A Referent Model of Documents

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ABSTRACT

Heterogeneous project groups of today may be expected to use the mechanisms of the Web for sharing of information. Meta-data has been proposed as a mechanism for expressing semantics of documents, and hence facilitate information retrieval, understanding and use in such settings. This paper argues that semantic modeling languages are able to define and visualise meta-data schemes. As such, they are able to facilitate communication towards mutual understanding of documents. The created models may be made available in an interface, and hence aid users in expressing meta-data for search and classification of documents. The paper presents our overall approach, the Referent Model Language, its foundations and a small modeling example. The paper reports on work in progress[1].

1. Introduction

In todays era of computer networks, it is expected that heterogeneous project groups may be formed regardless of their physical location. Such groups may then be left to communicate "by wire", using the mechanisms of the Web for sharing of information. While the Web provides excellent facilities for publishing and distribution of information, it lacks fundamental mechanisms for communication and negotiation towards a shared agreement as to the meaning of the underlying information.

Much work has been done on studies in the use of meta-data to express semantics of information in order to facilitate information discovery and usage. However, recent standardising attempts have shown that the need for meta-data is both application and situation dependent. I.e. the needed meta-data scheme is *designed* by its users according to their interpretation of the underlying information. This paper argues that semantic modeling languages are able to visualize interpretations of information and to serve as a design vehicle for meta-data schemes. The created models may also be made available as an interface to the underlying information. As such, they may guide users in their classification and retrieval of information.

The next section of this paper presents the problem in some detail and contains references to related work. Section 3 presents the framework we apply for describing semantics of documents and describes the needs to be fulfilled by our modeling language. Section 4 presents the Referent Model Language, its foundations and a small modeling example. Section 5 concludes the paper with a discussion of further work.

2. The problem

Sharing of information is normally done by maintaining a Common Information Space [Schmidt and Bannon, 1992]. For a group left to cooperate across the Web, this means that they create some kind of common Web-site in order to distribute and share the needed documents[2] - Figure 1.

In order to facilitate the successful retrieval and use of these documents, the group will also need to reach some kind of understanding as to what they actually mean. On the web today, this is normally done using some kind of meta-data scheme - Figure 1b. That is, meta-data is used to organize and present documents according to their

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1. Parts of this work is performed under the CAGIS project, funded by the Norwegian Research Council.

2. Since most information objects that may be published on the web through various gateways may be defined as "document-like objects" [Weibel, 1995], we limit the description in this paper to information contained in documents.

perceived meaning. At system-level, metadata may be stored within the HTML code or in separate Object Descriptor Files accompanying the documents. At semantic level, meta-data appears in various ways in the user interface to the underlying documents: As topic/subject hierarchies like Yahoo, as forms for creating search expressions like AltaVista or in general for connecting the documents to their perceived context (tasks, projects).

In general, the term *meta-data* is widely used - two different classifications of the term are given in e.g. [Kashyap and Sheth, 1997] and [Weibel, 1998]. Our interest in meta-data is concerned with its use as a mechanism to capture and visualize meaning of information, hence we limit our study to *Descriptive meta-data* [Weibel, 1995]. Examples of such are statements regarding the *purpose* of a document, the *keywords* best representing its content, the *motivation* behind it, its *authors,* its *title* etc. In this paper, we further limit the discussion to the use of *keywords* or *terms* used to express statements regarding the intellectual content of a document.

Such use of meta-data is equivalent to the assertion of statements regarding the documents connection to the part of the real-world they refer to. As any communication in language; successful communication of meaning by way such statements can only be achieved if the participants have some kind of mutual understanding of what these statements refer to. For example, successful use of keywords is dependent that the participants are aware of each others interpretation with respect to the real-world objects the keywords refer to. A user will find the documents she is looking for in the “Yahoo:Computers & Internet:Mobile Computing” section only if she shares the Yahoo-interpretation of this subject.

Ontologies [Guarino and Poli, 1995] are being used in cooperative settings in order to express a conceptualization of some part of the real-world. The existence of a shared ontology may then facilitate communication about this reality. Used in connection with a meta-data approach to describing semantics of documents, an ontology represents the “protocol” for expressing statements connecting documents to their real-world referents.

Ontologies are designed [Gruber, 1995] [Uschold, 1996]. Their need varies depending on the participants background, their knowledge of each other as well the kind and nature of the domain to be described and the intended usage of the ontology. In our setting, this reflects the fact that the need for meta-data is situation dependent. The design of an ontology experiences the same problems as any design, i.e. multiple stakeholders, varying viewpoints, differing needs etc. For the use of ontologies to express meta-data statements, the ”design goal” is to reach some level of understanding that can be made explicit. Furthermore, this explicit representation of the part of the world the documents refer to should be made visible and available for the users wanting to express meta-data statements.

This paper argues that semantic modeling languages (See e.g. [Hull and King, 1986]; [Bubenko, et al., 1997]) are able to define and visualize such ontologies, as they in their very nature are intended to serve as explicit representations of conceptualisations. As such, they are able to define and express the semantics of concepts and their properties. Furthermore, these languages are intended to serve as design vehicles at a semi-formal level between human and computer understandability. Hence, the models should be able to visualize conceptualizations and make them visible and available in an interface to sharing of information.

