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ONTOLOGICAL ENGINEERING FOR THE CADASTRAL DOMAIN

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ABSTRACT

The term 'ontology' has been used in many ways and across different communities. In th following we will introduce ontologies as an explication of some shared vocabulary or conceptualization of a specific subject matter. The main problem with the use of a shared vocabulary according to a specific conceptualization of the world is that much information remains implicit. Ontologies have set out to overcome the problem of implicit and hidden knowledge by making the conceptualization of a domain (e.g. mathematics) explicit.

Ontological engineering is thus an approach to achieve a conceptual rigor that characterizes established academic disciplines, like geodesy. Many university courses address more application oriented fields, like cadastral law, and spatial planning, and they may benefit from the ontological engineering approach. The paper provides an introduction to the field of ontological engineering by means of examples from the cadastral domain.

1. Introduction

The Cadastral Domain:

The 'FIG Statement on the Cadastre' (1995) characterizes the Cadastre as 'a land information system for social and economic development'. The Statement develops on the *components* of the information system: records of interests in land, a geometric description of land parcels, and further information structures, as well as on the *use* of the system for taxation, securing of property rights, and general land management.

The phenomenon of Cadastre is complex, and it is a challenge to describe it in a way that i independent of a specific country. The description must include an account of the variety o *users* and others agents, who are involved in the updating and development of the cadastre. The description must include a survey of the *rules*, which govern the cadastral activities, as well as an assessment of the general compliance with the rules. The Cadastre is an information system. Hence, the objects, which are recorded in the land information system(s) need to be described in a general way: the units of real estate, the diverse types of real property rights, as well as the boundary marks, geodetic monuments, and other markings in the terrain. Likewise, the documents, the information structures and their transformations, the information flows, and the databases of the information system must be described.

The *Cadastral Domain* includes the above elements and related issues, e.g. the economic and legal implications of a change of boundary location, and the historical and cultural context of the cadastre. Another term for this field of study is the *Cadastral Problem Domain,* or you may call it the *Cadastral Universe of Discourse.* A survey of the Cadastral Problem Domain is provided recently b Stubkjær (1996).

Ontological Engineering:
The present paper focuses on methods available for describing the cadastral universe of discourse in a way that supports learning and teaching, and research and development. Ontological engineering developed during the 1990s from artificial intelligence and computational linguistics. Both fields depend on knowledge representation and knowledge engineering. An *ontology* is characterized as "a software artifact designed with a specific use and computational environment in mind" (Smith, 1999). Therefore the first step of the ontological engineering process is the definition of the intended use of the ontology. In section 2 we define data modeling for the cadastral domain to be the intended use of the ontologies we want to build. There are established (and ever developing) methods for the analysis and design of information systems, and more specifically for establishing *data models* to map the content of databases (section 2a). Other descriptions of the content of databases exist in terms of catalogues o *meta-data* that describe the content, quality and accessibility of data (section 2b).

However, most data modeling approaches fail to capture all aspects of the information that is represented by the data. Often hidden assumptions and silent agreements as well as dependencies between different kinds of data are missed. Beyond this, the integration of different data models is a difficult problem. Ontologies are developed to provide an interface between diverse domains or universes of discourse. For example, ontological engineering is applied for establishing standards in the field of Geographic Information, as appears from the EuroConference on the Ontology and Epistemology for Spatial Data Standards (EuroConference, 1999). In section 3 we address the topic of building an ontology for the cadastral domain using existing concepts of the Cyc ontology we explore from a cadastra point of view.

The computational environment of knowledge engineering has developed from stand-alone computer programs and databases to ontologies shared through the Internet. We discuss the consequences this development has for the implementation and use of ontologies (section 4) We propose the new XML-standard of the World-Wide Web as an implementation language for ontologies and briefly introduce the ontology language OIL that has been developed to bridge the gap between knowledge representation formalisms and web standards like XML. Concluding, ontological engineering is suggested as a means for description of the cadastral universe of discourse that supplement other approaches, for example Soft Systems Methodology, and the use of the Unified Modeling Language (section 5).

