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**Ontology-based
Metadata
for e-learning Content**

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LIST OF ABBREVIATIONS

AHS	Adaptive Hypermedia System
API	Application Program Interface
CLS	Cognitive Style of Learning
DAML	DARPA Agent Markup Language
DCES	Dublin Core Element Set
DOM	Document Object Model
DTD	Document Type Definition
ER	Entity Relationship
HTML	Hypertext Markup Language
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
LOM	Learning Object Metadata
OIL	Ontology Inference Layer
OWL	Ontology Web Language
MARC	Machine Readable Cataloging
RDF	Resource Description Framework
RDFS	Resource Description Framework Schema
SGML	Standard Generalized Markup Language
URI	Uniform Resource Identifier
URL	Unified Resource Locator
W3C	World Wide Web Consortium
Web	World Wide Web
XML	Extensible Markup Language

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ABSTRACT

Nowadays, the popularity of the Web encourages the development of Hypermedia Systems dedicated to e-learning. Nevertheless, most of the available Web teaching systems apply the traditional paper-based learning resources presented as HTML pages making no use of the new capabilities provided by the Web. There is a challenge to develop educative systems that adapt the educative content to the style of learning, context and background of each student. Another research issue is the capacity to interoperate on the Web reusing learning objects. This work presents an approach to address these two issues by using the technologies of the Semantic Web. The approach presented here models the knowledge of the educative content and the learner's profile with ontologies whose vocabularies are a refinement of those defined on standards situated on the Web as reference points to provide semantics. Ontologies enable the representation of metadata concerning simple learning objects and the rules that define the way that they can feasibly be assembled to configure more complex ones. These complex learning objects could be created dynamically according to the learners' profile by intelligent agents that use the ontologies as the source of their beliefs. Interoperability issues were addressed by using an application profile of the IEEE LOM- Learning Object Metadata standard.

Keywords: e-learning, Adaptability, Metadata, Ontology, Interoperability, Semantic Web, RDF, RDF Schema, DAML+OIL, OWL, LOM.

Metadados para Conteúdo Educativo com Base em Ontologias.

RESUMO

Atualmente a popularidade da Web incentiva o desenvolvimento de sistemas hipermídia dedicados ao ensino a distância. Não obstante a maior parte destes sistemas usa os mesmos recursos do ensino tradicional, apresentando o conteúdo como páginas HTML estáticas, não fazendo uso das novas tecnologias que a Web oferece. Um desafio atual é desenvolver sistemas educativos que adaptem seu conteúdo ao estilo de aprendizagem, contexto e nível de conhecimento de cada aluno. Outro assunto de pesquisa é a capacidade de interoperar na Web reutilizando objetos de ensino. Este trabalho apresenta um enfoque que trata esses dois assuntos com as tecnologias da Web Semântica. O trabalho aqui apresentado modela o conhecimento do conteúdo educativo e do perfil do aluno pelo uso de ontologias cujo vocabulário é um refinamento de vocabulários padrões existentes na Web como pontos de referência para apoiar a interoperabilidade semântica. As ontologias permitem a representação numa linguagem formal dos metadados relativos a objetos de ensino simples e das regras que definem suas possíveis formas de agrupamento para desenvolver objetos mais complexos. Estes objetos mais complexos podem ser projetados para se adequar ao perfil de cada aluno por agentes inteligentes que usam a ontologia como origem de suas crenças. A reutilização de objetos de ensino entre diferentes aplicações é viabilizada pela construção de um perfil de aplicação do padrão IEEE LOM-Learning Object Metadata.

Palavras-Chave: EAD, Adaptabilidade, Metadados, Ontologia, Interoperabilidade, Web Semântica, RDF, RDF Schema, DAML+OIL, LOM.

1 INTRODUCTION

Nowadays, the popularity of the Web encourages the development of Hypermedia Systems dedicated to e-learning. The Web frees the teacher and student of restrictions like space and time while providing a powerful vehicle to disseminate knowledge.

With respect to educative Hypermedia Systems, adaptability and interoperability are issues of intensive research in order to obtain both adaptation mechanisms that enable the presentation of the most suitable training to each individual learner and educative content reusable across the Web by different educative systems.

The work presented here addresses research done concerning these two issues by applying the technologies of the Semantic Web.

Recent efforts in the development of the RDF framework (Lassila, 1998; Lassila & Swick, 1999) and the RDF Schema language (Brickley & Guha, 2000) to represent structures that can convey meaning on the Web are intended to make the realization of the *Semantic Web* possible (Berners-Lee, 1999; 2000). Richer languages to construct ontologies, such as DAML+OIL (Connolly et al., 2001; 2001b) and OWL (Bechhofer et al., 2003) leverage this purpose.

The foundation of the Semantic Web is the explicit representation of the background and meaning of Web resources in a way that enables both machine processing and machine understanding. This implies metadata represented in such a way that conveys not only information, but also the semantics of the structures used to represent such information in order to enable interoperability at the semantic level.

On the other hand, educational Adaptive Hypermedia Systems (AHS) model the knowledge concerning both the students' profiles and the domain to be taught in order to use this knowledge to adapt the learning content to the needs of each user (Brusilovsky, 1998; Brusilovsky, 1999; Rousseau, Garcia-Macías, Valdeni & Duda, 1999; Brusilovsky, 2002; Souto et al., 2002). The knowledge concerning the student's profile is composed of information that describes the most relevant characteristics of the student for the purpose of adaptability. The knowledge about the domain to be taught concerns the description of each elementary subject that conforms the knowledge space to be covered by the educative content.

The objective of the work presented here is twofold. The first objective is to make an analysis about the foundation of the Semantic Web in order to determine the way its technologies can be applied to improve adaptability and achieve interoperability on the Adaptive Hypermedia Systems domain. The second objective is the prototyping

implementation of the steps needed to reach such achievements in the adaptive hypermedia system AdaptWeb. The AdaptWeb is an in-progress research project presently in operation at the Federal University of Rio Grande do Sul.

To achieve the first objective of this work, the research results in metadata representation for the Web and ontologies were explored. According to the research carried out, the described proposal showed in Figure 1.1 was made in order to achieve the second objective.

Concerning the proposed architecture the *Authoring Module* provides a methodology and an editing tool to support the authoring task that generates the educative content of the system: the Hyperspace.

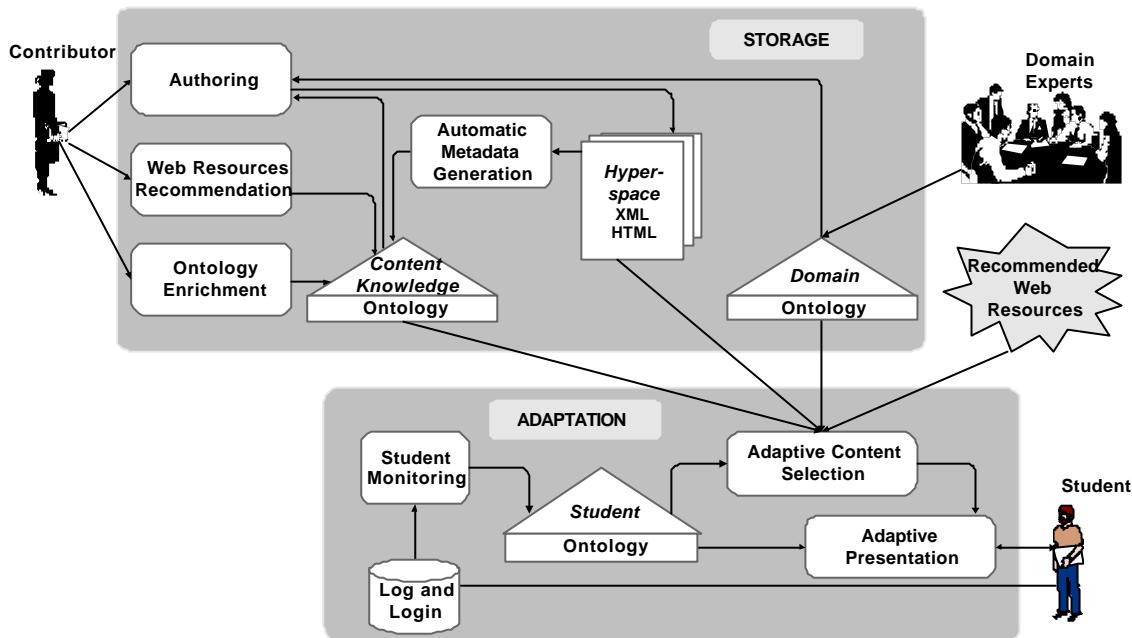


Figure 1.1: AdaptWeb proposed architecture.

Three ontologies were implemented, the *Domain Ontology* containing the knowledge about the structure of the domain to be taught, The *Student Ontology* containing the student profile, and finally the *Content Knowledge Ontology*, containing a structure of knowledge capable of providing composition rules represented in a principled way to enable configuration of complex learning objects tailored to the student's profile. This repository of knowledge sets the stage to implement a powerful adaptation mechanism since it is encoded in a formal Web ontology capable of supporting reasoning services.

In addition, interoperability is achieved by having the ontologies vocabularies based on the standard metadata model LOM (IEEE Learning Technology Standards Committee, 2002). It was necessary to construct an *application profile* of the standard LOM in order to address the particular needs of the AdaptWeb educative context.

During the authoring process, the author can consult the *Domain Ontology* to be aware of the structure of the domain about which he or she is creating educative content. Also, he or she can consult the *Content Knowledge Ontology* to be aware of existing learning objects concerning a given subject to eventually reuse them.

Each time that new content is authored, the Automatic Metadata Generation wrapper generates its fundamental metadata as RDF descriptions that are instances of the Content Knowledge Ontology.

The *Ontology Enrichment* by edition makes the Content Knowledge ontology augmentation by human agents possible at any time. Recommendation of Web resources to be used as educative support material is possible by the specification of certain characteristics of the resource and the identification of the person who makes the recommendation.

The *Student Monitoring* agent continuously updates the *Student Ontology* according to the student's activities.

The *Adaptive Content Selection* agent selects the contents to be presented to the student by creating a learning trajectory tailored to the student's profile based on the knowledge available about the student and the educative content.

The *Adaptive Presentation* module determines the presentation style according to the preferences stated in the student model using different presentation styles by XSLT transformations, disabling links and enabling search by keywords.

At the beginning of the work described here, the Authoring Module had already been implemented.

The prototyping implementation of the following elements was done:

- The Domain Ontology
- The Content Knowledge Ontology
- The Student Ontology
- The Automatic Metadata Generation Module
- The Web Resources Recommendation Procedure

The work is presented as follows. Chapter 2 describes the main features of Adaptive Hypermedia Systems. Chapter 3 describes and categorizes Metadata. Chapter 4 presents the result of the exploration in the Ontologies field. Chapter 5 presents a detailed description of the work carried out. Finally, Chapter 6 gives the conclusions and possible future work.

2 ADAPTIVE HYPERMEDIA SYSTEMS

Unlike traditional paper-based learning resources presented as HTML pages, where the same content is presented to all students, Adaptive Hypermedia Systems (AHS) in the e-learning domain adapt the content and presentation style of the educative material to each student's profile.

Users with different goals, preferences and background knowledge may be interested in different pieces of educative content and want to use different styles of navigation. To cover such requirements, an AHS builds a user model to keep knowledge of the learner's profile which will be used in adaptation tasks at training time (Brusilovsky, 1998; Brusilovsky, 1999; Rousseau, Garcia-Macías, Valdeni & Duda, 1999; Brusilovsky, 2002; Souto et al., 2002).

Educational AHSs explicitly model the knowledge of the domain to be taught in the form of elementary knowledge pieces or concepts that form a knowledge space. Then, an adaptive educational hypermedia system can be considered as having two interconnected networks or "spaces": a network of concepts forming the *Knowledge Space* and a network of hypertext pages with educational material forming the *Hyperspace*. The links between the two spaces tell the system what is presented on a particular page or page fragment in the hyperspace in terms of the knowledge space. Figure 2.1 shows the information structure of a typical adaptive hypermedia system.

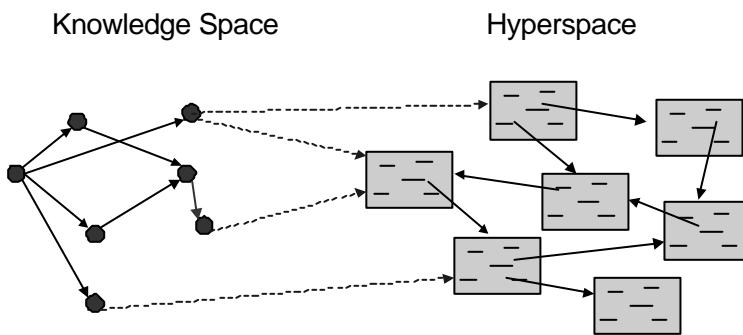


Figure 2.1: Information Space in an Adaptive Hypermedia System.(Brusilovsky, 2002).

As stated in (Souto et al., 2002) the adaptation of the instructional content to the student's individual characteristics implies that the system must: (i) recognize the cognitive patterns of each student's learning and its pedagogical implications; (ii) know the training knowledge space being proposed, (iii) know the organization of the instructional material, and (iv) be able to dynamically generate the best suited selection and sequence of content for each student in a particular course stage. Next, features on

the Knowledge Space Model, the Student Model, and the connection between the Knowledge Space and the Hyperspace of educative content will be briefly presented.

2.1 Knowledge Space Model

The Knowledge Space Model of an AHS is formed of a structured set of knowledge elements representing each elementary fragment of knowledge of the given domain. These elements are called *concepts* or *topics*.

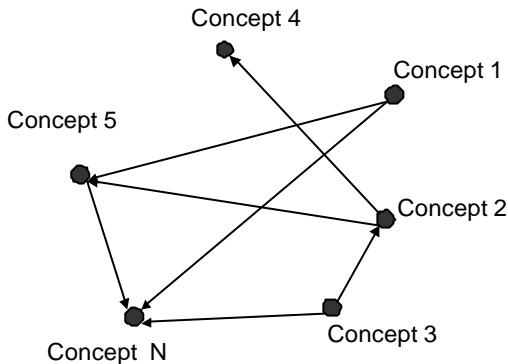


Figure 2.2: Concepts in the Knowledge Space of an Adaptive Hypermedia System
Adapted from (Brusilovsky, 2002)

Concepts on the Knowledge Space are related to each other forming a kind of semantic network representing the structure of the covered domain (Figure 2.2) (Brusilovsky, 2002). Different kinds of link represent relations between concepts. For example the prerequisite link, which represents the fact that one of the related concepts has to be learned before the other.

With respect to the internal structure of concepts, some AHS use only names denoting fragments of the domain knowledge, while others use a set of attributes to describe them.

2.2 Student Model

The student's model is intended to keep knowledge of the learner's profile, which will be used at the training time to adapt the content and navigation style to the user's characteristics.

Some of the student's features that can be used to define his or her profile are the knowledge he or she has in the domain being taught, his or her general knowledge background, learning goals and cognitive style of learning (Souto et al., 2002). Likewise, things related to the technological environment of the student, like his or her network connection speed (Palazzo et al., 2003) can help in deciding which media is more suitable to provide the educational content.

In order to represent the knowledge the student has in the domain being taught, most educational AHS use the *overlay model* (Brusilovsky, 2002). The overlay model keeps some data indicating an estimation of the user's knowledge for each concept in the Knowledge Space. This data can be a qualitative value like one of *good*, *average* or *poor*, or can be an integer quantitative value (Figure 2.3), among other possibilities. The

simplest form of the overlay model uses a binary value indicating whether the user knows the topic content or not.

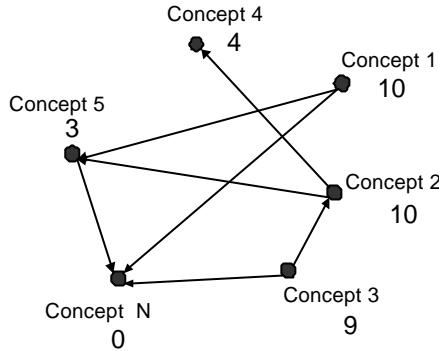


Figure 2.3: A simple overlay student model.

Adapted from (Brusilovsky, 2002)

Advanced educational AHSs represent learning goals as sequences of subsets of concepts of the domain to be learned. Hence, the student himself can select a pre-organized customized sequence of subsets of topics over a discipline as his or her learning goals.

2.3 Connecting Domain Knowledge with Educational Content

It is necessary to connect the Hyperspace containing the HTML or XML pages of educative content with the knowledge Space that models the domain to be taught in order to let the system “know” at training time what is presented on each page of this Hyperspace. According to (Brusilovsky, 2002), there are four main features that change the approach in making the connection process: cardinality, granularity, navigation and expressive power.

Cardinality indicates if each fragment of educational material is related to one and only one domain model concept or if it can be related to many concepts. While the first option is simpler, the second is more powerful enabling the use of the same piece of content for training in different topics of the domain.

Expressive Power concerns the amount of information the author can associate with each link between a concept and a page or page fragment on the hyperspace. The most common case is simply the presence of the link, but more information including, for example, the definition of different kinds of connections between concepts and pages, such as the prerequisite role are very useful.

Granularity concerns the precision of the connections. The whole hypertext page can be connected with concepts on the domain, or the connection can be defined at the level of page fragments.

Navigation aspects indicate if the link connecting the Hyperspace and the Knowledge Space is used only in a conceptual level by adaptation mechanisms or if the link is also used for navigational purposes. The second option enables very rich navigation opportunities, such as the navigation from any page with educational material to all concepts connected to it, and from each concept in the domain being taught to all pages connected to this concept.

3 METADATA

Metadata is structured information describing resources, created to help in the task of discovering, managing and using them without the need to be read, viewed or explored in some way.

According to (Gilliland-Swetland, 2000) metadata is the total sum of what one can say about any information object at any level of aggregation, considering that an *information object* is anything that can be addressed and manipulated by a human or a system as a discrete entity. Any information object may be atomic or the resulting aggregation of other information objects. Additionally, any information object has three describable features using metadata: content, context and structure. ***Content*** is related to *what* the object contains or is about. ***Context*** indicates features such as *where* the object is stored, *who* created or updated the object, and *how* it can correctly be used, and ***structure*** represents the set of existing associations within or among individual information objects.

Metadata kept with the object it describes, such as an HTML document containing <META> tags explaining the semantics of its content, is called *implicit or internal metadata*, while metadata kept elsewhere is called *explicit or external metadata*. Although metadata kept with the object it describes is simpler, explicit metadata makes it possible to have a structured repository facilitating search and retrieval.

Catalogs are good examples of metadata-based tools for managing collections of items. Catalogs contain concise, well structured, explicit metadata descriptions of the items in a collection with only the most essential information characterizing them. These descriptions are created according to cataloging rules and metadata standards. An example of a metadata standard to represent bibliographic descriptions is MARC (Machine Readable Cataloging) (<http://www.loc.gov/marc/>), which was developed in the 1960s to be used by library catalogers to construct indexes, abstracts, and catalog records to arrange, track and facilitate access to library objects.

3.1 The Importance of Metadata

The generation of metadata is a very time consuming task, even for trained people. Following, a brief list of uses to justify the cost of metadata creation is given.

Resource Discovery

Metadata enable effective search of resources across multiple repositories, since dealing with descriptive surrogates of resources is easier than dealing with the resources themselves.

Use Facilitation

The use of a certain object by different communities can be facilitated by the existence of different metadata records describing it according to metadata schemes tailored to the needs of each community.

Interoperability

Interoperability is the ability to exchange data across different data structures and software platforms with minimal loss of content and functionality. Structural metadata explaining the semantics of data stored in different sources enable interoperability at the semantic level by solving heterogeneity problems such as having the same name for different kinds of data in different repositories. If the metadata explaining different sources were not created with the same basic vocabulary, then mappings between metadata repositories would also be needed.

Preservation

Since digital information can be lost or corrupted, metadata describing how a digital information object was created and maintained, how it behaves, and how it relates to other information objects is useful to enable the object to continue to be accessible across migrations of software and hardware.

3.2 Categorizing Metadata

Metadata can be classified by several dimensions, such as functionality, physical location, generation process, essence of its content, status along time, degree of structuring, and degree of objectivity.

Table 3.1 presents an exhaustive classification of metadata according to its functionality, identifying metadata for administrative, descriptive, preservation, technical and use purposes.

Table 3.1: Types of Metadata and their Functions (Gilliland-Swetland, 2000)

Type	Definition	Examples
Administrative	Metadata used in managing and administering information resources	<ul style="list-style-type: none"> - Acquisition information - Rights and reproduction tracking - Documentation of legal access requirements - Location information - Selection criteria for digitization - Version control and differentiation between similar information objects - Audit trails created by recordkeeping systems
Descriptive	Metadata used to describe or identify information resources	<ul style="list-style-type: none"> - Cataloging records - Finding aids - Specialized indexes - Hyperlinked relationships between resources - Annotations by users - Metadata for recordkeeping systems generated by records creators

Preservation	Metadata related to the preservation management of information resources	- Documentation of physical condition of resources - Documentation of actions taken to preserve physical and digital versions of resources, e.g., data refreshing and migration.
Technical	Metadata related to how a system functions or how metadata behave	- Hardware and software documentation - Digitization information, e.g., formats, compression ratios, scaling routines - Tracking of system response times - Authentication and security data, e.g., encryption keys, passwords
Use	Metadata related to the level and type of use of information resources	- Exhibit records - Use and user tracking - Content re-use and multi-versioning information

Table 3.2 describes characteristics of metadata according to certain dimensions or attributes, such as their source, method of creation, nature, status, structure, semantics and aggregation level.

Table 3.2: Attributes and Characteristics of Metadata (Gilliland-Swetland, 2000)

Attribute	Characteristics	Examples
Source of metadata	Internal metadata generated by the creating agent for an information object at the time when it is first created or digitized External metadata relating to an information object that is created later, often by someone other than the original creator	- File names and header information - Directory structures - File format and compression scheme - Registrarial and cataloging records - Rights and other legal information
Method of metadata creation	Automatic metadata generated by a computer Manual metadata created by humans	- Keyword indexes - User transaction logs - Descriptive surrogates such as catalog records and Dublin Core metadata
Nature of metadata	Lay metadata created by persons who are neither subject nor information specialists, often the original creator of the information object Expert metadata created by either subject or information specialists, often not the original creator of the information object	- Metatags created for a personal Web page - Personal filing systems - Specialized subject headings - MARC records - Archival finding aids

Status	Static metadata that never change once they have been created	-Title, provenance, and date of creation of an information resource
	Dynamic metadata that may change with use or manipulation of an information object	- Directory structure - User transaction logs - Image resolution
	Long-term metadata necessary to ensure that the information object continues to be accessible and usable	- Technical format and processing information - Rights information - Preservation management documentation
	Short-term metadata, mainly of a transactional nature	
Structure	Structured metadata that conform to a predictable standardized or unstandardized structure	- MARC - TEI and EAD - local database formats
	Unstructured metadata that do not conform to a predictable structure	- Unstructured note fields and annotations
Semantics	Controlled metadata that conform to a standardized vocabulary or authority form	- AAT - ULAN - AACR2
	Uncontrolled metadata that do not conform to any standardized vocabulary or authority form	- Free-text notes - HTML metatags
Level	Collection metadata relating to collections of information objects	- Collection-level record, e.g., MARC record or finding aid - Specialized index
	Item metadata relating to individual information objects, often contained within collections	- Transcribed image captions and dates - Format information

Additionally, metadata can be classified by the nature of their input as objective or subjective metadata (Duval, Hodgins, Sutton & Weibel 2002). **Objective metadata** are those whose input is constituted by assertions of facts determinable objectively, such as authorship, date of creation and version. This kind of metadata can be generated automatically, even inferable. On the other hand, **subjective metadata** is produced by assertions than can be derived from a subjective point of view, such as the assignment of keywords. Likewise, subjective metadata may be intended to represent the subjective opinion of a person about some fact, such as the recommendation a teacher might make about the quality of the content of a Web site for educative purposes. This kind of metadata can not be generated automatically.

3.3 Metadata and the World Wide Web

"The Semantic Web is an extension of the current Web in which information is given well-defined meaning, better enabling computers and people to work in cooperation."
 (Berners-Lee, Hendler, Lassila, 2001)

The repositories currently available to search for information on the Web are centralized metadata catalogs. On the one hand, there are portals with the capacity to search using thesaurus and classification schemes like Yahoo! (McGuinness, 2003) which are very expensive to maintain because they involve a great amount of human work. On the other hand, there are search services over databases automatically populated by crawlers which generate poor rates of *recall* and *precision* due to their lack of semantics.

Nevertheless, according to (Gill, 2000) the use of centralized metadata repositories to catalog the resources of the entire Web is not promising in the long term. What would be needed is the widespread adoption of standards for metadata structure to implement a distributed metadata catalog model that enables interoperability at the semantic level.

It is expected that the search on the next generation of the Web, called **Semantic Web**, can be based on metadata records generated according to decentralized definitions situated in *namespace schemas* and *application profiles*, using *crosswalks* when needed.

3.3.1 Namespace Schemas

Namespace schemas are intended to define metadata standards on the Web. A namespace schema is a set of metadata elements definitions that stand on the Web as reference points to be used to create metadata descriptions about resources of a specific domain in a standardized way. Generally, a namespace schema is designed for a registration authority, and maintained as a stable reference on the Web. Such a design is made following a minimalist approach that implies a minimum set of elements with simple structure in order to facilitate the adoption of the schema by communities of users, such as the Dublin Core schema (Dublin Core, 1999).

3.3.2 Application Profiles

The purpose of an application profile is to adapt or combine existing schemas into a package tailored to the functional requirements of a particular application while retaining interoperability with the original base schemas (Duval, Hodgins, Sutton & Weibel 2002). Part of such an adaptation may include the elaboration of local metadata elements that are important for a given community or organization, but which are not expected to be important in a wider context. The main goal of application profiles is to increase the semantic interoperability of the resulting metadata instances within a community of practice by going beyond the universal consensus of a single standard without compromising the basic interoperability that the standard provides across the boundaries of these communities.

Since an application profile must operate within the interoperability constraints defined by the standard, additional restrictions in the status of data elements can be made when defining an application profile, but no relaxing on this status is possible. Following, a set of mechanisms considered adequate to adapt a schema in order to create an application profile is presented (Duval, Hodgins, Sutton & Weibel 2002).

Cardinality enforcement refers to the possibility to change the cardinality constraints in the occurrence of the element in metadata descriptions. Then, a given element with no cardinality constraints in the schema or with a loose restriction may be forced to be mandatory according to the profile specification.

Value Space Restrictions refers to the possibility to restrict the values of the element into values of a given set. It is typically used when the application uses a set of values more restricted than those defined by the standard, eventually a set of values defined by enumeration. For example, a set of strings indicating names of persons authorized to do something.

Relationship and dependency specification indicates that an application profile can define interrelationships between data elements and their value spaces. Then, the presence of a data element may impose conditions on the presence of others. For example, if a metadata element indicates that the type of the resource being described is a text, then the extension of the file containing such a resource could not be “gif”.

Declaration of namespaces indicates that application profiles can define their local elements through the use of a locally defined namespace and also invoke multiple namespace definitions to include elements from existing schemas to form a new compound schema that meets the functional requirements of the application. For example, the mechanisms given above can be applied to elements defined in different schemas that are invoked by the XML namespaces (W3C, 1999) declaration of the application profile definition to define new, local elements.

3.3.3 Crosswalks

What metadata schemas and application profiles define are sets of properties, or metadata elements organized in *vocabularies* that give the necessary components to write metadata descriptions.

Since various application profiles tailor standards to different communities on the same domain, it is necessary to have a mechanism to translate metadata descriptions generated according to an application profile into metadata description according to other application profiles to achieve interoperability on such a domain.

A crosswalk is a set of mappings defined among the elements of two different vocabularies probably related to the same domain of knowledge in order to translate metadata descriptions. As can be seen, crosswalks enhance the Web interoperability.

3.3.4 Metadata Registries

The concept of machine-understandable documents does not imply some magical artificial intelligence which allows machines to comprehend human numblings. It only indicates a machine's ability to solve a well-defined problem by

performing well-defined operations on existing well-defined data. Instead of asking machines to understand people's language, it involves asking people to make the extra effort. (Berners-Lee, 1998)

Metadata registries are intended to make both people and software aware of metadata schemas in use by different communities. The expectation is that registries will provide the means to identify and refer to established schemas and application profiles, potentially including the means for machine mapping among them (Duval, Hodgins, Sutton & Weibel 2002). Such registries will be available for consultation for:

- Application profile designers who want to identify existing metadata schemas or other application profiles that could meet their application needs.
- Creators and managers of metadata, to be aware of the definition and usage recommendations concerning a given element they want to use.
- Applications resolving URIs associated with a metadata Schema.
- End users who are interested in knowing existing metadata to be able to correctly use them in their search or processing.

A *registering profile* was presented in (Baker, Dekkers, Heery, Patel & Salokhe, 2001), intended to register and describe application profiles in the context of the SCHEMAS project (SCHEMAS, 2000).

The description of the application profile is made with a set of classes and properties that enable:

- Identifying the application profile,
- identifying the standard metadata schema tailored to the application profile,
- identifying the terms of the standard used in the profile and
- describing the semantics given to the refined definitions.

3.5 Dublin Core Metadata Initiative

The Dublin Core Metadata Element Set (DCMES) is a set of elements resulting from the work of The Dublin Core Metadata Initiative organization (Dublin Core, 1999), which stands for “promoting the wide-spread adoption of interoperable metadata standards and developing specialized metadata vocabularies for describing resources that enable more intelligent information discovery systems”.

Since the DCMES was intended to be used by authors to describe their own Web resources, it was designed to be simple to understand and use. It was envisioned to be so general as to enable the description of Web based documents across multiple disciplines. Web documents with embedded descriptions by means of the <META> tag of HTML could be indexed by search engines to enable information retrieval using semantic search. Unfortunately, most search engines do not trust the META tags content because of the abuse that can result from its use, for example repeating keywords to boost a site's ranking in search results.

Table 3.3 shows the Dublin Core Element Set which is a set of properties intended to represent features needed to describe resources on the Web. Each element is optional

and repeatable when used in a metadata description. More information of their use can be encountered at (Dublin Core, 1999).

Table 3.3: Dublin Core Elements

Metadata Coverage	Element	Description
Intellectual Property	Contributor	An entity responsible for making contributions to the content of the resource.
	Creator	An entity primarily responsible for making the content of the resource.
	Publisher	An entity responsible for making the resource available.
	Rights	Information about rights held in and over the resource.
Content	Coverage	The extent or scope of the content of the resource.
	Description	An account of the content of the resource.
	Type	The nature or genre of the content of the resource.
	Relation	A reference to a related resource.
	Source	A reference to a resource from which the present resource is derived.
	Subject	A topic of the content of the resource.
	Title	A name given to the resource.
	Audience	A class of entity for whom the resource is intended or useful.
Instantiation	Date	A date of an event in the life cycle of the resource.
	Format	The physical or digital manifestation of the resource.
	Identifier	An unambiguous reference to the resource within a given context.
	Language	A language of the intellectual content of the resource.

