during the creation of annotations: using elements of a thesaurus ensures a higher degree of standardization within the different annotations. The system supports the SKOS format for thesauri, and requires at least the URL of each thesaurus to link it and make it available for the user.

AnnoMAD Text is intended to allow users to put a conceptual layer on top of the formatted text, either during the editing of the text itself or after document finalization. An annotation can be created as textual comments or using the semantic information provided by the underlying ontologies. Annotations can be assigned to whole documents or to a portion of text in order to create meaningful descriptions in a formal way.

The AnnoMAD Text interface allows user to perform different operations, mainly:

- *to load entities and properties from one or more ontologies*: the default ontology, already present in the system, is the CIDOC-CRM ontology, but the user has the possibility to load RDF/OWL files containing different ontologies which can be used afterwards for the definition of semantic annotations and relationships

- *to define global annotations* for the most common entities and concepts. This particular class of annotations is created as a set of instances of specific entities at a global level rather than starting from a specific document. Once defined, global annotations remain available for the whole system and can be reused many times and in many documents.
  Global annotations may include, for instance, common entities, like the ones related to the archaeologists involved in the excavation (*actors*) or to the periods for artifact dating (e.g. “Bronze Age”, “Iron Age” and so on). Global annotations can be createdÊ from scratch, using the Annotations panel, or imported from existing RDF triples deriving, for instance, from another AnnoMAD Text installation or written using a semantic editor (e.g. Protégé).

- *to create and edit a new document*, intended to be the digital copy of the paper version of the original document. The editing process is carried out through the main panel: it provides an online text editor with basic editing features, useful for formatting the document for future publication and for adding HTML tags for web presentation. At this stage is also possible, by using the “Add Original” button, to link the new document with the image or scan of the original document, if available. The “Browse Orig-

inal" button, can be used at any time to show the scanned version of the original document in a separate window.

- *to create local annotations*, that is to put a conceptual layer on top of the formatted text. This is the main feature provided by AnnoMAD Text and can be performed at any time on the current document, either during or after the editing session. The operation itself consists in putting a piece of semantic information on top of a selected portion of the text, or to assign this information to the whole document.
  Local annotation assignment works the same way as the other editing features: the user has the possibility to select a portion of the text and to assign an annotation to it by using the annotation features provided on the right-hand side of the interface. The "Annotate" button opens the popup window from which it is possible to create the unique identifier and/or the annotation name (also using one of the connected thesauri) and to bind the annotation with one of the entities provided by the various ontologies available whitin the system (CIDOC-CRM is the default ontology, already available in the basic installation of the tool). Annotations can also be defined using the semantic description of geographic features coming from AnnoMAD GIS.
  This operation is a very interesting aspect of the annotation process, whose final result is the straightforward creation of a complex metadata object containing both the spatial and the semantic description of a certain entity (see below). If no text is selected the new annotation is assigned by default to the whole document or, optionally, it can be defined as a *global annotation*. Finally, existing annotations can be edited or removed from the archive using the corresponding buttons of the "Annotations" panel. Local and global annotations, once created, can also be assigned to different documents or multiple fragments of text by selecting it and then clicking the "Assign" button.

- *to establish semantic relations between existing annotations*: a *relation* is a meaningful link that connects two annotations and works like a verb connecting two sentences in a phrase. Usually, when we talk about ontologies, this link is referred to as a *property* connecting two *entities* of the same or of different classes. In AnnoMAD Text a relation assignment can be made by using the "Add" button in the "Relations" panel. The popup shows a list of available annotations to choose as *subject* of the phrase. Once an annotation is selected from the panel, a list of all available properties related to the subject will populate the "Properties" combo box.
  Choosing one property will cause the related annotation available as *object* of the sentence to be shown to the user in order for him/her to complete the semantic phrase and to establish the relation. Relations can be defined using *local annotations* (i.e. related to the current document), annotations defined in other documents or *global annotations*. Finally, the "Create Annotation" button gives the possibility to define new global annotations to be used for extending the relationship scope on-the-fly.

As a final result of the editing and annotation operations the tool produces a standard HTML version of the document and a set of RDF triples representing the semantic layer of each document. Documents and annotations can be stored in any semantic-enabled archive or published and shared over the web. The HTML version of the document and the semantic annotations can also be exported or converted into different formats to be integrated in various scenarios. The RDF guarantees long term preservation and interoperability of the semantic information.