2. Define Purpose: Information Modeling

The first step in ontological engineering is the definition of the purpose the ontology is built for. This step is necessary, because the purpose always influences the way certain concepts are modeled. In knowledge engineering this phenomenon is known as the "Interaction Problem" (Bylander & Chandrasekaran 1988). As the cadastral domain is mainly about special purpose information systems in this paper, the purpose we will assume in this paper is information modeling. In order to clarify this purpose, we will start with a discussion of wel known techniques for data modeling and related them to ontological engineering.

Data modeling developed as a means to specify a new or changed information system. Data models provide a means of communication between the users, the system developers and management that describe the information system. Two examples of data modeling, modeling the content of databases, and meta-databases, respectively, serve as a reference for the presentation of ontological engineering.

2a. Modeling the Content of Data Bases

Worboys demonstrates the use of the entity-relationship family of models for spatia information. A planar configuration of nodes, directed arcs and areas is described graphically as Fig. 1, and as a database scheme as follows:

AREA(AREA-ID)
NODE(NODE-I)
ARC(ARC-ID, BEGIN-NODE, END-NODE, LEFT-AREA, RIGHT-AREA)

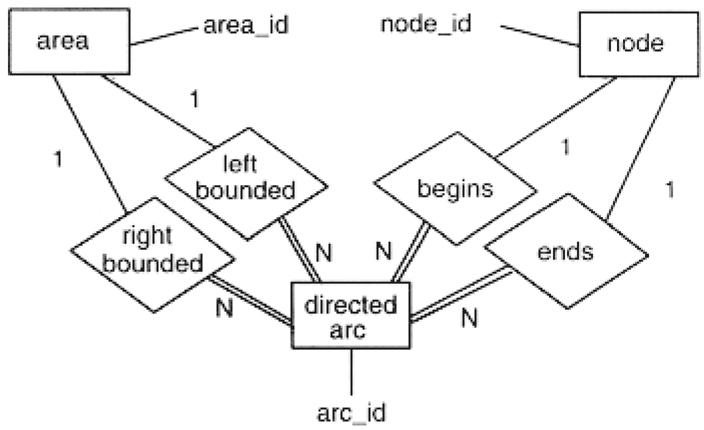

Figure 2.19 E-R model of planar configurations of nodes, directed arcs and areas.

Fig. 1 *E-R model of planar configurations of nodes, directed arcs and areas*
After: Worboys, 1997; Figure 2.19

Worboys describes how the extended entity-relationship model allows for specifying subclass/superclass and generalization/specialization. This facility is extended in ontolog descriptions. Furthermore, while ER-models do refer to real world entities their emphasis is on specifying database schemes that can be implemented in current database software. Ontologies, on the other hand, mainly aim at describing real world objects, events and actors.

2b. Meta-databases

Meta-databases are established in several European countries, together with the developmen of a pre-standard for meta-data (CEN/ENV 12657:1998). The meta-database is a catalog, describing the digital maps and other collections of geo-related data. For example, the Danish meta-database provides entries via data product type, area name, organisation, co-ordinates in diverse geodetic reference systems and title of product (Info). The individual entries give an overview of each dataset and where to get further information about the dataset. In fact the overview is quite comprehensive. The main entry includes abstract, purpose, usage, datatype, e.g vector-data with topology, as well as reference to documentation, to related datasets and to example datasets. Further meta-data description includes dataset quality, spatial reference system, coverage in time and space, identifiers of objects in a map dataset, e.g. number of control points, as well as copyright, price and other accessibility information.

In the present context, it is interesting to note that the conceptual schema of the meta-data pre-standard is formally specified according to the conceptual language EXPRESS, cf. ENV ISO 10303-11:1994. This applies generally to the pre-standards that were developed by the effort of CEN/TC 287 Geographic Information during the late 1990s (CEN TC 287, 1998). While the various ontological engineering projects use a different conceptual language than EXPRESS for the specification of schemas, the objectives and techniques applied are basically the same.