To facilitate more complex and precise metadata descriptions a set of qualifiers are available in (Dublin Core, 1999). Qualifiers can be used to refine a DC element's semantics in order to make it more suitable for the application context, for example, using the qualifier *EducationLevel* of the element *audience* to give additional and more specific information about the audience to whom the resource is intended to be useful. Another use of qualifiers is to identify encoding schemas that contain controlled vocabularies to which the possible values of some metadata element will be restricted. Table 3.4 shows Dublin Core Qualifiers. More information of their use can be encountered at (Dublin Core, 1999).

Table 3.4: Dublin Core Qualifiers

DCMES Element	Element Refinement(s)	Element Encoding Scheme(s)
Title	Alternative	-
Subject	-	LCSH MeSH DDC LCC UDC
Description	Table Of Contents Abstract	-
Date	Created Valid Available Issued Modified Date Copyrihted Date Submitted	DCMI Period W3C-DTF
Type	-	DCMI Type Vocabulary
	-	IMT
Format	Extend Medium	-
Identifier	-	URI
Source	Bibliographic Citation	-
Language	-	ISO 639-2 RFC 3066
Relation	Is Version Of Has Version Is Replaced By Replaces Is Required By Requires Is Part Of Has Part Is Referenced By References Is Format Of Has Format Conforms To	URI
Coverage	Spatial	DCMI Point ISO 3166 DCMI Box TGN
	Temporal	DCMI Period W3C-DTF
Rights	Access Right	-
Audience	Mediator Education Level	-

3.6 Resource Description Framework (RDF)

The Resource Description Framework (RDF) is an application of XML (Bray, Paoli, Sperberg-McQueen & Maler, 2000) intended to support the encoding of structured metadata on the Web. RDF provides unambiguous methods of expressing semantics and publishing machine-understandable metadata descriptions based on vocabularies defined by different communities by means of namespace schemas and application profiles.

RDF uses XML as a common syntax for exchanging and processing metadata. XML syntax provides vendor independence, user extensibility, validation, human readability and the ability to represent complex structures. RDF imposes a formal constraint on the XML syntax to convey unambiguous expression of semantics.

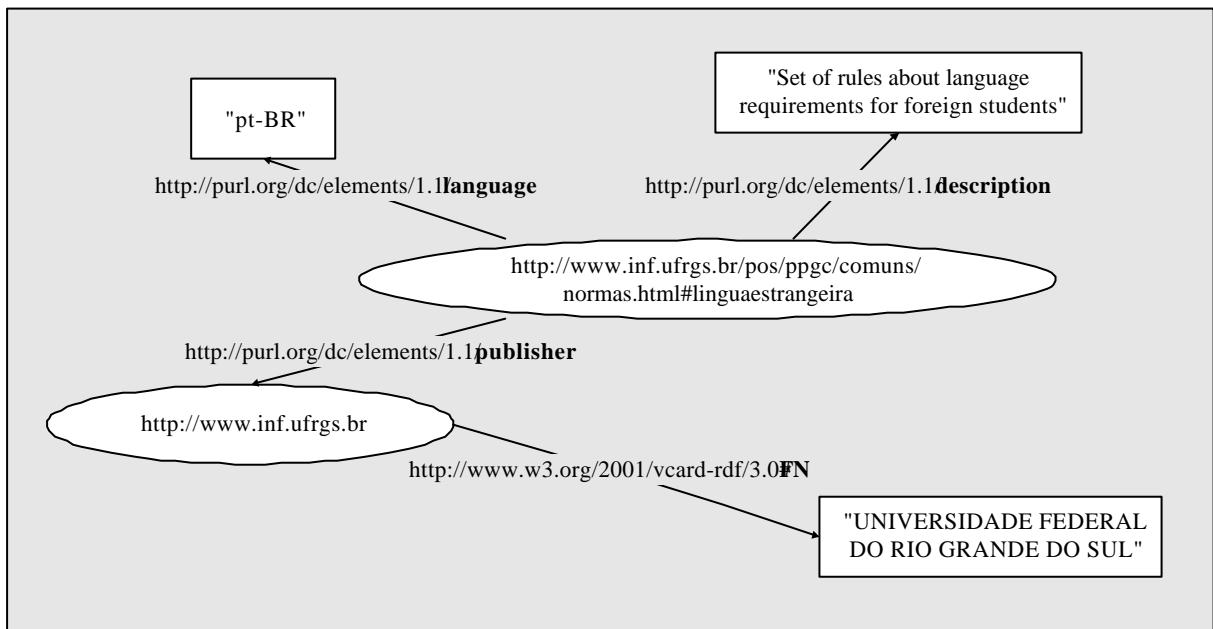


Figure 3.1: RDF description of a digital resource

The RDF data model enables resources description by means of a vocabulary that contains *resources*, *properties* and *statements*.

Resources are objects uniquely identifiable by a Uniform Resource Identifier (URI) (Berners-Lee, Fielding & Masinter, 1998). RDF uses Uniform Resource Locator references (URIrefs) to anchor resources and property definitions on the Web. To describe things that are not on the Web, that can not be retrieved, such as a house, a reference to them must be on the Web as, for example, an identifier in a document, which in turn has a URI.

Properties are attributes or relations used to describe resources.

Statements are structures containing a resource, a property, and a value indicating what the value of the property for the given resource is. The value of a property can eventually be another resource identifier.

Figure 3.1 depicts an example in the node and arc diagram representation of RDF in which the resource <http://www.inf.ufrgs.br/pos/ppgc/comuns/normas.html#linguaestrangeira> is explained by stating that its *description* stands for a set of rules about language requirements for foreign students, the human *language* in which the resource is written is indicated by the string “pt-BR” indicating Portuguese used in Brazil into certain non specified encoding schema. Additionally, the institution publishing it is pointed out by the property *publisher*. The institution also has a description provided by the property *FN*.

The property FN defined in the Vcard namespace schema (Vcard, 2001) stands for the formal name of a person or institution. All the remaining properties used to describe the resource were obtained from the Dublin Core namespace schema that was explained in the previous section.

RDF statements can also be written as triples *{predicate, subject, object}* where predicate is the property used to describe, subject is the resource being described, and object is the value of the property for the given subject. The triples corresponding to the Figure 3.1 graph are:

```
{
  [ http://purl.org/dc/elements/1.1#Description ,
    [ http://www.inf.ufrgs.br/pos/ppgc/comuns/normas.html#linguaestrangeira ],
    "Rules about idiom requirements to foreign students" ]

  { http://purl.org/dc/elements/1.1#Language ,
    [ http://www.inf.ufrgs.br/pos/ppgc/comuns/normas.html#linguaestrangeira ],
    "pt-BR" }

  { http://purl.org/dc/elements/1.1#Publisher ,
    [ http://www.inf.ufrgs.br/pos/ppgc/comuns/normas.html#linguaestrangeira ],
    [ http://www.inf.ufrgs.br ] }

  { http://www.w3.org/2001/vcard-rdf/3.0#FN ,
    [ http://www.inf.ufrgs.br/pos/ppgc/comuns/normas.html#linguaestrangeira ],
    "UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL" }
}
```

Considering that RDF descriptions should be available on the Web, an XML syntax for RDF was defined (Lassila & Swick, 1999). The XML representation of the RDF graph in Figure 3.1 is:

```
?xml version="1.0"?
<rdf:RDF
  xmlns:rdf="http://www.w3c.org/1999/02/22-rdf-syntax-ns#"
  xmlns:dc="http://purl.org/dc/elements/1.1#"
  xmlns:vcard="http://www.w3.org/2001/vcard-rdf/3.0#">
  <rdf:Description rdf:about="http://www.inf.ufrgs.br/pos/ppgc/comuns/normas.html#linguaestrangeira">
    <dc:description>Rules about idiom requirements to foreign students
    </dc:description>
    <dc:language>pt-BR</dc:Language>
    <dc:publisher rdf:resource = http://www.inf.ufrgs.br>
      <vcard:FN>UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL</vcard:FN>
    </dc:publisher>
  </rdf:Description>
</rdf:RDF>
```

In the description above the namespaces mechanism provided by XML is used to refer to the places on the Web where both the used properties and the RDF elements are defined (indicated by the prefix *rdf*, *dc* and *vcard*). This use of the namespaces mechanism enables metadata creation using vocabularies from multiple metadata schemas that are managed in a decentralized way by different communities.

As can be seen in the code above, serialization of RDF statements in XML consists of an element *Description* which indicates what resource is being explained by means of the *about* attribute. The properties describing the resource are XML sub-elements of the *Description* element.

When the value of a property is given by a URI identifying a resource (not a literal value), then the attribute *resource* defined in the RDF namespace is used, this is the case of the property *Publisher* in the example above.

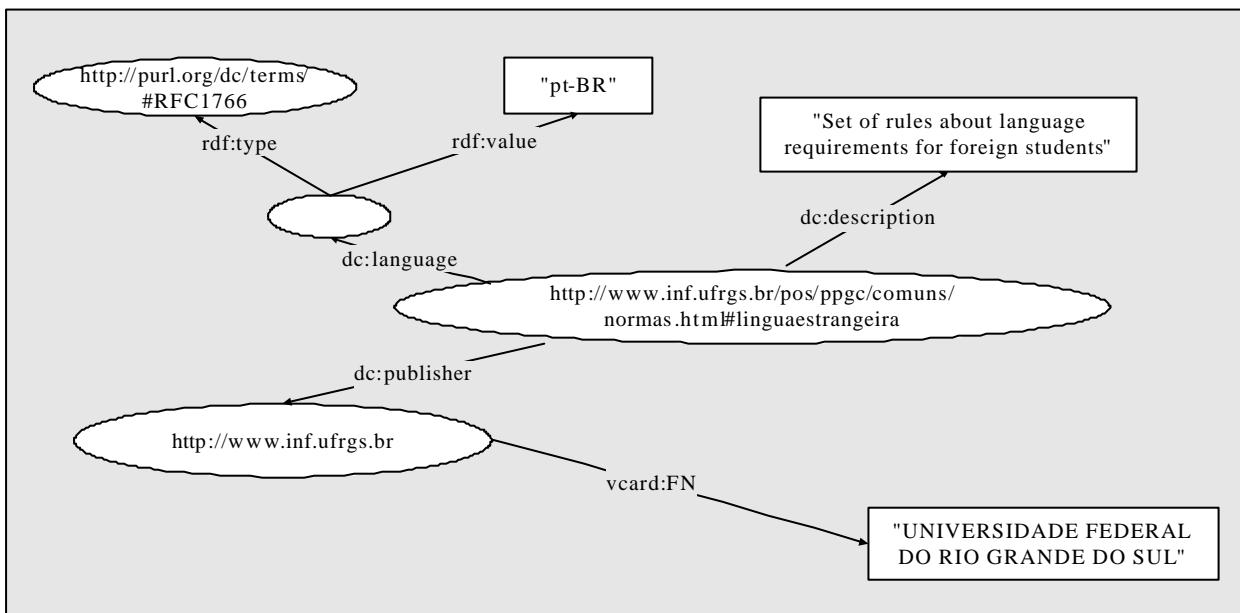


Figure 3.2: RDF description of a digital resource using property *rdf:value*

Figure 3.2 shows how the properties *rdf:type* and *rdf:value* can be used to indicate that the value of the *dc:language* property has its semantics defined in the resource <http://purl.org/dc/terms/#RFC1766>, which, in turn, is a resource intended to reveal rules to encode languages in strings like “pt-BR” or “es-UY” meaning the Portuguese used in Brazil and Spanish used in Uruguay respectively.

The XML representation of the RDF graph in Figure 3.2 is:

```
?xml version="1.0"?
<rdf:RDF
    xmlns:rdf="http://www.w3c.org/1999/02/22-rdf-syntax-ns#"
    xmlns:dc="http://purl.org/dc/elements/1.1#"
    xmlns:vcard="http://www.w3.org/2001/vcard-rdf/3.0#">
    <rdf:Description rdf:about="http://www.inf.ufrgs.br/pos/ppgc/comuns/normas.html#linguaestrangeira">
        <dc:description>Rules about idiom requirements to foreign students
```

```

</dc:description>
<dc:language>
  <rdf:type rdf:resource="http://purl.org/dc/terms/#RFC1766"/>
  <rdf:value>pt-BR</rdf:value>
</dc:Language>
<dc:publisher rdf:resource = http://www.inf.ufrgs.br>
  <vcard:FN>UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL</vcard:FN>
</dc:publisher>
</rdf:Description>
</rdf:RDF>

```

The formal grammar of RDF is given in (Lassila & Swick, 1999), as well as a reification mechanism and some containers to represent metadata descriptions of groups of resources. Up to now, we have seen how to build RDF metadata descriptions by drawing on multiple pre-existing vocabularies to give the properties used in such descriptions. The next section will present a language envisaged to define new vocabularies.

3.7 RDF Schema Language

The essence of the RDF Schema language is to provide the needed primitives to define new vocabularies that will be used in RDF metadata descriptions. Those primitives are a set of RDF resources that can be used to describe other RDF resources, including classes and properties. Application-specific RDF vocabularies can be constructed out of the structured definition of new classes and properties.

A class in RDF Schema corresponds to the generic concept of *Type* or *Category*, such as the class concept in the Object-oriented paradigm. On the other hand, unlike the Object-oriented paradigm, attributes or properties in RDF Schema are not defined within the scope of a class, but within a global scope, eventually restricted to a class or set of classes by range or domain specifications.

RDF and RDF Schema provide the core classes *Resource*, *Class* and *Property* which are the fundamentals to create any particular Schema. Any new class or property defined in a particular RDF schema must be an instance of these.

RDF Schema properties are used to denote attributes, to define an element as a instance of a class and to state that a class is a subclass of another, that is:

- An attribute is denoted by giving a value to the property characterizing the described resource.
- An individual is considered an instance of a class by the property *rdf:type* indicating the individual is “of the type” the class defines.
- A class is stated as a subclass of another by using the property *rdfs:subClassOf*

New classes can be defined stating that they are instances of the class *rdfs:Class* or that they are *rdfs:subClassOf* another class already defined. New properties are defined by stating that they are instances of the class *rdf:Property* or that they are *rdfs:subPropertyOf* another property already defined.

Some of the properties available to create new vocabularies are shown in Table 3.5.

Table 3.5: RDF and RDF Schema properties used in definitions of vocabularies

Property name	Domain	range	comment
rdf:type	rdfs:Resource	rdfs:Class	The subject is an instance of a class.
rdfs:subClassOf	rdfs:Class	rdfs:Class	The subject is a subclass of a class.
rdfs:subPropertyOf	rdf:Property	rdf:Property	The subject is a subproperty of a property.
rdfs:domain	rdf:Property	rdfs:Class	A domain of the subject property.
rdfs:range	rdf:Property	rdfs:Class	A range of the subject property.
rdfs:label	rdfs:Resource	rdfs:Literal	A human-readable name for the subject.
rdfs:comment	rdfs:Resource	rdfs:Literal	A description of the subject resource.
rdfs:seeAlso	rdfs:Resource	rdfs:Resource	Further information about the subject resource.
rdfs:isDefinedBy	rdfs:Resource	rdfs:Resource	The definition of the subject resource.

Figure 3.3 depicts an RDF Schema with classes `Brazilian_University`, `Brazilian_Federal_University` and `Universitary_Course`. The UFRGS – Universidade Federal do Rio Grande do Sul was defined as an instance of `Brazilian_Federal_University` and the `Phd_Computer_Science` course was defined as an instance of `Universitary_Course`. The properties `years_duration` and `home_page` were defined to denote attributes.

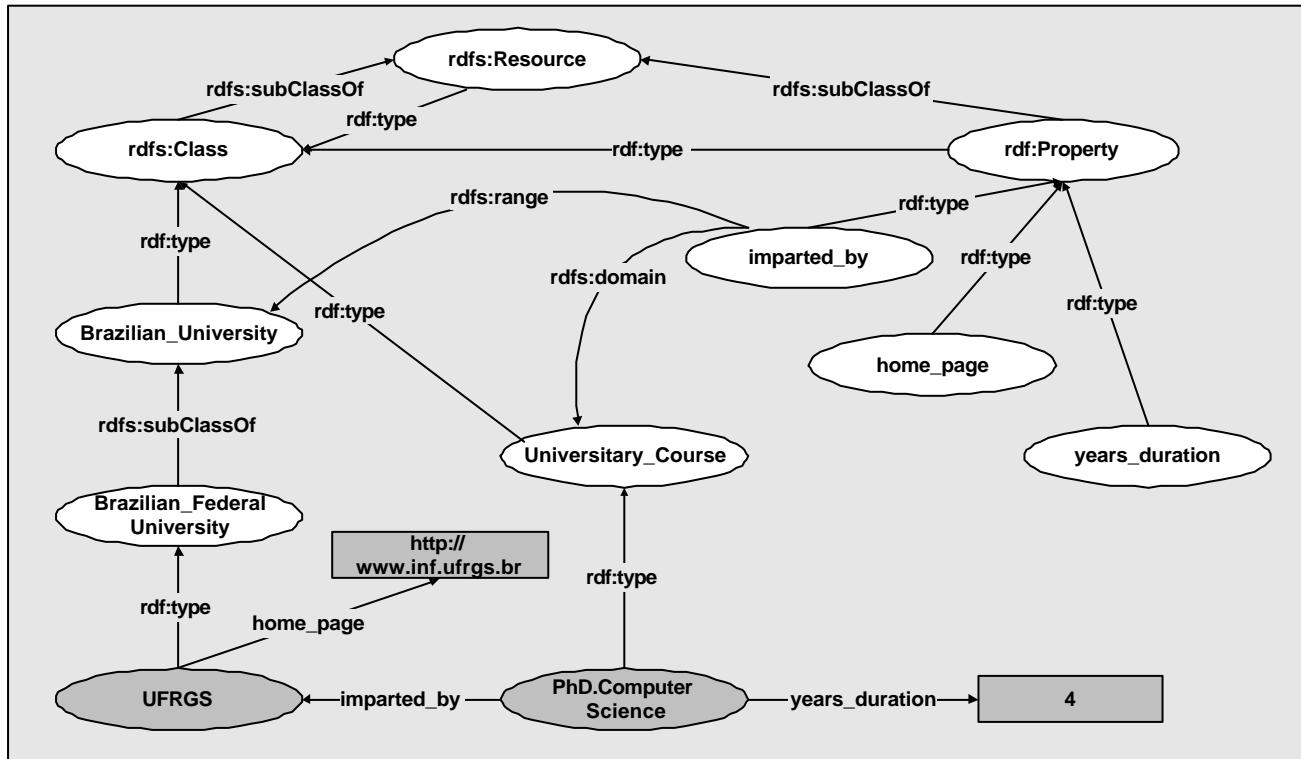


Figure 3.3: Classes and Instances in a RDF Schema

The property *imparted_by* was created to indicate the relation between a course and the university that imparts it. Range and domain restrictions were specified stating that only instances of the class `University_Course` can be related to instances of `Brazilian_University` by this property. It is possible to use the property *imparted_by* to relate instances of `Brazilian_Federal_University` (i.e.,UFRGS) because RDF Schema provides inheritance of attributes in subclasses.

Following is the XML serialization of the Schema in Figure 3.3.

```
<?xml version="1.0"?>
<rdf:RDF
  xmlns:rdf="http://www.w3c.org/1999/02/22-rdf-syntax-ns#"
  xmlns:rdfs="http://www.w3c.org/2000/01/rdf-schema#">

  <rdf:Description rdf:ID="Brazilian_University">
    <rdf:type rdf:resource="http://www.w3.org/2000/01/rdf-schema#Class"/>
  </rdf:Description>

  <rdf:Description rdf:ID="Brazilian_Federal_University">
    <rdf:type rdf:resource="http://www.w3.org/2000/01/rdf-schema#Class"/>
    <rdfs:subClassOf rdf:resource="#Brazilian_University"/>
  </rdf:Description>

  <rdf:Description rdf:ID="University_Course">
    <rdf:type rdf:resource="http://www.w3.org/2000/01/rdf-schema#Class"/>
  </rdf:Description>

  <rdf:Description rdf:ID="imparted_by">
    <rdf:type rdf:resource="http://www.w3c.org/1999/02/22-rdf-syntax-ns#Property"/>
    <rdfs:domain rdf:resource="#University_Course"/>
    <rdfs:range rdf:resource="#Brazilian_University"/>
  </rdf:Description>

  <rdf:Description rdf:ID="years_duration">
    <rdf:type rdf:resource="http://www.w3c.org/1999/02/22-rdf-syntax-ns#Property"/>
    <rdfs:domain rdf:resource="#University_Course"/>
    <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#integer"/>
  </rdf:Description>

  <rdf:Description rdf:ID="home_page">
    <rdf:type rdf:resource="http://www.w3c.org/1999/02/22-rdf-syntax-ns#Property"/>
  </rdf:Description>

  <rdf:Description rdf:ID="UFRGS">
    <rdf:type rdf:resource="#Brazilian_Federal_University"/>
    <home_page>http://www.inf.ufrgs.br </home_page>
  </rdf:Description>

  <rdf:Description rdf:ID="Phd_Computer_Science">
    <rdf:type rdf:resource="#University_Course"/>
    <years_duration> 4 </years_duration>
    <imparted_by rdf:resource="#UFRGS"/>
  </rdf:Description>

</rdf:RDF>
```

It is also possible to represent instances in a compact way:

```
<Brazilian_Federal_University rdf:ID="UFRGS">
  <home_page>http://www.inf.ufrgs.br </home_page>
```

```

</Brazilian_Federal_University>

<Universitary_Course rdf:ID="Phd_Computer_Science">
    <years_duration> 4 </years_duration>
    <imparted_by rdf:resource= "#UFRGS" />
</Universitary_Course >
```

Because real word applications are generally modeled with properties applying to various domains and ranges, the rough range and domain property restrictions provided by RDF Schema are sometimes too strong to be used. Then, it becomes necessary to find a balance between the need to express range or domain constraints and the need to have usable properties across the whole schema.

Data on the Web the continuously change without the observer's control. Then, RDF, by using RDF Schema when needed, is adequate to model metadata about Web resources because it supports descriptions that can evolve to represent the new features of the resources being described. RDF enables the smooth evolution of the metadata description structure, for example, by associating a property to a resource at any time because of the fact that RDF properties are defined within a global scope.

3.8 Learning Object Metadata Standard (LOM)

Designers of online materials have a number of software tools to create learning resources. They are very useful in allowing learning resources creation that might otherwise require extensive programming skills. Nevertheless, common agreement upon standards is needed in order to design instructional material that can share common mechanisms to find and use it.

The IEEE Learning Object Metadata (LOM) Draft Standard specification, approved on June 12, 2002 (IEEE Learning Technology Standards Committee, 2002), was developed to provide structured metadata descriptions of learning resources called *Learning Objects* in order to enable semantic interoperability among applications on the e-learning domain.

According to the LOM specification, a learning object is any entity, digital or non-digital, that may be used for learning purposes. Examples of learning objects are multimedia content, instructional content, learning objectives, instructional software and software tools, persons, organizations and events referenced during technology supported learning.

This specification defines a conceptual model of the metadata structure including a set of elements to be used in learning objects metadata descriptions, such as the element name, author, owner and prerequisites, but does not include information on how to represent these meta-data in a machine-readable format. Rather, it is intended to be referenced by other standards that define such implementations.

The purpose of the IEEE Learning Object Metadata (LOM) Standard is to facilitate search, evaluation, acquisition, and use of learning objects, for example, for learners, instructors or automated software processes. Likewise, it is intended to facilitate the sharing and exchange of learning objects by enabling the development of catalogs and inventories while taking into account the diversity of cultural and lingual contexts in

which the learning objects and their metadata are reused. Following is the detailed list of purposes of LOM (IEEE Learning Technology Standards Committee, 2002).

- To enable learners or instructors to search, evaluate, acquire, and utilize Learning Objects.
- To enable the sharing and exchange of Learning Objects across any technology supported learning systems.
- To enable the development of learning objects into units that can be combined and decomposed in meaningful ways.
- To enable computer agents to automatically and dynamically compose personalized lessons for an individual learner.
- To compliment the direct work on standards that are focused on enabling multiple Learning Objects to work together within an open distributed learning environment.
- To enable, where desired, the documentation and recognition of the completion of existing or new learning & performance objectives associated with Learning Objects.
- To enable a strong and growing economy for Learning Objects that supports and sustains all forms of distribution; non-profit, not-for-profit and for profit.
- To enable education, training and learning organizations, both government, public and private, to express educational content and performance standards in a standardized format that is independent of the content itself.
- To provide researchers with standards that support the collection and sharing of comparable data concerning the applicability and effectiveness of Learning Objects.
- To define a standard that is simple yet extensible to multiple domains and jurisdictions so as to be most easily and broadly adopted and applied.
- To support necessary security and authentication for the distribution and use of Learning Objects.

3.8.1 LOM Data Model

The base schema of LOM was envisaged to be extended and represented in different syntax forms by different communities of users. By specifying a common conceptual data schema, the LOM Standard specification ensures that different representations of Learning Object Metadata compliant with the standard will have a high degree of semantic interoperability.

The conceptual data schema of LOM groups metadata elements into nine categories intended to contain different kinds of metadata, named General, Life Cycle, Meta-Metadata, Technical, Educational, Rights, Relation, Annotation and Classification, whose purpose is (IEEE Learning Technology Standards Committee, 2002):

General category is intended to group the general information that describes the learning object as a whole;

Life Cycle groups the features related to the history and current state of the learning object;

Meta-Metadata groups information about the metadata instance used to describe the learning object;

Technical groups the technical requirements and technical characteristics of the learning object;

Educational groups the educational and pedagogic characteristics of the learning object;

Rights groups the intellectual property rights and conditions to use the learning object.

Relation groups features that define the relationship between the learning object and other learning objects;

Annotation category provides comments on the educational use of the learning object and provides information on when and by whom the comments were created;

Classification category describes the learning object in relation to a particular classification system.

The following metadata items were also defined for each metadata element:

name: the name by which the data element is referenced;

explanation: the definition of the data element;

size: the number of values allowed;

order: whether the order of the values is significant;

example: an illustrative example.

For leaf nodes on each hierarchy, the LOMv1.0 Base Schema also defines:

value space: the set of allowed values for the data element, typically in the form of a vocabulary formed of a list of values or a reference to another standard in which the list is defined;

datatype: indicates whether the values are a strings of characters (LangString), specifications of a point in time (DateTime), or the specification of an interval in time (Duration);

Vocabulary: indicates the structure of a vocabulary item.

Figure 3.4 depicts the category 2-Life Cycle of LOM intended to group the contextual metadata related to the history and current state of learning objects. Here, the element 2.1-Version indicates the edition of the learning object being described, element 2.2-Status indicates the status or condition of the learning object taking a value from the value space defined by {"draft", "final", "revised", "unavailable"}.

Items depending on 2.3-Contribute are intended to give information about the people or organizations that have contributed to the state of the learning object during its life cycle. Item 2.3.1-Role should be filled in with an element indicating the kind of contribution from the set {"author", "publisher", "unknown", "initiator", "terminator", "validator", "editor", "graphical designer", "technical implementer", "content provider",

“technical validator”, “educational validator”, “script writer”, “instructional designer”, “subject matter expert”}.

Item 2.3.2-*Entity* should be filled in with the proper information about the entities that played the role indicated in element 2.3.1 in the life cycle of the object. This information will be given according to the vocabulary described in the vCard Schema (Vcard 2001), for example, by giving a value to the property FN described in Section 3.6 of this work. Lastly, the date where the contribution was made must be provided filling in the item 2.3.3-*Date*.

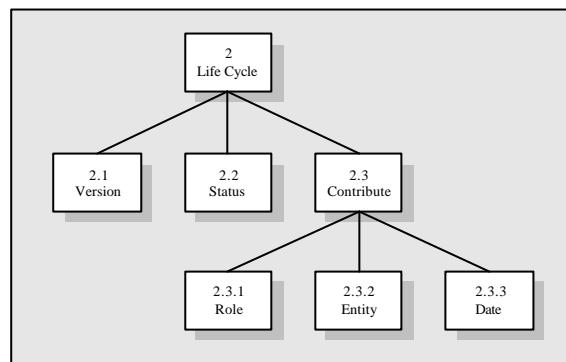


Figure 3.4: Structure of category 2 – Life Cycle of the LOM data model

The use of controlled vocabularies, as indicated in the example above, for sub-elements 2.2-*Status* and 2.3.1-*Role* is optional, but is strongly recommended since they increase the degree of semantic interoperability among applications by increasing the likelihood that such metadata will be understood by other applications or users.

Table 3.6 shows mappings defined in (IEEE Learning Technology Standards Committee, 2002) between the Dublin Core Metadata Element Set and LOM elements of category 2-Life Cycle.

Table 3.6: Mappings from DCES to category 2-Life Cycle of the LOM data model

DC Element	LOM Element
Date	2.3.3 –Life Cycle. Contribute.Date when 2.3.1-Life Cycle.Contribute.Role has the value “Publisher”
Creator	2.3.2 –Life Cycle. Contribute.Entity when 2.3.1-Life Cycle.Contribute.Role has the value “Author”
Publisher	2.3.2–Life Cycle. Contribute.Entity when 2.3.1-Life Cycle.Contribute.Role has the value “Publisher”

3.8.2 RDF binding for LOM

There are several possibilities to represent LOM metadata descriptions on the Web. One is to use an XML binding, i.e., the XML language (Bray, Paoli, Sperberg-McQueen & Maler, 2000) with a specific XML Schema (Fallside, 2000) designed to validate documents with LOM descriptions of learning objects.

Since XML support has reached a mature level, a number of projects are currently underway in the LOM implementation through XML bindings, such as ARIADNE (<http://www.riadne-eu.org>), CanCore (<http://www.cancore.org>) and Heal (<http://www.healcentral.org>).

On the other hand, a less explored alternative is the use of an RDF binding, i.e., to use RDF as the language to represent statements with assertions about the value of LOM properties for resources. A RDF binding was presented in (Nilsson, 2001).

The main design decisions taken in developing such an RDF binding were (Nilsson, 2003):

- The binding should extend the Dublin Core RDF vocabularies whenever possible.
- The binding should reuse the vCard RDF binding.
- The binding should use URIs, not literals, for all vocabulary terms.
- The binding should try to maintain the intended semantics of LOM and RDF, while not necessarily perfectly represent the exact structure of the LOM information model.
- The binding should be relatively straightforward to translate into an XML format for LOM without losing any LOM information (other information might be lost, however).

The fundamental advantage of using an RDF binding lies in the capacity of RDF to reuse different vocabulary definitions that can be included in a new metadata schema definition in a standard way. This facilitates the reuse of existing standards as Dublin Core in metadata descriptions of learning objects. Nilsson, (2001b; 2003) and Nilsson, Palmer and Brase (2003) give detailed explanations of the differences between XML and RDF bindings approaches.

The RDF binding for LOM (Nilsson, 2001) has been implemented by definitions across various namespace schemas so that each LOM category has its own namespace. Additionally, there is a root namespace containing common constructs.

Table 3.7 shows a list of LOM categories, the URI of the namespace that implements the category in the described RDF binding, and the abbreviations used in the rest of this work to refer to these namespaces, when needed.