The AnnoMAD Text web interface was built using the Adobe Flex framework, a versatile Software Development Kit ideal for the development and deployment of cross-platform and cross-browser rich internet applications using the Adobe Flash browser plugin. Thanks to the latter, applications developed with Flex can run in any kind of browser without any of the compatibility bugs that usually affect Javascript and Ajax applications.

AnnoMAD Text is also designed to support a wide range of communication protocols and can easily be deployed in many standard client/server frameworks. It can be also used as a client for ingesting and retrieving semantic information to/from different containers and databases, including Digital Libraries. Some successful tests have been carried out by interfacing AnnoMAD Text with the RDF Metadata Repository developed by FORTH for the 3D-COFORM project, to send and retrieve annotated texts with their semantic layer of information, using standard communication protocols like SOAP and REST.

2.2. AnnoMAD GIS

The second tool of our system, AnnoMAD GIS, is a set of scripts and plugins written to integrate the Open Source QuantumGIS [QGI] (based on the popular and also open source GRASS GIS software [GRA]) and its pretty user interface with the other tools of the AnnoMAD System and to use it for the management of all the geographic information that usually represents an important part of the archaeological excavation documentation.

QuantumGIS is a multiplatform GIS software developed by the Open Source Geospatial Foundation (OSGeo) under the GNU GPL License. The software is currently used for the creation of the Geographic Information System for the archaeological site of Hala Sultan Tekke, the testing environment of our system.

QuantumGIS is an excellent tool to visualize, manage, edit, analyze data, and compose printable maps. It comes with an easy-to-use user interface and an extremely extensible and modular architecture, composed of a set of core functions and plugins that allow a high degree of personalization.

The Python language can be used to create new plugins or to extend the existing ones in order to build complex applications and to define and implement robust data integration and data exchange operations. The native support for GML and other standard formats makes QuantumGIS the perfect mate for the developers of geographic integrated systems. AnnoMAD GIS is build on top of the 1.0.2 version (aka "Kore") of QuantumGIS, the current official long term support (LTS) version.

We have extended QuantumGIS by defining a set of actions to create semantic information related to geographic features (points, polygons etc.) and a GML Publication plugin to export the geographic data in GML format towards a semantic enabled geographic server (e.g. AnnoMAD DB but also other online systems like MapServer and GeoServer) from which clients can afterwards build customized maps [DFLP09].

In the latest release of AnnoMAD GIS we added a new and optimized set of features, developed as Python plugins, intended to increase the level of interoperability with the other system components by performing advanced operations on the set of typical GIS functionalities provided by the GRASS/QuantumGIS framework (e.g. functions for creating/importing raster and vector layers, for georeferencing the maps, for defining features and perform spatial interrogations, and so on) [FL07]. Specifically:

- *to cast geographic features as AnnoMAD Text global entities*, to be used for annotating free-text documents. This function transforms each feature of the GIS in an instance of the CIDOC-CRM *E53.Place* class and make it available through AnnoMAD Text as a *global annotation* carrying, in addition, the feature specific spatial information, encoded in GML format and embedded by using the CIDOC-CRM E73.Information_Object entity as, for example, shown below:

```
<crm:E53.Place rdf:about="F231">
  <crm:P67B.is_referred_to_by>
    <crm:E73.Information_Object>
      <gml:Polygon>
        <gml:outerBoundaryIs>
          <gml:LinearRing>
            <gml:coordinates>
              <(coordinates here)/>
            </gml:coordinates>
          </gml:LinearRing>
        </gml:outerBoundaryIs>
      </gml:Polygon>
    </crm:E73.Information_Object>
  </crm:P67B.is_referred_to_by>
</crm:E53.Place>
```

  Textual descriptions concerning the same geographic features can be annotated from AnnoMAD Text using this kind of global entities to establish meaningful links between GIS and free-text documents. Geographic global entities can be imported directly through the AnnoMAD Text interface or shared using and made available online through the AnnoMAD DB server.

- *to assign existing AnnoMAD Text annotations to geographic features*. Mainly this operation allows users to import already defined annotations from the AnnoMAD Text component and to "enrich" them with the related GML spatial information. Once an annotation is enriched, all the text fragments and documents annotated using it are automatically bound with the related geographic GML information coming from AnnoMAD GIS.