The meta-data description differs from the database models of the previous section in the way that the description refers to real world objects, rather than to data elements of a database. The meta-data catalogue does refer to data, which generally are stored in a database, but the catalogue does not refer to the data structure of the database, as an ER-model would do. Rather, the catalogue describe the data from a users' or manager's view. The meta-data description differs from ontologies mainly in the scope of its content: An ontology mostly would regard real world objects, events, etc. and not 'only' their representation in dat structures. However, you may say that a meta-data description, based on a formal schema, is an ontology o datasets.

3 Ontology Modeling and Integration: Exploring the Cyc-Ontology

The second step of the ontological engineering process is concerned with the actual modeling of the domain of interest. This step can be further subdivided in three activities (Uschold & King 1995):

1. Ontology Capture
2. Integration of Existing Ontologies
3. Ontology Coding

In the first step, important concepts and relations of the domain of discourse are identified and drafted in order to get an overview of the domain and ensure completeness of the resulting model. In principle, this step has already been done by researchers in the cadastral domain (Stubkjær 1996). Especially for complex domains like the one we are concerned with, the step of integrating existing ontologies is essential in order to reduce the modeling effort. In the following, we concentrate on this point by exploring an existing ontology in order to identify concepts that could be part of an ontology of the cadastral domain. The coding step is addressed in the next section.

The Cyc ontology was established for the purpose of It is publicly available on the internet (Cycorp, 1997), provided you identify yourself and your purpose. The content is divided in 43 sections, of which the following 14 are an extract that is presented in the Cyc sequence that is, without ordering from a cadastral point of view:

- Fundamentals
- Top Level
- Types of Predicates
- Spatial Relations
- Mathematics
- "Doing"
- Transfer Of Possession
- Agents
- Organizations
- Actors
- Professions
- Geography
- Information
- Agreements

Within the Geography section the top-most entity is #$ SpatialThing:

#$SpatialThing

The collection of all things that have a spatial extent or location relative to some other #$ SpatialThing. Note well that to say that an entity is a member of this collection is to remain agnostic about two issues. First, a #$SpatialThing may be #$PartiallyTangible, like #$Texas-State or wholly #$Intangible, like the #$ArcticCircle or a line or a plane referenced in a geometric theorem. Second, although we do insist on location relative to anothe SpatialThing, a #$SpatialThing may or may not be located in the physically observable universe. It is far from clear that all #$SpatialThings are so located: eg, a trajectory through the phase space of some physical system. If the intent is to imply location in the empirically observable cosmos, the user should employ this collection's spec, #$SpatialThing-Localized.

isa: #$ObjectType

genls: #$Individual

some subsets: #$RadiallySymmetricObject #$BilaterallySymmetricObject #$Surface-Generic #$Border #$GeometricThing #$PureSpace #$ClothingItem #$Surface-Abstract #$Surface-Physical #$Angle #$TwoDimensionalShape #$Line #$FrameOfReference #$ThreeDimensionalShape #$AbstractShape
(plus 898 more public subsets, 11848 unpublished subsets)

The ontology makes clear that spatial phenomena are not all related to land. It needs some investigation to find out that the relation to land most appropriately can be established by the subsets #$Place and #$ GeographicalRegion, rather than by the reference to #$SpatialThing-Localized. Of the subsets mentioned, #$RadiallySymmetricObject applies for boundary marks and geodetic monuments. Other subsets applies to the cadastral domain as well: #$Border, #$FrameOfReference and #$GeometricThing, but are not commented due to space restrictions.

Cadastral processes cannot be made without taking the legal aspects into consideration. Only two examples of sets are provided here: #$TransferringPossession regards the series of events that transfer rights and objects, in the Cyc ontology subsumed under the term: possession. A subset not commented is #$TransferringOwnership. The other example, #$objectOfPossessionTransfer differs from the previous examples, as it refers to a set o *relations* between a *change in user rights* and *something existing*. These relations are a means to establish connectivity within the ontology as alternatives to the isa- and genls-relations.