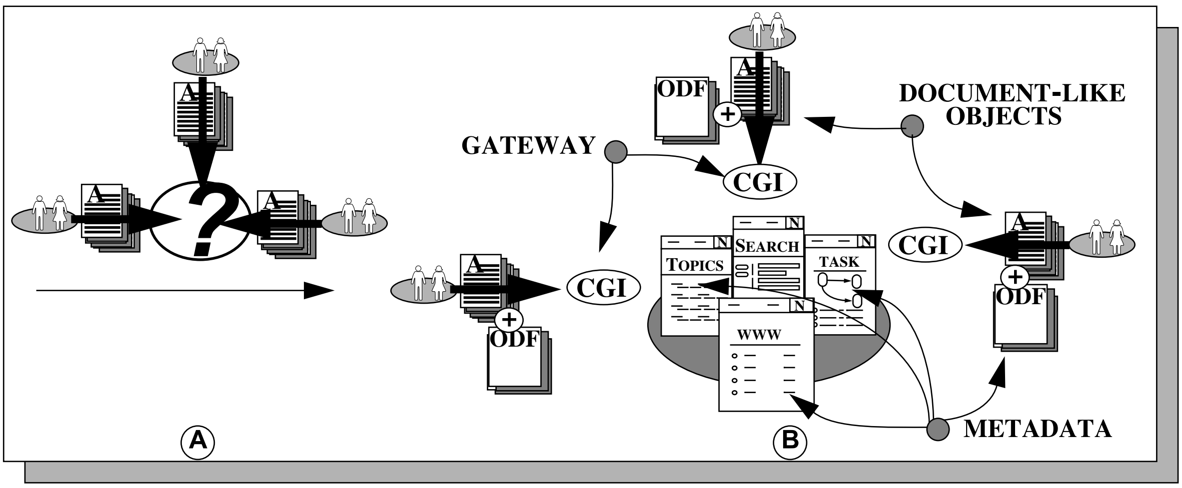

Figure 1. Using metadata to communicate meaning

2.1 Related work

Metadata has been the subject of much research and debate, particularly as a result of the increased popularity of the Web. The Dublin Core proposal [Weibel, 1995] and the following workshops [Lagoze, et al., 1996][Weibel, 1997][Weibel, 1998], present the most active standardization attempts. The W3 consortium meta-data group [W3Metadata, 1997?] and its Resource Description Framework initiative [W3RDF, 1998] applies a semantic network based approach to description of meta-data for networked resources, building on the MetaContentFramework [Guha, 1996]. The meta-data structures proposed in digital library systems [z39.50BIB1, 1995][USMARC, 1996] are in most cases too complex to suit our "groupware" setting. Furthermore, large scale approaches like these can naturally not afford the kind of flexibility and tailorability in the use of keywords and meta-data attributes as we are looking for.

A lot of work is done on the study of formal ontologies in general [Wiederhold, 1994][Gruber, 1995][Guarino and Poli, 1995][Guarino, 1995] as well as their application to ensure interoperation in heterogeneous information systems: [Daruwala, et al., 1997][Wiederhold, 1994][Kashyap and Sheth, 1994][Kashyap and Sheth, 1997][Mena, et al., 1996]. These formal approaches contains theories for model and ontology creation and mapping between different ontologies. Most of these formal based approaches do not contain the needed mechanisms for collaborative user-construction of the ontologies. An approach to collaborative ontology construction is found in the Ontolingua system [Gruber, 1992][Farquhar, 1996?] which provides a Web-based "forms" interface to creation, browsing and manipulation of ontologies along with repository support for management of the various ontologies.

3. Describing semantics of documents

This section of the paper defines our framework for classifying documents by way of semantic meta-data and illustrates the needs to be fulfilled by the modeling language.

As mentioned, the use of meta-data to capture the semantics of a set of documents refers to the assertion of statements regarding the real-world objects or concepts the documents are perceived to refer to. As any knowledge representation scheme, the assertion of such statements is subject to a conceptualization of the underlying world [Gruber, 1995]. By conceptualization, we refer to the selection and naming of concepts, the perceived definition of these concepts, as well as their properties and relations [Gruber, 1995][Uschold, 1996].

For example stating that: *"This document describes the mandatory exercise number 3 in course No 78054 - Systemering 3",* we connect the particular document to the concepts *exercise* and *course* and we assume that these two concepts are related. Furthermore, we express certain properties of these concepts - e.g. that courses have *numbers* and *titles* while exercises may be *mandatory* - and we do not only refer to the concepts in general but we may refer to a particular instance of such - e.g. the course with the property *Number = '78054'*.

Figure 2 illustrates the connection between documents, the real-world concepts and conceptualisations. A readers interpretation of the part of reality is found in her conceptualization over the selected real-world objects. In our approach, this conceptualization is captured and made explicit in a model. The semantic link between a document and the real world objects it refers to is then found by connecting the document to the model. It is this semantic link that is supposed to be captured and communicated by the assertion of meta-data statements. As shown in the example above, such statements may refer to both general concepts, particular instances of these and also to any property the concept may be perceived to have or any relation it takes place in.

Based on the above, we may list the following needs to be fulfilled by our modeling language in order for it to be actively used in the sharing of documents across the web:

- The modeling language must form a basis for expressing and defining the needed concepts, their properties and relations - I.e. for designing the ontology. As shown, we must be able to express both general concepts and particular instances.

