

Incorporating TimeML into a GIS

Marta Guerrero Nieto, María José García Rodríguez, Adolfo Urrutia Zambrana, Willington Siabato, Miguel-Ángel Bernabé Poveda

Grupo Mercator - Universidad Politécnica de Madrid
C^a de Valencia, km.7, 28031 Madrid, Spain
{mguerrero, adolfo.urrutia, mjosegr}@topografia.upm.es
{w.siabato, ma.bernabe}@upm.es

Abstract. This study approaches a methodology for the integration of temporal information belonging to a historical corpus in a Geographic Information System (GIS), with the purpose of analyzing and visualizing the textual information. The selected corpus is composed of business letters of the Castilian merchant Simón Ruiz (1553-1597), in the context of the DynCoopNet Project (Dynamic Complexity of Cooperation-Based Self-Organizing Commercial Networks in the First Global Age), that aims to analyze the dynamic cooperation procedures of social networks.

The integration of historical corpus into a GIS has involved the following phases: (1) recognition and normalization of temporal expressions and events in 16th century Castilian following the TimeML annotation guidelines and (2) storage of tagged expressions into a Geodatabase. The implementation of this process in a GIS would allow to later carrying out temporal queries, dynamic visualization of historical events and thus, it addresses the recognition of human activity patterns and behaviours over time.

Keywords: TimeML, historical corpus, GIS, semantic annotation.

1 Introduction

Events are placed in time and space; both are needed to get a full representation of historical events. Traditionally these two components have been studied separately by History and Geography, although both disciplines require for their understanding and reasoning the joint consideration of space and time of any given phenomenon. The Geographic Information Systems (GIS) have greatly facilitated management, editing analysis and visualization of geographic data related to the territory. However, the use of GIS as a tool of spatio-temporal analysis and dynamic representation of historical facts with the purpose of reviewing and strengthening many aspects of geographic history [1] is an issue which has been contemplated since de 70's [2]. At the present time one of the subjects which is currently an open research line is the

incorporation of reasoning and quantification of time and the recognition of temporal patterns.

One of the objectives of the DynCoopNet Project, in which this research study is framed, is to inquire into the dynamics of cooperation commercial networks that were established in the First Global Age (1400-1800). Our contribution to that project is to encourage the use of GIS in social science and humanities and approach the studies of confrontation and review of historical events, incorporating for that end tools capable of carrying out analysis in a temporal GIS.

In this paper we propose a methodology for incorporation of the time variable into a GIS. First, we aim at identifying temporal expressions using TimeML that allows describing both definite and indefinite temporal expressions; it also allows defining the events and establishing temporal relationships inspired by Allen's temporal algebra [3]. Second, we propose the incorporation of temporal concepts included in written texts into a GIS. For that purpose we intend to extract the temporal information from a historical corpus made up of letters written in 16th century Castilian by the merchant Simón Ruiz by using Natural Language Processing (NLP) tools.

In the next section the temporal component will be studied in depth taking into account the two research areas as described. Subsequently the annotation guide used to extract temporal information will be described, and in the fourth section the methodology used in the identification and normalization of temporal expressions of the Spanish language will be shown, also paying attention to the integration of TimeML into the Geodatabase. Finally the conclusions of the study and future work will be outlined.

2 Time

The temporal information has been researched from different disciplines. From the computational viewpoint, temporal information processing has aroused great interest in the scientific community, as attested by the large number of workshops which have taken place in the area of creation of extraction and temporal analysis tools (TERQAS [4], TANGO [5], DAGSTUHL [6], MUC [7]); in the area of temporal semantic annotation languages (TIDES [8], TimeML [9]); in the area of annotation systems (TERSEO [10], TARSQI [29]) and in different evaluation workshops (TERN [11], TempEval [12]). Likewise, in the field of geographic information a large number of studies have approached this subject. The incorporation of the temporal variable into GIS has been investigated along the 1990 decade. The first studies focussed on the management of time in the data bases [13] [14]; recent research is focussed on spatio-temporal modelling. This data modelling is being carried out from a conceptual framework and a technical viewpoint [15] [16]. Many models are based on the addition of the temporal variable within the spatial databases, restricted to individual layers, such as the 'Spatio-temporal Cube' Model [17], 'Snapshot' Model [18] or the Composite