#$TransferringPossession

A collection of events. In an instance of #$ TransferringPossession, the possession of a single object (i.e., the #$objectOfPossessionTransfer) is transferred from one #$Agent to another. Thus, a #$ TransferringPossession event alters the rights of TWO different agents to use the object in question; one agent loses some #$UserRightsAttribute over it, while the other agent gains some #$ UserRightsAttribute over it. Each #$TransferringPossession event is both a #$LosingUserRights event and a #$GainingUserRights event.

Note: In #$Buying events, #$Bartering events, #$Renting events, TWO such #$TransferringPossessions occur, because there are TWO objects which transfer possession. For example, in buying a car, the right to use the buyer's money is transferred to the auto seller, while the ownership of the car is transferred to the buyer. Both of the #$TransferringPossession events (one for each object) are #$ subEvents of the instance of #$Buying, #$Renting, etc. See #$ExchangeOfUserRights.

isa: #$DefaultDisjointScriptType #$ScriptType #$TemporalObjectType

genls: #$SocialOccurrence #$GainingUserRights #$LosingUserRights

some subsets: #$MoneyTransfer BorrowingSomething #$TakingCustodyOfAnimal #$Stealing-Generic #$MoneyTransaction #$GivingSomething #$TransferringOwnership #$Paying #$ArrestingSomeone #$Trapping #$MonetaryExchangeOfUserRights #$ GiftGiving #$Buying #$Renting #$ SaleByCreditCard
(plus 1 more public subset, 54 unpublished subsets)

#$objectOfPossessionTransfer : <#$ChangeInUserRights> <#$SomethingExisting>

The predicate #$objectOfPossessionTransfer identifies the object which `changes hands' in a particular event wherein some user's rights to it are changed. (#$ objectOfPossessionTransfer EVENT OBJECT) means that in EVENT, all or some rights to use OBJECT are transferred from one agent (the #$ fromPossessor) to another (the #$toPossessor). EVENT is an element of #$ChangeInUserRights (q.v.), for example, a buying, renting, lending, repossessing, etc.
isa: #$ActorSlot #$AsymmetricBinaryPredicate #$IrreflexiveBinaryPredicate
genlPreds: #$transferredThing
some more specialized predicates: #$objectPaidFor objectTendered

The entity *Real Estate* is described as follows:

#$RealEstate

A collection of tangible objects. Each element of #$ RealEstate is either a parcel of land or a land-based property that can be bought, sold, or rented. This includes buildings and parts of buildings such as office suites or condominiums, as well as parcels of land. Some prominent examples: #$ GuantanamoNavalBase, #$NewYorkHiltonAtBroadway, #$WorldTradeCenter.
isa: #$ProductType #$ExistingObjectType
genls: #$SolidTangibleProduct
some subsets: #$Building #$GroundsOfOrganization #$ RailroadStation-Physical #$ ThreeStoryBuilding #$TwoStoryBuilding #$OneStoryBuilding #$ModernShelterConstruction #$ModernHumanResidence #$SingleResidenceUnit
(plus 1 more public subset, 80 unpublished subsets)

The conception here is that the set #$ RealEstate is a subset of the set #$SolidTangibleProduct cf. the genls line. This is consistent with the notion that a element (unit) of #$ RealEstat belongs to the set ProductType, cf. the isa line. However, while this conception may satisfy a construction engineer or settler, is does not comply with the compound conception of real estate that is needed in a cadastral context. Firstly, the notion lacks reference to #$Border and the relation #$bordersOn. This could be achieved by arranging #$ RealEstate as a subset o #$GeographicalRegion. A subset of GeographicalRegion is #$GeopoliticalEntity. The latter is another term for *jurisdiction* and as one may conceive a *real estate* as a *jurisdiction* that is governed by a citizen, one arrives at the following generalisations: The set of *real estates* is contained within the set of *jurisdictions* (or #$GeopoliticalEntity) that again is contained within #$GeographicalRegion and further within #$Place and #$SpatialThing. In this way we have repaired the set relation (genls) of #$RealEstate.
The isa-relation can be repaired as well: The Cyc-comment to #$GeographicalRegion states that ".. Each element of #$GeographicalRegion is a #$PartiallyTangible that may be represented on a map of the Earth." ".. like #$Texas-State .." (in the note to #$SpatialThing"). An element of #$RealEstate is an element of GeographicalRegion and thus also member of the #$PartiallyTangible collection. This fits with the cadastral conception of *real estate* as consisting of tangible land (and buildings), but the boundary of which may not be tangible.