Table 3.7: RDF binding namespaces

LOM Category	Namespace	Abbreviation
	http://kmr.nada.kth.se/el/ims/schemas/lom-base#	lom
1 - General	http://kmr.nada.kth.se/el/ims/schemas/lom-general#	lom-gen
2 - Life Cycle	http://kmr.nada.kth.se/el/ims/schemas/lom-lifecycle#	lom-life
3 - Meta-Metadata	http://kmr.nada.kth.se/el/ims/schemas/lom-metametadata#	lom-meta
4 - Technical	http://kmr.nada.kth.se/el/ims/schemas/lom-technical#	lom-tech
5 - Educational	http://kmr.nada.kth.se/el/ims/schemas/lom-educational#	lom-edu
6 - Rights	http://kmr.nada.kth.se/el/ims/schemas/lom-rights#	lom-rights
7 - Relation	http://kmr.nada.kth.se/el/ims/schemas/lom-relation#	lom-rel
8 - Annotation	http://kmr.nada.kth.se/el/ims/schemas/lom-annotation#	lom-ann
9 - Classification	http://kmr.nada.kth.se/el/ims/schemas/lom-classification#	lom-cls

Figure 3.5 shows metadata compliant with the viewed LOM RDF Binding used to describe the resource <http://www.inf.ufrgs.br/pos/ppgc/comuns/normas.html#linguaestrangeira>.

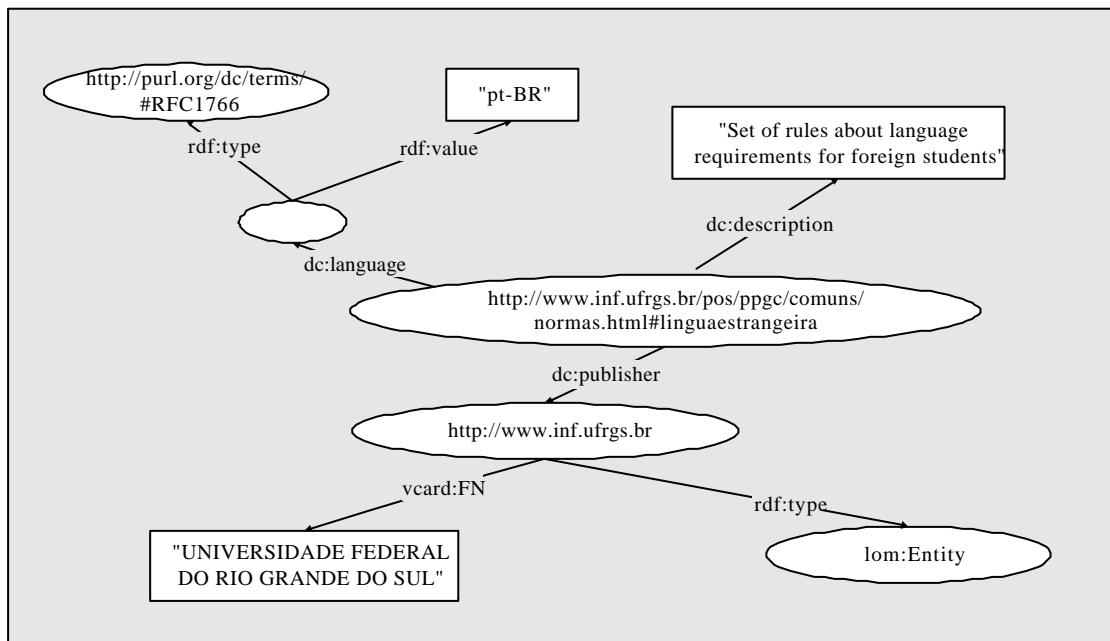


Figure 3.5: Description of a digital resource using a LOM RDF binding

Following is the RDF serialization corresponding to Figure 3.5.

```
?xml version="1.0"?
<rdf:RDF
    xmlns:rdf="http://www.w3c.org/1999/02/22-rdf-syntax-ns#"
    xmlns:dc="http://purl.org/dc/elements/1.1#"
    xmlns:vcard="http://www.w3.org/2001/vcard-rdf/3.0#">
    <rdf:Description
        rdf:about="http://www.inf.ufrrgs.br/pos/ppgc/comuns/normas.html#linguaestrangeira">
        <dc:description>Rules about idiom requirements to foreign students
        </dc:description>
        <dc:language>
            <rdf:type rdf:resource="http://purl.org/dc/terms/#RFC1766"/>
            <rdf:value>pt-BR</rdf:value>
        </dc:Language>
        <dc:publisher rdf:resource = http://www.inf.ufrrgs.br>
            <rdf:type rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-base#Entity"/>
            <vcard:FN>UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL</vcard:FN>
        </dc:publisher>
    </rdf:Description>
</rdf:RDF>
```

Because the metadata needed to describe resources of a particular community of users implies a set of metadata elements conveying the semantics relevant only to the context of this community, sometimes, the specific elements needed by these communities are not available on a standard metadata schema, or are available with a semantics that is too general for the purpose of their applications. According to Section 3.3.2 this is the case in which an *application profile* must be developed in order to specify all the metadata elements needed for these applications. Several *application profiles* as ARIADNE (<http://www.ariadne-eu.org>), CanCore (<http://www.cancore.org>) and Heal (<http://www.healcentral.org>) were developed in order to give more specific semantics to a subset (eventually the entire set) of the LOM specification appropriate for the needs of a given learning context. For interoperability purposes, some crosswalks were made to provide mappings between them.

4 ONTOLOGIES

Since Aristotele's time there has been an interest to represent the existing knowledge of the world with a methodology that identifies classes of objects with common properties in a hierarchical structure where some classes are specializations of others. This way to represent knowledge was called *Ontology*.

One of the most cited definitions of ontology is (Gruber, 1993):

"An ontology is a formal, explicit specification of a shared conceptualization."

Another definition is (Studer, Benjamins & Fensel, 1998):

"An ontology may take a variety of forms, but necessarily it will include a vocabulary of terms and some specification of their meaning. An ontology is virtually always the manifestation of a shared understanding of a domain that is agreed between a number of parties. Such agreement facilitates accurate and effective communication of meaning, which in turn leads to other benefits such as inter-operability, reuse and sharing."

Ontologies in Computer Science evolved from semantic networks (Quillian, 1967) and were proven to be quite useful in representing and facilitating the sharing of the knowledge about a domain by human and automatic agents. Ontologies have been used in Configuration Systems, Software Engineering, Information Retrieval, Conceptual Modeling, Interoperability, Enterprise Modeling, Electronic Commerce, and many other fields in the research and production areas.

4.1 Ontology Components

Despite the representation language being used, ontologies share a common set of characteristics in order to make knowledge representation and inference tasks possible. Next, a set of elements of the specification and use of ontologies will be presented. It is intended to give an intuitive view, not an exhaustive account.

Concepts

A concept (also called class or frame) is the description of the common features that a set of individuals have. A concept can be anything of which anything can be stated that could be relevant to the intended purpose of the ontology. It can be physical or digital objects. An object can be a procedure description, a functionality, action or strategy,

among others. The idea behind concepts may be viewed as similar to the idea behind classes in the object-oriented modeling paradigm. On the other hand, from a logical point of view, a concept is a unary predicate which denotes a set of individuals.

Each concept has an associated term as its name, a description in natural language, and a set of properties (also called slots or roles) that characterize it. Concepts can be defined by extension, i.e., enumerating their elements, or by intension, i.e., giving restrictions that their elements must maintain.

Properties

Properties (also called roles or slots) contribute to identify concepts by characterizing them. They can be used in intensional definitions of concepts, to relate individuals or to give attribute values. The values a property could have can be restricted to elements of a given class or can have cardinality constraints restricting their minimum or maximum number of possible values.

Properties are the way to represent the existent relations among concepts into a domain. They are the basis for the hierarchical structure of the ontology. Two relations are especially important: *taxonomy* and *mereology*.

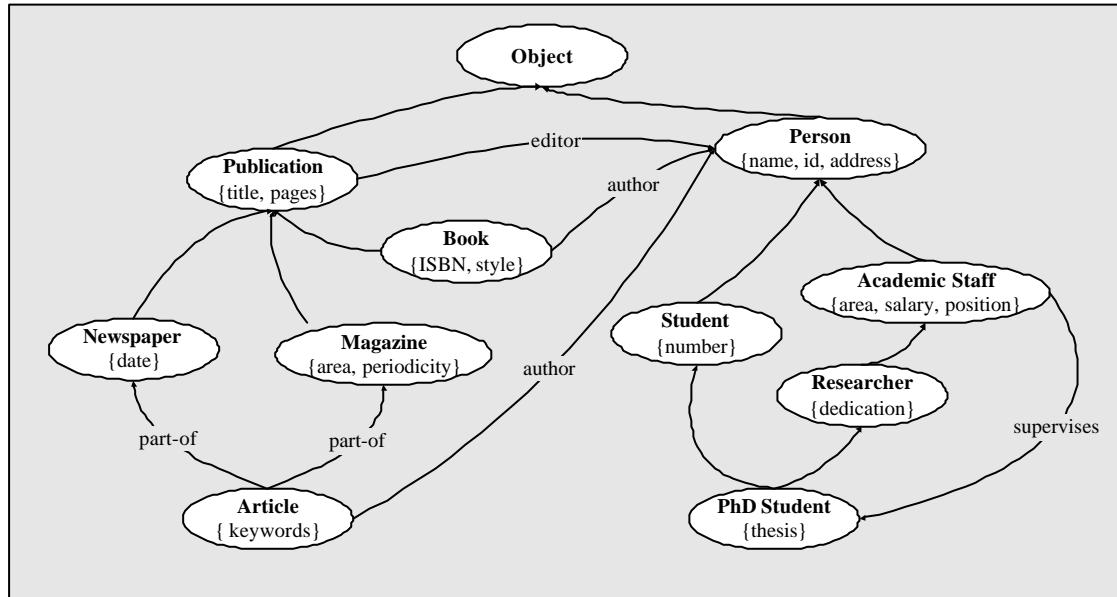


Figure 4.1: Concepts and properties in an ontology

Taxonomy

The taxonomy (*subclass-Of*, *is-A*) relation, also called *Subsumption* describes the specialization of general concepts into more specific ones. Figure 4.1 indicates the taxonomical links among concepts by arrows without tags. Inheritance of the concept's properties across the taxonomy is modeled in a different way by different ontological representation languages, but it is always available.

Mereology

The mereology (*part-of*) relation is defined in some ontological systems to model the situation that a whole is composed of parts, and it was interesting to model those parts as separate concepts. Figure 4.1 indicates mereology relations by tags "part-of". There

are different ways in which parts contribute to the structure of a whole (Artale, Franconi, Guarino & Pazzi, 1996):

Component/Object: The object is structured and its components are separable having their specific functionality. For example, “Wheels are parts of cars”;

Member/Collection: The members do not play any functional role with respect to the whole that they are part of, and they can be separated from it. For example, “A tree is part of a forest”;

Portion/Mass: The whole is a homogeneous aggregate, so these portions are similar to it, and separable from it. For example, “This slice is part of a pie”;

Constituent/Object: Expresses the idea that can be paraphrased using *is partly* or *is made of*. For example, “The bike is partly steel”. In this kind of *part-of* relation the constituent of the object cannot be separated from the object, and it does not have any functional role;

Feature/Activity: Designates a phase of an activity. A phase, such as a component, has a functional role, but is not separable. For example, “Grasping is part of stacking objects”;

Place/Area: Indicates a spatial relation among regions occupied by different objects. Such as the Portion/Mass, each part is formed of the same material of the whole, but it cannot be separated. For example, “An oasis is part of a desert”.

The co-existence of different kinds of *part-of* relations caused the definition of the relation *part-of* without the transitive property in some ontologies. Whereas each identified kind of *part-of* relation holds the transitive property, when relations *part-of* of different kinds are mixed in a reasoning using transitivity, semantically erroneous conclusions may be obtained.

Axioms

Axioms contribute to specify the definition of the ontology elements constraining their interpretation. They state facts that must always hold which are useful to verify correctness on creation time or deducing new information on query time.

Structural axioms constrain the structure of the ontology. For example “Concept A and concept B are disjoint”, meaning that no individual can be an instance of concept A and also an instance of concept B, or stating the transitive condition of a given relation.

Non structural axioms are local to a concept and constrain its interpretation stating conditions about its attributes. For example “The value of the attributes *force*, *mass* and *acceleration* of any instance of the concept *Solid* holds *force=mass*acceleration*”

Instances

Ontology instances are individuals holding concepts definitions and facts representing relations between individuals.

Ontology Operations

Ontological representation languages enable the execution of a certain basic set of operations to cover updating and querying tasks on ontologies. The most simple queries an ontology can answer, despite the representation language used and the purpose it was constructed for, are:

- What are the instances of a given concept?

- Given an individual, what are the concepts to which it pertains?
- Which individuals have a given value in a given property?
- Which individuals are related to a given individual by a given property?

Likewise, new concepts can be defined, properties related to concepts and values changed or added during the entire life of the ontology. At editing time, the consistency of the ontology can be automatically checked, for example, to reject a value that was intended to fill a property for a given concept if it is not in concordance with the restrictions defined on the property values for this concept. At query time, inference can be made by using explicitly stated facts and the ontology axioms to infer implicit new facts.

4.2 Categorizing Ontologies

Ontologies can be of different types depending on such factors as the domain intended to be modeled or the use for which they are constructed or the complexity they need to have. Following is a classification of ontologies in two dimensions, the degree of axiomatization and the subject of conceptualization.

Classification by the degree of axiomatization

According to (Sowa, 2000), ontologies can be classified as *formal*s and *terminological*s by the degree of axiomatization in their definitions.

Formal ontologies have their categories and individuals distinguished by axioms and definitions stated in logic or in some computer-oriented language that can automatically be translated into logic. In formal ontologies, it is possible to do complex inferences supported by their logical fundamentals to check consistency in their building time and to infer new facts on query time. An example of a formal ontology is the ontology *Cyc* (<http://www.Cyc.com>).

Terminological ontologies need not have axioms restricting the use of their concepts. Examples of terminological ontologies are *Wordnet* (<http://www.cogsci.princeton.edu/~wn/>) used for natural language processing and *The Electronic Dictionary - EDR* (<http://www.iijnet.or.jp/edr/>).

Theoretically, the difference between terminological and formal ontologies is one of degree. As more axioms are added to a terminological ontology, it may evolve into a formal one. The amount of time and human knowledge that formal ontologies need makes their cost prohibitive for certain applications, and they are generally restricted to a reduced number of terms. On the other hand, terminological ontologies are structurally simpler, cheaper, and can be larger.

Classification by the subject of conceptualization

Following are the categories into which ontologies can be classified by the subject of their conceptualization according to (van Heijst, Schreiber & Wielinga, 1997).

Domain ontologies contain conceptualizations that are specific for particular domains. They can be reused in various applications of the same domain (e.g., electronic, medical and mechanic domain).

Generic ontologies are similar to domain ontologies, but the concepts that they define are considered to be generic across many fields. Typically, generic ontologies define concepts like state, event, process, action, component, etc. The concepts in domain ontologies are often defined as specializations of concepts in generic ontologies. Generic ontologies are constructed to be reused and extended. An issue is that there is no consensus in the research community as to what is the best way to express the general knowledge about the world that they are intended to represent. The top of both Aristoteles's ontology and some current generic ontologies is shown in Figure 4.2.

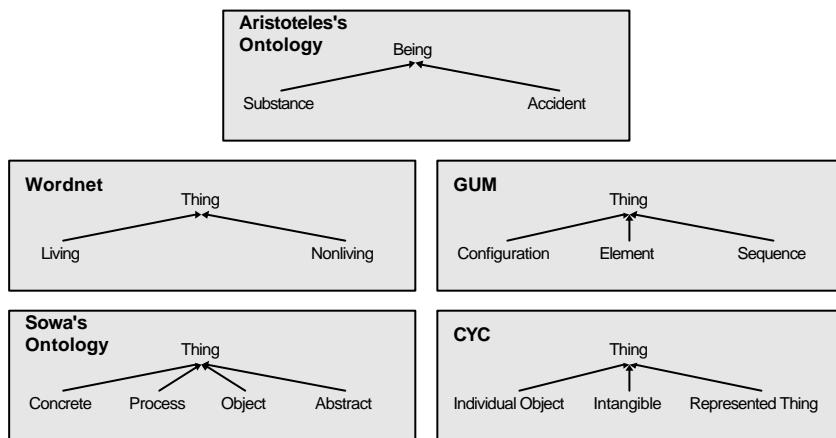


Figure 4.2: Top of generic ontologies

Examples of these kinds of ontologies are the proposal of Sowa (Sowa, 2000), The *Sensus ontology* constructed by the Information Sciences Institute – ISI of the University of Southern California, *Microkosmos ontology* developed by the Computer Research Laboratory of the New Mexico State University, *CYC* <http://www.Cyc.com>, *Wordnet* <http://www.cogsci.princeton.edu/~wn/> and *The Generalized Upper Model – GUM*.

Representation ontologies explain the conceptualizations that underlay knowledge representation formalisms. That is, they provide a representational framework without making claims about the world. Domain ontologies and generic ontologies are described using the primitives provided by representation ontologies. An example in this category is the *Frame Ontology*, which is used in Ontolingua (Gruber, 1993). This ontology defines terms like relation, function, class, and the other primitives used in modeling ontologies in an object-oriented or frame-based way.

Application ontologies contain all the definitions that are needed to model the knowledge required for a particular application. Typically, application ontologies are a mix of concepts that are taken from domain ontologies and from generic ontologies.

Application ontologies are not constructed to be reused. According to the characteristics of each group viewed, it can be observed that the more an ontology is suitable to be used in a defined context of a domain, the less suitable it is to be reutilized in other contexts of the same domain.

4.3 Ontologies and Information Systems

Guarino (1998) discussed the role an *explicit* ontology can play within an information system and argued in favor of an architectural perspective in which the ontology plays a central role at system development or run time, calling the resulting system an *ontology-driven information system*.

Ontologies can serve as a fundamental aid in the Software Engineering field, supporting the software developer by relating knowledge about the domain of the application being developed with existing code components to facilitate their reuse (Devambu, Brachman, Selfridge & Ballard 1991).

Conceptually modeling the universe of discourse of an information system with an ontology (Borgida, 1995) makes it possible to take advantage of the ontology capacity to automatically check the model consistency and subsumption i.e., detecting that all the classes are feasible of having at least one instance according to their restrictions, and detecting subclass relations not explicitly stated by the modeler, perhaps because he or she was not aware of them, but that are inferable from those explicitly stated.

Ontologies can play a central role in *Configuration Systems*. According to (McGuinness, 2002) a configuration system addresses the problem to assemble a complex artifact from its components. Potentially, the components have subcomponents, thus the artifact may be modular or hierarchical in nature. Likewise, each of the components typically has a number of properties and connections to other components. A domain model can be defined with concepts containing descriptions of parts, and interactions between properties can be defined to condition the values of some properties to the values given to others. The input description for the configuration problems should be able to be given incrementally by human or automatic agents. The input could also be incomplete and inconsistent. Ontologies can be used to complete the input with the knowledge the system has on the domain and also to detect inconsistencies. Configuration Systems need not only to achieve an output with the result of the configuration process, but also to give the user the explanation about the line of reasoning followed that justifies the parts used in the final product.

Considering the Information Retrieval field, search engines such as Google (<http://www.google.com>), AltaVista (<http://www.altavista.com>) or Lycos (<http://www.lycos.com>) search in a full text way from the huge quantity of documents they have indexed. They recognize the relevance of an indexed document with respect to a posed question by how many times the words forming the question appear in the document. If some documents contain only synonyms of the words of the query, these documents will not be recognized as relevant, and if the words are used in indexed documents with different semantics than in the query, these indexed documents will be retrieved as relevant (although actually they are not relevant). On the other hand, with search engines powered by ontologies, the semantic context in which a word is used could be inferred many times and then the irrelevant documents could be omitted from the result

set. Likewise, the query could be answered not only with documents containing the words in the query, but also with documents containing words that the ontology states are synonymous or related. As examples (Desmontils & Jacquin, 2001) presented a Web site indexed with the aid of a terminological ontology, and (Freitas-Junior et all, 2002) presented a method of cross-language information retrieval (CLIR) to classify both the information of the documents in a given collection and the user queries according to the concepts of the terminological ontology MeSH (Medical Subject Headings) (National Library of Medicine, 2000). These concepts are used as semantic units that minimize the linguistic problems like polysemy.

Ontologies are used in Intelligent Integration of information as metadata explaining the information content of data repositories enabling semantic queries into these subjacent sources with no need to consider the underlying structure of the sources in the query formulation. An example of this kind of information system is OBSERVER (Mena, Illarramendi, Kashyap & Sheth, 2000).

In Natural Language Processing, ontologies can help the semantic analysis of text by representing grammatical structures as related concepts in order to reduce the existent gap in the interpretation of the semantic ambiguity of the natural language. Since then, ontologies can be useful in text mining and machine translation. Wordnet (<http://www.cogsci.princeton.edu/~wn/>) is an ontology used in Natural Language Processing.

Ontologies play a main role in Enterprise Modeling by creating and maintaining an organizational memory that lets the different enterprise areas interoperate in a common language and with unified rules, for example modeling *Business Process*. They can also be the basis for the agents interoperation language in automated manufacturing processes. The TOVE ontologies (<http://www.ie.utoronto.ca/EIL>) and the Enterprise Ontology (<http://www.aiai.ed.ac.uk/project/enterprise>), are examples of this kind of ontologies.

In the field of Knowledge Engineering, ontologies and *Problem Solving Methods (PSMs)* are intended to enable the reuse of the domain knowledge across different intelligent applications. While ontologies are the repositories of the declarative knowledge and rules of the domain, PSMs specify the reasoning to solve concrete problems in a procedural way.

The Electronic Commerce area can take advantage of ontologies in several ways, for example, enabling a more intelligent access to online information and services, or providing structure to interoperability. For example, Yahoo! (<http://www.yahoo.com>) introduced metadata structures resembling ontologies early on by means of human tagging to help its users navigate into the content of the site. The idea was to have a small number of top level categories allowing drill-down in each of them to specialize the search. Another example is The Universal Standard Products and Services Classification Code – UN/SPSC (<http://www.unspsc.org>). The UN/SPSC is a freely available class taxonomy classifying products and services. Many B2B sites are currently using and extending it to better achieve their particular purposes.

In the medical domain, we can find several taxonomies, as MeSH (Medical Subject Headings) (National Library of Medicine, 2000) that enable the search in digital

medical collections as MEDLINE (<http://www.ncbi.nlm.nih.gov/PubMed>) providing, among others, semantic expansion of queries so that searching for a more general topic can retrieve results of more specific topics in the taxonomy and vice-versa.

4.4 Design Criteria

A set of design criteria to help in the ontology design task is presented in (Gruber, 1993), (Guarino, Borgo & Masolo, 1996) and (van Heijst, Schreiber & Wielinga, 1997). Some of them are:

Clarity. An ontology should effectively communicate the intended meaning of the defined terms;

Completeness. Concepts definitions should be made whenever possible by both necessary and sufficient conditions;

Coherence. One ontology should be able to infer facts that are consistent with its definitions. That is, the defined axioms should be locally consistent.

Unfortunately, there is no concordance in the research community about a consensual methodology to design them. (Gruninger & Fox, 1995), (Uschold & King 1995) and (Fernández, Gómez-Pérez & Juristo, 1997) present three different methodologies.

4.5 Representation Languages

The development of an ontology implies the representation of the knowledge of the domain being modeled into the syntax of a formal knowledge representation language. The two approaches that have influenced the knowledge representation languages envisaged to be used on the Web, such as OIL (Fensel et al., 2001), DAML (Hendler & McGuinness, 2000), DAML+OIL (Horrocks, 2002) and OWL (Bechhofer et al., 2003) are Description Logics and Frame-based languages. Both of them have a common root in semantic networks introduced by Quillian (1967).

Semantic networks were developed as an alternative to logic-based formalisms and were based on studies about the way human beings organize knowledge in their brains. The knowledge in a semantic network is represented by concepts located on nodes and edges representing atomic properties and subclass/superclass links. Following sections will present a non exhaustive view of Description Logics and Frame Based languages.

4.5.1 Frame-based Languages

Frame systems were introduced in (Minsky, 1975) with the basic idea to represent knowledge by modeling objects like object oriented systems do. Each object is described in a class called *frame*.

Each frame contains attributes called *slots* representing properties of the modeled object which, in turn, can themselves be other complex concepts described by frames. A slot has the scope of the concept it describes and contains characteristics called *facets* as the type of data the attribute has, a descriptive comment, and cardinality restrictions. Subsumption among classes and membership of an instance to a class must be explicitly declared.

A subset of an ontology represented in F-Logic (Erdmann & Studer, 2000) is shown in Figure 4.3, while the graphical representation of its taxonomy is depicted in Figure 4.4. The first group of sentences in Figure 4.3 defines the taxonomy of concepts (frames), the second, the properties (slots), and the third, the axioms.

```

Object[].
Person :: Object.
Employee :: Person.
AcademicStaff :: Employee.
Researcher :: AcademicStaff.
PhDStudent :: Researcher.
Student :: Person.
PhDStudent :: Student.
Publication :: Object.
Book :: Publication.
Article :: Publication.
JournalArticle :: Article.
Journal :: Publication.

Person[name =>> STRING; email =>> STRING; editor =>> Book;
publication =>> Publication; address =>> STRING].
Employee[employeeNo =>> STRING].
AcademicStaff[supervises =>> PhDStudent].
Researcher[cooperatesWith =>> Researcher].
Student[studentID =>> NUM].
PhDStudent[supervisor =>> AcademicStaff].
Publication[author =>> Person; title =>> STRING; year =>> NUM; abstract =>> STRING].
Book[editor =>> Person].
JournalArticle[journal =>> Journal; firstPage =>> NUM; lastPage =>> NUM].
Journal[editor =>> Person; volume =>> NUM; number =>> NUM;
containsArticle =>> JournalArticle].

FORALL Pers1, Pers2
Pers1:Researcher[cooperatesWith ->> Pers2] <->
Pers2:Researcher[cooperatesWith ->> Pers1].
FORALL Pers1, Publ1
Publ1:Publication[author ->> Pers1] <-> Pers1:Person[publication ->> Publ1].
FORALL Pers1, Publ1
Publ1:Book[editor ->> Pers1] <-> Pers1:Person[editor ->> Publ1].
FORALL Pers1, Pers2
Pers1:PhDStudent[supervisor ->> Pers2] <-> Pers2:AcademicStaff[supervises ->> Pers1].
FORALL Publ1, Publ2
Publ2:Journal[containsArticle ->> Publ1] <-> Publ1:JournalArticle[journal ->> Publ2].

```

Figure 4.3: Partial view of an ontology represented in a Frame-based language

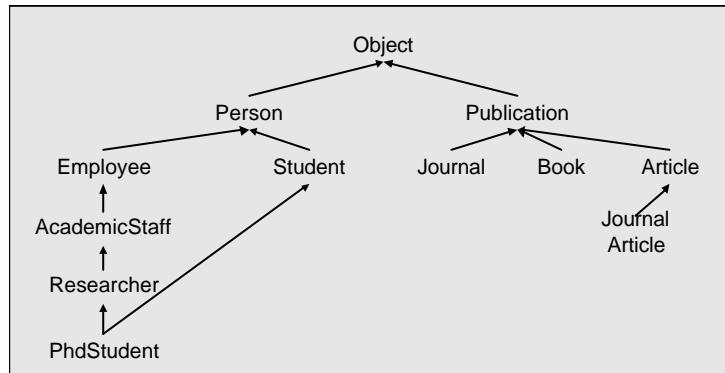


Figure 4.4: Graphical representation of Figure 4.3 ontology

The ontology code presented in Figure 4.3 can be understood considering that:

c1::c2 means that class C1 is a subclass of class C2

o:c means that O is an instance of class C

c1[A=>c2] For the instances of class C1, an attribute A is defined whose value must be an instance of class C2.

o[A=>v] The instance O has an attribute A with value V

FORALL is a quantifier denoting all elements holding the condition that follows the quantifier.

Queries for the ontology in Figure 4.3 can be posed by substituting the variables of the expressions like **o:c[A -> v]** for values restricting the query result, meaning that the object O is an instance of the class C with an attribute A that has a certain value V. For example, if we are interested in finding the home page and email address of all researchers with name “Lydia Silva Muñoz”, we can achieve that with the following query:

```
FORALL Obj, EM
Obj:Researcher[Name ->> "Lydia Silva Muñoz"; email ->> EM]
```

The resulting answer could be:

```
Obj = http://www.fing.edu.uy/~lsilva
EM = lsilva@fing.edu.uy
```

By using the axioms in Figure 4.3, it can be inferred that if a Researcher A *cooperatesWith* an individual B, then B must be a Researcher as well, and he or she also *cooperatesWith* A.

A representative example of frame-based systems is the Frame Logic (F-Logic) formalism (Kifer, Lausen & Wu, 1995). F-Logic is a very expressive language with sound reasoning services and a rich set of epistemological primitives. Inheritance in F-Logic was defined in a non monotonic way, so that sub-class of a given class inherits the properties of the more general class unless they were overwritten.

4.5.2 Description Logics

Description Logics were introduced in (Brachman & Schmolze, 1985), embracing the following three ideas:

- The basic syntactic building blocks are atomic concepts, atomic roles, and individuals;
- The expressive power of the language is restricted in that it uses a small set of constructors for building concepts and roles (properties);
- Subsumption and membership relationships can be inferred from the definition of concepts and the properties of the individuals.

Properties, called *roles* in Description Logics have a global scope. Properties are used in concept definitions by indicating *value restrictions* as a part of the concept definition. Value restrictions are restrictions on the value the property can have so that one individual can be considered as pertaining to the concept. An example of value

restriction is the indication that for all elements pertaining to concept C, the property R must take a value from concept C'. Additionally, monotonic inheritance of properties and restrictions is defined, which makes it impossible to override inherited characteristics and facilitates reasoning tasks.

In Description Logics a concept can be *primitive* or *defined*. When a concept is *primitive*, its definition is taken to be a necessary, but not sufficient condition for membership. When a concept is *defined*, its definition is taken to be a necessary and sufficient condition for membership, i.e., it defines *all* the elements that pertain to the class.

Defining a concept in an intensional manner is about using concept descriptions that can be embedded to form complex expressions. Operators such as conjunction, disjunction, negation and role quantifications are supplied to form these descriptions. Below is a set of examples presented in (Borgida, Brachman, McGuinness & Resnick, 1989).

```
define-role [perpetrator]
define-role [victim]
define-role [site]
...
define-concept [CRIME,
  (PRIMITIVE
   (AND (AT-LEAST 1 perpetrator)
      (ALL perpetrator PERSON)
      (AT-LEAST 1 victim)
      (AT-LEAST 1 site)
      (AT-MOST 1 site))))]
```

At the beginning of the example above indicating a concept definition, the roles (attributes) `perpetrator`, `victim` and `site` are defined with a global scope to the ontology. Following, a concept `CRIME` is defined as *primitive*. Everything that comes after the word “**PRIMITIVE**” is the set of role value restrictions (glued by the prefix operator **AND**) that constitutes the definition of the concept `CRIME`. The definition indicates the instances pertaining to the `CRIME` concept must have at least one value in the role `perpetrator`. All the values in the role `perpetrator` must be instances of the concept `PERSON`, and it must have exactly 1 value in the role `site`, taking into account that real crimes have at least one perpetrator, which is a person, a victim, and a unique site of occurrence. Since this is a *primitive* definition, the role value restrictions it has are necessary conditions, but not sufficient for membership.