Spatio-temporal Model [19]. The most recent spatio-temporal models are associated to objects: Moving Object Data Models [20], Spatio-Temporal Object-Oriented Data Model [21], and Object-Relationship Model [22]). Other studies are currently developing advances in spatio-temporal databases, such as the Intentionally-Linked Entities Model (ILE) [23], which allows representing complex entities and establishing a relational context. However, although great conceptual efforts have been made for the building of databases and prototypes based on spatio-temporal databases and their implementation for a particular application, there is no global model as yet that might be used for any application.

As discussed above, this study will be used markup languages to integrate temporal information of historical phenomena. The specific markup language for geographic information is GML (Geographic Markup Language), delineated by the Open Geospatial Consortium (OGC) in 2000. This language has been defined for modelling, transportation and storage of geographic information [24]; however, even though it has a temporal reference system, it lacks a detailed description. Actually there have been initiatives to extend the geographic markup language over the temporal domain so as to being able to represent this type of information [25]. The choice of the temporal markup language has been made subservient to the geographic tool since an already known language was needed and used for this tool, at the same time enabling description of the temporal variable and information interchange.

Temporal information stored as metadata of the geographic data of a document may be appropriate for queries related to the date of that document but they are insufficient if event duration is queried or other dates other than the publishing date wants to be obtained [26]. For the incorporation of temporal expressions coming from a natural language document into a database, those expressions must be presented with a certain structure and they must be subjected to normalization. To this end the TimeML markup language has been used.

3 TimeML temporal markup language

The TimeML temporal semantic annotation is a linguistic specification to annotate events and temporal expressions, that it provides a systematisation for the extraction and representation of temporal information and for information interchange. It came into being with the aim of annotating newspaper articles, although, as we will see, it may be extended to another type of text information. The most characteristic properties of this language are: interpretation of temporal expressions, temporal annotation of events, and arrangement of events to others through a temporal anchorage. TimeML, developed in 2002 [4] [5], is being consolidated as an ISO standard (ISO WD 24617-1:2007), and it is compatible with ISO 8601 which specifies the standard notation to store dates. It should be noted that it has been approved as an annotation language for TempEval, whose objective is to evaluate the automatic systems in text semantic analysis [12].

TimeML combines and extends characteristics of other temporal annotation standards such as STAG [27] (guide to annotate events and time in newspaper texts, whose tag for temporal information is TIMEX) and TIDES [8], developed to mark temporal expressions of a document and identify the value of the temporal expression (TIMEX2). In TimeML the temporal expressions are marked with the TIMEX3 tag, which intends to indicate an improvement in relation to previous tags.

For treatment of the different *timexes* there are different annotation languages and an annotated corpus for the English language, TimeBank, made up of 183 articles of the US press [28]. There are also automatic tools of temporal annotation, TARSQI [29] and TERSEO [10] and temporal ontologies, among them Time Ontology and its forerunner DAML Time 2006 [20] standing out since it is related to TimeML. Yet the majority of those resources cannot be used for the Spanish language or they have ended up being obsolete, so the creation of Spanish corpora annotated in TimeML and the development of specific tools would be necessary.

3.1 TimeML: description and characteristics

This markup language has three basic tags: TIMEX3, EVENT, SIGNAL and three link subtypes: TLINK, ALINK and SLINK. Next a brief explanation of each tag is presented:

- TIMEX3 is used to mark temporal expressions: *21st March 2001, yesterday, at 6 PM, next year.*
- EVENT is used to mark events mentioned in a text: *to occur, to believe, to study, to begin.*
- SIGNAL is used to annotate temporal signals: *before, after, during.*
- TLINK is used to mark temporal relationships: *Louise went to Romania from the 21st to the 27th of March* (the temporal information is related to the event *to go*).
- ALINK is used to annotate aspectual relationships: *Mary will begin presentation of her paper at 12 noon* (the verb *will begin* is showing a phase of the event).
- SLINK is used to annotate relationships of modality or evidentiality: *John said he would go to Romania in March.* (*conjecture is made before the realisation of the event*).