From the above explorative investigation of the Cyc ontology it appears that the ontolog provides assistance to the explication and regimentation of cadastral concepts, in the sense that 'building blocks' and relations among these blocks are offered and provides a basis for a 'dialogue'. The available ontologies cannot be used uncritically, and the potential of the software to assist in the provision of consistency among definitions and relations has not been tested.

4 Implementation and Use: XML, Logic and Interoperability

Many ontology modeling languages have been developed during the past decade (Corcho & Gomez-Perez 2000) that can be used to implement Ontologies. However, not all of these languages are suited for real-life applications. Some languages are too expressive to suppor automatic reasoning and many rely on a specialized run-time environment. Recently, the world-wide web standardization comity W3C has recommended languages for data and meta-data modeling. In the following we briefly introduce XML as a language for data modeling on the world wide web and argue that it is a good choice for the implementation of ontologies and mention the language OIL (Ontology Interchange Language 2000) that integrates XML with a logical model making automated inference possible. In the second part of the section we mention two applications of the logical model underlying OIL that are also relevant for the cadastral domain.

4a Web Standards and the OIL Language

XML is a standard for the Internet that extends the functionality of the HTML. The HyperText Markup Language (HTML) is the most widely used means for the exchange of information via the Internet. HTML provides primitives called tags that enable browsers to display free and structured text, raster images, and even audio and video sequences. HTML enable us to disseminate information, but the meaning of this information is - with the exception of keywords - not available in a machine-understandable form. XML, the eXtended Markup Language, is providing means to systematically record the meaning at the level of individual data (data objects). An example of a (incomplete) schema definition follows:

```
<comple
Type name="address">
        <element name = "personName" type = "string" />
        <element name = "street" type = "string" />
        <element name = "city" type = "string" />
        <element name = "zipCode" type = "integer" />
        ..
</complexType>
```

Furthermore, the user can define own tags in order to indicate the type of contents annotated by the tag. The following example 'translate' the ER model example of section 2 into a XML schema:

```
<complexType name = "choro">
        <element name = "area" type = "area-id" /> NB the id-types are defined elsewhere
        <element name = "node" type = "node-id" />
        <element ref = "arc" />
</complexType>

<complexType name = "arc" />
        <element name = "ident" type = "arc-id" />
        <element name = "beginNode" type = "node-id" />
        <element name = "endNode" type = "node-id" />
        <element name = "leftArea" type = "area-id" />
        <element name = "rightArea" type = "area-id" />
</complexType>
</choro>
```

In order to systematize these definitions, XML schemas have been introduced (Fallside, 2000). XML schemas can be conceived as a definition language for data structures. The XML schemas can overcom *structural heterogeneity* , for example that different information systems store their data in different structures. A graphics-oriented XML schema may thus provide a means for the exchange of information between differen GIS software. However, the XML-family of standards does not (at the time of writing) provide means for the structuring of semantic information. Here the options still are either to extend one of the available ontologies (Ontolingua, Cyc, or the proposed Ontology Interchange Language), or to establish a domain-specific ontology by means of a declarative (frame-based) language like Lisp or Prolog.

Our conclusion about current web standards is, that using XML and especially XML schemata is a suitable way of exchanging data on the object with a well-defined syntax and structure. Further simple RDF, an XML application, provides a uniform syntax for exchanging meta-information in a machine-readable format. However, in their current state neither XML nor RDF provides sufficient support for the integration of heterogeneous structures or different meanings of terms. There is a need for semantic modeling and reasoning about structure and meaning. Promising candidates for semantic modeling approaches can be found in the areas of Knowledge Representation. Description logics, for example, are a family of logic-based representation formalisms that cover a decidable subse of first-order logic. Description logics are mostly used to describe terminological knowledge in terms of concepts and binary relations between concepts that can be used to define a concept term by necessary and sufficient conditions that have to be fulfilled by all instances of the concept. The main inference mechanism used in these formalisms is subsumpti checking. A concept is said to subsume another concept if the membership of the latter implies membership in the former. Efficient inference algorithm exist that can be used to calculate inheritance hierarchies from the conditions specified in a knowledge base.