To introduce axioms, `DOMESTIC-CRIME` can be considered as a crime perpetrated at the domicile of the perpetrator, i.e. the role `site` of the crime has to have the same value as the role `perpetrator` `domicile`.

```
define-concept [DOMESTIC-CRIME,
  (AND CRIME
   (AT-MOST 1 perpetrator)
   (SAME-AS (site)(perpetrator domicile))))]
```

An axiom can be created indicating that typical suspects of domestic crimes are always adults who have no jobs.

```
assert-rule [DOMESTIC-CRIME,
  (ALL typical-suspect
    (AND ADULT
      (AT-MOST 0 jobs)))]
```

Following is a set of possible queries to the ontology.

```
ask-necessary-set ? : DOMESTIC-CRIME
```

The query above will return all the instances of the DOMESTIC-CRIME concept.

```
ask-necessary-set (AND DOMESTIC-CRIME
  (ALL perpetrator ?:THING) )
```

The query above will return all the perpetrators of some domestic crime.

The query below will return all the persons that were inferred using the axiom above as being typical suspects for the instance crime 15.

```
ask-description
  [ (AND (ONEOF crime15)
    (ALL typical-suspect ?: PERSON))]
```

The set of declarations defining concepts and roles on a Description Logic language is called **TBox**, indicating *Terminological Box*, because it is the space where the terminology of the ontology is defined. Likewise, the set of assertions about individuals in terms of the TBox, is called **ABox**, by *Assertional Box*.

Description Logics allows the creation of new global properties at any moment in the life of an ontology. Such properties can be used to incrementally define a concept making the dynamic evolution of the ontology schema possible.

4.5.3 DAML+OIL

DAML+OIL arose from the convergence of efforts made in developing the previously existing Web ontology languages OIL (Fensel et al., 2001) and DAML (Hendler & McGuinness, 2000). These languages were envisaged with the prime goal of being more expressive than RDF Schema, while still based on the Web standards XML, RDF and RDF Schema. Additionally, DAML+OIL was taken as the starting point for the development of OWL, the language intended to be the standard for ontology representation and whose use could greatly contribute to the Semantic Web realization (www.w3.org/2001/sw/WebOnt/charter).

While built on RDF and RDF Schema, DAML+OIL addresses the lack of RDF Schema primitives to represent cardinality constraints, transitivity, inverse and uniqueness of property values, disjointness between classes, and intensional definitions, among others. DAML+OIL is also built on the namespaces mechanism of XML and the XML Schema data types.

DAML+OIL has a syntax based on RDF which enables the availability of DAML+OIL ontologies on the Web as RDF documents. Its primitives to declare classes and properties `daml:Class`, `daml:DatatypeProperty` and `daml:ObjectProperty` are specializations of primitives `rdfs:Class` and `rdfs:Property` of RDF Schema. Instances are declared by RDF Descriptions.

Class definitions

Classes can be defined in DAML+OIL by stating that they are sub-classes of other classes, by the enumeration of their individuals in an extensional definition, or by an intensional definition that gives the conditions that the individuals pertaining to the class must hold.

Property restrictions are used to define classes by intension. The next class definition is an example of using property restrictions in defining a class (Connolly et al., 2001b):

```
<daml:Class rdf:ID="Person">
  <rdfs:subClassOf rdf:resource="#Animal"/>
  <rdfs:subClassOf>
    <daml:Restriction>
      <daml:onProperty rdf:resource="#hasParent"/>
      <daml:toClass rdf:resource="#Person"/>
    </daml:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
    <daml:Restriction daml:cardinality="1">
      <daml:onProperty rdf:resource="#hasFather"/>
    </daml:Restriction>
  </rdfs:subClassOf>
</daml:Class>
```

This is a conjunction of assertions stating that the class `Person` is a sub-class of the class `Animal` and is also a sub-class of the anonymous class formed of all the objects that hold to be related to another person through the property `hasParent`, and also a sub-class of the other anonymous classes formed by all the objects that hold to have only one value in the property `hasFather`.

Class expressions are used in DAML+OIL in making class definitions. A *class expression* can be:

- a *class name* like RDF Schema class definitions;
- an *enumeration of instances*;
- a *property-restriction* (explained below),
- a *boolean combination of class expressions*, like the example above.

A **Class definition** denoting that class C is partially made up of a `daml:Class` element having zero or more of the following:

- **rdfs:subClassOf** elements containing *class-expressions*. Each `rdfs:subClassOf` asserts that class C currently being defined is a sub-class of *class-expression*.

- **daml:disjointWith** elements each containing a *class-expression*. Each *disjointWith* element asserts that C is disjoint with the *class-expression* in the element, ie. C must have no instances in common with it, for example (Connolly et al., 2001b):

```
<daml:Class rdf:ID="Female">
  <rdfs:subClassOf rdf:resource="#Animal"/>
  <daml:disjointWith rdf:resource="#Male"/>
</daml:Class>
```

- **daml:disjointUnionOf** elements each containing a list of *class-expression*. Each *disjointUnionOf* element asserts that C has the same instances as the disjoint union of the *class-expression* element, for example (Connolly et al., 2001b):

```
<daml:Class rdf:about="#Person">
  <rdfs:comment>every person is a man or a
  woman</rdfs:comment>
  <daml:disjointUnionOf rdf:parseType="daml:collection">
    <daml:Class rdf:about="#Man"/>
    <daml:Class rdf:about="#Woman"/>
  </daml:disjointUnionOf>
</daml:Class>
```

The example above also illustrates how the schema in DAML+OIL can evolve by adding new elements to a class definition. Remember the class `Person` was already defined at the beginning of the section.

- **daml:sameClassAs** elements containing a *class-expression*. A *sameClassAs* element asserts that C is equivalent to the *class-expression* in the element, ie. C and the *class-expression* must have the same instances, for example (Connolly et al., 2001b):

```
<daml:Class rdf:ID="HumanBeing">
  <daml:sameClassAs rdf:resource="#Person"/>
</daml:Class>
```

- **Boolean combinations of class expressions** like:
 - A list of *class-expressions* glued with a **daml:intersectionOf** element defining the class with the elements common to all those classes.
 - A list of *class-expressions* glued by a **daml:unionOf** element defining the class with all the elements in those classes.
 - A *class-expression* in a **daml:complementOf** element defining the class with all the elements that are not in that class.

- **Enumeration elements**.

Each enumeration element asserts that C contains exactly the instances enumerated in the element.

for example:

```
<daml:oneOf parseType="daml:collection">
  <daml:Thing rdf:about="#Eurasia"/>
  <daml:Thing rdf:about="#Africa"/>
  <daml:Thing rdf:about="#America"/>
```

```

<daml:Thing rdf:about="#Australia"/>
<daml:Thing rdf:about="#Antarctica"/>
</oneOf>

```

It is worth noting that the first two elements cited as forming a *class definition* denote necessary, but not sufficient conditions for class membership. The final four elements state both necessary and sufficient conditions.

DAML+OIL distinguishes *individual objects* as members of classes defined by their own specifications or by RDF Schema specifications, and *datatypes objects* as those defined in the XML Schema and used in DAML+OIL specifications.

Property restrictions

A *property restriction* is a kind of *class expression* defining the anonymous class containing the objects satisfying it.

Property restrictions are denoted by the element **daml:Restriction** containing the **daml:onProperty** sub-element and one of the following elements:

- A **daml:toClass** element containing a *class-expression* defines the class of objects x which holds that if the pair (x,y) is an instance of the restricted property, then y is an instance of the *class-expression* denoted in the **daml:toClass** element. The first example of the current section has an occurrence of the element **daml:toClass**.
- A **daml:hasValue** element containing a reference to an *individual object* or a *datatype* value defines the class of all objects for which the property P has at least one value equal to the named object or datatype value (and perhaps other values as well), for example:

```

<daml:Class rdf:ID="TallThing">
  <daml:sameClassAs>
    <daml:Restriction>
      <daml:onProperty rdf:resource="#hasHeight"/>
      <daml:hasValue rdf:resource="#tall"/>
    </daml:Restriction>
  </daml:sameClassAs>
</daml:Class>

```

The example states that the class `TallThing` is formed of the objects that have at least one occurrence of the property `hasHeight` with the concrete value defined in the ontology as `tall`.

- A **daml:hasClass** element containing a *class-expression* or a *datatype* reference defines the class of all objects for which at least one value of the property P is a member of the class expression or datatype, for example:

```

<daml:Class rdf:ID="Adult">
  <daml:intersectionOf rdf:parseType="daml:collection">
    <daml:Class rdf:about="#Person"/>
  </daml:intersectionOf>
</daml:Class>

```

```

<daml:Restriction>
  <daml:onProperty rdf:resource="#age"/>
  <daml:hasClass rdf:resource="#over17"/>
</daml:Restriction>
</daml:intersectionOf>
</daml:Class>

```

The example states that the class `Adult` is formed of the objects having at least one occurrence of the property `age` whose value is an element of the datatype reference `over17` defined as all the integers greater than 17 in another site of the ontology.

- A **daml:cardinality** element containing a non-negative integer N defining the class of all objects that have exactly N distinct values for the property P . The first example of the current section has an occurrence of the element `daml:cardinality`.

Additionally, other property restrictions are available, such as those intended to restrict the maximum or minimum cardinality of the set of values a property can have for a given concept.

Property definitions

DAML+OIL distinguishes *Object Properties* intended to relate objects to other objects, and *Datatype Properties* intended to relate objects to data type values. A property definition can have zero or more of the elements indicated below.

- **rdfs:subPropertyOf**, indicating a superproperty of the defined property.
- **rdfs:domain**, containing a *class-expression* restricting the domain of the property to instances of that *class-expression*. As in RDF Schema, if there is more than one rdfs:domain specification, the property can only be applied to instances pertaining to all specified domains.
- **rdfs:range**, containing a class expression restricting the range of the property to instances of that class expression. As in RDF Schema, if there is more than one rdfs:range specification, the property can only result in instances pertaining to all domains specified.
- **daml:samePropertyAs**, indicating a property equivalent to the named property, i.e., they must have the same instances.
- **daml:inverseOf**, containing a property inverse to the property in the definition.

In order to give more expressivity to the language, it is possible to characterize properties as *transitive*, *unique* and *unambiguous*.

P is a **transitive property** when it holds that if pair (x,y) is an instance of P , and pair (y,z) is an instance of P , then pair (x,z) is also an instance of P .

P is a **unique property** if it holds that P can have only one value y for each instance x , i.e: there cannot be two distinct instances y_1 and y_2 such that the pairs (x, y_1) and (x, y_2) are both instances of P .

P is an **unambiguous property** if it holds that an instance y can only be the value of P for a single instance x , i.e: there cannot be two distinct instances x_1 and x_2 such that both (x_1, y) and (x_2, y) are both instances of P .

4.6 Editing Support

At the moment this work was being developed, three editors were available to work with DAML+OIL: Ontoedit, developed at the University of Karlsruhe (<http://ontoserver.aifb.uni-karlsruhe.de/ontoedit>), Protégé, developed at the University of Stanford, (<http://www.smi.stanford.edu/projects/protege/>) and OilEd, developed at the University of Manchester, (<http://www.cs.man.ac.uk/~horrocks/software>).

As OilEd was specifically designed to generate OIL code, it supports most of the features of DAML+OIL. Then, was considered very suitable for the purpose of this work. OilEd provides a graphical interface that enables ontology elements definition by intension and extension in a friendly way. Figure 4.5 shows OilEd class definition panel.

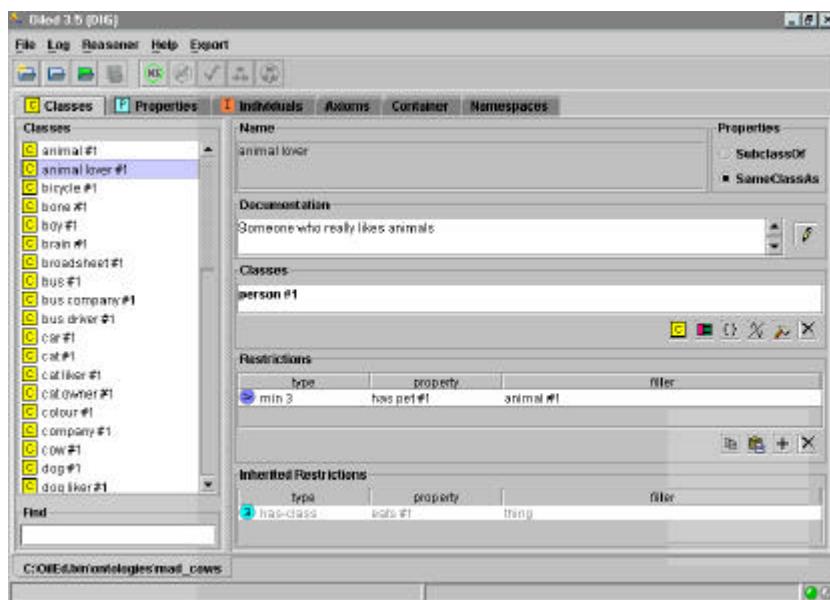


Figure 4.5: OilEd Definition Class Panel

4.7 Reasoning Support

Intelligent applications capable of deducing implicit consequences of its explicitly represented knowledge need reasoning services.

Ontologies must have their knowledge represented in a language with a defined formal semantics in order to provide reasoning services. That formal semantics

describes with precision the meaning of each of its possible representation primitives. Nevertheless, formal semantics and reasoning services can be obtained by mapping an ontology language to a logical formalism, such as Description Logics. Reasoning systems, such as FaCT (Horrocks, 1998) and RACER (Haarslev & Moller, 2003) can provide reasoning services to DAML+OIL ontologies by translating DAML+OIL primitives into pure Description Logics primitives.

Following is the list of basic computations that RACER (Haarslev & Moller, 2003) can carry out over the definitions of concepts and properties in the TBox of an ontology expressed in Description Logic.

- Concept consistency (satifiability) w.r.t. a TBox: Is the set of objects described by a concept empty?
- Concept subsumption w.r.t. a TBox: Is there a subset relationship between the set of objects described by two concepts?
- Find all inconsistent concepts mentioned in a TBox. Inconsistent concepts might be the result of modeling errors.
- Determine the parents and children of a concept w.r.t. a TBox: The parents of a concept are the most specific concept names mentioned in a TBox which subsume the concept. The children of a concept are the most general concept names mentioned in a TBox that the concept subsumes. Considering all concept names in a TBox the parent (or children) relation defines a graph structure which is often referred to as taxonomy.

If an ABox is also given with instances, among others, the following types of queries are possible:

- Check the consistency of an ABox w.r.t. a TBox: Are the restrictions given in an ABox w.r.t. a TBox too strong, i.e., do they contradict each other? Other queries are only possible w.r.t. consistent ABoxes.
- Instance testing w.r.t. an ABox and a TBox: Is the object for which an individual stands a member of the set of objects described by a certain query concept? The individual is then called an instance of the query concept.
- Instance retrieval w.r.t. an ABox and a TBox: Find all individuals from an ABox such that the objects they stand for can be proven to be a member of a set of objects described by a certain query concept.
- Computation of the direct types of an individual w.r.t. an ABox and a TBox: Find the most specific concept names from a TBox of which a given individual is an instance.
- Computation of the fillers of a role with reference to an individual.
- Check if certain concrete domains constraints are entailed by an ABox and a TBox.

There is a limit to the inference support that an ontology can have. As was explained earlier in (Levesque & Brachman, 1987), a tradeoff must be achieved between the desired expressiveness of the language, i.e., the capacity the language has to represent knowledge about different aspects of the reality being modeled, and the capacity to deal with this knowledge in order to reason with it. The more expressive power a language has, the less capacity it has to address sound reasoning services.

5 ADAPTWEB METADATA REPOSITORY

This chapter presents both the definition of a methodology to apply the Semantic Web technologies to achieve interoperability and improve adaptability in an educational adaptive hypermedia system, and the use of such a methodology in the AdaptWeb Project (Palazzo et all., 2003).

According to what was discussed in Chapter 2, an educational Hypermedia System envisaged to achieve adaptability needs to have not only the ***Hypermedia repository***, also called *Hyperspace*, containing the HTML and XML pages of educative content, but also a repository containing knowledge about the domain to be taught, i.e., the ***Knowledge Space*** composed of the description of each elementary subject that conforms the knowledge space to be covered by the educative content.

In order to keep the knowledge about the domain to be taught in the AdaptWeb Project, a taxonomy called ***Domain Ontology*** was designed and populated. But, what is considered the main contribution of the work described here is the conception and implementation of the ***Content Knowledge Ontology***, as a result of applying the Semantic Web technologies for adaptability and interoperability purposes. The Content Knowledge Ontology is a structure of knowledge concerning the actual pieces of educative content, capable of providing composition rules represented in a principled way to enable the configuration of complex learning objects tailored to the student's profile, setting the stage to implement a powerful adaptation mechanism. This knowledge structure is based on standard metadata to enable interoperability and is encoded in a formal Web ontology capable of supporting reasoning services. This application ontology is considered a part of the Knowledge Space of the Adaptive Hypermedia System AdaptWeb.

Similarly, according to what was discussed in Chapter 2, the system must have a ***Student Model*** representing the knowledge concerning the profile of each individual learner which will be used at run time to decide which goals and preferences must be covered by the educative content that the system provides to the learner. Such a student profile is also object to changes over time because of the student's activities. The student model was modelled and implemented as an application ontology.

In order to achieve interoperability on the semantic level that enables the reuse of learning objects across the Web, the definition and implementation of a new *application profile* (see section 3.3.2) of the standard LOM (IEEE Learning Technology Standards Committee, 2002) adequate for the educative context of the AdaptWeb project was made. Such an application profile was taken as the basis for the vocabulary of the implemented ontologies.

The steps of the proposed methodology to apply Web technologies to educative hypermedia systems in order to achieve interoperability and enhance adaptability are:

- 1) Conceptually model the educative content structure of the system and the student's profile. The models can be represented in semantic languages such as ER, UML or in an expressive ontology language such as DAML+OIL. The model must include the rules that govern the educative content composition to obtain complex learning objects tailored to the profile of each individual learner. These rules must be based on the adaptability requirements identified in the educative context.
- 2) Take a pre-existent application profile of the standard LOM suitable to the needs of the particular educative context, i.e., representing the metadata elements that are considered relevant to the application. If none is available holding such conditions, then, refine an existent one or create a new one.
- 3) Construct one ontology to represent the subjects of the domain to be taught (the Domain Ontology) in a simple taxonomy.
If the models created in step 1 are ontologies, then, base their vocabularies on the definitions made on the application profile used by using the XML namespaces mechanism. Otherwise, construct one ontology to represent the composition rules of the learning objects (the Content Knowledge Ontology), and another for the student's profile (The Student Ontology) based on the existent conceptual model and the application profile vocabulary.
- 4) Populate the Domain Ontology with the taxonomy of subjects of the domain to be taught. Populate the Content Knowledge Ontology with individuals containing metadata descriptions about the hypermedia repository content. Indicate how each individual of the hypermedia repository is related to subjects in the Domain Ontology. Enrich the ontologies content by edition when necessary. Refresh such ontologies each time new content is authored in the system.
- 5) Populate the Student Ontology with the knowledge about each student into the system. Refresh the Student Ontology with the results of the activities of the student in the system.
- 6) Create intelligent agents that are able to define the more suitable learning trajectory to each given student at run time based on the Domain, Content Knowledge and Student ontologies.

Steps 5 and 6 were considered out of the scope of this work.

This chapter is organized as follows. Section 5.1 situates the work into the context of the AdaptWeb project. Section 5.2 gives a general view of the steps taken and results obtained. Section 5.3 introduces the analysis made. Section 5.4 presents the design

resulting from the application of the presented methodology to the AdaptWeb educative context and Section 5.5 describes implementation features.

5.1 Work in Context

This work is part of the in-progress research project AdaptWeb presently in operation at the Federal University of Rio Grande do Sul. The AdaptWeb project is an adaptive Web-based learning hypermedia prototype whose purpose is to adapt the content, the presentation, and the navigation in an asynchronous educational environment according to each student's profile.

Much work has been done up to now on the AdaptWeb project. Following, the achievements related to the work currently being described are briefly explained.

Research was done to better characterize the learners' profile by identifying their *Cognitive Style of Learning* (CLS) (Souto et al., 2002) (Souto et al., 2002b). The Cognitive Style of Learning is an individual aspect that describes the way in which a person habitually approaches or responds to the learning task (Riding & Rayner, 2000).

The AdaptWeb hypermedia repository (*hyperspace*) was designed and implemented to store the structure of the educative content authored into the system context (Amaral, 2002). That implementation consists of a structured set of XML and HTML files containing the pages to be presented to the learners. There is a case study implemented concerning the discipline "Numerical Methods" that was also used in the work currently being described. More information about the Hypermedia Repository can be found in (Amaral, 2002).

An authoring tool was designed and implemented to facilitate the structured content creation, guiding the author to include different contents according to different learning goals (Freitas, 2002). The authoring process is composed of the following stages:

- Specification of the course purpose;
- Specification of the course contents outline;
- Specification of contents structure, components, and visualization; classification of contents as foundation topics, examples, additional examples, exercises and complementary material (pictures, movies, simulations, and links to additional information); Also, the complexity level of exercises and examples are stated as easy, medium, or complex.

The next section will present a general view of the work being described in this document.

5.2 General View

Figure 5.1 shows the general view of the steps taken in the development of this work. Circles indicate activities while rectangles indicate obtained results. Arrows indicate the input or output results of activities.

The results called *Hypermedia Repository*, *LOM Metadata Standard* and *Student Workflow Suggested as a Tutorial Path* are not consequences of this work. The white areas are not covered by this work, but are included for the purpose of clarity. Additionally, dotted elements represent results to be carried out at run time.

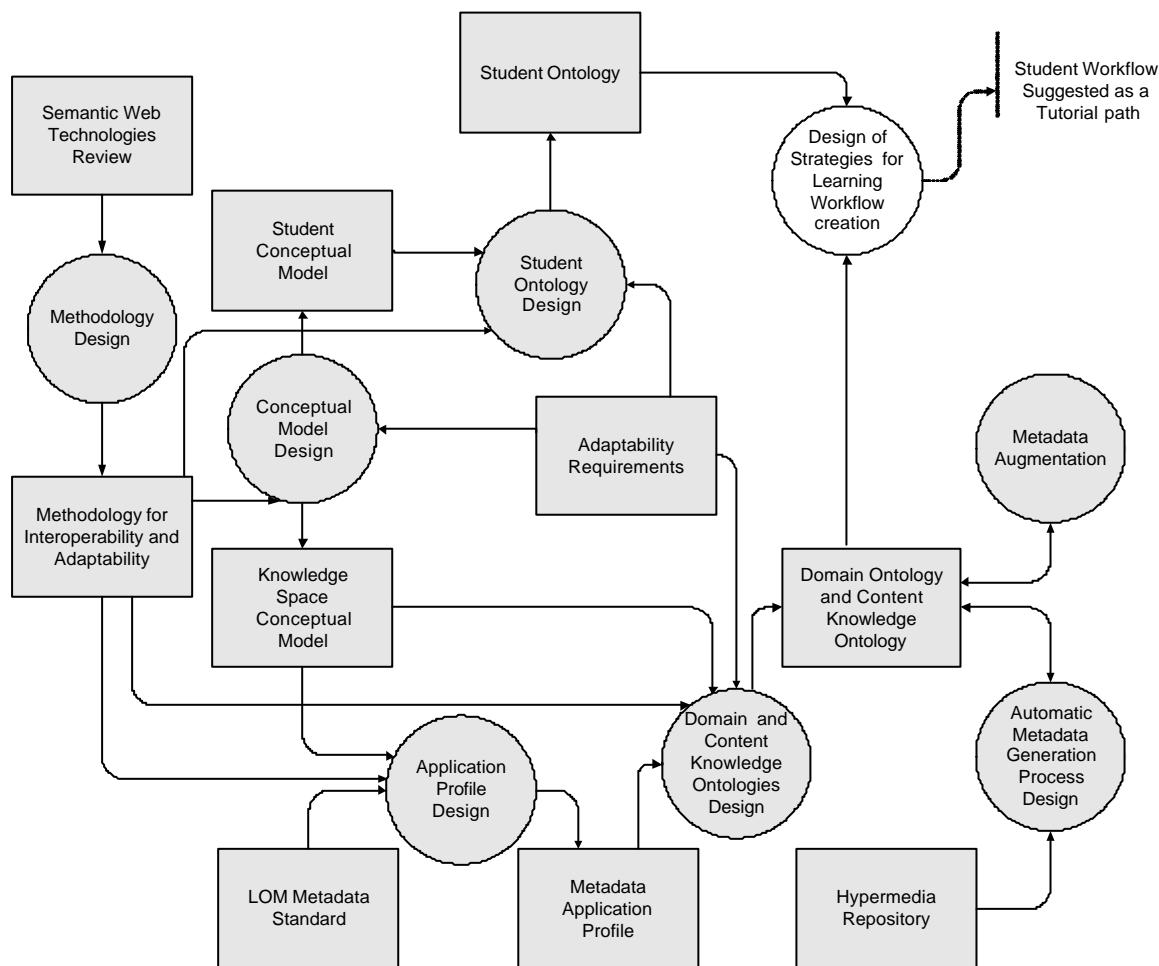


Figure 5.1: General View

Once the Semantic Web Technologies were studied and a methodology to apply them designed, the main *Adaptability Requirements* of the system in which the methodology

will be used, i.e. the AdaptWeb system, were identified in the analysis stage (see Section 5.3). On the basis of such requirements, a *Conceptual Model* containing both the *Student Model* and the *Knowledge Space Model* was designed. Based on the *Student Conceptual Model*, the *Student Ontology* was designed in order to maintain a machine understandable repository with the student's profile. Based on both the *Knowledge Space Conceptual Model* and the *LOM Metadata Standard Specification*, a *Metadata Application Profile* was designed intended to address the metadata needs for the educative context of the particular project. Based on the identified *Adaptability Requirements* and the vocabulary defined by the constructed *Metadata Application Profile*, the *Content Knowledge Ontology* was created to maintain the knowledge of each piece of the educative content of the system. Also, the *Domain Ontology* was created based on the defined application profile and the scope and structure of the domain to be taught. Lastly, the process that automatically generates metadata instances describing the hypermedia repository elements in terms of the Knowledge Space Model was implemented and a procedure to augment the system's metadata by edition was also proposed and used.

5.3 Analysis

The analysis consisted of the identification of the main adaptability requirements for the AdaptWeb project and the study of the implemented hypermedia repository containing the already existent educative material in the system.

5.3.1 Hypermedia Repository

The Hypermedia repository of the AdaptWeb project was already implemented at the beginning of this work and it was formed by a set of XML and HTML files following a hierarchical approach resembling the structure of a textbook with chapters and sections (Amaral, 2002). The existence of several relevant entities described below arises from its analysis.

The entity *Topic* refers to the minimal unit of educational self-explainable content. A Topic is the explanation of some idea. Topics are considered to be part of the learning content of a discipline. The explanation of a topic can come with some *examples*, *exercises* and *complementary material* supporting the topic study.

A topic may have sub-topics giving more detailed explanations of some of its parts. These topics are related to their sub-topics in a kind of XML document that maintains the hierarchical structure of each discipline in the system (validated by the DTD *Estrutura_Tópico* shown below). Such a document also indicates which topics are a prerequisite to other topics in the discipline context. Additionally, it contains an implicit path to traverse topics represented by the sequence and nesting of elements given by the XML document structure.

Figure 5.2 shows the hierarchical structure of topics of discipline *Computação Algébrica e Numérica* (Numerical Methods) which corresponds to the case study presented in (Amaral, 2002) that already populates the Hypermedia Repository at the beginning of the work currently being described.

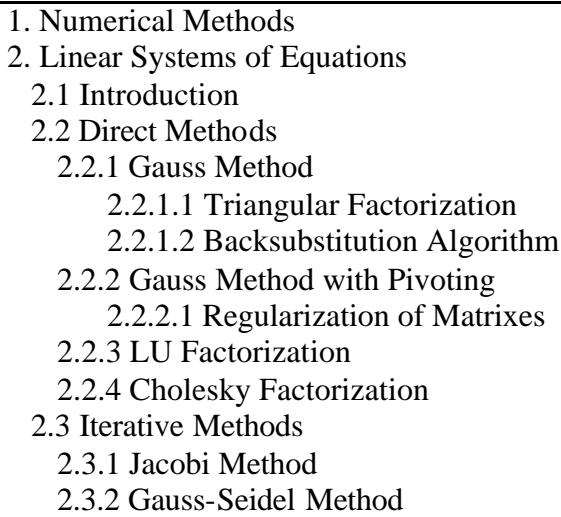


Figure 5.2 Hierarchical structure of topics. Adapted from (Amaral, 2002)

The *Prerequisite* relation among topics was identified as transitive, which means that a student must have taken all topics considered a prerequisite of the topic he or she intends to take. For example: if topic *A* is a prerequisite of topic *B*, and topic *B* is prerequisite of topic *C*, then topics *A* and *B* must be taken by all students who intend to take topic *C*. Also, the relation *isPartOf* was identified as transitive, meaning that the parts forming a topic *T* are also considered to be parts of any topic of which *T* is part of.

Following, the DTD called *Estrutura_Topo* intended to validate XML files containing the structure of a discipline is presented.

```

<!ELEMENT material (topico+)
<!ATTLIST material disciplina CDATA #REQUIRED>
<!ELEMENT topico (prereq*,curso+,topico*)>
<!ATTLIST topico numtop      CDATA #REQUIRED
           desctop     CDATA #REQUIRED
           abreviacao  CDATA #REQUIRED
           arquivoxml  CDATA #REQUIRED
           palchave    CDATA #REQUIRED>

<!ELEMENT prereq EMPTY>
<!ATTLIST prereq identprereq CDATA #REQUIRED>
<!ELEMENT curso (elementos*)>
<!ATTLIST curso identcurso CDATA #REQUIRED>
<!ELEMENT elementos (exemplo*, exercicio*, matcomp*)>
<!ELEMENT exemplo EMPTY>
<!ATTLIST exemplo possuiexemp CDATA #REQUIRED>
<!ELEMENT exercicio EMPTY>
<!ATTLIST exercicio possuiexec CDATA #REQUIRED>
<!ELEMENT matcomp EMPTY>
<!ATTLIST matcomp possuimatcomp CDATA #REQUIRED>
```

The educative material explaining a topic is related to the material supporting that explanation by a kind of XML document validated by the DTD *Elementos_Topo*, which is presented below.

```
<!ELEMENT textomaterial (conceito+,exercicio*,exemplo*,matcomp*)>
```

```

<!ATTLIST textomaterial disciplina CDATA #REQUIRED
           numtop CDATA #REQUIRED>
<!ELEMENT conceito (conteudo,curso+)>
<!ATTLIST conceito arquivo CDATA #REQUIRED>
<!ELEMENT exercicio (conteudo,curso+)>
<!ATTLIST exercicio idexerc CDATA #REQUIRED
           descexerc CDATA #REQUIRED
           arqexerc CDATA #REQUIRED
           compexerc CDATA #REQUIRED>
<!ELEMENT exemplo (conteudo,curso+)>
<!ATTLIST exemplo idexemp CDATA #REQUIRED
           descexemp CDATA #REQUIRED
           arqexemp CDATA #REQUIRED
           compexemp CDATA #REQUIRED>
<!ELEMENT matcomp (conteudo,curso+)>
<!ATTLIST matcomp idmatcomp CDATA #REQUIRED
           descmatcomp CDATA #REQUIRED
           arqmatcomp CDATA #REQUIRED>
<!ELEMENT conteudo (elementoconteudo*)>
<!ELEMENT elementoconteudo EMPTY>
<!ATTLIST elementoconteudo arqelem CDATA #IMPLIED
           ambitec CDATA #IMPLIED>
<!ELEMENT curso EMPTY>
<!ATTLIST curso identcurso CDATA #REQUIRED>

```

DTDs were used to extract useful information to understand the hypermedia repository structure. There is a case study on the hypermedia repository concerning the discipline “Computação Algebrica e Numerica” (Amaral, 2002).