TimeML offers the possibility of expressing different granularities. It owns four types for time expression (TIMEX3):

- DATES is used for expressions referring to a calendar: *on the 22nd of March 2010, last Sunday, yesterday morning.*
- DAY TIMES is used for a temporal expression less than a day: *this afternoon, at twenty minutes to three.* Attention should be paid to the

distinction between these two types of times because of the different granularity of the expressions.

- DURATION is used to describe a duration in time: *for four days, two years ago*.
- SET is used for expressions of repetition in time: *twice a week, every eight days*.

The natural language does not have a single way of expressing a specific granularity but there may be different temporal expressions referring to the same granule. Granularity is the level of detail with which the time is measured; it may be stated that natural language does not have a canon for time expression [26]; however it is known that the granularity of linguistic temporal expressions differs adapting to the Gregorian calendar. Equivalencies may be found between the natural language and this calendar, at least in western languages. Hence the differences proposed to model time following the calendar [30] [31].

In order to ensure the consistency of data structure in all the documents, a DTD has been used. It allows defining the data format and the document structure, its elements and tag nesting. Thus, those documents may be validated since the element structure of the elements and their description may be known.

4 Methodology for incorporation of temporal expressions into a GIS

The purpose of this methodology is the incorporation of the temporal variable, described by means of a temporal markup language coming from a text information, into a GIS. The corpus used comes from a selection of 20 letters of the Spanish merchant Simón Ruiz, dated in the 16th century.

The procedure has been divided into three steps:

- Automatic identification of the temporal expressions of the corpus using the *GeoParser* server.
- Manual normalization of the temporal expressions with TimeML.
- Incorporation of TimeML into a Geodatabase.

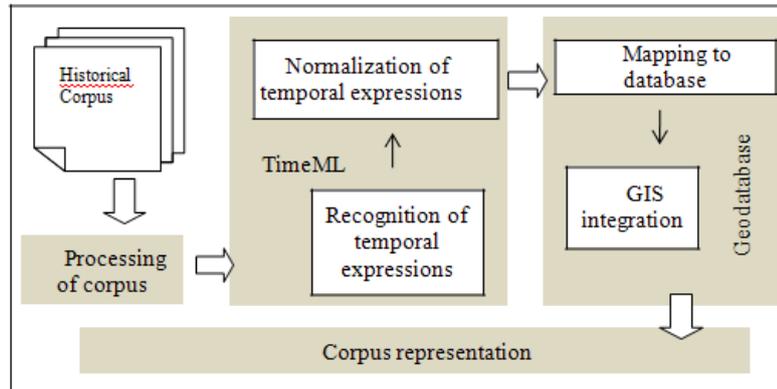


Fig. 1. Diagram of the processes included in the proposed methodology.
Source : author of the study.

4.1 Identification of the temporal expressions

No automatic tool associated to TimeML has been developed yet for recognition of temporal expressions in the Spanish language. In view of this lack, we have opted to use *GeoParser*, a text processing tool that identifies these expressions and recognizes the geographic scope of the document, as well as the whole geographic entities mentioned throughout the document. This tool, a spinoff of the DIGMAP Project [32], has been used with the aim of assisting in the detection of temporal expressions, disambiguation and assignment of a geographic environment to those expressions. In this case the document to deal with is written in old Castilian, so that it is necessary to carry out some modifications in the lexicon of the application, so that these expressions are properly recognized, therefore normalized.