- *to express some of the most common relationships among spatial objects* (e.g. the "is contained in" spatial relationship) *using CIDOC-CRM properties* (e.g. the P89F.falls_within property). This way it is possible to define semantic relationships between aggregated annotations directly from AnnoMAD GIS. This operation provides a preliminary coherence control between semantic and geographic information.

- *to call a different component for the visualization of non-geographic data*: it is possible, for instance, to click on a polygon in AnnoMAD GIS and ask the system to display the related semantic information (if any) in AnnoMAD Text or in a web browser by calling the semantic interface provided by AnnoMAD DB.

- *to export the entire GIS project towards AnnoMAD DB* or towards any other WMS server, for example MapServer. It is therefore possible to exchange information over the web and to build a basic WebGIS on-the-fly. The basic version of QuantumGIS already provides many import/export features of a project from a given WMS server. This kind of operation could be very handy to reimport a whole AnnoMAD GIS project into another instance of QuantumGIS or in a brand new installation of the software.

2.3. AnnoMAD DB

Both AnnoMAD Text and AnnoMAD GIS work as independent tools and, because of their modular nature, they can eventually be linked to other frameworks in order to build up interoperable environments depending on the user's needs. The extensive support for many Java and C++ APIs provided by the Adobe Flex Framework, and the support for standards like GML and RDF facilitate the use of semantic containers (e.g. Sesame [SES] and AllegroGraph [ALL]) to store and retrieve information generated by the AnnoMAD system.

Nonetheless, to improve the efficiency of our framework, we have also developed a featured data archive capable to store both semantic and geographic information, to reply to simple and complex queries, and to generate on-the-fly aggregated objects to be used in different contexts. The core of

AnnoMAD DB is SAD, a semantic archive built to store the digital version of all the the text documents and the related semantic annotations. SAD was developed at PIN during the EPOCH European project and has already been tested and used in many different applications. The current version of SAD is entirely written in PHP and takes advantage of the ARC2 RDF classes [ARC], an open source set of PHP libraries specifically oriented towards the management of semantic information and query features.

SAD makes it possible to store and manage every kind of HTML/XML based information, including RDF and GML spatial data. Information stored in the archive is available for every kind of operation or request. The Semantic Archive also supports many popular protocols such as REST [RES], SOAP [SOA], JSON [JSO], for communication with the other components of the AnnoMAD system and with other external frameworks, and provides SPARQL query features to semantically retrieve information.

The current release of the DB also implements a basic set of semantic interfaces and a basic reasoner able to compare spatial and semantic relations and to check for data consistency within the system. This final release of AnnoMAD DB will provide a more powerful reasoner able to check for the coherence of the DB by comparing, for instance, the semantic statements of the annotations defined in AnnoMAD Text and the geographic "facts" inferred from the spatial information in AnnoMAD GIS, asking the user for disambiguation in case of doubts.

3. Testing the system

The initial version of the AnnoMAD System was mainly focused on managing the complexity of the excavation information produced during the extensive excavations of an archaeological site in south-eastern Cyprus. During the excavation campaigns from 1971 until 2005, directed by the late P. Åström, a Late Bronze Age harbour town was exposed near the mosque of Hala Sultan Tekke [Åst07].

3.1. The archaeological excavation

During fieldwork, relevant data were entered on forms, which are preserved in the Hala Sultan Tekke archive. Every feature discovered on the ground was given a Feature number. This means that a part of a layer, a wall, a pit, a heap of stones, etc. could be defined as a feature. The archive contains sheets for the description of layers, tombs, features, objects and for the classification and statistics of pottery. In addition to these find reports, photographs, plans, drawings and sections are also included.

The archaeological finds testify of the daily life, the various trade relations and the involvement in the copper industry. The oldest remains date to the end of the Middle Bronze Age (ca. 1600 BCE). The greater part of the excavation however, reveals the last phases of the settlement, just before its final abandonment at the end of the Late Bronze Age (ca. 1110 BCE). Despite the work that has already been published in twelve preliminary excavation reports, the post-excavation analysis of the site is required: the site's stratigraphic sequence and its architectural contexts still have to be fully defined, synthesized and published, as well as key artifact assemblages, which yet require analysis and reporting.