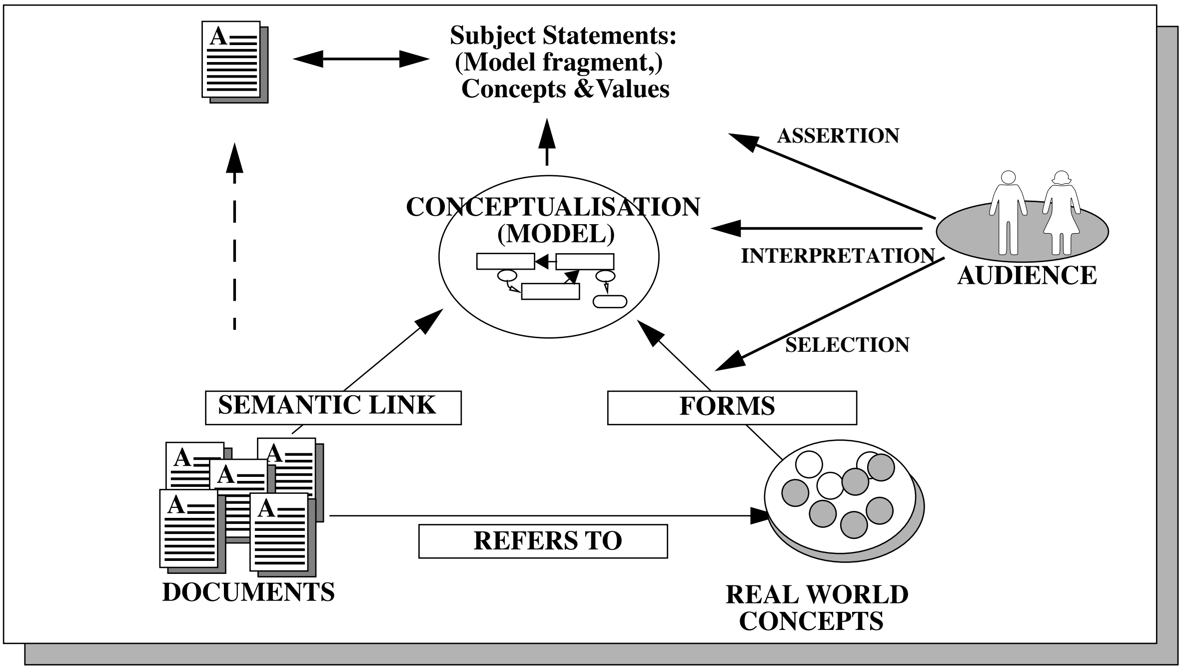

Figure 2. A Modeling Framework for documents.

- The models - as visualizations of the conceptualization - should be made directly available for the task of classifying or retrieving documents. That is, the users should be able to select model fragments and instanciate them as needed in order to create the desired meta-data statements. These statements must then be stored along with the document (e.g. in the aforementioned Object Descriptor Files). Similarly, users should be able to select model fragments in order to perform search and retrieve documents.
- Each of the various domains participating in the collaborating group (Figure 1a) may have their own interpretation of their documents as well as their own world view of the concepts in question. Hence, we must be able in order to relate concepts across various models. For this, we propose to use the modeling language to create a hierarchy of models. Also the hierarchy of models must be visible, enabling users to see and be aware of the different viewpoints.

4. The Referent Model Approach

This section of the paper presents the Referent Model Language. The language is created on the basis of basic set theory and linguistics. The basis from set-theory gives the language the needed generality and the ability to express declarative statements about the world, yet at the same time it provides the needed formal basis.

The triangle of meaning as found in linguistics fits well with the mathematical notation of sets, and gives us the "modeling convention" needed in order to attack problems of semantic heterogeneity. It is these two together that will be used in order to create a model hierarchy and relate concepts from different models.

4.1 Basic constructs & Graphical notation

The basic need for our modeling language is to be able to name and define concepts from the underlying domains. We want to be able to refer to both sets and individual concepts as well as their properties. The graphical notation for this is shown in Figure 3. Mathematically, sets are defined either by listing all their members (1) or by using the set-builder notation (2):

$$\text{Set} = \{a_1, a_2, \ldots\ldots, a_n\} \qquad (1)$$

$$\text{Set} = \{X \mid \text{All } X \text{ that satisfies some condition(s) } C_i \text{ , } i=1..n\} \qquad (2)$$

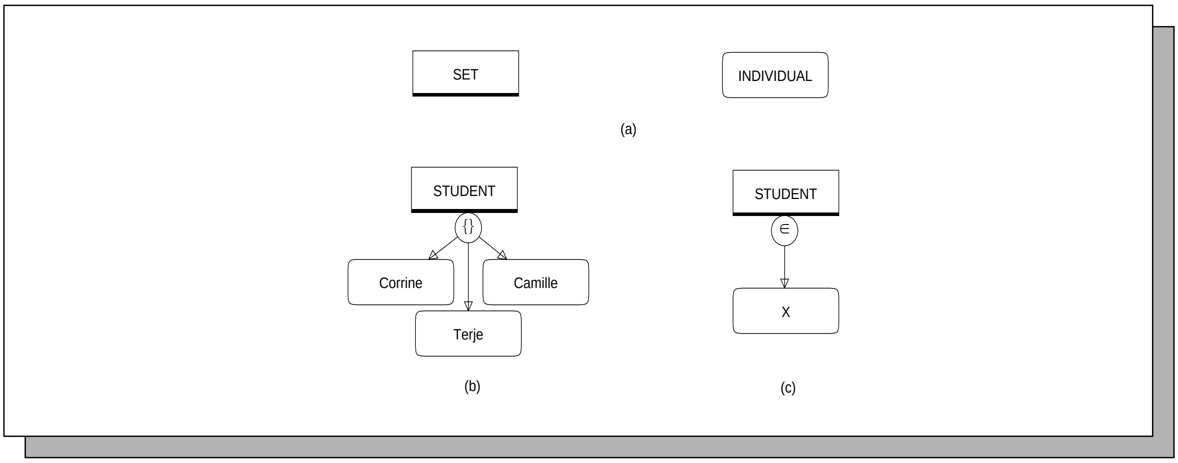

Figure 3. Basic Constructs: a) Set & Individual b) Particular Elements c) Arbitrary Elements

These formal definitions shows the two ways of relating individual concepts to sets - either by enumeration of the *particular* individuals (Figure 3b) or by defining the *arbitrary* individuals and stating the conditions that qualifies them to be members of the set (Figure 3c).