5.3.2 Requirements Identification

Following is the list of the main requirements related to adaptability. It was constructed considering the main system behaviour patterns desirable to achieve adaptability. This is not an exhaustive list, but it contains issues that the system should be capable of achieving.

1. Select the most suitable set of learning objects related to the learning goals of a student, taking into account his or her Cognitive Style of Learning (CLS). For example, according to the CLS, once the basic exposition of a topic is given, some students could be interested in more detailed explanations, while others in challenging exercises.
2. Select the most adequate order to present a set of learning objects to a student based on both pre-existing learning trajectories defined at authoring time between learning objects and the student’s Cognitive Style of Learning. For example, the student’s CLS could indicate that he or she prefers some easy examples previous to the theoretical explanation of a topic.
3. Select the most suitable set of learning objects to be presented to a learner based on both the network connection speed that the learning objects need to be used correctly and the network connection speed the student is using in the current session. For example, a learning object composed only of text would be more adequate for a student who had declared a dial-up connection.
4. Adequate the educative content of disciplines to different audiences based on their general knowledge background and learning goals.

5. Dynamically recognize and take into account the student's knowledge on each part of the educative content being taught when selecting the next learning material to provide to him or her.
6. Guide the sequence of content generation by the rules that govern the composition of learning objects to form complex ones. Complex learning objects could be, for example, courses, while simple ones could be topics explanations or exercises. Such rules are given at authoring time for the creators of the educative content.
7. Enable the recommendation for the use of Web resources not authored into the AdaptWeb context, but considered valuable to support the learning of a given topic. Recommendations for Web resources can only be made by teachers authorized to do so.
8. Given a student with the intention to learn about a topic T , recognize what is the set S of prerequisite topics that the student must previously have taken. Such a set is recursively formed by the set P of prerequisites of the topic T , plus the prerequisites of topics in P , and so on.
9. Given a student who has taken a set S of topics, identify what topics the student is able to take considering the prerequisite relation. The obtained set must contain all topics that have a topic of S as its prerequisite, plus topics with no prerequisites.

5.4 Design

The design of the work described here was carried out in various stages. At the beginning, a conceptual model of the metadata needed for the AdaptWeb system, represented in the ER language (Chen, 1976) was created. Such a model is presented in Sections 5.4.1 and 5.4.2. After that, an application profile of the metadata standard LOM was designed for interoperability purposes which is presented in Section 5.4.3. Section 5.4.4 shows the design of ontologies to represent both the knowledge of the domain to be taught and the knowledge of the educative content in a machine understandable repository. Finally Section 5.4.5 presents the design of the ontology intended to represent the learners' profile.

5.4.1 Knowledge Space Model

The metadata concerning the Knowledge Space Model (see Section 2.1) is related to both what the application could need to know about each learning object at run time and what the people who creates the educative content would need to know in order to decide if some existent learning object could be reutilized by its inclusion in some new learning material.

It was found useful to maintain the features that describe each learning object, some characteristics that enable their correct use, and a detailed account of its relations with other parts of the educative content.

A conceptual model of the Knowledge Space Model was constructed. The language used was the Entity Relationship (ER) modeling language (Chen, 1976), and the notation was taken from (Batini, Ceri & Navathe, 1992). Such a model is shown at Figure 5.3.

To begin with, a general entity *LearningObject* was modeled to contain common metadata related to all learning objects in the system context. It is important to note that metadata is represented not only by attribute values, but also by the modeled structure.

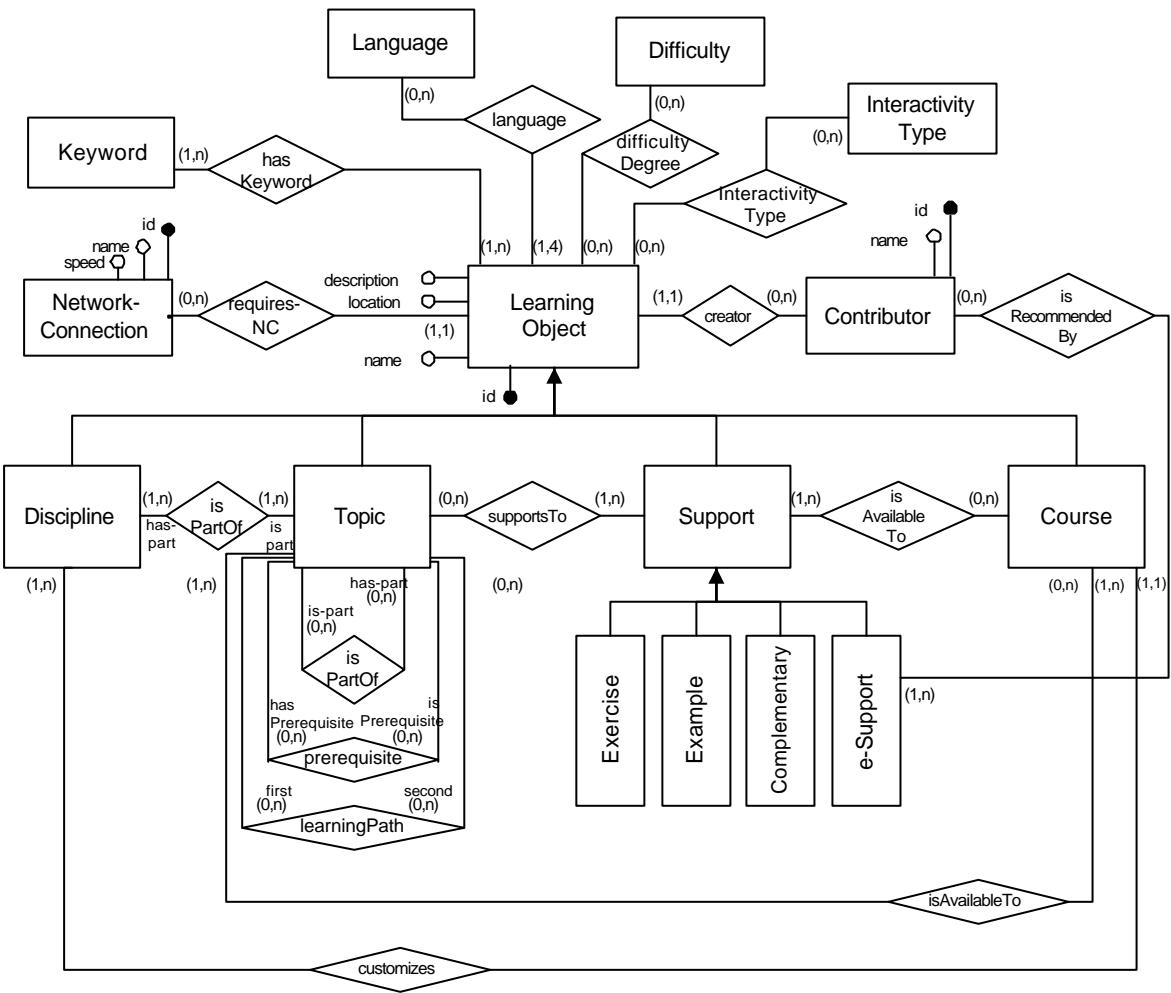


Figure 5.3: Knowledge Space Model

Entities *Discipline*, *Topic*, *Support* and *Course* were defined as specialized entities of *LearningObject*. A Topic is the concrete explanation of some concept or idea. The explanation of a topic can be supported by some examples, exercises and

complementary material, represented in entities *Example*, *Exercise*, *Complementary* and *e-Support*. Additionally, a topic may have sub-topics giving more specific explanations related to the prime topic by the *isPartOf* relation, i.e.,these are considered part of the explanation of the prime topic. The order of the topics to be presented to students according to learning purposes is given by the *learningPath* relation.

Relation *prerequisite* indicates the fact that a student must have taken all topics being a prerequisite of the topic he or she intends to currently take. The prerequisite relation was modeled with the roles *isPrerequisite* and *hasPrerequisite*. As described in 5.3.1 the *prerequisite* relation is transitive.

Relation *isPartOf* was modeled with the roles *isPart* and *hasPart*. Similarly, relation *learningPath*, indicating the natural order in which to take two learning objects is indicated by roles *first* and *second*. As described in 5.3.1 the *isPartOf* relation is transitive.

Entity *Course* represents disciplines customizations to be directed to specific groups of students with common background knowledge and learning goals. The learning content of a course is composed of the discipline topics that are considered adequate for the intended audience of the course, i.e.,the topics *available* for the course. Exercises, Examples and Complementary material supporting a Topic explanation may or may not be available for a course even if the topic they support is available. Then, a different set of Exercises, Examples and Complementary material is provided for different courses.

Entity *e-support* was envisaged to contain metadata concerning Web resources not authored into the system context, but considered adequate to complement the explanation of a given topic. Each element of e-support must be related to a registered contributor in entity *Contributor* by relation *isRecommendedBy* indicating that this contributor considers the resource adequate to support the explanation of some topic. This recommendation is highly subjective metadata, which was indicated as very valuable in (Duval, Hodgins, Sutton & Weibel 2002) (Duval & Hodgins, 2003).

5.4.2 Student Model

The student model is intended to keep those elements that characterize the student profile for adaptability purposes. Figure 5.4 shows the designed ER conceptual model of the student profile.

The student model consists of the central entity *Student* with attributes about the basic data of the student, plus relations that contribute to its characterization. First of all, attribute *wantsTutorial* was used to indicate if the student currently prefers to work in a tutored mode according to his hyperspace experience. The intention of a student to take a given course is considered a learning goal that is modeled by the existence of one instance of relation *hasLearningGoal* connecting the student with the course.

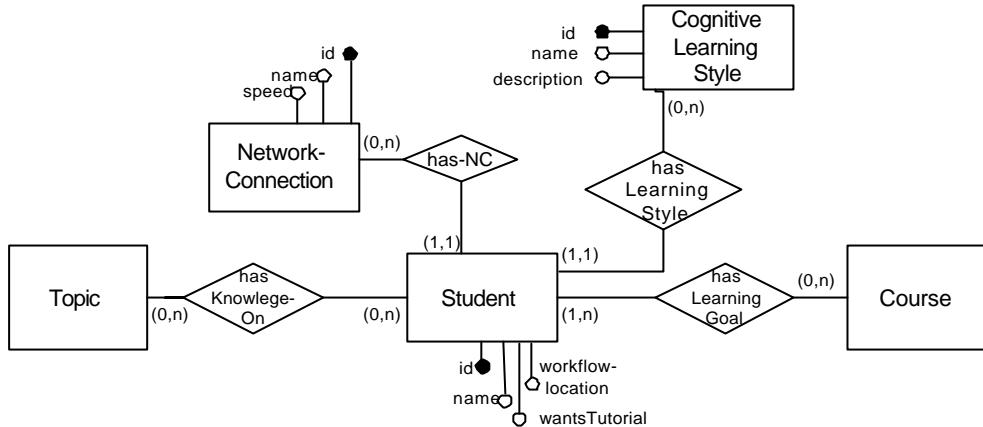


Figure 5.4: Student Model

The student's knowledge on each topic covered by the educative content is modeled by the relation *hasKnowledgeOn*, with an element of entity *Course*, so that if an instance of the relation *hasKnowledgeOn* exists relating the student to a *Topic*, then the system must believe the student has knowledge about this topic.

The kind of Network Connection the student has declared in the current session is modeled by the relation *hasNetworkConnection* between the student and one element of entity *NetworkConnection*.

The entity *CognitiveLearningStyle* is intended to contain the four CLS identified in (Souto et al., 2002), i.e., (i) Analogue-Analytical; (ii) Concrete-Generic; (iii) Deductive-Evaluative and (iv) Relational-Synthetic. According to his CLS, a student may prefer to visit the examples about a topic, try to do the exercises, and then go on to the page containing the explanation of the topic, while another student with a different CLS may prefer to read the explanation of the topic content first.

Finally, the attribute *workflowLocation* is intended to indicate the URL where the learning trajectory that the system has defined for the student is stored.

Figure 5.5 shows an integrated view of the conceptual model comprising the Student and Domain Models.

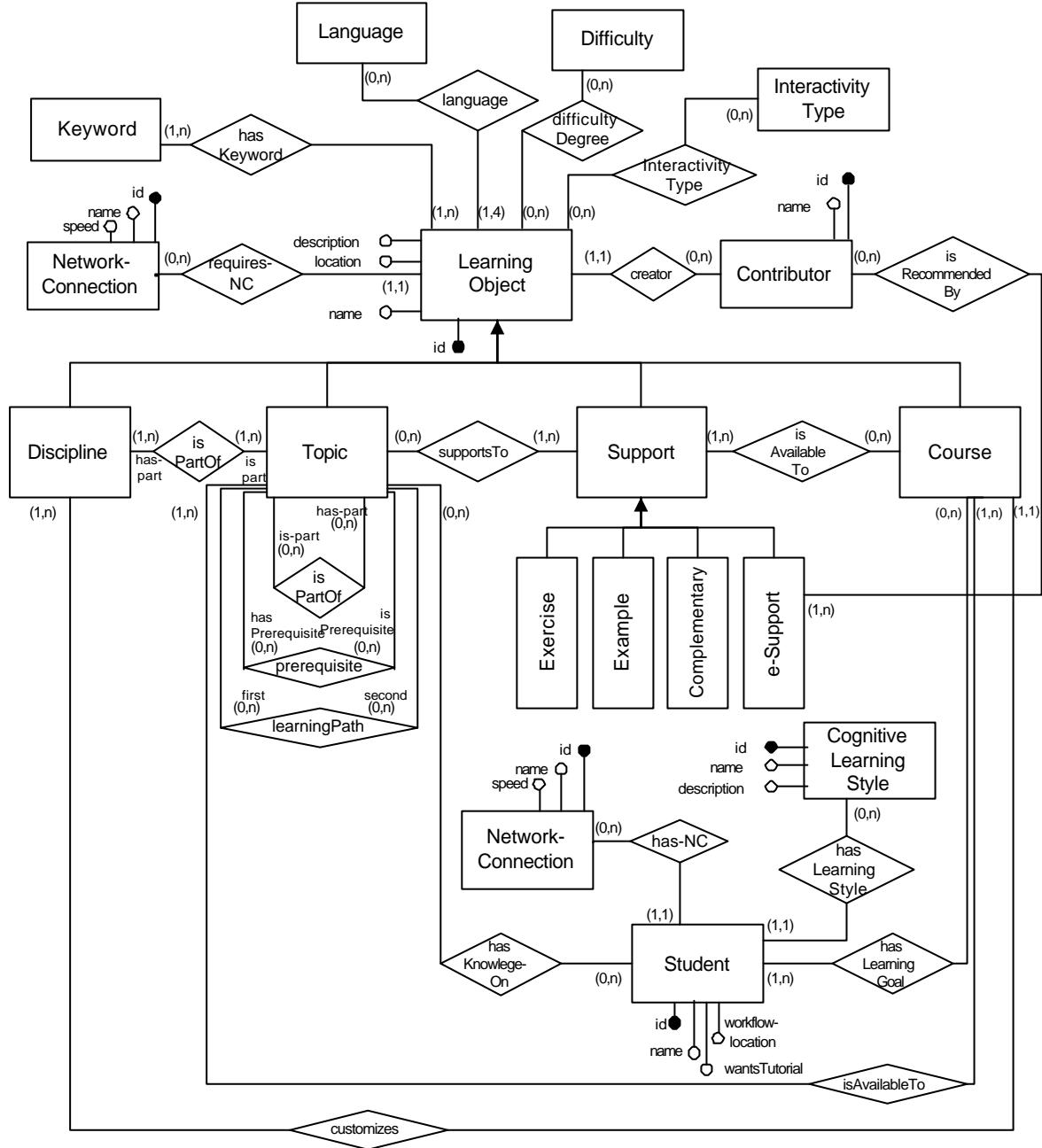


Figure 5.5: Integrated Conceptual Model

5.4.3 Application Profile Definition

An application profile of the Learning Object Metadata (LOM) (IEEE Learning Technology Standards Committee, 2002) was defined in order to have the AdaptWeb metadata represented in terms of the LOM standard while taking into account the particularities needed for the accomplishment of the application goals. To have metadata describing the learning objects of the AdaptWeb project in terms of the LOM standard enables reuse of the generated educative content across applications that agree with such a standard.

Since the LOM specification is conceptual, there are a number of implementations of LOM metadata in XML motivated by the current maturity of the support available for that language. Nevertheless, the use of RDF to represent LOM metadata provides a standard way to reuse standard vocabularies, making possible the realization of the “machine understanding” concept. Additionally, the RDF representation makes possible the incremental development of the application profile by the easy addition of new elements. Therefore, the use of RDF to represent LOM metadata was considered relevant to this work. The RDF binding presented in (Nilsson, 2001) was taken as the basis for the application profile definition.

In practice, application profiles have references to standard namespaces from which vocabulary elements were taken. Additionally, the namespaces where the RDF and RDF Schema definitions are located must be referenced in any application profile implemented using RDF. Table 5.1 shows the abbreviations that were used to indicate such namespaces when they were needed in this work. The namespaces containing the RDF binding definitions for LOM elements are enumerated in Chapter 3.

Table 5.1: Namespaces used in the AdaptWeb application profile

Schema	Namespace	Abbreviation
RDF	http://www.w3.org/1999/02/22-rdf-syntax-ns#	rdf
RDF Schema	http://www.w3.org/2000/01/rdf-schema#	rdfs
Dublin Core Elements	http://purl.org/dc/elements/1.1/#	Dc
Dublin Core Qualifiers	http://purl.org/dc/terms/#	dcterms
AdaptWeb Profile	http://www.inf.ufrgs.br/~tapejara/AWOntology.daml#	awo
Vcard	http://www.w3.org/2001/vcard-rdf/3.0#	vcard

The Application Profile definition implemented in this work was made in three stages:

- 1- Inclusion in the profile of those LOM properties suitable to represent elements of the conceptual model.
- 2- Definition of new properties to represent elements of the conceptual model not covered by any LOM element. These definitions were made by means of the refinement of existing LOM metadata standard properties given on the RDF binding definition (Nilsson, 2001) and taking into account features described in Chapter 3 about refinement mechanisms usable on the creation of application profiles.
- 3- Definition of value space restrictions over the properties values in order to allow only the use of the values that are suitable to the AdaptWeb context.

Table 5.2 shows the list of LOM properties that were found to be adequate to represent elements of the AdaptWeb domain model in the first stage of the profile definition. The list indicates the property whose semantics is defined on the LOM specification, the standard property or set of standard properties indicated by the RDF binding to use in the profile implementation, the property description given by the LOM standard, and the element on the AdaptWeb conceptual model which is represented by the LOM property.

Table 5.2: LOM properties used in the application profile

LOM Property	RDF Binding	Description	Conceptual Model Element
1.1- Identifier	lom-tech:location	A globally unique label that identifies this learning object	<i>location</i> attribute of <i>Learning Object</i> entity
1.1.1 Catalog	lom-gen:catalog	The cataloging scheme for the identifier. (Fixed value “URI”)	
1.3- Language	dc:language using dcterms: RFC1766	Language used to communicate to the intended user.	<i>language</i> relation
1.4- Description	dc:description	Description of the content of the Learning Object.	<i>description</i> attribute of <i>LearningObject</i> entity
1.5- keyword	dc:subject	A keyword describing a topic in the Learning Object.	<i>hasKeyword</i> relation
2.3- Contribute	dc:creator and lom:Entity using Vcard:FN	Entity (people, organization) that contributed to the state of the Learning Object.	<i>creator</i> relation and <i>name</i> attribute of <i>Contributor</i> entity
3.3- Metadata Schema	lom-meta: metadataScheme	The specification used to create the metadata instance. (Fixed value "LOMv1.0")	
4.4-Requirement	lom-tech: requirement	Technical capabilities necessary to use the Learning Object.	requires-NC relation
5.1- Interactivity Type	lom-edu: interactivityType	Predominant mode of learning of the Learning Object. Ex: expositive, interactive	<i>interactivityType</i> relation
5.2- Learning Resource Type	lom-edu: learningResource Type	Specific kind of Learning Object. Ex: Exercise, Example.	<i>learningType</i> attribute of <i>LearningObject</i> entity
5.8- Difficulty	lom-edu:difficulty	How hard it is to work with the Learning Object. Ex: Easy, Difficult.	<i>difficultyDegree</i> relation

Multivaluated attributes, such as attribute keyword or language of entity LearningObject, are represented in metadata descriptions by the repeated occurrence of the indicated properties in order to cover all the attribute values.

At the second stage, the local properties shown in Table 5.3 were defined as refinements of standard properties.

Table 5.3: Local properties defined in the application profile

Local Property	Standard Parent	Property Description	Conceptual Model Element
hasPrerequisite	dcterms: requires	Indicates a topic that must be taken previously to take the topic for which the property has been stated.	<i>prerequisite</i> relation
isPartOf	dcterms: ifPartOf	Indicates the whole of which the topic is part of.	<i>isPartOf</i> relation
isAvailableTo	dcterms:isPart Of	Indicates to which course a Topic or Support material is available.	<i>isAvailableTo</i> relation
customizes	dcterms: isVersionOf	Indicates a course being a customization of a Discipline to a certain general knowledge background profile.	<i>customizes</i> relation
supportsTo	dc:source	Indicates a Support educative material supports a Topic exposition.	<i>supportsTo</i> relation
defines	dc:subject	Indicates that the learning object defines a subject in the domain being taught.	
applies	dc:subject	Indicates that the learning object applies to a subject in the domain being taught.	
describes	dc:subject	Indicates that the learning object describes a subject in the domain being taught.	
introduces	dc:subject	Indicates that the learning object introduces a subject in the domain being taught.	
is Recommended By	lom-life: educational Validator	Indicates the person responsible for recommendations to use an external learning object.	<i>isRecommended By</i> relation
learningPath	dc:relation	Indicates the order in which the topics explaining an idea must be presented to the student according to the learning purposes.	<i>learningPath</i> relation

At the third stage, the set of possible values to certain properties was restricted. Table 5.4 shows the list of restricted properties. These restrictions facilitate interoperation by the use of controlled vocabularies. As an example, the values that can be used to indicate the creator of a piece of educative content, i.e., the values that can be used in the property *dc:creator* are the elements represented by the *Contributor* entity in the ER model.

Table 5.4: Value space restrictions on properties

Restricted Property	ER Model element representing the Value Set	Set Description
dc:creator	<i>Contributor</i> entity	Teachers authorized to create and recommend educative content in the system.
lom-tech: requirement	<i>Network Connection</i> entity	Possible network connections of importance for the educative environment AdaptWeb.
KEYWORD	<i>Keyword</i> entity	Set of keywords that indicate subjects treated in the learning object.
dc:language	<i>Language</i> entity	Only the languages represented in encoding RFC1766 that are currently enabled to AdaptWeb learning objects: Portuguese, Spanish and English.
lom-edu: interactivity Type	<i>InteractivityType</i> entity	Only elements of lom-edu:InteractivityType that are applicable to AdaptWeb learning objects.
lom-edu:difficulty	<i>Difficulty</i> entity	Only elements of lom-edu:Difficulty that are applicable to AdaptWeb learning objects.
supportsTo	<i>Topic</i> entity	Set of learning objects representing topics to be taught.

At this stage, a RDF document could contain all the specifications stated above representing the application profile for the AdaptWeb educative context. It could be implemented by the use of RDF Schema constructors to create the classes and properties representing the profile elements. Nevertheless, as the AdaptWeb metadata repository was implemented using formal ontologies, these definitions were embedded into the ontologies code.

5.4.4 Knowledge Space Ontologies Design

The Information Space of the AdaptWeb project is composed of both the ***Hypermedia Repository*** or ***Hyperspace*** and the ***Knowledge Space*** (See Section 2).

The Hypermedia Repository containing the educative content, which is populated using the authoring module of the system, is organized in a hierarchical structure of XML and HTM related documents (see Section 5.3.1) where more specific topics (sub-topics) contribute to the explanation of more general ones.

The implementation of such a Knowledge Space is a machine understandable, explicit metadata repository containing administrative, descriptive, technical and use metadata (Guilliland-Swetland, 2000) represented in terms of standard schemas anchored in the Web. This repository is populated automatically with metadata describing the educative content every times that new learning objects are stored into the Hypermedia Repository.

Two models were constructed to such a Knowledge Space: a model of the knowledge of the domain being taught and a model of the knowledge about the educative content. These models are The *Domain Ontology* and The *Content Knowledge Ontology* respectively (Figure 5.6).

The Domain Ontology organizes the subjects of the domain to be taught that are used in the educative content in a simple terminological domain ontology.

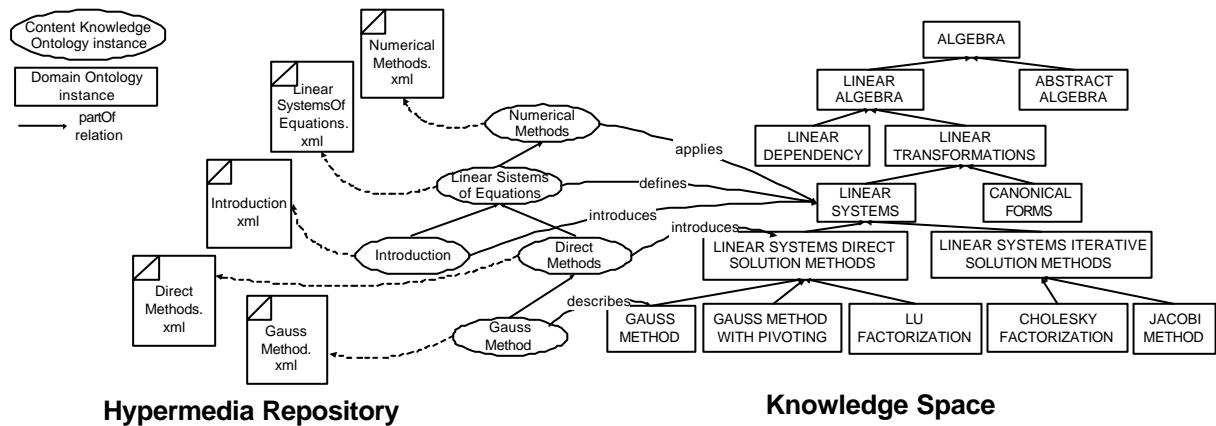


Figure 5.6: Instances in the AdaptWeb Information Space

The Content Knowledge Ontology is a formal application ontology that describes the actual pieces of instructional content that populates the Hyperspace given the rules to correctly assemble them (e.g. prerequisite rules defined as transitive properties) in order to automatically compute complex learning objects adequate for each student's profile. Qualified links relate the Content Knowledge Ontology elements to Domain Ontology ones indicating how each piece of the educative content approaches the subjects on the

Domain Ontology, e.g. *apply*, *define*, *introduces*, *describes*. These links can be used to search by keywords at learning time and also at authoring time to search for content about a certain subject to eventually reuse it.

Figure 5.6 partially shows the Information Space of the AdaptWeb system, including instances of the Hypermedia Repository, the Content Knowledge Ontology and the Domain Ontology. These instances are based on an implemented case study relative to the discipline Numerical Methods. While the hyperspace storage based in XML documents enables different presentation styles by XSLT transformations, the Content Knowledge Ontology enables personalization by selecting at run time the more adequate content for each individual learner by the use of ontology services, such as reasoning.

In order to be able to represent cardinality constraints, transitive condition of relations, and explicitly defined inverse relations, among others, it was decided to use the Web ontology language DAML+OIL (Horrocks, 2002) based on Description Logics to model and implement the knowledge of the domain to be taught.

Having the knowledge of the actual pieces of educational content represented in a formal ontology sets the stage for the use of reasoning services such as inference or consistency check over the metadata repository.

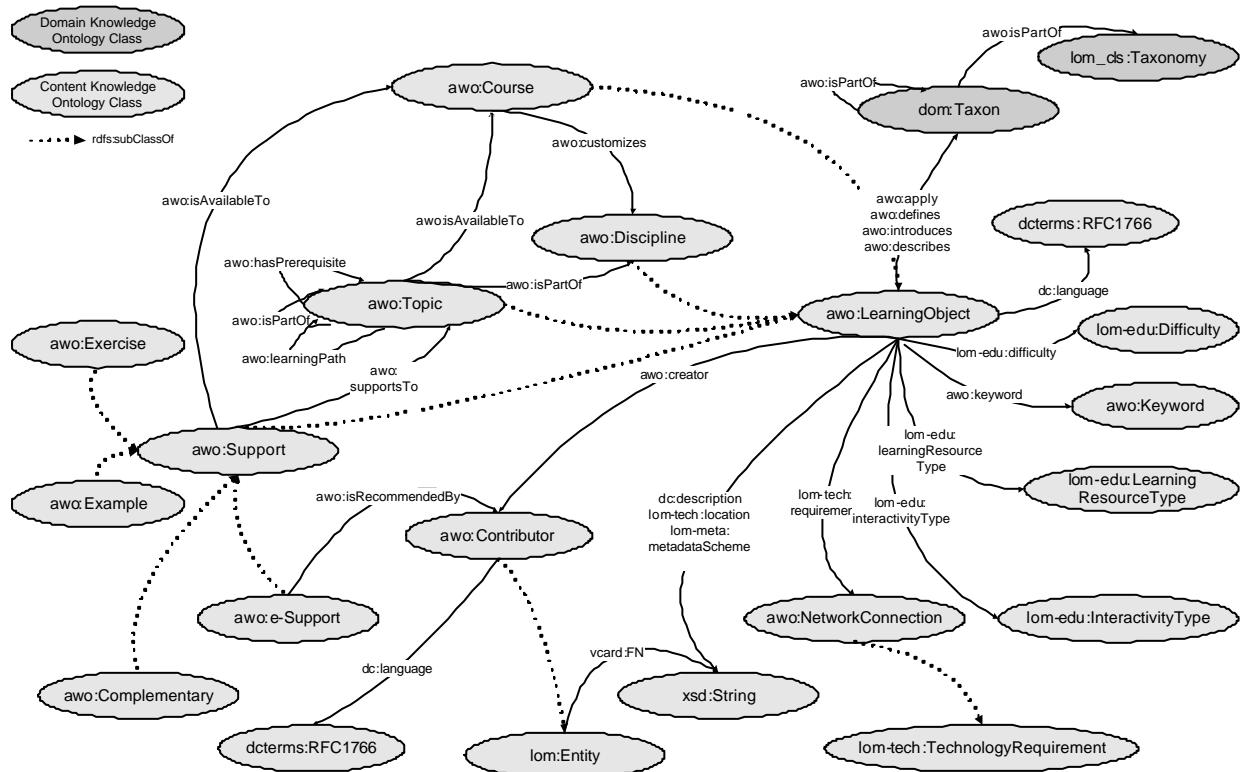


Figure 5.7: Classes and Relations of Domain and Content Knowledge Ontologies

The entities in the ER Model were modeled as classes in the ontologies and binary relations as *ObjectProperty* properties. One ontology class was defined for each entity in the ER model with the same name (except *language* entity which was represented in the Content Knowledge Ontology by class *RFC1766*). The Content Knowledge Ontology relations are those indicated in the profile definition plus their inverses. Specialization of entities in the ER model corresponds to *subclassOf* relation in a Description Logics ontology, with the corresponding monotonic inheritance of attributes. Oposite roles in relations between elements of the same entity were represented by inverse relations. Attributes were modeled as *DatatypeProperty* properties and cardinality constraints were added to class definitions.