This recognition process implements the Named Entity Recognition Method (NER), based on seeds and supplemented by searches in gazetteers and register queries containing names of historical periods. This approach has been extended with rules of expression for recognition of dates, durations and frequencies extracted from the TimeML annotation schema. This process has been carried out manually, marking the temporal expressions recognized by the *GeoParser*, as well as those that were not identified.

The procedure for recognition of these temporal expressions is facilitated by the *DateTime* tag, with which *GeoParser* marks and describes the already identified expressions.

An additional advantage of the utilization of *GeoParser* is that it facilitates the incorporation of the expression identified in the GIS since not only identifies but it also infers the geographic context to which it is related. For this purpose it relies on a gazetteer having a register of placenames, historical periods and description of their properties, e.g. it contains place types, coordinates, temporal intervals, hierarchies, alternative names and semantic

associations. The gazetteer used [33] integrates data from multiple sources, among them GeoNames and the directory of historical periods ECAI [34].

4.2 Normalization of temporal expressions in TimeML

The normalization of temporal expressions has been carried out semi-automatically due to the fact that at the present time *GeoParser* does not normalize recognized expressions; besides, since we are dealing with a historical corpus of old Castilian, the adaptation of TimeML has been necessary in accordance with that linguistic variety and the incorporation of its rules. This adaptation has already been carried out for the English, Chinese and Italian languages, the adaptation for the Spanish language being underway [35] [36]. It is relevant to note that for the time being no studies have been undertaken about the old correspondence in TimeML. So far the ground on which work about temporal extraction has been done is newspaper or legal texts [37].

After identification of temporal expressions in Renaissance Castilian, the next step has been the TimeML annotation of those expressions that had not been previously normalized. From the beginning XML has been chosen as language, without forgetting that TimeML is not dependent on this format.

Next an example is shown of the corpus of normalization of these temporal expressions in TimeML where the guide values appear: `TIMEX3`, `EVENT` and `TLINK`.

“A primero de agosto recibí la de v.m. de 12 del pasado” (On the first of August I received yours of the 12th of the past month from your honour)

```
<TIMEX3 tid="tid12" type="DATE" value="1570-08-01"
anchorTimeID="tid11">primero de agosto</TIMEX3>

<SIGNAL sid="sid1"> a </SIGNAL>

<EVENT eid="eid28" aspect="PERFECTIVE" mood="NONE"
pos="VERB" vform="NONE" class="OCCURRENCE"
tense="PAST" stem="RECIBIR">recibi</EVENT>

<TIMEX3 tid="tid13" type="DATE" value="1570-07-12"
anchorTimeID="tid11">12 del pasado </TIMEX3>

<SIGNAL sid="sid2"> de </SIGNAL>

<TIMEX3 tid="tid11" type="DATE" value="1570-08-08">
ocho de agosto de 1570</TIMEX3>

<TLINK relType="INCLUDES" lid="lid31" timeID="tid12"
relatedToEventInstance="eid28" signalId="sid1"/>

<TLINK relType="BEFORE" lid="lid32" timeID="tid13"
relatedToEventInstance="eid28" signalId="sid2"/>
```

The type of temporal information we are likely to find in the letters is varied and rich due to the rhetoric of that time and the type of document, with temporal expressions of the type: “*a tantos días*” (*within that many days*), “*de pocos días a esta parte*” (*from a few days hither*) or “*diez del que viene*” (*tenth of next*). As can be observed by the example, the linguistic expressions used in the letters may be deictic, i.e. knowledge of the narrative moment in which the expressions are framed is needed to be able to pin down the time interval comprised by the expression. The corpus used allows using the temporal metadata in order to determine at which moment the events occur, so as to be able to locate them on a timeline. This is achieved with the *AnchorTime* attribute, as in the example, allowing establishment of a temporal axis.

In order to arrange the events of the corpus, there are two ways of proceeding: extrinsic and intrinsic. The former means arranging the letters of Simón Ruiz only taking into account the document publishing dates, i. e. the metadata. The latter consists of arranging all the temporal expressions appearing in the document. Since this one is a more sophisticated process, it is necessary to deal with the entire information of the corpus.