The Ontology Interchange Language (2000) has been developed in the context of the On-To-Knowledge Project (http://www.ontoknowledge.org) as a proposal for a language for specifying and exchanging ontologies. OIL tries to provide a core set of features that have been widely accepted to be useful. OIL combines frame-based modeling primitives, reasoning facilities from description logics and a tight integration wit meta-data standards on the Web such as RDF/RDF-Schema and XML-Schema (Klein et. al. 2000). The close relationship between OIL and the description logic language SHIQ supports terminological reasoning about concept descriptions. OIL specifications can be translated into the description logi language SHIQ by straightforward syntactical replacements.

4b Schema Integration and Semantic Interoperability

We give two examples of how ontologies can be used to enhance the data modeling process. Both examples are concerned with the problem of bringing together different data models tha might exist in deferent information systems (i.e. cadastres). Due to space constraints, we only give the idea of both approaches. For details the reader may refer to the original papers:

Schema Integration:

(Franconi and Ng 2000) propose a tool for intelligent conceptual modeling. The tool implements a rich conceptual modeling language that extends the entity relationship mode (compare section 2) with ontological constructs (inheritance, constraints on relationships and concept memberships, aggregation and inter-schema constraints). These constructs are implemented using the SHIQ language. The main benefit of these additional constructs lies in the ability to perform a consistency check when two separately modeled database schemas are to be integrated to build a larger information system or to merge different systems which might become important for the cadastral domain in order to improve the efficiency of land transaction procedures.

Semantic Interoperability:
Beyond the integration of database schemas (Stuckenschmidt and Wache 2000) propose the use of the OIL language in order to achieve semantic interoperability between heterogeneous information sources. The approach assumes a integrated schema where similar data fields contain values from completely different vocabularies or scales. In common data-modeling approaches the exact definition of scales, Measures and contexts is often neglected. Ontologies offer the possibility to exactly define what an value in a database field means and to translate the meaning in to the context of a different information source. We think that the ability to exchange information between different databases while preserving the intended meaning will gain importance in the future. This holds especially for legal subjects which also occur in the cadastral domain.

5. Conclusion

The paper has introduced ontological engineering as a means to establish a description of the cadastral universe of discourse, a description that is independent of the diversities of national rules and practices. Selected cadastral concepts are related to a generally available ontology, and the outcome provides a basis for the suggestion of developing a cadastral ontology. The paper has pointed to specific elements of the WWW-technology (the XML schema and the SVG-standard) supplemented by a logical layer, which support international co-operation regarding the cadastral ontology project in a cost-effective way. The approach does not make superfluous methodologies like Soft Systems Methodology (SSM), or the use of the Unified Modeling Language (UML). Rather it suggests a representation method that is compatible with other approaches and support international co-operation. We think that the effort to develop an ontology for the cadastral domain pays off in clearer notions and a solid basis for the integration and co-ordination of standards and processes.

References

Benjamins, V. R. and Fensel, D. (1998) The Ontological Engineering Initiative (KA)2, in N. Guarino (ed.) Formal Ontology in Information Systems, IOS Press.

Brickley, R. Guha, and A. Layman (1998): *Resource description framework (RDF) schema specification*. W3C Working Draft, August 1998. http://www.w3c.org/TR/WD-rdf-schema.

Bylander & Chandrasekaran, (1988) Generic tasks in knowledge-based reasoning: The right level of abstraction for knowledge acquisition. In B. Gaines and J. Boose, editors, *Knowledge Acquisition for Knowledge Based Systems*, volume 1, pages 65--77. Academic Press, London, 1988.