A graphical representation of the resulting ontology is shown in Figure 5.7 in which ellipses indicate classes and directed arrows indicate ontology properties that point from the property subject to the property value, like properties on RDF graphs. The *subclassOf* property is indicated by dotted links without labels. Inverse properties are not shown for clarity.

The abbreviation *awo* stands for the namespace defined by the Content Knowledge Ontology, which is given in Appendix A, the abbreviation *dom* stands for the namespace defined by the Domain Ontology, which is given in Appendix B. The other abbreviations can be encountered in Tables 3.7 and 5.1.

Table 5.5 shows the correspondences between the ER model representation and the DAML+OIL (Horrocks, 2002) representation. This list only indicates the correspondences made in this work and is not intended to be an exhaustive account of the possible correspondences over the primitives of both languages.

Table 5.5: Correspondences between ER and DAML+OIL

ER element	DAML+OIL element
Entity	Class
Relation, eventually with specified roles	ObjectProperty relation eventually defining the inverse relation.
Attribute	DatatypeProperty
Specialization	SubClassOf
Cardinality restrictions on participation of entities in relations	Cardinality restrictions on properties values for classes

Table 5.6 shows features defined for local properties, such as range and domain restrictions and transitivity. An inverse property was defined for each relevant property that could be used to answer queries or for the workflow learning trajectory

configuration. Transitivity and inverse properties are used by reasoning systems such as FaCT (Horrocks, 1998) or RACER (Haarslev & Moller, 2003) to make inference.

Table 5.6: Features of Local Properties

Local Property	Domain	Range	Feature	Inverse
hasPrerequisite	Topic	Topic	Transitive	isPrerequisiteOf
isPartOf	Topic		Transitive	hasPart
isAvailableTo		Course		has Available
customizes	Course	Discipline	Functional	isCustomizedBy
supportsTo	Support	Topic		isSupportedBy
defines	Topic	Taxon		
apply	Topic	Taxon		
describes	Topic	Taxon		
introduces	Topic	Taxon		
isRecommendedBy	e-Support	Contributor		recommends
subject	LearningObject	Taxonomy		

Figure 5.8 shows the result of the application of the refinement mechanism to achieve tailorization without loss of compatibility in the profile implementation. Such a refinement implies that the semantics of local properties are specializations of the semantics of the standard properties from which local properties are a refinement. This fact enables the eventual interpretation of a local property with the semantics of the more general one if the definition of the local property is not understandable to some Web agent. Since the more general property is defined in a standard namespace, it is supposed that it will be recognized by any Web agent.

The top element of the Domain Ontology was declared as an element of class Taxonomy defined in <http://kmr.nada.kth.se/el/ims/schemas/lom-classification>. The Domain Ontology subjects are grouped into class *dom:Taxon*. All the properties used in the AdaptWeb metadata repository are those proposed by the RDF binding (Nilsson, 2001) or refinements of them.

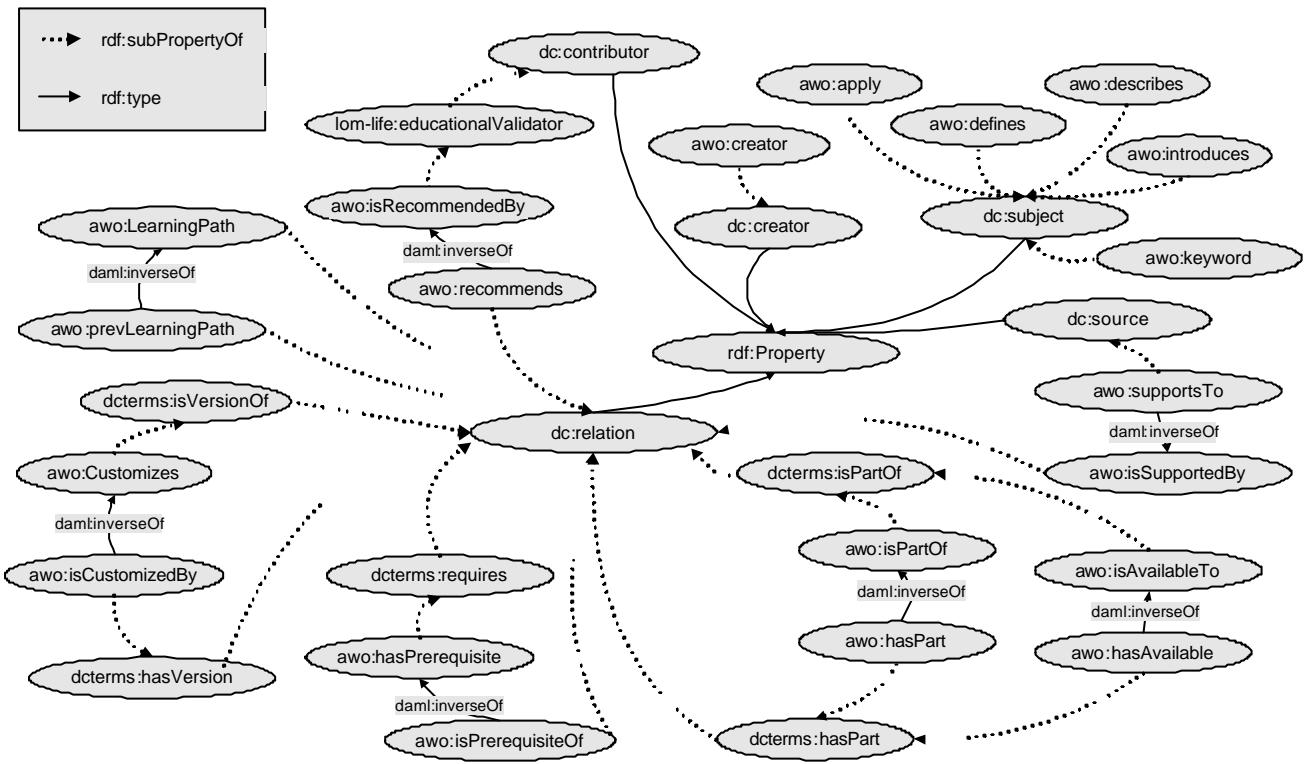


Figure 5.8: Refinement of properties to achieve compatibility and customization

Below, a piece of the Content Knowledge Ontology code defining the property *isPartOf* is presented. Here the declaration of the transitivity condition and the definition of property *hasPart* as its inverse can be seen.

```

<daml:ObjectProperty rdf:about="#isPartOf">
    <rdfs:comment xml:lang="en-US">Represents that the element is part of a whole. It can be a Topic being part of the educative material explaining a Discipline, or a Topic being part of the educative material explaining other Topic. </rdfs:comment>
    <rdfs:subPropertyOf
        rdf:resource="http://purl.org/dc/terms/#isPartOf"/>
        <rdfs:domain>
            <daml:Class rdf:about="#Topic"/>
        </rdfs:domain>
    </daml:ObjectProperty>
    <daml:TransitiveProperty rdf:about="#isPartOf"/>

    <daml:ObjectProperty rdf:about="#hasPart">
        <rdfs:comment xml:lang="en-US">Represents which topics form a discipline or other topic.</rdfs:comment>
        <rdfs:subPropertyOf rdf:resource="http://purl.org/dc/terms/#hasPart"/>

        <daml:inverseOf rdf:resource="#isPartOf"/>
    </daml:ObjectProperty>

```

Cardinality restrictions were also declared. Below is a piece of the ontology code with some cardinality restrictions in properties of *LearningObject* class, which means:

- Up to 4 languages can be indicated as the human languages in which the content of a learning object is expressed.
- Up to 10 keywords can be indicated concerning the content of the learning object.
- Only 1 value can represent the kind of connection that a learning object needs to be correctly presented to the learner, and this value must also pertain to class *NetworkConnection*.

```

<daml:Class rdf:about="#LObject">
  <rdfs:comment xml:lang="en-US">Learning objects used by the system with
  different levels of granularity, i.e., discipline, course, topic, support
  material, etc. This material is described by metadata compliant with the IEEE
  standard LOM.</rdfs:comment>
  <daml:intersectionOf rdf:parseType="daml:collection">
    <daml:Restriction>
      <daml:onProperty
        rdf:resource="http://purl.org/dc/elements/1.1/#language"/>
        <daml:maxCardinality>3</daml:maxCardinality>
    </daml:Restriction>
    <daml:Restriction>
      <daml:onProperty rdf:resource="#keyword"/>
      <daml:maxCardinality>10</daml:maxCardinality>
    </daml:Restriction>
    <daml:Restriction>
      <daml:onProperty
        rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
        technical#requirement"/>
        <daml:hasClassQ rdf:resource="#NetworkConnection"/>
        <daml:maxCardinalityQ>1</daml:maxCardinalityQ>
    </daml:Restriction>
  </daml:intersectionOf>
</daml:Class>
```

The OilEd editor (Bechhofer, 2001) was used to edit the ontologies described in this section at all stages of their design. Likewise, the reasoner RACER (Haarslev & Moller, 2003) was used to check their model satisfiability.

Up to now, only the steps taken to define the Domain and Content Knowledge ontologies models have been described. With regard to the population with instances of such ontologies, while instances of the Domain Ontology are intended to be populated by domain experts, section 5.5 will present the automatic population of the Content Knowledge Ontology.

5.4.5 Student Ontology Design

The ontology that models the student profile was obtained from the translation of the ER model elements into DAML+OIL (Horrocks, 2002) elements as was done with the Content Knowledge Ontology. Table 5.7 shows the correspondences used to create the ontology properties.

Figure 5.9 shows a graphical representation of the Student Ontology in which class *Student* grouping registered students, and class *CognitiveLearningStyle* grouping CLS presented in (Souto et al., 2002b) were defined. The remaining classes were defined in the Content Knowledge Ontology or in the XML Schema namespace indicated by the string “xsd”. The ontology code is provided in Appendix C – Student Ontology.

Table 5.7: Student Ontology Properties

Ontology Property	Domain	Range	Feature	ER Element
hasLearningStyle	Student	Cognitive LearningStyle	Functional	<i>hasLearningStyle</i> relation
hasLearningGoal	Student	awo:Course		<i>hasLearningGoal</i> relation
hasKnowledgeOn	Student	awo:Topic		<i>hasKnowledgeOn</i> relation
lom-tech:requirement	Student	awo:Network Connection	Functional	<i>has-NC</i> relation
locationLearning TrajectoryWF	Student	String		<i>WorkflowLocation</i> attribute of entity <i>Student</i>
wantsTutorial	Student	Boolean		<i>wantsTutorial</i> attribute of entity <i>Student</i>

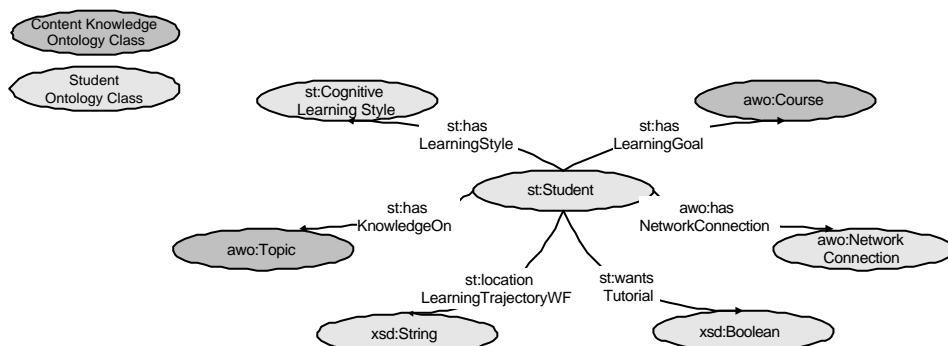


Figure 5.9: Student Ontology

5.5 Implementation

It can be considered that the implementation of the proposed solution was begun in the Design stage where the Domain Ontology, the Content Knowledge Ontology and the Student Ontology models were represented using the DAML+OIL language (Horrocks, 2002) using the editor OilEd (Bechhofer, 2001) and the reasoner RACER (Haarslev & Moller, 2003). Such representation produced XML documents containing DAML+OIL code.

The complete ontologies code is provided in Appendix A – Content Knowledge Ontology, Appendix B – Domain Ontology and Appendix C – Student Ontology.

The process by which the Content Knowledge Ontology is automatically populated with metadata instances describing the learning objects in the repository of hypermedia content (*the Hyperspace*), as well as how this ontology can be enriched by edition in order to register recommendations about educative content not authored into the system context will be presented here.

5.5.1 Automatic Metadata Generation

The information of the XML files of the Hypermedia Repository (see Section 5.3.1) was enriched and transformed into metadata that explicitly describe such a hypermedia repository in RDF statements by means of the Automatic Metadata Generation process. Such RDF statements are the instances of the Content Knowledge Ontology.

In order to achieve such a transformation, the semantics of the tags of XML elements was made explicit and the semantics that convey the hierarchical structure of elements in XML documents was inferred.

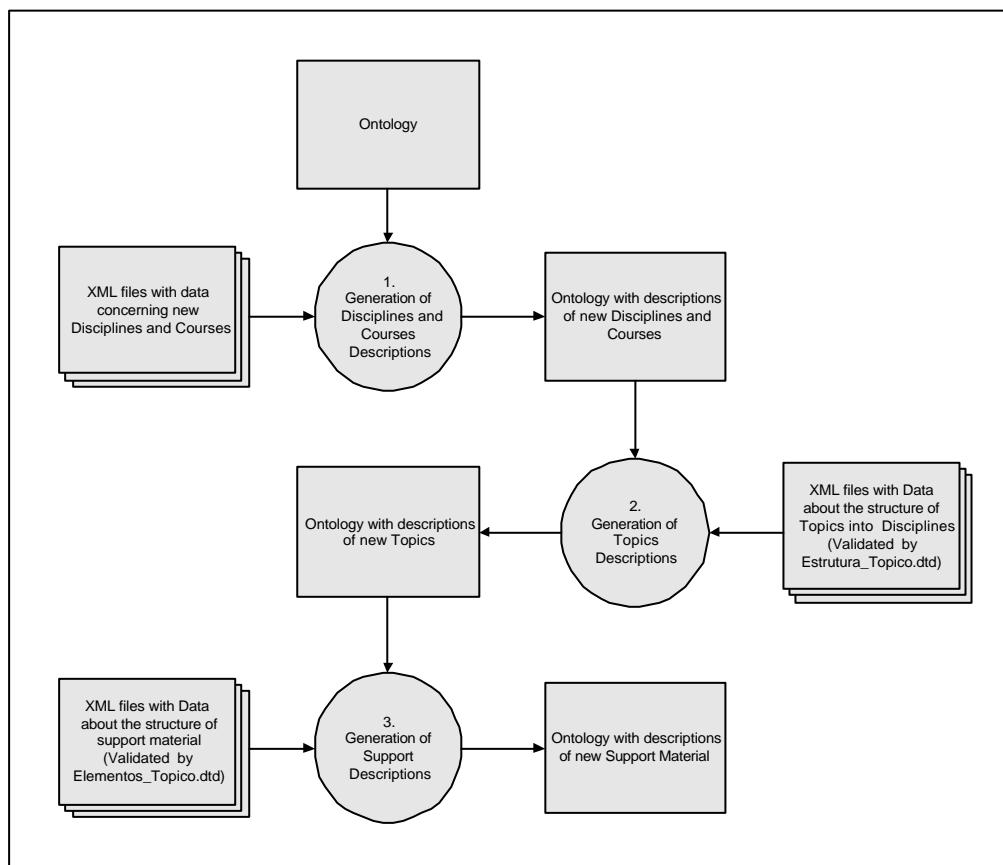


Figure 5.10: Automatic Metadata Generation Stages

Figure 5.10 sketches the automatic metadata generation process. The steps implied are shown below.

- 1) In the first step, data concerning new disciplines and courses, such as the name, description and indication of which course customizes which discipline is transformed into RDF statements describing new disciplines, new courses and the relations among them.
- 2) In the second step, each file containing the topics that are part of the structure of each discipline with indications of prerequisites was processed. The *learningPath* relation was inferred from the order between topic elements on the same level of the XML tree structure. The *isPartOf* relation was inferred from the nested position of topic elements of the same discipline in the XML tree structure. RDF statements were created to indicate instances of class *Topic* and the relations between topics and disciplines and courses. Also, relations between topics by *prerequisite*, *isPartOf* and *learningPath* relations were codified in this step.
- 3) In the third step, one RDF description was added for each support material, i.e. *Exercise*, *Example* or *Complementary*. Also, the necessary properties to relate the material to the topic that it supports were added. Additional properties were created to indicate the support material attributes, such as its complexity degree.

The described process, which is responsible for the metadata generation, was encoded using the language PHP, particularly the set of methods of the API DOM.

Below is the RDF code describing the Exercise “Exercício Introdutório 7-S7-T2.1-D1”. The complete ontology code is provided in Appendix A – Content Knowledge Ontology.

```

<rdf:Description rdf:about="#Exercicio Introdutório 7-S7-T2.1-D1">
  <rdf:type> <daml:Class rdf:about="#Exercise"/> </rdf:type>
  <lom-tech:requirement rdf:resource="#dial-up"/>
  <awo:supportsTo rdf:resource="#Introducao"/>
  <dc:description>
    <rdf:string rdf:value="Exercício Introdutório 7"/>
  </dc:description>
  <lom-meta:metadataScheme
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  metamodel#LOMv1.0"/>
  <lom-tech:location>
    <rdf:string rdf:value="Ex7Facil.html"/>
  </lom-tech:location>
  <lom-gen:catalog>
    <rdf:string rdf:value="URI"/>
  </lom-gen:catalog>
  <dc:creator rdf:resource="#Prof. Angélica"/>
  <lom-edu:learningResourceType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Exercise"/>
  <lom-edu:interactivityType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-educational#Active"/>
    <dc:language rdf:resource="#pt-BR"/>
    <lom-edu:difficulty
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-educational#Easy"/>
    <awo:isAvailableTo rdf:resource="# Matematicas"/>
    <awo:isAvailableTo rdf:resource="# Engenharia"/>
    <awo:isAvailableTo rdf:resource="# Computacao"/>
  </rdf:Description>
```

5.5.2 Metadata Augmentation

Relation *isRecommendedBy* sets the stage for the recommendation of educative content not authored into the system context.

The recommendation process is very simple. First of all, an element in class *e-Support* to contain all the information describing the Web resource being recommended must be created. The resource identification is given by its URL. Secondly, the person who recommends the material must be selected among the individuals of class *Contributor*. After that, the topic which the resource being described supports must be selected from the set of elements of class *awo:Topic*. Finally, the basic metadata describing the Web resource must be provided, such as a name, language, keywords, and a description of its content. The ontology makes use of the property *rdfs:comment* to enable all kind of explanations that could be useful to characterize the learning object content.

Following is a piece of the ontology code indicating the metadata corresponding to a recommended element of *e-Support*.

```

<rdf:Description rdf:about="#Método de Jacobi - UNIMONTES">
  <rdfs:comment><![CDATA[ ]]></rdfs:comment>
  <rdf:type>
    <daml:Class rdf:about="#e-Support"/>
  </rdf:type>
  <ns0:supportsTo rdf:resource="#Método de Jacobi"/>
  <ns3:location>
    <rdf:string rdf:value=
      "http://www.metododejacobi.hpg.ig.com.br/jacobi.htm"/>
  </ns3:location>
  <ns0:creator rdf:resource="#UNIMONTES"/>
  <ns4:difficulty rdf:resource=
    "http://kmr.nada.kth.se/el/ims/schemas/lom-educational#MediumDifficulty"/>
  <ns0:isRecommendedBy rdf:resource="#Lydia"/>
  <ns0:isAvailableTo rdf:resource="#Computacao"/>
</rdf:Description>
```

The environment for editing the ontology in the metadata augmentation stage is given by the editor OilEd presented in Chapter 4.

6 CONCLUSIONS AND FUTURE WORK

The work presented here consisted of the research done to determine the way technologies of the Semantic Web could be applied to better achieve adaptability on the behaviour patterns of a hypermedia system and to achieve interoperability on the e-learning domain.

The foundation of the Semantic Web is the explicit representation of background and meaning of Web resources in a way that enables both machine processing and machine understanding; this implies metadata describing such resources represented in a way that it conveys not only data, but also the semantics of the structures used to represent such data in order to enable interoperability at the semantic level.

The use of standards for metadata representation for the educative domain to describe the background and meaning of learning objects was found to be necessary to achieve semantic interoperability on the Web. The standard LOM (IEEE Learning Technology Standards Committee, 2002) widely accepted by the e-learning community was considered adequate to be used in this work.

Since the LOM specification is at the conceptual level, there are a number of implementations of LOM metadata in the XML language motivated by the current maturity of the support available for that language. On the other hand, there is a specification to represent LOM elements using RDF (Nilsson, 2001), that was considered relevant for the purpose of this work. Since RDF provides a standard way to reuse vocabularies defined in standard schemas such as Dublin Core, it makes the realization of the *machine understanding* concept possible. Additionally, the RDF representation facilitates the incremental development of the application profile by the easy addition of new elements.

A methodology to apply the Semantic Web technologies in order to achieve interoperability and improve adaptability in adaptive hypermedia systems was defined. The application of such a methodology to the AdaptWeb system motivated the definition of a new application profile of the metadata standard LOM that adapts the standard specification to the application educative context with no loss of compatibility.

A Description Logics based language envisaged to build ontologies on the Web was selected to represent the metadata structure about the educative content and the learner's profile in a way that enables inference services at modeling and query time.

The resulting scenario sets the stage for dynamic curricula generation adapted to student profiles. Such a generation could be made by intelligent agents that could take

the implemented ontologies as the source of its beliefs. Such tasks as the selection of the most adequate learning path could be solved with the aid of reasoning services as those provided by FaCT (Horrocks, 1998) or RACER (Haarslev & Moller, 2003) applied to the knowledge contained in the ontologies. Additionally, queries ad-hoc could be made to the ontology by the use of an appropriate tool, such as RICE (Cornet, 2003).

Following is a list of the main contributions of this work.

- A method to apply the technologies of the Semantic Web in order to give the basis to better achieve the adaptability and interoperability goals of a hypermedia system into the e-learning domain. The application of such a method for the AdaptWeb project motivates the other contributions enumerated below.
- The Entity Relationship (ER) model of the AdaptWeb metadata repository.
- The RDF based *Application Profile* of LOM for the AdaptWeb learning object metadata built in order to adapt the standard to the educative context of the application without loss of compatibility.
- The Content Knowledge Ontology, representing the semantic structure of the educative content of the system that sets the stage for the automatic configuration of complex learning objects based on more simple ones.
- The Domain Ontology, representing in a simple taxonomy the structure of the domain to be taught.
- A wrapper that automatically populates the Content Knowledge Ontology with RDF statements representing metadata about elements of the domain to be taught and links to their location on the hypermedia repository. The wrapper has embedded the criteria to recognize semantics behind the names of tags and XML structures of the educative content repository.
- A method to enrich the metadata concerning learning objects created into the system context, and also to recommend learning objects not authored into the system, but considered adequate to support the explanation of a given topic.
- The design and implementation of the Student Model as an application ontology that maintains the most relevant students' features for the purpose of adaptability.

Some of the work needed to implement the proposed method to improve the adaptability and to achieve interoperability on the AdaptWeb project was not considered in the scope of the work in description. Following is the list of future works that could be carried out.

- Use the reasoner services that a system like FaCT (Horrocks, 1998) or RACER (Haarslev & Moller, 2003) could provide to make inference and consistence

verification over the ontology individuals. Such reasoning could be available when the ontology is asked by using an API, or using an interactive interface such as RICE (Cornet, 2003) Reasoning services were used to check the model satisfiability at the ontology design time.

- Design and implement the intelligent agents that could create the more appropriate learning trajectory for a given student based on the knowledge represented on both the Content Knowledge Ontology and the Student Ontology.
- Adjust the application profile with the addition of new elements and the refinement of existent ones. Such incremental evolution on the profile definition can be made smoothly since it was implemented in RDF.
- Implement the Student Knowledge Ontology population with the information given by the auto assessment of the student at the beginning of each session. Continually update such information to represent the main features of the activities of the student in the system.

REFERENCES

- AMARAL, M. **Organização e Armazenamento de Conteúdo Instrucional no Ambiente AdaptWeb Utilizando XML**. 2002. Master's thesis (Mestrado em Ciência da Computação) - Instituto de Informática, UFRGS, Porto Alegre.
- ARTALE, A. et al. Part-whole relations in Object-centered Systems: an overview. **Data and Knowledge Engineering**, [S.l.], v. 20, n.3, p. 347-383, 1996.
- BAKER, T. et al. What Terms Does Your Metadata Use? Application Profiles as Machine-Understandable Narratives. **Journal of Digital Information**, [S.l.], v.2, n.2, 2001.
- BATINI, C.; CERI, S.; NAVATHE, S. **Database Design:** An entity-relationship Approach. Redwood City: Benjamin/Cummings, 1992. p.532
- BECHHOFER, S. **OilEd 3.5 Manual**. [S.l.]: Information Management Group, Departament of Computer Science, University of Manchester, 2001. Available at <<http://oiled.man.ac.uk>>. Visited on Feb. 2004.
- BECHHOFER, S.; VAN HARMELEN, F.; HENDLER, J.; HORROCKS, I.; MCGUINNESS, D.; PATEL-SCHNEIDER, P.; STEIN, L. **OWL Web Ontology Language Reference**. W3C Note 18 Aug. 2003. Available at <www.w3.org/TR/owl-ref>. Visited on Feb. 2004.
- BERNERS-LEE, T. **Semantic Web on XML**. Keynote presentation for XML 2000. Available at <<http://www.xml.com/pub/a/2000/12/xml2000/timbl.html>>. Visited on Feb. 2004.
- BERNERS-LEE, T. **Weaving the Web**. San Francisco: Harper, 1999. Available at <<http://www.harpercollins.com/hc/bookpage/index.asp?isbn=0062515861>>. Visited on Feb. 2004.
- BERNERS-LEE, T. **What the Semantic Web can Represent**. Sept. 1998. Available at <<http://www.w3.org/DesignIssues/RDFnote.html>>. Visited on Feb. 2004.
- BERNERS-LEE, T.; FIELDING, R.; MASINTER, L. **Uniform Resource Identifiers (URI): Generic Syntax** Internet Draft Standard RFC 2396. 1998. Available at <<http://www.isi.edu/in-notes/rfc2396.txt>> .Visited on Feb. 2004.

BERNERS-LEE, T.; HENDLER, J.; LASSILA, O. The Semantic Web. **Scientific American**, [S.I.], v.284, n.5, p.34-43, May 2001.

BORGIDA, A. et al. CLASSIC: a structural data model for objects. In: ACM SIGMOD INTERNATIONAL CONFERENCE ON MANAGEMENT OF DATA, 1989, Portland Oregon **Proceedings** ... [S.I.: s.n.], 1989. p. 59-67.

BORGIDA, A. et al. Description Logics in Data Management. **IEEE Transactions on Knowledge and Data Engineering**, New York, v.7, n.5, p. 671-682, Oct. 1995.

BRACHMAN, R.; SCHMOLZE, J. An Overview of the KL-ONE Knowledge Representation System. **Cognitive Science**, [S.I.], n.2, p. 171–216, 1985.

BRAY, T. et al. **Extensible Markup Language (XML) 1.0**. 2nd ed. W3C Recommendation 6 Oct. 2000. Available at <www.w3.org/XML>. Visited on Feb. 2004.

BRICKLEY, D.; GUHA, R.V. **Resource description framework (RDF) schema specification 1.0**. W3C Candidate Recommendation 27 March 2000, World Wide Web Consortium. Available at <www.w3.org/TR/rdf-schema>. Visited on Feb. 2004.

BRUSILOVSKY, P. Developing Adaptive Educational Hypermedia Systems: From Design Models to Authoring Tools. In: MURRAY, T.; BLESSING, S.; AINSWORTH, S. (Ed.). **Authoring Tools for Advanced Technology Learning**. [S.I.]: Ablex, 2002.

BRUSILOVSKY, P. Methods and Techniques of Adaptive Hypermedia. In: BRUSILOVSKY, P.; KOBSA, A.; VASSILEVA, J. (Ed.). **Adaptive Hypertext and Hypermedia**. Boston: Kluwer Academic, 1998. p. 1-43.

BRUSILOVSKY, P. Adaptive and Intelligent Technologies for Web-based Education. **Special Issue on Intelligent Systems and Teleteaching**, Kunstliche Intelligenz, v.13, n.4, p. 19-25, 1999.

Available at <citeseer.ist.psu.edu/article/brusilovsky99adaptive.html>. Visited on Feb. 2004.

CHEN, P. The Entity Relationship Model – Toward a Unified View of Data. **ACM Transactions on Database Systems**, [S.I.], v.1, n.1, p. 9-36, 1976.

CONNOLLY, D. et al. **DAML+OIL (March 2001) Reference Description** W3C Note 18 Dec. 2001. Available at <www.w3.org/TR/daml+oil-reference>. Visited on Feb. 2004.

CONNOLLY, D. et al. **Annotated DAML+OIL Ontology Markup**. W3C Note 18 Dec. 2001. Available at <www.w3.org/TR/2001/NOTE-daml+oil-walkthru-20011218>. Visited on Feb. 2004.

CORNET, R. **RICE (RACER interactive Client Environment Manual)**. Amsterdam: Department of Medical Informatics, University of Amsterdam, 2003. Technical Report. Available at <www.b1g-systems.com/ronald/rice/rice-manual.pdf>. Visited on Feb. 2004.