The tag marking the temporal relationships is the *TLINK*, those relationships being based on the thirteen binary relationships of Allen’s temporal algebra. The *TLINKS* represent the temporal relationships existing between two events, two times, or between an event and a time. In the example, the event would be “*recibi*” (*I received*), which is accompanied by two temporal expressions, “*primero de agosto*” (*the first of August*) and “*12 del pasado*” (*the 12th of the past month*). The temporal relationships between these three elements are marked with the *TLINK* tag, as can be seen in the example.

It is relevant to remember that the XML is not inherent to the TimeML since the latter may turn into other formats; as a matter of fact, a web annotation tool is being developed that generates data in database tables from text annotation [39].

4.3 Incorporation of TimeML as part of a geodatabase

After having annotated the corpus in TimeML we go on with the integration of the text in the geographic information system. The GIS have different data formats, all of which assume a database-oriented structuring of information: geodatabases, tables in MS Access, tables in MS Excel (with certain restrictions), etc. The porting of TimeML annotation into any of these formats is guaranteed by the fact that TimeML does not allow for recursive entities, and hence it provides a stable, predictable structure, so that a relational database could be designed to store the information contained by TimeML annotation.

In order to automate the transfer of information, creation of a mapping algorithm between both structures (database and corpus) is required with the purpose of saving and extracting the information freely. Such tool could be

implemented as an internal module of the database manager or as an independent software component [38]. Consequently both entities (geodatabase and the DTD defining TimeML) would be practically identical. This would facilitate introduction of the information, and in addition, the annotated expressions of the corpus would not undergo any change. The XML and the geodatabase turn into the two faces of the storage of the temporal expressions.

Finally, having the information within the geodatabase, the representation of the annotated corpus will depend on peculiarities the historical events described; for example if we were dealing with the binnacle of a ship's captain, the representation of shipping routes, goods transported, oceanic currents, winds and storms could be emphasized, but if the corpus was made up of texts describing land voyages, the representation details would be substantially different, highlighting other aspects. In this regard, as far as representation of the linguistic annotation of the corpus is concerned, we may add that this is a future line of research which involves the dynamic display of events.

5 Conclusion and future work

A methodology has been designed for the recognition and normalization of temporal expressions following the TimeML specifications; the procedure followed has been presented and the union of the two scopes for the development of the temporality in the GIS has been pointed out. Likewise the methodology for link linguistic corpora and the Geographic Information Systems has been presented.

The functional advantages of integrating document texts in natural language and the representation of their temporality in a GIS have been exposed.

The advantages of utilization of the TimeML have been described: its standard character, its format as a database, its applicability to any language by providing a defined grammar and above all, by allowing the arrangement of events on a timeline. TimeML, as other markup languages, allows massive treatment of text information.

Some of the limitations to carry out the proposal have been described: (a) to achieve the representation of the temporal information tagged in the corpus, the Geographic Information System should have a spatio-temporal database allowing storage and querying of the information coming from the corpus, i.e. a temporal GIS reflecting the TimeML; (b) corpora tagged in TimeML are scarce for languages other than English which prevents the use of automatic learning techniques and gives rise to the use of semi-automatic and manual annotation; (c) adaptation of TimeML guide to old Castilian is needed to facilitate identification of temporal expressions in this type of texts.

As future work we intend to get the recognition, normalization and quantification of temporal expressions in wider Spanish historical corpora as

well as the integration of temporal and spatial linguistic annotation. In addition we have anticipated the creation of an analysis tool allowing the utilization of temporal expressions at the time of specifying the query within a spatio-temporal GIS, as well as the extension of the SQL queries with diffuse temporal expressions and temporal proper names, i.e. we seek facilitate the implementation of natural languages queries containing temporal expressions in a GIS.