Furthermore, we need to be able to specify general relations between sets. In set-theory, any relation between sets is itself a set of tuples whose parts are selected from all the participating sets. The elements of any relation are thus always a subset of the cartesian product of the participating sets. Interpreting the set-builder notation in this sense, we find that the qualifying conditions limits which tuples from the cartesian product we allow to participate in the relation. The graphical notations for relations and functions are shown in Figure 4a. Functions in set theory are relations that are many-to-one or one-to-one. We use the arrow to point from many to one and a filled circle to indicate full coverage.

Several relations may be defined between any two sets. Sometimes two relations may happen to consist of the same tuples. Sometimes one relation may be defined by a composition of other relations. The actual member tuples as well as the cardinality and coverage for such *derived* relations may be calculated by looking at the different participating relations. In Figure 4a, we illustrate that the *TakesCourseAt* relation is derived from the *Student.Takes* and *Course.LecturedAt* relations by way of a dotted line.

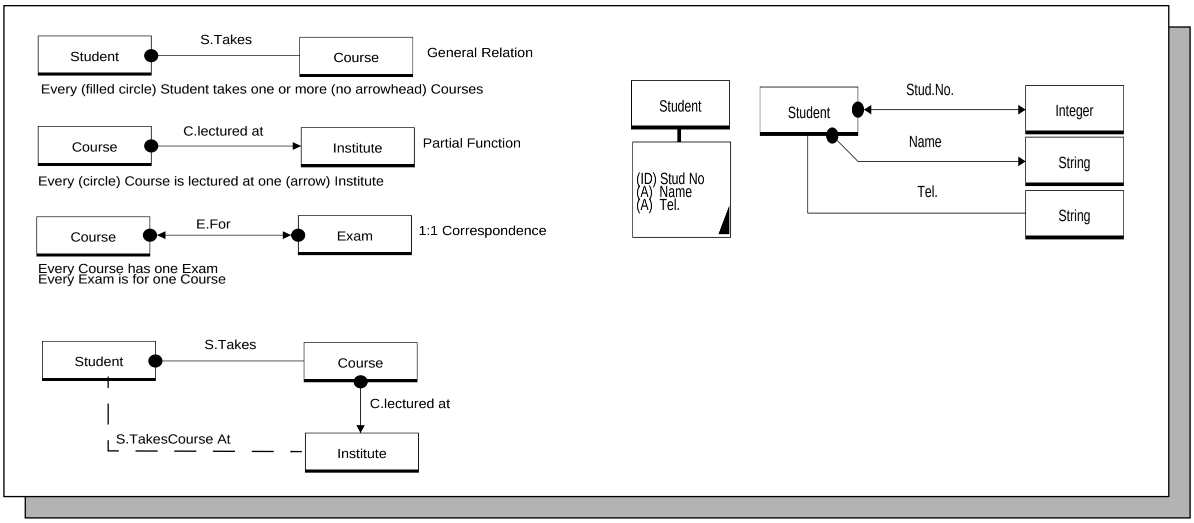

Figure 4. a) Relations and Functions b) Properties are relations into Value Sets

Our real world concepts may have properties. A property is considered a relation from a set member and into a Value Set. Figure 4b shows the shorthand notation for this and an example of the corresponding value set relations. If such a property is of a one-to-one correspondence between each and every element of a set and to value set, it is said to form an ID-function. That is, this particular value may be used to uniquely identify or distinguish this particular individual. The *Student Number* property in Figure 4b, may be considered to separate one student from another. Other properties may be considered optional - e.g. a student may or may not have a *Telephone*.

Furthermore, we need to be able to infer general abstractions over the basic sets. For this, we have defined graphical notations for the abstraction mechanisms of CAGA - see e.g. [Hull and King, 1986] - which all have their corresponding mathematical notation. The graphical notations for these constructs are shown in Figure 5. The set of courses may be divided into two disjoint subsets "*MSc*" and "*PhD*" courses. All courses we know of are either of these. These to sets forms an exhaustive partition of the set of all courses. This is shown by the filled circle (exhaustive) and the disjoint subset symbol (partition). The same set of courses may also be divided into several possibly overlapping subsets - e.g. *Difficult Course*, *Basic Course* and *MathCourse*. For example, a basic course in math may be considered to be a difficult course by its students. Furthermore, we may define how each member from the set of all courses may be considered to be a tuple, that is aggregated from its different part sets. A course may be a tuple consisting of one - and only one - exam (filled circles and arrowheads), possibly (no circle) *n* exercices and at least one lecture. A curriculum and an exam must belong to only one course.

All these abstraction constructs may be defined by the set-builder notation. For subsets, we simply define:

$$\text{DifficultCourseSet} = \{X \mid \text{course}(X) \text{ AND difficult}(X)\} \tag{3}$$

$$\text{PhDCourseSet} = \{X \mid \text{course}(X) \text{ AND onlyforPhDstudents}(X) \text{ AND NOT mscCourse}(X)\} \tag{4}$$

For the aggregation constructs, each element of the set course is considered to be a tuple consisting of elements from the part sets similar to an n-ary relation. In our models, we use ordinary relations from the aggregated set to the part-of sets in order to illustrate also cardinality and coverage from these sets.

4.2 The triangle of meaning

While the graphical notation of our language and its set-theoretical definitions gives us the ability to name and define concepts from the underlying domain, we need a convention for connecting these concepts to the underlying documents. This connection lies in the ability to express meta-data statements that are connected to the model. For this, we choose to interpret our set-theoretical definitions in terms of the triangle of meaning found in linguistics - Figure 6a.