- DECKER, S. et al. Ontobroker: Ontology based access to distributed and semi-structured information. In: MEERSMAN, R. et al. (Ed.). **DS-8: Semantic Issues in Multimedia Systems.** [S.l.]: Kluwer Academic, 1999. p. 351-369. Available at <citeseer.ist.psu.edu/article/decker98ontobroker.html>. Visited on Feb.2004.
- DESMONTILS, E.; JACQUIN, C. Indexing a Web Site with a Terminology Oriented Ontology. In: INTERNATIONAL SEMANTIC WEB WORKING SYMPOSIUM, SWWS, 2001,Stanford, CA, USA. **Proceedings...** [S.l.: s.n.], 2001. p. 549-565.
- DEVAMBU, P. et al. LASSIE: A knowledge-based software information system. **Communications of the ACM**, New York , v. 34, n.5, p.35-49, 1991.
- DUBLIN CORE METADATA INITIATIVE. **Dublin Core Metadata Element Set, Version 1.1:** Reference Description. Available at <<http://purl.org/dc/documents/rec-dces-19990702.htm>>. Visited on Feb. 2004.
- DUVAL, E et al. Metadata Principles and Practicalities. **D-Lib Magazine**, [S.l.], v.8, n.4, Apr. 2002. Available at <<http://www.dlib.org/dlib/april02/weibel/04weibel.html>> Visited on Feb. 2004.
- DUVAL, E.; HODGINS, W. A LOM Research Agenda. In: INTERNATIONAL CONFERENCE WORD WIDE WEB, May 2003, Budapest, Hungary. **Proceedings...** Available at <<http://www2003.org/cdrom/papers/alternate/P659/p659-duval.html.html>>. Visited on Feb. 2004.
- ERDMANN, M.; STUDER, R. How to structure and access XML documents with ontologies. **Data and Knowledge Engineering (Special Issue on Intelligent Information Integration**, [S.l.], v.36, n.3, p. 317-335, 2001. Available at <<http://citeseer.nj.nec.com/erdmann00how.html>>. Visited on Feb. 2004.
- FALLSIDE, D. **XML-Schema Part 0:** Primer. W3C Working Draft, 7 April 2000. Available at <<http://www.w3.org/TR/2000/WD-xmleschema-0-20000407>>. Visited on Feb. 2004.
- FENSEL, D. et al. Oil: An Ontology infrastructure for the Semantic Web. **IEEE Intelligent Systems**, [S.l.], v.16, n.2, p.38-45, 2001.
- FERNÁNDEZ, M.; GÓMEZ-PÉREZ, A.; JURISTO, N. METHONTOLOGY: From Ontological Art Towards Ontological Engineering. In: WORKSHOP ON ONTOLOGICAL ENGINEERING, AAAI 1997, Stanford, USA. Available at <delicias.dia.fi.upm.es/miembros/ASUN/SSS97.ps>. Visited on Feb. 2004.
- FRANCONI, E. **Description Logics Course.** University of Manchester. Available at <<http://www.cs.man.ac.uk/~franconi/dl/course>>. Visited on Feb. 2004.
- FREITAS, V. **Autoria Adaptativa de Hipermídia Educacional.** Master's thesis (Mestrado em Ciência da Computação)- Instituto de Informática, UFRGS, Porto Alegre.
- GILLILAND-SWETLAND, A. Setting the Stage. In: BACA, M. (Ed.). **Introduction to Metadata: Pathways to Digital Information.** Los Angeles: Getty Research Institute,

2000. Available at <<http://www.getty.edu/research/institute/standards/intrometadata>>. Visited on Feb. 2004.

GILL, T. Metadata and the World Wide Web. In: BACA,M. (Ed.).**Introduction to Metadata**: Pathway to Digital Information. Los Angeles: Getty Research Institute, 2000. Available at <http://www.getty.edu/research/institute/standards/intrometadata/2_articles/gill/index.html>. Visited on Feb. 2004.

GRUBER, T. A translation approach to portable ontology specifications. **Knowledge Acquisition**, [S.l.], v.5, n.2, p.199–220, 1993.

GRUNINGER, M.; FOX, M. Methodology for the Design and Evaluation of Ontologies. In: INTERNATIONAL JOINT CONFERENCE ON ARTIFICIAL INTELLIGENCE,1995. **Proceedings...** [S.l.: s.n.],1995.

GUARINO, N.; BORGO, S.; MASOLO, C. Stratified ontologies: the case of physical objects. In: WORKSHOP ON ONTOLOGICAL ENGINEERING, ECAI, 1996, Budapest. **Proceedings...** [S.l.: s.n.], 1996. p. 5–15.

GUARINO, N. Formal Ontology and Information Systems. In: GUARINO, N. (Ed.). **Formal Ontology and Information Systems**. Amsterdam, Nederlands: IOS Press, 1998. p. 15.

HAARSLEV, V.; MOLLER, R. **RACER User's Guide and Reference Manual**. Version 1.7.7. 2003 Available at <<http://www.fh-wedel.de/~mo/racer/index.html>>. Visited on Feb. 2004.

HEERY, R.; PATEL, M. Application Profiles: Mixing and Matching Metadata Schemas. **ARIADNE Magazine**, [S.l.], n.25, Sept. 2000. Available at <<http://www.riadne.ac.uk/issue25/app-profiles/>>. Visited on Feb. 2004.

HENDLER, J.; MCGUINNESS, D. The DARPA Agent Markup Language. **IEEE Intelligent Systems Trends and Controversies**. Available at <http://www.ksl.stanford.edu/people/dlm/papers/ieee-dam101_abstract.html>. Visited on Feb. 2004.

HORROCKS, I. The FaCT system. In : TABEAUX, 1998. **Proceedings...** [S.l.: s.n.], 1998. p. 307-312.

HORROCKS, I. DAML+OIL: a Description Logic for the Semantic Web. **IEEE Data Engineering Bulletin**, [S.l.], v. 25, n.1, p. 4-9, 2002.

IEEE LEARNING TECHNOLOGY STANDARDS COMMITTEE. **IEEE 1484.12.1**: Draft Standard for Learning Object Metadata (LOM). 2001. Available at http://Itsc.ieee.org/wg12/s_p.html. Visited on Feb. 2004.

KIFER, M.; LAUSEN, G.; WU, J. Logical foundations of Object-Oriented and frame-based languages. **Journal of the ACM**, New York, v. 42, n. 4, p. 741-843, 1995.

LASSILA, O. Web Metadata: A Matter of Semantics. **IEEE Internet Computing**, [S.l.], v. 2, n. 4, p. 30-37, 1998.

LASSILA, O.; SWICK, R. **Resource description framework (RDF) model and syntax specification.** Technical report, W3C. W3C Recommendation. Available at <<http://www.w3.org/TR/REC-rdf-syntax>> .Visited on Feb. 2004.

LEVESQUE, H.; BRACHMAN, R. Expressiveness and tractability in knowledge representation and reasoning. **Computational Intelligence**, [S.I.], v.3, p. 78-93, 1987.

MANOLA, F.; MILLER, E. **RDF Primer.** W3C Working Draft 23, 2003. Available at <<http://www.w3.org/TR/rdf-primer>> . Visited on Feb. 2004.

McGUINNESS, D. Description Logics for Configuration. In: BAADER, F.; MCGUINNESS, D.; NARDI, D. ; PATEL-SCHNEIDER, P. (Ed.). **The Description Logic Handbook:** Theory, Implementation, and Applications. [S.I.]: Cambridge University Press, 2002. Available at <<http://www.ksl.stanford.edu/people/dlm/papers/dlhb-configuration.pdf>> . Visited on Feb. 2004.

McGUINNESS, D. Spinning the Semantic Web. In: FENSEL, D.; HENDLER, J.; LIEBERMAN, H.; WAHLSTER, W. (Ed.). **The Semantic Web:** Why, What, and How, [S.I.]: MIT Press, 2001. p. 171-194, 2003. Available at <<http://www.ksl.stanford.edu/people/dlm/papers/ontologies-come-of-age-abstract.html>> . Visited on Feb. 2004.

MENA, E. et al. OBSERVER: An Approach for Query Processing in Global Information Systems based on Interoperation across Pre-existing Ontologies. **International Journal on Distributed And Parallel Databases (DAPD)**, [S.I.], v. 8, n. 2, p.223-272, 2000.

MILLER, E. An Introduction to the Resource Description Framework. **D-Lib Magazine**, [S.I.], May 1998.

MINSKY, M. A Framework for Representing Knowledge. In: WINSTOW, P.H. (Ed.). **The Psychology of Computer Vision.** New York: McGraw-Hill, 1975.

NATIONAL LIBRARY OF MEDICINE. **MeSH – Tree Structures & Alphabetic List.** 12th ed. Bethesda, MA, USA: [s.n.], 2000.

NILSSON, M.; PALMER, M.; BRASE, J. **IEEE Learning Object Metadata RDF binding.** May 2001. Available at <<http://kmr.nada.kth.se/el/ims/metadata.html>> . Visited on Feb. 2004.

NILSSON, M. **The Semantic Web:** How RDF will change learning technology standards. CETIS, 2001. Available at <<http://www.cetis.ac.uk/content/20010927172953>> . Visited on Feb. 2004.

NILSSON, M. **Semantic issues with the LOM RDF binding.** [S.I.]: Centre for user oriented IT design/ Knowledge Management Research Group, 2003. Available at <<http://kmr.nada.kth.se/el/ims/md-lom-semantics.html>> . Visited on Feb. 2004.

NILSSON, M.; PALMER, M.; BRASE, J. The LOM RDF binding - principles and implementation. In: ANNUAL ARIADNE CONFERENCE, 3., 2003. **Proceedings...** [S.I.: s.n.], 2003.

- OLIVEIRA, J. P. M. de; SILVA MUÑOZ, L.; DE FREITAS, V.; MARÇAL, V.; GASPARINI, I.; ABRAHAO AMARAL, M. AdaptWeb: an Adaptive Web-based Courseware. In: ANNUAL ARIADNE CONFERENCE, 3., 2003. **Proceedings...** [S.l.: s.n.], 2003. de
- QUILLIAN, M. Word Concepts: A Theory and Simulation of some Basic Semantic Capabilities. **Behavioral Science**, [S.l.], n.12, p. 410-430, 1967.
- RIDING, R.; RAYNER, S. **Cognitive Style and Learning Strategies**. London: David Fulton Publishers, 2000.
- ROUSSEAU, F.; MACIAS,G; VALDENI, J. ; DUDA, A. User Adaptable Multimedia Presentations for the WWW. In: WWW 8 CONFERENCE, 1999, Toronto, Canada. **Proceedings...** [S.l.: s.n.], 1999.
- SOWA, J **Knowledge Representation**: Logical, Philosophical, and Computational Foundations. Pacific Grove, CA: Brooks Cole Publishing Co., 2000. Available at <<http://www.jfsowa.com/ontology/index.htm>>. Visited on Feb. 2004.
- SOUTO, M. et al. Web Adaptive Training System Based on Cognitive Student Style. In: IFIP WORLD COMPUTER CONGRESS, 2002, Montreal, Canada. **Proceedings...** [S.l.: s.n.], 2002. p. 25-30.
- SOUTO, M. et al. Towards an Adaptive Web Training Environment Based on Cognitive Style of Learning: an Empirical Approach. In: INTERNATIONAL CONFERENCE ON ADAPTIVE HYPERMEDIA AND ADAPTIVE WEB BASED SYSTEMS, 2., 2002, Malaga, Spain. **Proceedings...** [S.l.: s.n.], 2002.
- STUDER, R.; BENJAMINS,V.; FENSEL, D. Knowledge engineering, principles and methods. **Data and Knowledge Engineering**, [S.l.], v. 25, n. 1-2, p. 161–197, 1998.
- THE SCHEMAS PROJECT. 2000. Available at: <<http://www.schemas-forum.org/>>. Visited on Feb. 2004.
- USCHOLD. M.; KING. M. Towards a Methodology for Building Ontologies. WORKSHOP ON BASIC ONTOLOGICAL ISSUES IN KNOWLEDGE SHARING, 1995. **Proceedings...** [S.l.: s.n.], 1995.
- VAN HEIJST, G.; SCHREIBER, A.; WIELINGA, B. Using Explicit Ontologies in KBS Development. **International Journal of Human-Computer Studies**, [S.l.], v. 46, n.2/3, p. 183–292, 1997.
- VCARD SCHEMA. Available at <<http://www.w3.org/2001/vcard-rdf/3.0.>>. Visited on Feb. 2004.
- W3C CONSORTIUM. **Namespaces in XML**. Jan. 1999. Available at <<http://www.w3c.org/TR/REC-xml-names>>. Visited on Feb. 2004.

APPENDIX A CONTENT KNOWLEDGE ONTOLOGY

```

<?xml version="1.0" encoding="ISO-8859-1" ?>
- <rdf:RDF xmlns:daml="http://www.daml.org/2001/03/daml+oil#"
  xmlns:dc="http://purl.org/dc/elements/1.1/#"
  xmlns:dcterms="http://purl.org/dc/terms/#"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#" xmlns:lom-
  edu="http://kmr.nada.kth.se/el/ims/schemas/lom-educational#" xmlns:lom-
  tech="http://kmr.nada.kth.se/el/ims/schemas/lom-technical#" xmlns:lom-
  meta="http://kmr.nada.kth.se/el/ims/schemas/lom-metametadata#"
  xmlns:lom="http://kmr.nada.kth.se/el/ims/schemas/lom-base#" xmlns:lom-
  life="http://kmr.nada.kth.se/el/ims/schemas/lom-lifecycle#"
  xmlns:vcard="http://www.w3.org/2001/vcard-rdf/3.0#"
  xmlns:tax="http://www.inf.ufrgs.br/~tapejara/Ontology/Domain.daml#"
  xmlns:ns0="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.daml#"
  " xmlns:xsd="http://www.w3.org/2000/10/XMLSchema#">
- <daml:Ontology rdf:about="">
  <dc:title>AdaptWeb Ontology</dc:title>
  <dc:date>November of 2003</dc:date>
  <dc:creator>Lydia Silva Muñoz, José Palazzo Moreira de
    Oliveira.</dc:creator>
  <dc:description>Metadata repository implementing an application
    profile of the standard LOM of the IEEE.</dc:description>
  <dc:subject>Metadata for Educational Content</dc:subject>
  <daml:versionInfo>2.0</daml:versionInfo>
</daml:Ontology>
- <daml:ObjectProperty rdf:about="http://purl.org/dc/terms/#isPartOf">
  <rdfs:comment xml:lang="en-US" />
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="http://purl.org/dc/elements/1.1/#creator">
  <rdfs:comment xml:lang="en-US" />
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="http://purl.org/dc/terms/#hasPart">
  <rdfs:comment xml:lang="en-US" />
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="http://purl.org/dc/terms/#requires">
  <rdfs:comment xml:lang="en-US" />
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="http://purl.org/dc/terms/#relation">
  <rdfs:comment xml:lang="en-US" />
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="http://purl.org/dc/terms/#isVersionOf">
  <rdfs:comment xml:lang="en-US" />
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="http://purl.org/dc/terms/#hasVersion">
  <rdfs:comment xml:lang="en-US" />
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
  lifecycle#educationalValidator">
  <rdfs:comment xml:lang="en-US" />
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="http://purl.org/dc/elements/1.1/#source">
  <rdfs:comment xml:lang="en-US" />
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="#customizes">
  <rdfs:comment xml:lang="en-US">Represents the customization of a
    discipline for a specific kind of general background knowledge that
    the students intended to be the audience have. The result of this
    customization is called Course.</rdfs:comment>

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<rdfs:subPropertyOf
  rdf:resource="http://purl.org/dc/terms/#isVersionOf" />
- <rdfs:domain>
  <daml:Class rdf:about="#Course" />
</rdfs:domain>
- <rdfs:range>
  <daml:Class rdf:about="#Discipline" />
</rdfs:range>
</daml:ObjectProperty>
<daml:UniqueProperty rdf:about="#customizes" />
- <daml:ObjectProperty rdf:about="#isCustomizedBy">
  <rdfs:comment xml:lang="en-US"><./rdfs:comment>
  <rdfs:subPropertyOf
    rdf:resource="http://purl.org/dc/terms/#hasVersion" />
    <daml:inverseOf rdf:resource="#customizes" />
  </daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="#isPartOf">
  <rdfs:comment xml:lang="en-US">Represents that the element is part of
    a whole. It can be a Topic being part of the educative material
    explaining a Discipline, or a Topic being part of the educative
    material explaining another Topic.</rdfs:comment>
  <rdfs:subPropertyOf rdf:resource="http://purl.org/dc/terms/#isPartOf" />
- <rdfs:domain>
  <daml:Class rdf:about="#Topic" />
</rdfs:domain>
</daml:ObjectProperty>
<daml:TransitiveProperty rdf:about="#isPartOf" />
- <daml:ObjectProperty rdf:about="#hasPart">
  <rdfs:comment xml:lang="en-US">Represents which topics form a
    discipline or other topic.</rdfs:comment>
  <rdfs:subPropertyOf rdf:resource="http://purl.org/dc/terms/#hasPart" />
  <daml:inverseOf rdf:resource="#isPartOf" />
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="#isAvailableTo">
  <rdfs:comment xml:lang="en-US">Stands for the availability of a Topic
    for the indicated Course or for the availability of support
    material for the indicated Course.</rdfs:comment>
  <rdfs:subPropertyOf rdf:resource="http://purl.org/dc/terms/#isPartOf" />
- <rdfs:domain>
  <daml:Class rdf:about="#LObject" />
</rdfs:domain>
- <rdfs:range>
  <daml:Class rdf:about="#Course" />
</rdfs:range>
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="#hasAvailable" />
  <rdfs:comment xml:lang="en-US">Represents which educative content the
    course has available.</rdfs:comment>
  <rdfs:subPropertyOf rdf:resource="http://purl.org/dc/terms/#hasPart" />
  <daml:inverseOf rdf:resource="#isAvailableTo" />
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="#isPrerequisiteOf">
  <rdfs:comment xml:lang="en-US">Indicates the topics having the current
    one as their prerequisite.</rdfs:comment>
  <rdfs:subPropertyOf rdf:resource="http://purl.org/dc/terms/#relation" />
  <daml:inverseOf rdf:resource="#hasPrerequisite" />
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="#hasPrerequisite" />
  <rdfs:comment xml:lang="en-US">Means that the topic indicated as
    prerequisite must be taken previously to take the topic for which
    the property has been stated.</rdfs:comment>
  <rdfs:subPropertyOf rdf:resource="http://purl.org/dc/terms/#requires" />
- <rdfs:domain>
  <daml:Class rdf:about="#Topic" />
</rdfs:domain>
- <rdfs:range>
  <daml:Class rdf:about="#Topic" />
</rdfs:range>
</daml:ObjectProperty>
<daml:TransitiveProperty rdf:about="#hasPrerequisite" />
- <daml:ObjectProperty rdf:about="#learningPath" />

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<rdfs:comment xml:lang="en-US">The order of the topics that explain a
common idea must be presented to the student according to learning
purposes.</rdfs:comment>
<rdfs:subPropertyOf rdf:resource="http://purl.org/dc/terms/#relation"
/>
- <rdfs:domain>
  <daml:Class rdf:about="#Topic" />
</rdfs:domain>
- <rdfs:range>
  <daml:Class rdf:about="#Topic" />
</rdfs:range>
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="#prevLearningPath">
  <rdfs:comment xml:lang="en-US">Indicates the previous topic in a
learning path.</rdfs:comment>
<rdfs:subPropertyOf rdf:resource="http://purl.org/dc/terms/#relation"
/>
  <daml:inverseOf rdf:resource="#learningPath" />
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="#supportsTo">
  <rdfs:comment xml:lang="en-US">Indicates that the learning object
supports the theoretical explanation of the topic which is the
value of the property.</rdfs:comment>
<rdfs:subPropertyOf
  rdf:resource="http://purl.org/dc/elements/1.1/#source" />
- <rdfs:domain>
  <daml:Class rdf:about="#Support" />
</rdfs:domain>
- <rdfs:range>
  <daml:Class rdf:about="#Topic" />
</rdfs:range>
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="#isSupportedBy">
  <rdfs:comment xml:lang="en-US">Indicates learning content supporting
the topic explanation.</rdfs:comment>
<rdfs:subPropertyOf rdf:resource="http://purl.org/dc/terms/#relation"
/>
  <daml:inverseOf rdf:resource="#supportsTo" />
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="#isRecommendedBy">
  <rdfs:comment xml:lang="en-US">Indicates the name of the person
responsible for recommending a resource located in an Internet
address to support the explanation of a given Topic.</rdfs:comment>
<rdfs:subPropertyOf
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  lifecycle#educationalValidator" />
- <rdfs:domain>
  <daml:Class rdf:about="#e-Support" />
</rdfs:domain>
- <rdfs:range>
  <daml:Class rdf:about="#Contributor" />
</rdfs:range>
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="#Recommends">
  <rdfs:comment xml:lang="en-US">Indicates learning content recommended
by the teacher.</rdfs:comment>
<rdfs:subPropertyOf rdf:resource="http://purl.org/dc/terms/#relation"
/>
  <daml:inverseOf rdf:resource="#isRecommendedBy" />
</daml:ObjectProperty>
- <daml:Class rdf:about="#Contributor">
  <rdfs:comment xml:lang="en-US">Person that recommends Learning Objects
created by another person who also creates Learning Objects, if the
last is the case, the Contributor appears also as the value of the
property "creator" for each authored Learning
Object.</rdfs:comment>
<rdfs:subClassOf
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  base#Entity" />
</daml:Class>
- <daml:Class rdf:about="#Keyword">
  <rdfs:comment xml:lang="en-US">Word used to indicate a subject in a
Learning Object.</rdfs:comment>
</daml:Class>
- <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
  base#Entity">

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<rdfs:comment xml:lang="en-US">Instances of this class are persons or
organizations, described by VCards.</rdfs:comment>
</daml:Class>
- <daml:Class rdf:about="#LObject">
  <rdfs:comment xml:lang="en-US">Learning objects used by the system
  with different levels of granularity, i.e. discipline, course,
  topic, support material, etc. This material is described by
  metadata compliant with the IEEE standard LOM.</rdfs:comment>
- <daml:intersectionOf rdf:parseType="daml:collection">
  - <daml:Restriction>
    <daml:onProperty
      rdf:resource="http://purl.org/dc/elements/1.1/#language"
    />
    <daml:maxCardinality>3</daml:maxCardinality>
  </daml:Restriction>
  - <daml:Restriction>
    <daml:onProperty rdf:resource="#subject" />
    <daml:maxCardinality>1</daml:maxCardinality>
  </daml:Restriction>
  - <daml:Restriction>
    <daml:onProperty rdf:resource="#keyword" />
    <daml:maxCardinality>10</daml:maxCardinality>
  </daml:Restriction>
  - <daml:Restriction>
    <daml:onProperty
      rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
      technical#location" />
    <daml:maxCardinality>4</daml:maxCardinality>
  </daml:Restriction>
  - <daml:Restriction>
    <daml:onProperty
      rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#interactivityType" />
    <daml:maxCardinality>1</daml:maxCardinality>
  </daml:Restriction>
  - <daml:Restriction>
    <daml:onProperty
      rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#learningResourceType" />
    <daml:hasClassQ
      rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#LearningResourceType" />
    <daml:maxCardinalityQ>10</daml:maxCardinalityQ>
  </daml:Restriction>
  - <daml:Restriction>
    <daml:onProperty
      rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
      technical#requirement" />
    <daml:hasClassQ rdf:resource="#NetworkConnection" />
    <daml:maxCardinalityQ>1</daml:maxCardinalityQ>
  </daml:Restriction>
  </daml:intersectionOf>
</daml:Class>
- <daml:Class rdf:about="#Discipline">
  <rdfs:comment xml:lang="en-US">Learning Object that represents a
  knowledge area about which the system is providing customized
  courses.</rdfs:comment>
  - <rdfs:subClassOf>
    <daml:Class rdf:about="#LObject" />
  </rdfs:subClassOf>
</daml:Class>
- <daml:Class rdf:about="#Course">
  <rdfs:comment xml:lang="en-US">Adaptation of a Discipline customized
  to a specific kind of general background knowledge which is the
  previous general knowledge that the students intended to be the
  audience of the course have. An indicator of the general background
  knowledge of a person is his or her profession or skilled
  occupation.</rdfs:comment>
  - <rdfs:subClassOf>
    <daml:Class rdf:about="#LObject" />
  </rdfs:subClassOf>
  - <rdfs:subClassOf>
    - <daml:Restriction>
      <daml:onProperty rdf:resource="#customizes" />
      - <daml:hasClass>
        <daml:Class rdf:about="#Discipline" />
      </daml:hasClass>
    </daml:Restriction>
  </rdfs:subClassOf>
</daml:Class>

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        </daml:Restriction>
    </rdfs:subClassOf>
</daml:Class>
- <daml:Class rdf:about="#Topic">
    <rdfs:comment xml:lang="en-US">A Learning Object representing a
        theoretical explanation about a topic of knowledge that is complete
        in the scope of the intended explanation. It can be subdivided in
        subtopics explaining specific parts of the Topic explanation on a
        deeper level of knowledge or specificity. A Topic can be suitable
        for all courses customizing a discipline or only for some of
        them.</rdfs:comment>
- <rdfs:subClassOf>
    <daml:Class rdf:about="#LObject" />
</rdfs:subClassOf>
- <rdfs:subClassOf>
    - <daml:Restriction>
        <daml:onProperty
            rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
            educational#interactivityType" />
        <daml:hasValue
            rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
            educational#Expositive" />
        </daml:Restriction>
    </rdfs:subClassOf>
- <rdfs:subClassOf>
    - <daml:Restriction>
        <daml:onProperty
            rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
            educational#learningResourceType" />
        <daml:hasValue
            rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
            educational#Lecture" />
        </daml:Restriction>
    </rdfs:subClassOf>
</daml:Class>
- <daml:Class rdf:about="#Support">
    <rdfs:comment xml:lang="en-US">Learning Object used to support the
        theoretical explanation of a topic in the system. It can be used to
        support the explanation of more than one topic and can be suitable
        or not for all the courses for which the topic is
        used.</rdfs:comment>
    - <rdfs:subClassOf>
        <daml:Class rdf:about="#LObject" />
    </rdfs:subClassOf>
    - <rdfs:subClassOf>
        - <daml:Restriction>
            <daml:onProperty rdf:resource="#supportsTo" />
        - <daml:hasClass>
            <daml:Class rdf:about="#Topic" />
        </daml:hasClass>
    </daml:Restriction>
    </rdfs:subClassOf>
    - <rdfs:subClassOf>
        - <daml:Restriction>
            <daml:onProperty rdf:resource="#isAvailableTo" />
        - <daml:hasClass>
            <daml:Class rdf:about="#Course" />
        </daml:hasClass>
    </daml:Restriction>
</rdfs:subClassOf>
</daml:Class>
- <daml:Class rdf:about="#Exercise">
    <rdfs:comment xml:lang="en-US">A kind of Support Learning Object that
        proposes an exercise to be solved by the student.</rdfs:comment>
    - <rdfs:subClassOf>
        <daml:Class rdf:about="#Support" />
    </rdfs:subClassOf>
    - <rdfs:subClassOf>
        - <daml:Restriction>
            <daml:onProperty
                rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
                educational#interactivityType" />
            <daml:hasValue
                rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
                educational#Active" />
            </daml:Restriction>
    </rdfs:subClassOf>

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- <rdfs:subClassOf>
  - <daml:Restriction>
    <daml:onProperty
      rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#learningResourceType" />
    <daml:hasValue
      rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#Exercise" />
  </daml:Restriction>
</rdfs:subClassOf>
- <rdfs:subClassOf>
  - <daml:Restriction>
    <daml:onProperty
      rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#difficulty" />
    <daml:hasClass
      rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#Difficulty" />
  </daml:Restriction>
</rdfs:subClassOf>
</daml:Class>
- <daml:Class rdf:about="#NetworkConnection">
  <rdfs:comment xml:lang="en-US">Its individuals indicate kinds of
  network connections.</rdfs:comment>
- <rdfs:subClassOf>
  - <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    technical#TechnologyRequirement" />
  </rdfs:subClassOf>
</daml:Class>
- <daml:Class rdf:about="#Example">
  <rdfs:comment xml:lang="en-US">A kind of Support Learning Object used
  to propose an example that clarifies a topic
  explanation.</rdfs:comment>
- <rdfs:subClassOf>
  - <daml:Class rdf:about="#Support" />
  </rdfs:subClassOf>
- <rdfs:subClassOf>
  - <daml:Restriction>
    <daml:onProperty
      rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#interactivityType" />
    <daml:hasValue
      rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#Expositive" />
  </daml:Restriction>
</rdfs:subClassOf>
- <rdfs:subClassOf>
  - <daml:Restriction>
    <daml:onProperty
      rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#learningResourceType" />
    <daml:hasValue
      rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#Lecture" />
  </daml:Restriction>
</rdfs:subClassOf>
</daml:Class>
- <daml:Class rdf:about="#Complementary">
  <rdfs:comment xml:lang="en-US">A kind of Support Learning Object used
  to propose complementary material that clarifies a topic
  explanation.</rdfs:comment>
- <rdfs:subClassOf>
  - <daml:Class rdf:about="#Support" />
  </rdfs:subClassOf>
- <rdfs:subClassOf>
  - <daml:Restriction>
    <daml:onProperty
      rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#interactivityType" />
    <daml:hasValue
      rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#Expositive" />
  </daml:Restriction>
</rdfs:subClassOf>
- <rdfs:subClassOf>
  - <daml:Restriction>

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<daml:onProperty
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#learningResourceType" />
<daml:hasValue
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Lecture" />
</daml:Restriction>
</rdfs:subClassOf>
</daml:Class>
- <daml:Class rdf:about="#e-Support">
    <rdfs:comment xml:lang="en-US">A Learning Object in the internet
        created out of the system environment. It must have a
        recommendation of a registered Contributor to be used to support a
        given topic explanation.</rdfs:comment>
    - <rdfs:subClassOf>
        - <daml:Class rdf:about="#Support" />
        </rdfs:subClassOf>
    </daml:Class>
- <daml:ObjectProperty rdf:about="http://purl.org/dc/elements/1.1/#language">
    <rdfs:comment xml:lang="en-US">A human language used within this
        learning object to communicate to the intended user. NOTE: If the
        learning object has no lingual content (as in the case of a
        picture), then the appropriate value for this data element would be
        "none". NOTE2: It would be language=langcode("-"Subcode)* with
        langcode a language code as defined by the code set ISO 639:1988
        and Subcode (which occurs an arbitrary number of times) a country
        code from the code set ISO 3166-1:1997.</rdfs:comment>
    - <rdfs:domain>
        <daml:Class rdf:about="#LObject" />
    </rdfs:domain>
    - <rdfs:range>
        <daml:Class rdf:about="http://purl.org/dc/terms/#RFC1766" />
    </rdfs:range>
</daml:ObjectProperty>
- <daml:DatatypeProperty
    rdf:about="http://purl.org/dc/elements/1.1/#description">
    <rdfs:comment xml:lang="en-US">A textual description of the content of
        this learning object. NOTE: This description need not be in
        language and terms appropriate for the users of the learning object
        being described. The description should be in language and terms
        appropriate for those that decide whether or not the learning
        object being described is appropriate and relevant for the
        users.</rdfs:comment>
</daml:DatatypeProperty>
- <daml:DatatypeProperty
    rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    technical#location">
    <rdfs:comment xml:lang="en-US">A string that is used to access this
        learning object. It may be a location (e.g., Universal Resource
        Locator), or a method that resolves to a location (e.g., Universal
        Resource Identifier). NOTE: This is where the learning object
        described by this metadata instance is physically
        located.</rdfs:comment>
    - <rdfs:domain>
        <daml:Class rdf:about="#LObject" />
    </rdfs:domain>
</daml:DatatypeProperty>
- <daml:ObjectProperty rdf:about="#creator">
    <rdfs:comment xml:lang="en-US">The person or entity responsible for
        making the content of the resource. Examples of a Creator include a
        person, an organisation, or a service.</rdfs:comment>
    <rdfs:subPropertyOf
        rdf:resource="http://purl.org/dc/elements/1.1/#creator" />
    - <rdfs:domain>
        <daml:Class rdf:about="#LObject" />
    </rdfs:domain>
    - <rdfs:range>
        <daml:Class rdf:about="#Contributor" />
    </rdfs:range>
</daml:ObjectProperty>
- <daml:DatatypeProperty rdf:about="http://www.w3.org/2001/vcard-rdf/3.0#FN">
    <rdfs:comment xml:lang="en-US">Formal Name.</rdfs:comment>
</daml:DatatypeProperty>
- <daml:ObjectProperty rdf:about="#keyword">
    <rdfs:comment xml:lang="en-US">A Subject present in the learning
        Object is expressed by means of a keyword.</rdfs:comment>

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<rdfs:subPropertyOf
  rdf:resource="http://purl.org/dc/elements/1.1/#subject" />
- <rdfs:domain>
  <daml:Class rdf:about="#LObject" />
</rdfs:domain>
- <rdfs:range>
  <daml:Class rdf:about="#Keyword" />
</rdfs:range>
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="#apply">
  <rdfs:subPropertyOf
    rdf:resource="http://purl.org/dc/elements/1.1/#subject" />
- <rdfs:domain>
  <daml:Class rdf:about="#LObject" />
</rdfs:domain>
- <rdfs:range>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Domain.d
      aml#Taxon" />
</rdfs:range>
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="#defines">
  <rdfs:subPropertyOf
    rdf:resource="http://purl.org/dc/elements/1.1/#subject" />
- <rdfs:domain>
  <daml:Class rdf:about="#LObject" />
</rdfs:domain>
- <rdfs:range>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Domain.d
      aml#Taxon" />
</rdfs:range>
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="#introduces">
  <rdfs:subPropertyOf
    rdf:resource="http://purl.org/dc/elements/1.1/#subject" />
- <rdfs:domain>
  <daml:Class rdf:about="#LObject" />
</rdfs:domain>
- <rdfs:range>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Domain.d
      aml#Taxon" />
</rdfs:range>
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="#describes">
  <rdfs:subPropertyOf
    rdf:resource="http://purl.org/dc/elements/1.1/#subject" />
- <rdfs:domain>
  <daml:Class rdf:about="#LObject" />
</rdfs:domain>
- <rdfs:range>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Domain.d
      aml#Taxon" />
</rdfs:range>
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="http://purl.org/dc/elements/1.1/#subject">
  <rdfs:comment xml:lang="en-US" />
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="#subject">
  <rdfs:comment xml:lang="en-US">Indicates an element in a taxonomy by
    idea or discipline.</rdfs:comment>
  <rdfs:subPropertyOf
    rdf:resource="http://purl.org/dc/elements/1.1/#subject" />
- <rdfs:domain>
  <daml:Class rdf:about="#LObject" />
</rdfs:domain>
</daml:ObjectProperty>
- <daml:ObjectProperty rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
  metamodel#metadataScheme">
  <rdfs:comment xml:lang="en-US">The name and version of the
    authoritative specification used to create this metadata
    instance.</rdfs:comment>
- <rdfs:domain>
  <daml:Class rdf:about="#LObject" />
</rdfs:domain>

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- <rdfs:range>
  <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metametadata#MetadataScheme" />
</rdfs:range>
</daml:ObjectProperty>
- <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
  metametadata#MetadataScheme">
  <rdfs:comment xml:lang="en-US">Instances of this class represent meta-
    data schemes.</rdfs:comment>
</daml:Class>
- <daml:ObjectProperty rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
  technical#requirement">
  <rdfs:comment xml:lang="en-US">The minimal technical capabilities
    necessary for using this learning object. Currently represents the
    minimum kind of student network connection needed for use the
    Learning Object.</rdfs:comment>
- <rdfs:domain>
  <daml:Class rdf:about="#LObject" />
</rdfs:domain>
- <rdfs:range>
  <daml:Class rdf:about="#NetworkConnection" />
</rdfs:range>
</daml:ObjectProperty>
- <daml:Class rdf:about="http://purl.org/dc/terms/#RFC1766">
  <rdfs:comment xml:lang="en-US">Internet RFC 1766 Tags for the
    identification of Language, specifies a two letter code taken from
    ISO 639, followed optionally by a two letter country code taken
    from ISO 3166.</rdfs:comment>
</daml:Class>
- <daml:ObjectProperty rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#learningResourceType">
  <rdfs:comment xml:lang="en-US">Specific kind of learning
    object.</rdfs:comment>
- <rdfs:domain>
  <daml:Class rdf:about="#LObject" />
</rdfs:domain>
- <rdfs:range>
  <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#LearningResourceType" />
</rdfs:range>
</daml:ObjectProperty>
- <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#LearningResourceType">
  <rdfs:comment xml:lang="en-US">Its individuals are the possible kind
    of Learning Objects.</rdfs:comment>
</daml:Class>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Exercise">
  <rdf:type>
    <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#LearningResourceType" />
  </rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Simulation">
  <rdf:type>
    <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#LearningResourceType" />
  </rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Questionnaire">
  <rdf:type>
    <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#LearningResourceType" />
  </rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Diagram">
  <rdf:type>
    <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#LearningResourceType" />
  </rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Figure">
  <rdf:type>

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<daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#LearningResourceType" />
</rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Graph">
- <rdf:type>
-   <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#LearningResourceType" />
</rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Index">
- <rdf:type>
-   <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#LearningResourceType" />
</rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Slide">
- <rdf:type>
-   <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#LearningResourceType" />
</rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Table">
- <rdf:type>
-   <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#LearningResourceType" />
</rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#NarrativeText">
- <rdf:type>
-   <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#LearningResourceType" />
</rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Exam">
- <rdf:type>
-   <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#LearningResourceType" />
</rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Experiment">
- <rdf:type>
-   <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#LearningResourceType" />
</rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#ProblemStatement">
- <rdf:type>
-   <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#LearningResourceType" />
</rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#SelfAssessment">
- <rdf:type>
-   <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#LearningResourceType" />
</rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Lecture">
- <rdf:type>
-   <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#LearningResourceType" />
</rdf:type>
</rdf:Description>
- <daml:ObjectProperty rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#difficulty">
```