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References

1. Gregory, I.N., Ell, P.S.: Historical GIS: Technologies, Methodologies and Scholarships. Cambridge University Press (2007)
2. Sack R.D.: Chronology and Spatial Analysis. *Annals of the Association of American Geographers*, vol.64, pp.439--452 (1974)
3. Allen, J. F.: Maintaining knowledge about temporal interval. *Communications of ACM*, 26, 11, pp. 832--843 (1983)
4. Pustejovsky, J.: TERQAS: Time and Event Recognition for Question Answering Systems. ARDA Workshop, MITRE, Boston (2002). Available at <http://www.timeml.org/site/terqas/index.html>
5. TANGO (TimeML Annotation Graphical Organizer), <http://www.timeml.org/site/tango/index.html>
6. Dagstuhl Seminar Proceedings. Annotating, Extracting and Reasoning about Time and Events, <http://drops.dagstuhl.de/opus/volltexte/2005/313/>
7. Advanced Research Projects Agency. Proceedings of the Sixth Message Understanding Conference (MUC-6) (1995). Software and Intelligent Systems Technology Office.
8. Ferro, L., Gerber, L., Mani, I., Sundheim, B., & Wilson, G.: TIDES 2005 Standard for the Annotation of Temporal Expressions. The MITRE Corporation (2005)
9. Pustejovsky, J., Castaño, J., Ingria, R., Saurí, R., Gaizauskas, R., Setzer, A., Katz, G., Radev, D.: TimeML: Robust specification of event and temporal expressions in text. In: AAAI Spring Symposium on New Directions in Question-Answering (Working Papers), Stanford, CA, pp. 28--34 (2003)
10. Saquete, E., Martínez-Barco, P., Muñoz, R., Negri, M., Speranza, M., Sprugnoli, R.: Automatic resolution rule assignment to multilingual Temporal Expressions using annotated corpora. In: Proceedings of the Thirteenth International Symposium on Temporal Representations and Reasoning, pp. 218--224 (2006)
11. DARPA TIDES (Translingual Information Detection, Extraction and Summarization). The TERN evaluation plan: Time Expression Recognition and Normalization. Working papers, TERN Evaluation Workshop (2004).

- Available at <http://timex2.mitre.org/tern.html>
12. Verhagen, M., Gaizauskas, R., Schilder, F., Hepple, M., Katz, G., Pustejovsky, J.: SemEval-2007. Task 15: TempEval Temporal Relation Identification. In: Proceedings of SemEval 2007, 4th International Workshop on Semantic Evaluation, ACL, Prague, pp.75--80 (2007)
Available at <http://nlp.cs.swarthmore.edu/semeval/tasks/index.php>
 13. Roddick, J.F. y Patrick, J.D.: Temporal semantics in information systems-A survey. *Information systems*, vol. 17, pp. 249--267 (1992)
 14. Tansel, A.U.: Temporal databases: theory, design, and implementation, Benjamin/ Cummings series on database systems and applications. Benjamin/ Cummings Pub. Co., Redwood City, Calif. (1993)
 15. Langran G.: Time in Geographic Information System. Taylor & Francis (1992)
 16. Peuquet, D.J.: Representations of Space and Time. Guilford Publications, New York (2002)
 17. Hägerstrand, T.: What about people in regional science? *Papers of the Regional Science Association*, vol. 24, pp. 7--21 (1970)
 18. Armstrong, M. P.: Temporality in spatial databases. In: Proceedings GIS/LIS'88, San Antonino, Texas, USA, Vol. 2, pp. 880 --889 (1988)
 19. Langran, G. y Chrisman, N.: A framework for temporal geographical information systems. *Cartographica*, vol. 25, no. 3, pp. 1--14 (1988)
 20. Erwig, M., Guting, R.H., Schneider, M., Vazirgiannis, M.: Spatio-Temporal Data Types: An Approach to Modeling and Querying Moving Objects in Databases. *GeoInformatica*, vol. 3(3), pp-- 265-291 (1999)
 21. Montgomery, L. D.: Temporal Geographic Information Systems Technology and Requirements: Where We are Today. Thesis, Department of Geography, Ohio State University, USA (1995)
 22. Claramunt, C., Parent, C., Spaccapietra, S., Theriault, M.: Database Modeling for environmental and Land Use Changes. *Geographical Information and Planning*, Chapter 20, Springer-Verlag (1998)
 23. Kantabutra, V.: A new type of database system: Intentionally-Linked Entities: a detailed suggestion for a direct way to implement the entity relationship data model. *CSREA: EEE 2007*, pp. 258--263 (2007)
 24. OpenGIS, Geography Markup Language (GML). Encoding Standard, OGC 07-036, v. 3.2.1. Available at <http://portal.opengeospatial.org>
 25. Zipf, A., Krüger, S.: TGML: Extending GML by Temporal Constructs: A Proposal for a Spatiotemporal Framework in XML. In: ACM-GIS 2001, the Ninth ACM International Symp. on Advances in Geographic Information Systems, Atlanta, USA (2001)
 26. Llidó Escrivá, D. M.: Extracción y recuperación de la información temporal, Thesis Universidad Jaume I, Castellón, Spain (2002)
 27. Setzer, A., Gaizauskas, R.: Annotating Events and Temporal Information. In: *Newswire Text*, In LREC 2000, pp. 1287--1294, Athens (2000)
 28. Pustejovsky, J., Hanks, P., Saurí, R., See, A., Gaizauskas, R., Setzer, A., Radev, D., Sundheim, B., Day, D., Ferro, L., Lazo, M.: The TIMEBANK Corpus. In: Proceedings of Corpus Linguistics 2003, pp. 647--656 (2003). Available at <http://www.timeml.org/site/timebank/documentation-1.2.html>
 29. Verhagen, M., Mani, I., Saurí, R., Littman, J., Knippen, R., Jang, S. B., Rumshisky, A., Phillips, J., Pustejovsky, J.: Automating temporal annotation with TARSQI. In: 43rd Annual Meeting of the Association for Computational Linguistics, Ann Arbor, Michigan (2005)