The triangle shows how the *symbols* of a language is used to refer to *referents*. A referent is intuitively thought of as any physical or abstract object of the world to be described - i.e. a referent is anything that may be referred to. Referents have their existence in the world regardless of whether they are referred to by some language symbol or not. Every referent in the world may be classified into various sets, where each set is viewed as the extension of a *concept*. For instance, our definition of the concept of student (intension) may be used to classify people into the set of all students (extension). The meaning of a language symbol is then conveyed by its connection to the referents it refers to, a connection found through the concept used to classify these referents

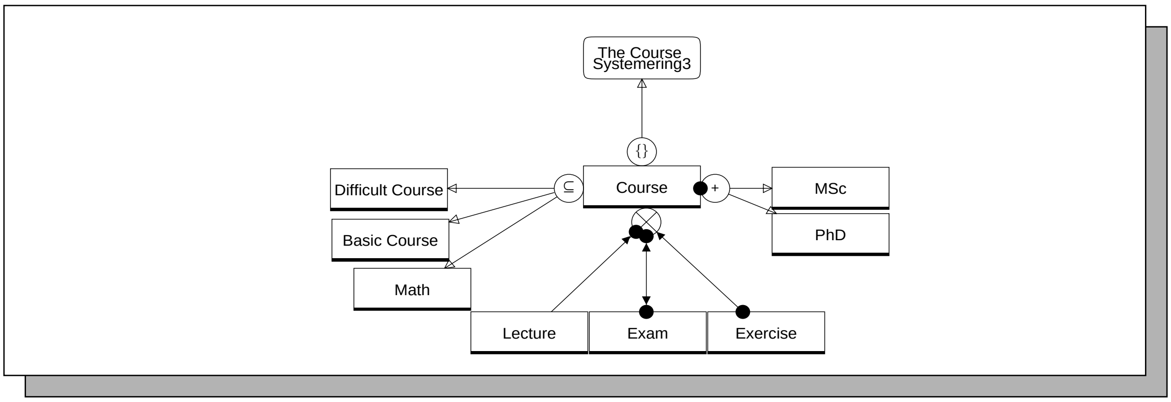

Figure 5. CAGA: General Abstraction Constructs

The reinterpretation of the meaning triangle within our context is shown in Figure 6b. Meta-data statements are supposed to communicate the meaning of a document presented on our shared web-site. These statements correspond to the symbols of the original triangle. Such meta-data statements - as symbols - refer to a set of real-world referents. Our modeling language is used to create abstract models of referents. The model represents the users conceptualization of the real-world referents that the symbols are intended to carry meaning about. The model hence defines and visualizes the concepts that may be used to express meta-data statements regarding the meaning of documents.

As mentioned in section 3 of this paper, our primary interest in descriptive meta-data, is its use in order to classify and retrieve information from a shared web-site. For this, we need to make the models available and directly usable in an interface to perform such tasks. This means that users should be able to select a model fragment and by this create meta-data statements or search expressions. Mathematically, the concepts in our Referent Models all have their proper set-definition. How to express statements from a Referent Model fragment is then found by looking at the set-builder definition of the concepts found in this fragment.

Mathematically, the set-builder conditions for a concept may be divided into *necessary*, *sufficient* and *non-defining* [Rosen, 1995]. Necessary conditions are assertions stating properties that must hold for every instance of the concept. Sufficient conditions are those who it is sufficient to have knowledge of in order to determine whether or not a given instance belongs to the concept. Non-defining assertions is used to denote additional properties of the concept. Transferred to our tasks of classification and retrieval of information, we find that necessary conditions may be used for the task of classification, while sufficient conditions may be used for the task of searching. That is, necessary conditions are the properties that has to be defined when expressing a meta-data statement based on this concept, while sufficient conditions are used to evaluate if a given meta-data statement belongs to this concept. Both the necessary and sufficient conditions are denoted *defining* conditions and the two are not necessarily different. The non-defining assertions may be used to express additional properties in order to create detailed meta-data descriptions.

In our approach, these mathematical conditions may either be found directly from the models or they may be explicitly defined by the users. The example of Figure 7 shows how a model fragment (a) may be expressed formally (b). In the example, we do not separate necessary and sufficient conditions. As defining assertions - selected from the model - we have used mandatory attributes (e.g. Student.Number & Student.Name) and full coverage relations (e.g. Student.Takes). In this respect, we take all defining assertions as necessary in order to express meta-data statements regarding a *particular* student. In order to refer to general concepts, only the concept *name* is needed.

As mentioned in section 2, meta-data statements on the web are normally stored as key=value pairs. Also a search expression created by instanciating a search form is represented as such key=value pairs. Figure 7c shows an example of how the mathematical statements (b) may be mapped into such structural pairs. In this example, the "+notation" of AltaVista is used to denote mandatory attributes or full coverage relations for a concept.