CEN TC 287 (1998) Geographic Information - Fundamentals - Overview http://forum.afnor.fr/afnor/WORK/AFNOR/GPN2/Z13C/PUBLIC/DOC/13425.PDF

CEN/ENV 12657:1998 Geographic Information - Data description - Metadata http://forum.afnor.fr/afnor/WORK/AFNOR/GPN2/Z13C/PUBLIC/WEB/ENGLISH/pren.htm

Corcho, O and Gomez-Perez A. (2000) A Road Map on Ontology Specification Languages. Proceedings of the workshop on Applications of Ontologies and Problem-Solving Methods at ECAI 2000, Berlin.

Cycorp (1997) Cycorp, Inc. (no post address information) http://www.cyc.com

Dahlgren, Kathleen (1995) A Linguistic Ontology, *International Journal of Human-Computer Studies*, 43, 809-818.

Erdman, E & R Studer (1999) Ontologies as conceptual models for XML documents. Research report. Institute AIFB, University of Karlsruhe.

EuroConference (1999) http://www.geoinfo.tuwien.ac.at/events/Euresco2000/gdgis.htm).

Fallside, David C (2000) XML-Schema Part 0: Primer. W3C Working draft, 25 February 2000. http://www.w3.org/TR/2000/WD-xmlschema-0-20000225/
Fensel, D (2000) Relating ontology languages and web standards http://www.cs.vu.nl/~dieter/ftp/paper/mod2000.pdf
Franconi, E. and Ng, G. (2000) The i•com Tool for Intelligent Conceptual Modelling, Proceedings of
Genesereth, M. R. and Fikes, R. (1991) Knowledge Interchange Format, Version 3.0 Reference Manual. Computer Science Department, Stanford University, June 1991.
Gruber, T. R. (1993) A Translation Approach to Portable Ontology Specifications, *Knowledge Acquisition*, 5, 199-220.
Gruber, T. R. (1995) Toward Principles for the Design of Ontologies Used for Knowledge Sharing, *International Journal of Human and Computer Studies*, 43(5/6), 907-928.
Guarino, Nicola (ed.) (1998) Formal Ontology in Information Systems. Amsterdam. IOS Press (Frontiers in Artificial Intelligence and Applications).
Klein, Michel, Dieter Fensel, Fran von Harmelen, and Ian Horrocks (2000) The relation between ontologies and schema languages: Translating OIL-specifications into XML-schema. http://www.ontoknowledge.org/oil/papersabstract.shtml
Kuipers, Benjamin (1998) A hierarchy of qualitative representations for space. in: Christian Freksa, Habel & Wender (eds) Spatial Cognition. *Lecture Notes in Artificial Intelligence* 1404. Berlin. Springer. Pp 337 - 350.
Ontology Interchange Language (2000) http://www.ontoknowledge.org/oil
Stubkjær, Erik (1996) A Theoretical Basis for Cadastral Development. In: ELIS' 94 European Land Information Systems. Proceedings, Third Seminar of the European Co-operation Network for Education and Research in Land Information Systems (EUROLIS), Sept. 1994. Delft; Delft University of Technology, 1996
Stuckenshcmidt and Wache (2000) Context Modeling and Transformation for Semantic Interoperability. Proceedings of KRDB 2000.
Visser, P.R.S. and Bench-Capon, T.J.M. (1998) A Comparison of Four Ontologies for the Design of Legal Knowledge Systems, *Artificial Intelligence and La* , 6 (1), 27-57.
Walsh, N (1999) Schemas for XML. July 1, 1999. http://www.xml.com/pub/1999/07/schemas/index.html
Wand, Y. and Weber, R. (1990) An Ontological Model of an Information System, *IEEE Transactions on Software Engineering*, 16(11), 1282-1292.
Uschold, M and King, M (1995) *Towards a Methodology for Building Ontologies* Proceedings of the Workshop on Basic Ontological Issues in Knowledge Sharing at IJCAI-95,Montreal.
Worboys, Michael F (1997) GIS: A computing perspective. London. Taylor & Francis. 376 p.

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