3.2. The HST Ontology

At the very beginning, to encode the texts and the geographic data and to create the annotations and their relationships, we used the entities and the properties provided by the CIDOC-CRM ontology. However CIDOC-CRM is an extensive and very complex ontology, often not as user friendly as required by archaeologists and in general by people involved in Cultural Heritage activities [Hod02] [Loc03].

To make the annotation process more intuitive to the archaeologists who use the application and to stress the system to check its capabilities to deal with different ontologies, we created a domain ontology, the HST ontology [HST], defining domain specific entities mapped on a subset of CIDOC-CRM classes. The HST core ontology was agreed upon by the archaeologists and the applications developers at the very beginning of the development process. Many extensions of the domain ontology pertaining to the case under study have also been added when required, during the encoding of the archaeological material, without modifications to the core. The HST ontology has proven to be a very flexible structure, already mapped to CIDOC-CRM and suitable not only for the specific needs of the Hala Sultan Tekke documentation, but also suitable in other similar contexts.

3.3. AnnoMAD in action

The AnnoMAD system has been used to integrate all kinds of semantic information extracted from different information sources (i.e. the archaeological site in situ, publications, the movable archaeological material, and the Hala Sultan Tekke archive). The value of the system can best be illustrated with an example, namely the information concerning a silver bowl registered as *N 1450*.

The silver bowl is considered as an isolated object, found at Hala Sultan Tekke. It was discovered during the excavation campaign of 1981 in a rubble wall which abuts an ashlar wall in *Building C* at *Area 8*. The find location is *grid FGb 476*. The bowl was published in 1982 by P. Åström and E. Masson. Åström also referred to the bowl in other articles. The Hala Sultan Tekke archive includes the find list of 1981, recording among other finds the silver bowl, its registration number, and the feature where it was found in, numbered *F 1587*.

The corresponding forms describe *F 1587* as a "triangular

area west of the ashlar wall" in layer 3b and 4. Moreover, they mention a second feature, numbered *F 1608*, which is described as a "stone concentration" under *F 1587*, in *Room 23A*. The latter feature actually represents the rubble wall which abuts the ashlar wall to the west in the courtyard of *Building C*. Furthermore, the forms give pottery descriptions and list registered finds, such as two net weights in lead. Nowadays, we can find the silver bowl on display at the Cyprus Museum in Nicosia. The pottery sherds associated with *F 1587* and *F 1608* were previously stored in the Dromolaxia storerooms and were recently transported to the Larnaka District Museum.

In AnnoMAD, the silver bowl, mentioned in many textual sources, is annotated as `HST_Find` (an entity of the HST ontology mapped on the `Physical_Man-made_Thing` entity of the CIDOC-CRM); *N 1450* is annotated as a `HST_Feature` (i.e. a CIDOC-CRM `Object_Identifier`); Wall *F 1608* is annotated as a `HST_Feature_Grid` (i.e. CIDOC-CRM `Spatial_Coordinates` enriched with GML description of the feature) and the publication of Åström and Masson is annotated as a `HST_Bibliographical_Reference` (i.e., a CIDOC-CRM `Information_Carrier`). The architectural and find contexts associated with the silver bowl can be defined using the AnnoMAD System by way of working with the CIDOC-CRM relationships and the geographic entities.

```
The silver bowl (HST_Find)
   is_found_in (P56)
      Wall F 1608 (HST_Feature)
   consists_of (P45)
      Rubble Stones (CRM_Material)
   has_current_location (P55)
      Cyprus Museum (HST_Museum, CRM_Place)
   falls_within (P10)
      Wall F 1587 (HST_Feature)

Wall F1587 (HST_Feature)
   contains (P89)
     Pottery Sherds (HST_Pottery, CRM_Material)

Pottery Sherds (HST_Pottery, CRM Material)
   moved_ from (P27)
      Dromolaxia (HST_Storeroom, CRM_Place)

Dromolaxia (HST_Storeroom, CRM_Place)
   has_current_location (P55)
     Larnaka District Museum (HST_Storeroom)
```

A vivid example showing how easy it is to build up and trace the story of an object starting from dispersed pieces of information, by encoding them in a formal notation using RDF and the concepts provided by the ontologies, to get back an automatically created logical chain of events understandable by machines.