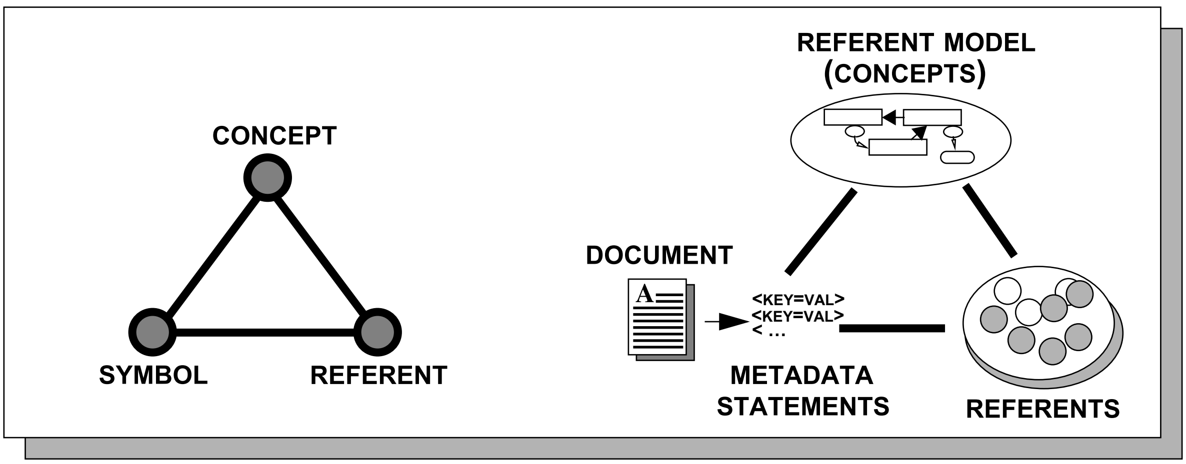

Figure 6. The triangle of meaning (a) and its reinterpretation in terms of Referent Modeling (b)

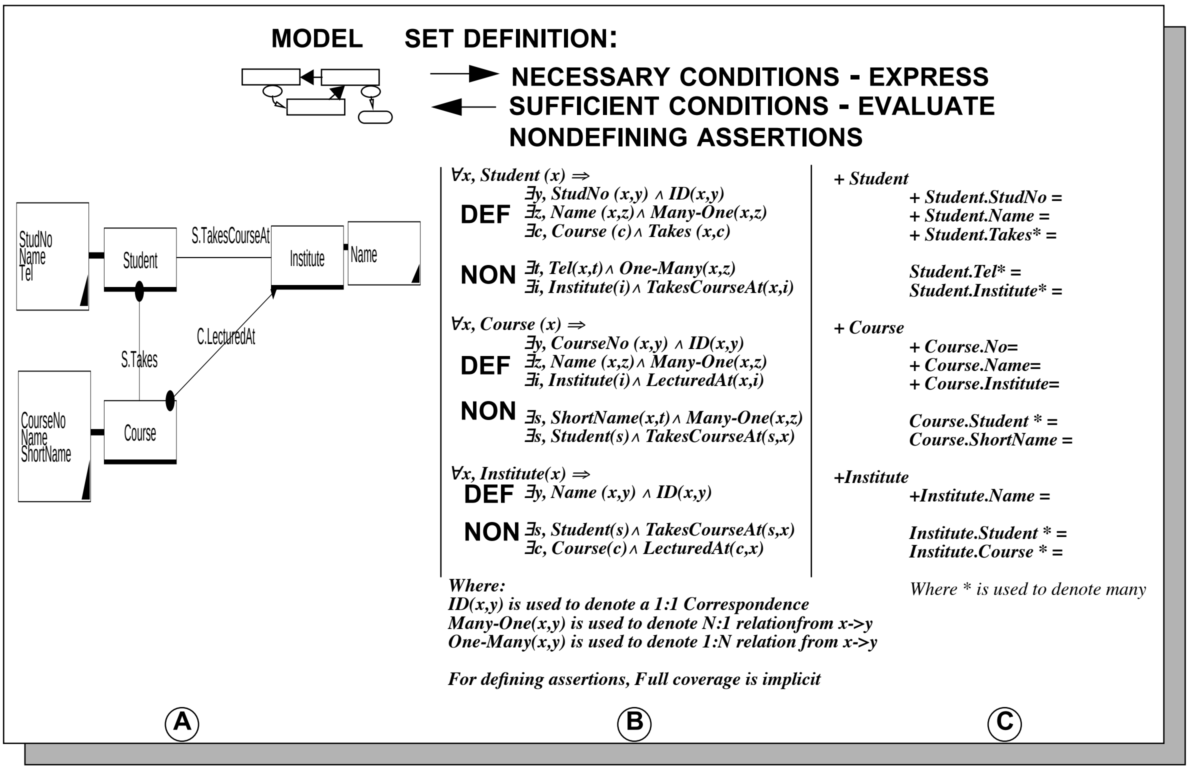

Figure 7. Expanding on model definitions to create statements

4.3 A model hierarchy

Between the domains of our heterogeneous group, there will always be different views. Every domain will have their own view of their underlying documents and their own mental model of the world referred to by these documents. Each domain's view may be expressed in a local model. In order to relate these views to each other, it becomes necessary to be able to relate concepts across several models. A common model may be built on the basis of these local models by selecting the concepts that are perceived to be related. These concepts are carried over to the common model, enabling the use of the relation and abstractions constructs of the Referent Model language across several models.

Figure 8 shows a modeling example. Our domain is that of university-courses, lecturing, exercices and exams. The two former parts of the Institute of Computer & Information Science (IDI) - IDT and IFI - both presented their respective courses and course documentation on the Web. The two local models[1] show the IDT and IFI interpretations of the central concept *course*. A course consists of *lectures*, an *exam* and possibly some *exercises* (IDT) or *essays* (IFI). A course is taken by *students*, lectures are given by some responsible *lecturer* (IDT) or *teacher* (IFI). The IDI model shows an example of how a common model over these constructs are created by adding generalization constructs (*Course Responsible* as the generalization of Teacher, Lecturer), by adding of instances (*IDT* & *IFI* instances of Institute) and through general relations (Course Responsible is *Responsible* for Course and *Employed In* Institute).