30. Hobbs, J. R., Pustejovsky, J.: Annotating and Reasoning about Time and Events. In: Proceedings, AAAI Spring Symposium on Logical Formalizations of Commonsense Reasoning, Stanford, California (2003)
31. Martins, B., Manguinhas, H., Borbinha, J., Siabato, W.: A geo-temporal information extraction service for processing descriptive metadata in digital libraries, e-Perimetron. In: International web journal on sciences and technologies affined to history of cartography and maps, vol.4 no.1 pp. 25--37 (2009)
32. Han, B., Gates, D., Levin, L.: Rom Language to Time: A temporal Expression Anchorer. In Proceedings of the 13th International Symposium on Temporal Representation and Reasoning (TIME 2006), Budapest, Hungary (2006)
33. Manguinhas, H., Martins, B., Borbinha, J., Siabato, W.: The DIGMAP Geo-Temporal Web Gazetteer Service, e-Perimetron. In: International web journal on sciences and technologies affined to history of cartography and maps, vol. 4 no.1, pp. 9--24 (2009)
34. Petras V., Larson R. Buckland M.: Time period directories: a metadata infrastructure for placing events in temporal and geographic context. In: Proceedings of the 6th ACM/IEEE-CS, Joint Conference on Digital Libraries (2006)
35. Saurí, R., Saquete, E., Pustejovsky, J.: Annotating Time Expressions in Spanish, TimeML Annotation Guidelines (in Press).
36. Saurí, R., Batiukova, O., Pustejovsky, J.: Annotating Events in Spanish, TimeML Annotation Guidelines (in Press).
37. Schilder, F., and Mcculloh, A.: Temporal information extraction from legal documents. In: Katz et al. <http://drops.dagstuhl.de/opus/volltexte/2005/318/>
38. Elmasri, R.: Fundamentals of database systems. Pearson Education, 4th ed., pp. 842--856 (2004)
39. Verhagen, M.: BAT: Brandeis Annotation Tool, v. 4.2, (2009) <http://www.timeml.org/site/bat/>