4. Conclusions and further work

The AnnoMAD System is the result of close collaboration between the computer system designers of PIN and The Cyprus Institute, and the archaeologists of MARI, University of Brussels. The feedback from the archaeologists was vital to improve the system, to fix the various bugs, the various system weaknesses and conceptual problems, and to insert extra or new requirements.

Future enhancement of the system will concern the query/retrieve features of the AnnoMAD DB and the creation of more efficient and user friendly interfaces for querying and browsing the stored data. An improvement of the reasoner for coherence checking and conceptual bug fixing is also required.

The implementation of new solutions and new features will hopefully lead to an improved version and to the development of a general purpose tool that can be used for every kind of textual documentation, not only archaeological, using any ontology required by users.

The final goal of our work is the release of a general-purpose tool, indifferent to the non homogeneity of sources, yet flexible enough to manage textual sources that can also be very different from each other and encompass archaeological records, historical sources and direct observations. The wide use of standards at any level of the encoding operations will guarantee interoperability even with data coming from different contexts, like geographic information and structured data from databases and Digital Libraries.

An adapted edition of the system is also going to be used within the 3D-COFORM project to encode and the manage medatada and other textual information concerning 3D models [ND06]. The final version of the 3D-COFORM Edition will be released as part of the 3D-COFORM Integrated Toolset at the end of the project in 2012.

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[SES] Sesame: RDF Schema Querying and Storage. http://www.openrdf.org.

[SOA] SOAP - Simple Object Access Protocol. http://www.w3.org/TR/soap/.

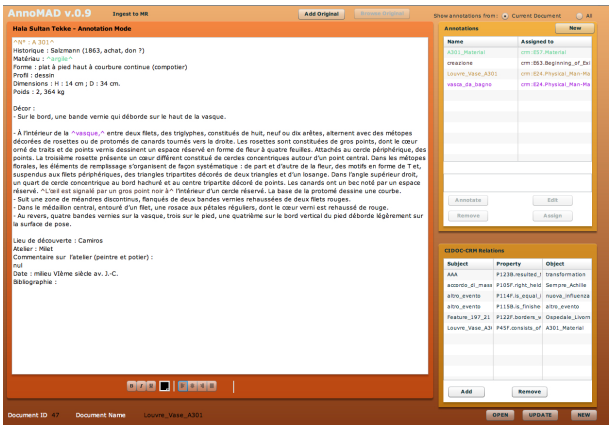

Figure 1: *AnnoMAD Text Interface*

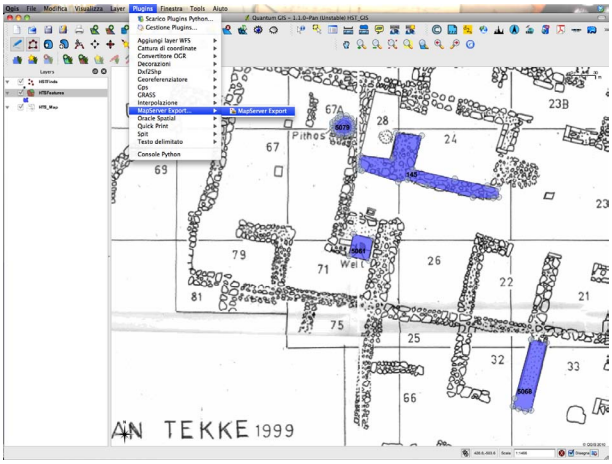

Figure 2: *AnnoMAD GIS Interface*

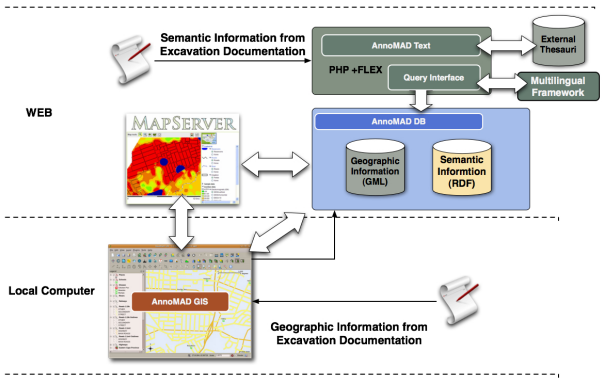

Figure 3: *AnnoMAD System Architecture*