1. The models are generated on the basis of the homepages of the courses IT232(IFI) and Systemering 3(IDT)

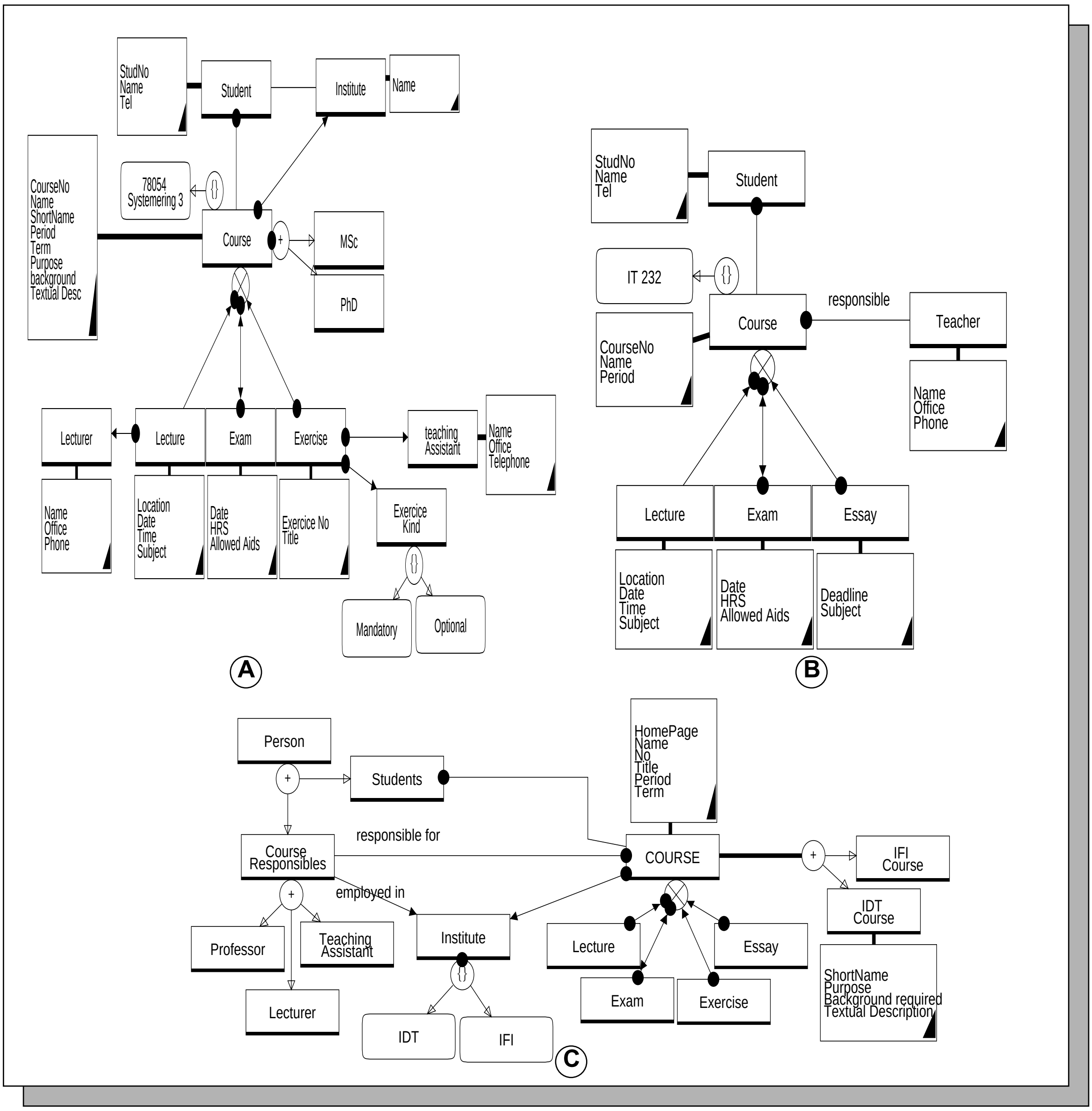

Figure 8. Model Hierarchy - Example

In constructing the common model, we are not aiming for a forced resolution into one model. We are just aiming to use the mechanisms of our language to visualize the connections perceived to exist between different views. On the formal level, only the concept names need to be different. That is, we may not allow the same name used to denote several concepts. We "solve" this by inferring a name space for each model and thus limiting this problem to within one model. Within each model, the naming problems are centered around Homonyms and Synonyms [Navathe, 1986]:

- **HOMONYMS:** The same concept used to denote disjoint sets of instances. At least one of the concepts needs to be renamed. We may visualize this in the model by using the disjoint subset symbol and enforcing total participation in either one of the subsets. This is shown in Figure 8c with the creation of the generic *Course* whose instances has to be either *IFI Course* or *IDT Course*.
- **SYNONYMS:** Different concepts used to denote the same or overlapping sets of instances. The sets may be renamed or related through the use of the overlapping subset construct. This is shown in the model by the generic *Course Responsible* and its overlapping subsets *Teacher* and *Lecturer.*

As mentioned, in our approach to describing semantics of documents, the modeling language is seen as the group's vehicle for expressing the conceptualization behind meta-data statements. Having such interpretations visible and available is one of the main aspects of our approach. Also the model hierarchy then, must be made visible. That is, users must be made aware of that the concepts she is referring are related to others in a common model and that several views exist. When classifying a document, it is left to the user to choose which concepts to use, for example to choose between the general concepts from the common model (course responsible) or one of the specializations of a local model (teacher or lecturer).

The approach to meta-data outlined in this paper assumes that the models may be made directly available in an interface to sharing of information on the web and that the tasks of classifying or retrieving a document may be performed as model-interactions. A sketch illustrating the needed components of such an interface is shown in Figure 9. The figure shows how the models and the model hierarchy is made available along with various lists of documents. In the document lists, descriptive meta-data is used to present documents to users. The model hierarchy and contextual information regarding origin and content of each model should be presented. From the model-hierarchy, users may select and view the desired model. Needed user-level actions for sharing of information may then be made available as user-model interactions. For example, the mechanisms of the set-builder definition explained in section 4.2, may be used to instantiate a selected model fragment and create the object descriptor file shown at the bottom of the figure.

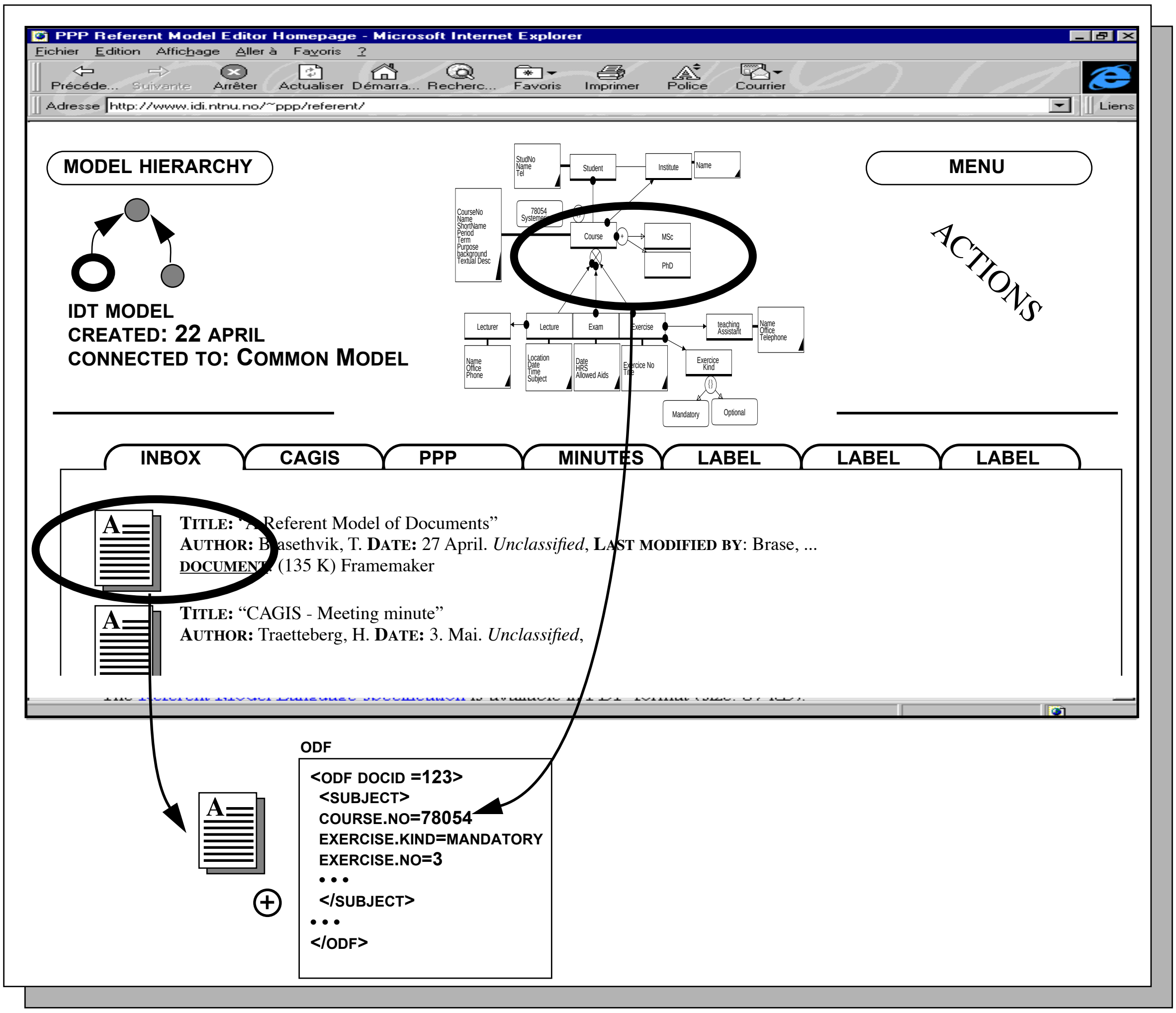

Figure 9. A user interface based on the models

5. Summing Up

We have presented an approach to sharing of information on the Web which aims to use a semantic modeling language as the basis for expressing semantics of information and relating different conceptualisations. The modeling language is considered a vehicle for a group collaborating at a distance with the Web as their medium for sharing of information. The paper has presented the overall framework, the modeling language and a small example. A modeling editor exists for our modeling language and repository and further tool support is under construction[1]. For an implementation of the system sketched in the end of this paper, it seems natural to aim for a java-interface to viewing and manipulation of models, while one may use XML to store and create meta-data statements in the object descriptor files. In order for the language to fully support expression of meaning, also support for the modeling process should be included. In this respect, interesting work is found in use of the TeamRooms system [Tuomi, 1998], supporting for example also synchronous communication and annotation of viewed objects on a Web page.

Furthermore, it is not reasonable to believe that the bare models alone is enough to communicate meaning of information or that they may serve as the single tool to place this information in the context of the groups work. To constitute a complete system, the outlined approach should for example be included in a workspace-like system found in CSCW. Within this respect, work is in progress to integrate the approach outlined in this paper with the ICE System [Farschian, 1998].

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