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<rdfs:comment xml:lang="en-US">How hard it is to work with or though
    this learning object for the typical intended target
    audience.</rdfs:comment>
- <rdfs:domain>
    <daml:Class rdf:about="#LObject" />
</rdfs:domain>
- <rdfs:range>
    <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
        educational#Difficulty" />
</rdfs:range>
</daml:ObjectProperty>
- <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Difficulty">
    <rdfs:comment xml:lang="en-US">Its individuals are the possible values
        to the property difficulty of a Learning Object.</rdfs:comment>
</daml:Class>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#VeryEasy">
    <rdf:type>
        <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
            educational#Difficulty" />
    </rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Easy">
    <rdf:type>
        <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
            educational#Difficulty" />
    </rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#MediumDifficulty">
    <rdf:type>
        <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
            educational#Difficulty" />
    </rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Difficult">
    <rdf:type>
        <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
            educational#Difficulty" />
    </rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#VeryDifficult">
    <rdf:type>
        <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
            educational#Difficulty" />
    </rdf:type>
</rdf:Description>
- <daml:ObjectProperty rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#interactivityType">
    <rdfs:comment xml:lang="en-US">Predominant mode of learning supported
        by this learning object.</rdfs:comment>
- <rdfs:domain>
    <daml:Class rdf:about="#LObject" />
</rdfs:domain>
- <rdfs:range>
    <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
        educational#InteractivityType" />
</rdfs:range>
</daml:ObjectProperty>
- <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#InteractivityType">
    <rdfs:comment xml:lang="en-US">Its individuals are the possible values
        to the property interactivityType of a Learning
        Object.</rdfs:comment>
</daml:Class>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Active">
    <rdf:type>
        <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
            educational#InteractivityType" />
    </rdf:type>
    <rdfs:comment xml:lang="en-US">"Active" learning (e.g., learning by
        doing) is supported by content that directly induces productive

```

action by the learner. An active learning object prompts the learner for semantically meaningful input or for some other kind of productive action or decision, not necessarily performed within the learning object's framework. Active documents include simulations, questionnaires, and exercises. NOTE: Activating links to navigate in hypertext documents is not considered to be a productive action.</rdfs:comment>

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</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Expositive">
  - <rdf:type>
    <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#InteractivityType" />
  </rdf:type>
  <rdfs:comment xml:lang="en-US">"Expositive" learning (e.g., passive
    learning) occurs when the learner's job mainly consists of absorbing
    the content exposed to him (generally through text, images or
    sound). An expositive learning object displays information but does
    not prompt the learner for any semantically meaningful input.
    Expositive documents include essays, video clips, all kinds of
    graphical material, and hypertext documents.</rdfs:comment>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Mixed">
  - <rdf:type>
    <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#InteractivityType" />
  </rdf:type>
  <rdfs:comment xml:lang="en-US">When a learning object blends the active
    and expositive interactivity types, then its interactivity type is
    "mixed".</rdfs:comment>
</rdf:Description>
- <rdf:Description rdf:about="#Prof.Angélica">
  - <rdf:type>
    <daml:Class rdf:about="#Contributor" />
  </rdf:type>
  - <vcard:FN>
    <xsd:string rdf:value="Maria Agélica Brunetto" />
  </vcard:FN>
</rdf:Description>
- <rdf:Description rdf:about="#Lydia">
  - <rdf:type>
    <daml:Class rdf:about="#Contributor" />
  </rdf:type>
  - <vcard:FN>
    <xsd:string rdf:value="Lydia Silva Muñoz" />
  </vcard:FN>
</rdf:Description>
- <rdf:Description rdf:about="#dial-up">
  - <rdf:type>
    <daml:Class rdf:about="#NetworkConnection" />
  </rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="#fast">
  - <rdf:type>
    <daml:Class rdf:about="#NetworkConnection" />
  </rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="#pt-BR">
  - <rdf:type>
    <daml:Class rdf:about="http://purl.org/dc/terms/#RFC1766" />
  </rdf:type>
  <rdfs:comment xml:lang="en-US">The Portuguese used in
    Brazil</rdfs:comment>
</rdf:Description>
- <rdf:Description rdf:about="#en-US">
  - <rdf:type>
    <daml:Class rdf:about="http://purl.org/dc/terms/#RFC1766" />
  </rdf:type>
  <rdfs:comment xml:lang="en-US">The English used in The United States
    of America</rdfs:comment>
</rdf:Description>
- <rdf:Description rdf:about="#es-UY">
  - <rdf:type>
    <daml:Class rdf:about="http://purl.org/dc/terms/#RFC1766" />
  </rdf:type>

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<rdfs:comment xml:lang="en-US">The Spanish used in
    Uruguay</rdfs:comment>
</rdf:Description>
- <rdf:Description rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metametadata#LOMv1.0">
    - <rdf:type>
        <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
            metatadata#MetadataScheme" />
    </rdf:type>
    <rdfs:comment xml:lang="en-US">IEEE Learning Object
        Metadata.</rdfs:comment>
    </rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
        daml# Computacao Algebrica e Numerica">
    - <rdf:type>
        <daml:Class
            rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
                d/Content.daml#Discipline" />
    </rdf:type>
    - <dc:description>
        <xsd:string xml:lang="pt-BR" rdf:value="Computacao Algebrica e
            Numerica" />
    </dc:description>
    <ns0:creator rdf:resource="#Prof.Angélica" />
    <dc:language rdf:resource="#pt-BR" />
    <lom-meta:metadataScheme
        rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
            metatadata#LOMv1.0" />
    </rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
        daml# Matematicas">
    - <rdf:type>
        <daml:Class
            rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
                d/Content.daml#Course" />
    </rdf:type>
    - <dc:description>
        <xsd:string xml:lang="pt-BR" rdf:value="Matematicas" />
    </dc:description>
    <ns0:creator rdf:resource="#Prof.Angélica" />
    <ns0:customizes
        rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
            Content.daml# Computacao Algebrica e Numerica" />
    <dc:language rdf:resource="#pt-BR" />
    <lom-meta:metadataScheme
        rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
            metatadata#LOMv1.0" />
    </rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
        daml# Engenharia">
    - <rdf:type>
        <daml:Class
            rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
                d/Content.daml#Course" />
    </rdf:type>
    - <dc:description>
        <xsd:string xml:lang="pt-BR" rdf:value="Engenharia" />
    </dc:description>
    <ns0:creator rdf:resource="#Prof.Angélica" />
    <ns0:customizes
        rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
            Content.daml# Computacao Algebrica e Numerica" />
    <dc:language rdf:resource="#pt-BR" />
    <lom-meta:metadataScheme
        rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
            metatadata#LOMv1.0" />
    </rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
        daml# Computacao">
    - <rdf:type>
        <daml:Class
            rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
                d/Content.daml#Course" />

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</rdf:type>
- <dc:description>
  <xsd:string xml:lang="pt-BR" rdf:value="Computacao" />
</dc:description>
<ns0:creator rdf:resource="#Prof. Angélica" />
<ns0:customizes
  rdf:resource="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Computacao Algebrica e Numerica" />
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  metatadata#LOMv1.0" />
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/Content.
  daml# Contexto e Objetivos da Computação Algébrica e Numérica">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generate
    d/Content.daml#Topic" />
</rdf:type>
- <dc:description>
  <xsd:string xml:lang="pt-BR" rdf:value="Contexto e Objetivos da
  Computação Algébrica e Numérica" />
</dc:description>
<ns0:keyword
  rdf:resource="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/
  Content.daml#Objetivos" />
<ns0:keyword
  rdf:resource="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/
  Content.daml#Computação" />
<ns0:keyword
  rdf:resource="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/
  Content.daml#Algébrica" />
<ns0:keyword
  rdf:resource="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/
  Content.daml#Numérica" />
- <lom-tech:location>
  <xsd:string rdf:value="Contexto.html" />
</lom-tech:location>
<ns0:apply
  rdf:resource="http://www.inf.ufrrgs.br/~tapejara/Ontology/Domain.dam
  l#Linear Systems" />
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  metatadata#LOMv1.0" />
<lom-edu:interactivityType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Expositive" />
<lom-edu:learningResourceType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Lecture" />
<ns0:creator rdf:resource="#Prof. Angélica" />
<dc:language rdf:resource="#pt-BR" />
<ns0:isPartOf
  rdf:resource="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Computacao Algebrica e Numerica" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Matematicas" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Engenharia" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Computacao" />
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/Content.
  daml#Objetivos">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generate
    d/Content.daml#Keyword" />
</rdf:type>
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  Content.daml# Sistemas Lineares de Equações Algébricas" />
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  Content.daml# Matematicas" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Engenharia" />
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  Content.daml# Computacao" />
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- <rdf:Description
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  daml#Sistemas">
- <rdf:type>
  <daml:Class
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    d/Content.daml#Keyword" />
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- <rdf:Description
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  daml#Equações">
- <rdf:type>
  <daml:Class
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    d/Content.daml#Keyword" />
</rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content .
  daml# Método de Gauss com Pivotamento">
- <rdf:type>

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d/Content.daml#Topic" />
</rdf:type>
- <dc:description>
  <xsd:string xml:lang="pt-BR" rdf:value="Método de Gauss com
  Pivotamento" />
</dc:description>
<ns0:keyword
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml#Gauss" />
<ns0:keyword
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml#Pivotamento" />
- <lom-tech:location>
  <xsd:string rdf:value="Sela_Gausspp.html" />
</lom-tech:location>
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  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Domain.dam
  l#Gauss Method With Pivoting" />
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  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  metametadata#LOMv1.0" />
<lom-edu:interactivityType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Expositive" />
<lom-edu:learningResourceType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Lecture" />
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<dc:language rdf:resource="#pt-BR" />
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  Content.daml# Método de Gauss" />
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  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Computacao Algebrica e Numerica" />
<ns0:isPartOf
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  Content.daml# Métodos Diretos" />
<ns0:hasPrerequisite
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  Content.daml# Método de Gauss" />
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  Content.daml# Matematicas" />
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  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Engenharia" />
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- <rdf:Description
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  daml#Gauss">
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    <daml:Class
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      d/Content.daml#Keyword" />
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</rdf:Description>
- <rdf:Description
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  daml#Pivotamento">
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    <daml:Class
      rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
      d/Content.daml#Keyword" />
  </rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
  daml# Método da Decomposicao LU">
  <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
      d/Content.daml#Topic" />
  </rdf:type>
</rdf:Description>

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- <dc:description>
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  Content.daml#Decomposicao" />
- <lom-tech:location>
  <xsd:string rdf:value="Sela_LU.html" />
</lom-tech:location>
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  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  metamodel#LOMv1.0" />
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  educational#Expositive" />
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  educational#Lecture" />
<ns0:creator rdf:resource="#Prof.Angélica" />
<dc:language rdf:resource="#pt-BR" />
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  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Método de Gauss com Pivotamento" />
<ns0:isPartOf
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Computacao Algebrica e Numerica" />
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  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Métodos Diretos" />
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  Content.daml# Sistemas Lineares de Equações Algébricas" />
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  Content.daml# Matematicas" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Engenharia" />
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- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
  daml#Decomposicao">
  - <rdf:type>
    <daml:Class
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      d/Content.daml#Keyword" />
    </rdf:type>
  </rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
  daml# Método de Cholesky">
  - <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
      d/Content.daml#Topic" />
    </rdf:type>
  <dc:description
    <xsd:string xml:lang="pt-BR" rdf:value="Método de Cholesky" />
  </dc:description>
  <ns0:keyword
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml#Cholesky" />
- <lom-tech:location>
  <xsd:string rdf:value="Sela_Cholesky.html" />
</lom-tech:location>
<ns0:describes
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Domain.dam
  l#Cholesky Factorization" />
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  metamodel#LOMv1.0" />

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<lom-edu:interactivityType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Expositive" />
<lom-edu:learningResourceType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Lecture" />
<ns0:creator rdf:resource="#Prof.Angélica" />
<dc:language rdf:resource="#pt-BR" />
<ns0:prevLearningPath
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Método da Decomposicao LU" />
<ns0:isPartOf
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Computacao Algebrica e Numerica" />
<ns0:isPartOf
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Métodos Diretos" />
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  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Método de Gauss" />
<ns0:hasPrerequisite
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Método de Gauss com Pivotamento" />
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  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Método da Decomposicao LU" />
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  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Matematicas" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Engenharia" />
</rdf:Description>
- <rdf:Description
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  daml#Cholesky">
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      d/Content.daml#Keyword" />
    </rdf:type>
  </rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
  daml# Condicionamento de Matrizes">
  - <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
      d/Content.daml#Topic" />
  </rdf:type>
  - <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Condicionamento de
      Matrizes" />
  </dc:description>
  <ns0:keyword
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml#Condicionamento" />
  <ns0:keyword
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml#Matriz" />
  - <lom-tech:location>
    <xsd:string rdf:value="Condicioamento_Matrizes.html" />
  </lom-tech:location>
  <ns0:describes
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Domain.dam
    l#Gauss Method" />
  <dc:language rdf:resource="#pt-BR" />
  <lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metametadata#LOMv1.0" />
  <lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Expositive" />
  <lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Lecture" />
  <ns0:creator rdf:resource="#Prof.Angélica" />

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<ns0:isPartOf
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Método de Gauss com Pivotamento" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Matematicas" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Engenharia" />
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- <rdf:Description
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    daml#Condicionamento">
    - <rdf:type>
        <daml:Class
            rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
            d/Content.daml#Keyword" />
        </rdf:type>
    </rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
    daml#Matriz">
    - <rdf:type>
        <daml:Class
            rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
            d/Content.daml#Keyword" />
        </rdf:type>
    </rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
    daml# Algoritmo Triangularizacao">
    - <rdf:type>
        <daml:Class
            rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
            d/Content.daml#Topic" />
        </rdf:type>
    </rdf:Description>
- <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Algoritmo
        Triangularizacao" />
</dc:description>
<ns0:keyword
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml#Triangularização" />
- <lom-tech:location>
    <xsd:string rdf:value="Sela_Triang.html" />
</lom-tech:location>
<ns0:apply
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Domain.dam
    l#Gauss Method" />
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metamodel#LOMv1.0" />
<lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Expositive" />
<lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Lecture" />
<ns0:creator rdf:resource="#Prof. Angélica" />
<dc:language rdf:resource="#pt-BR" />
<ns0:isPartOf
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Computacao Algebrica e Numerica" />
<ns0:isPartOf
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Método de Gauss" />
<ns0:hasPrerequisite
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Sistemas Lineares de Equações Algébricas" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Matematicas" />

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  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Engenharia" />
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  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Computacao" />
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- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
  daml#Triangularização">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
    d/Content.daml#Keyword" />
  </rdf:type>
</rdf:Description>
- <rdf:Description
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  daml# Algoritmo Retrosubstituição">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
    d/Content.daml#Topic" />
  </rdf:type>
- <dc:description>
  <xsd:string xml:lang="pt-BR" rdf:value="Algoritmo
  Retrosubstituição" />
</dc:description>
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  Content.daml#Retrosubstituição" />
- <lom-tech:location>
  <xsd:string rdf:value="SEla_Retro.html" />
</lom-tech:location>
<ns0:apply
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Domain.dam
  l#Gauss Method" />
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  metametadata#LOMv1.0" />
<lom-edu:interactivityType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Expositive" />
<lom-edu:learningResourceType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Lecture" />
<ns0:creator rdf:resource="#Prof. Angélica" />
<dc:language rdf:resource="#pt-BR" />
<ns0:prevLearningPath
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Algoritmo Triangularizacao" />
<ns0:isPartOf
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Computacao Algebrica e Numerica" />
<ns0:isPartOf
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Método de Gauss" />
<ns0:hasPrerequisite
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Algoritmo Triangularizacao" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Matematicas" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Engenharia" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Computacao" />
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- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
  daml#Retrosubstituição">
- <rdf:type>

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d/Content.daml#Keyword" />
</rdf:type>
</rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
daml# Exercicio Introdutorio 1-S1-T2.1-D1">
- <rdf:type>
    <daml:Class
        rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
d/Content.daml#Exercise" />
</rdf:type>
- <lom-tech:location>
    <xsd:string rdf:value="Ex1facil.html" />
</lom-tech:location>
<ns0:supportsTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
Content.daml# Introducao" />
- <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Exercicio Introdutorio 1"
/>
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
metametadata#LOMv1.0" />
<lom-edu:difficulty
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
educational#Easy" />
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    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
educational#Active" />
<lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
educational#Exercise" />
<ns0:creator rdf:resource="#Prof. Angélica" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
Content.daml# Matematicas" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
Content.daml# Engenharia" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
Content.daml# Computacao" />
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</rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
daml# Exercicio Introdutório 2-S2-T2.1-D1">
- <rdf:type>
    <daml:Class
        rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
d/Content.daml#Exercise" />
</rdf:type>
- <lom-tech:location>
    <xsd:string rdf:value="Ex2Facil.html" />
</lom-tech:location>
<ns0:supportsTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
Content.daml# Introducao" />
- <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Exercicio Introdutório 2"
/>
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
metametadata#LOMv1.0" />
<lom-edu:difficulty
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
educational#Easy" />
<lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
educational#Active" />

```

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<lom-edu:learningResourceType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Exercise" />
<ns0:creator rdf:resource="#Prof.Angélica" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Matematicas" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Engenharia" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Computacao" />
<lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
  daml# Exercicio Introdutório 3-S3-T2.1-D1">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
    d/Content.daml#Exercise" />
</rdf:type>
- <lom-tech:location>
  <xsd:string rdf:value="Ex3Medio.html" />
</lom-tech:location>
<ns0:supportsTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Introducao" />
- <dc:description>
  <xsd:string xml:lang="pt-BR" rdf:value="Exercicio Introdutório 3"
  />
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  metametadata#LOMv1.0" />
<lom-edu:difficulty
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#MediumDifficulty" />
<lom-edu:interactivityType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Active" />
<lom-edu:learningResourceType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Exercise" />
<ns0:creator rdf:resource="#Prof.Angélica" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Matematicas" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Engenharia" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Computacao" />
<lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
  daml# Exercicio Introdutório 4-S4-T2.1-D1">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
    d/Content.daml#Exercise" />
</rdf:type>
- <lom-tech:location>
  <xsd:string rdf:value="Ex4Medio.html" />
</lom-tech:location>
<ns0:supportsTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Introducao" />
- <dc:description>
  <xsd:string xml:lang="pt-BR" rdf:value="Exercicio Introdutório 4"
  />
</dc:description>
<dc:language rdf:resource="#pt-BR" />

```

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<lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metamodeldata#LOMv1.0" />
<lom-edu:difficulty
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#MediumDifficulty" />
<lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Active" />
<lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Exercise" />
<ns0:creator rdf:resource="#Prof.Angélica" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Matematicas" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Engenharia" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Computacao" />
<lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
    daml# Exercicio Introdutório 5-S5-T2.1-D1">
  - <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
      d/Content.daml#Exercise" />
  </rdf:type>
  - <lom-tech:location>
    <xsd:string rdf:value="Ex5Complexo.html" />
  </lom-tech:location>
  <ns0:supportsTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Introducao" />
  - <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Exercicio Introdutório 5"
    />
  </dc:description>
  <dc:language rdf:resource="#pt-BR" />
  <lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metamodeldata#LOMv1.0" />
  <lom-edu:difficulty
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Difficult" />
  <lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Active" />
  <lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Exercise" />
  <ns0:creator rdf:resource="#Prof.Angélica" />
  <ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Matematicas" />
  <ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Engenharia" />
  <ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Computacao" />
  <lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
    daml# Exercicio Introdutório 6-S6-T2.1-D1">
  - <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
      d/Content.daml#Exercise" />
  </rdf:type>
  - <lom-tech:location>
    <xsd:string rdf:value="Ex6.html" />

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</lom-tech:location>
<ns0:supportsTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Introducao" />
- <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Exercicio Introdutório 6"
    />
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metametadata#LOMv1.0" />
<lom-edu:difficulty
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#VeryEasy" />
<lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Active" />
<lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Exercise" />
<ns0:creator rdf:resource="#Prof. Angélica" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Matematicas" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Engenharia" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Computacao" />
<lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf>Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
    daml# Exercicio Introdutório 7-S7-T2.1-D1">
- <rdf:type>
    <daml:Class
        rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
        d/Content.daml#Exercise" />
</rdf:type>
- <lom-tech:location>
    <xsd:string rdf:value="Ex7Facil.html" />
</lom-tech:location>
<ns0:supportsTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Introducao" />
- <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Exercicio Introdutório 7"
    />
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metatadata#LOMv1.0" />
<lom-edu:difficulty
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Easy" />
<lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Active" />
<lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Exercise" />
<ns0:creator rdf:resource="#Prof. Angélica" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Matematicas" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Engenharia" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Computacao" />
<lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>

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- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
  daml# Exercicio Introdutório 8-S8-T2.1-D1">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
    d/Content.daml#Exercise" />
</rdf:type>
- <lom-tech:location>
  <xsd:string rdf:value="Ex8Facil.html" />
</lom-tech:location>
<ns0:supportsTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Introducao" />
- <dc:description>
  <xsd:string xml:lang="pt-BR" rdf:value="Exercicio Introdutório 8"
  />
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  metametadata#LOMv1.0" />
<lom-edu:difficulty
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Easy" />
<lom-edu:interactivityType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Active" />
<lom-edu:learningResourceType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Exercise" />
<ns0:creator rdf:resource="#Prof.Angélica" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Matematicas" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Engenharia" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Computacao" />
<lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
  daml# Biblioteca do Maple - cholesky-S1-T2.2.4-D1">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
    d/Content.daml#Complementary" />
</rdf:type>
- <lom-tech:location>
  <xsd:string rdf:value="BibMapCholesky.html" />
</lom-tech:location>
<ns0:supportsTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Método de Cholesky" />
- <dc:description>
  <xsd:string xml:lang="pt-BR" rdf:value="Biblioteca do Maple -
  cholesky" />
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  metametadata#LOMv1.0" />
<lom-edu:interactivityType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Expositive" />
<lom-edu:learningResourceType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Lecture" />
<ns0:creator rdf:resource="#Prof.Angélica" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Matematicas" />

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<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Engenharia" />
<lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
    daml# Programas em Maple html-S2-T2.2.4-D1">
- <rdf:type>
    <daml:Class
        rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
        d/Content.daml#Complementary" />
</rdf:type>
- <lom-tech:location>
    <xsd:string rdf:value="ProgMap_Cholesky.html" />
</lom-tech:location>
<ns0:supportsTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Método de Cholesky" />
- <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Programas em Maple html"
    />
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metametadata#LOMv1.0" />
<lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Expositive" />
<lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Lecture" />
<ns0:creator rdf:resource="#Prof. Angélica" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Matematicas" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Engenharia" />
<lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
    daml# Programas em Maple download-S3-T2.2.4-D1">
- <rdf:type>
    <daml:Class
        rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
        d/Content.daml#Complementary" />
</rdf:type>
- <lom-tech:location>
    <xsd:string rdf:value="ProgMap_Cholesky_Down.exe" />
</lom-tech:location>
<ns0:supportsTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Método de Cholesky" />
- <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Programas em Maple
    download" />
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metametadata#LOMv1.0" />
<lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Expositive" />
<lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Lecture" />
<ns0:creator rdf:resource="#Prof. Angélica" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Matematicas" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Engenharia" />

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<lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/Content.
  daml# Programas em PHP-S4-T2.2.4-D1">
  - <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generate
      d/Content.daml#Complementary" />
  </rdf:type>
  - <lom-tech:location>
    <xsd:string rdf:value="Cholesky_pt.html" />
  </lom-tech:location>
  <ns0:supportsTo
    rdf:resource="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Método de Cholesky" />
  - <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Programas em PHP" />
  </dc:description>
  <dc:language rdf:resource="#pt-BR" />
  <lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metametadata#LOMv1.0" />
  <lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Expositive" />
  <lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Lecture" />
  <ns0:creator rdf:resource="#Prof.Angélica" />
  <ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Matematicas" />
  <ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Engenharia" />
  <lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/Content.
  daml# Programas em PHP-S5-T2.2.4-D1">
  - <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generate
      d/Content.daml#Complementary" />
  </rdf:type>
  - <lom-tech:location>
    <xsd:string rdf:value="Cholesky_pt.php" />
  </lom-tech:location>
  <ns0:supportsTo
    rdf:resource="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Método de Cholesky" />
  - <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Programas em PHP" />
  </dc:description>
  <dc:language rdf:resource="#pt-BR" />
  <lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metametadata#LOMv1.0" />
  <lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Expositive" />
  <lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Lecture" />
  <ns0:creator rdf:resource="#Prof.Angélica" />
  <ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Matematicas" />
  <ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Engenharia" />
  <lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrrgs.br/~tapejara/Ontology/Generated/Content.
  daml# Programas em PHP-S6-T2.2.4-D1">

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- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated
d/Content.daml#Complementary" />
</rdf:type>
- <lom-tech:location>
  <xsd:string rdf:value="Cholesky2_pt.php" />
</lom-tech:location>
<ns0:supportsTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
Content.daml# Método de Cholesky" />
- <dc:description>
  <xsd:string xml:lang="pt-BR" rdf:value="Programas em PHP" />
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
metametadata#LOMv1.0" />
<lom-edu:interactivityType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
educational#Expositive" />
<lom-edu:learningResourceType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
educational#Lecture" />
<ns0:creator rdf:resource="#Prof.Angélica" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
Content.daml# Matematicas" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
Content.daml# Engenharia" />
<lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
daml# Exemplo do Método de Gauss-S1-T2.2.1-D1">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated
d/Content.daml#Example" />
</rdf:type>
- <lom-tech:location>
  <xsd:string rdf:value="Exp_gauss.html" />
</lom-tech:location>
<ns0:supportsTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
Content.daml# Método de Gauss" />
- <dc:description>
  <xsd:string xml:lang="pt-BR" rdf:value="Exemplo do Método de
Gauss" />
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
metametadata#LOMv1.0" />
<lom-edu:difficulty
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
educational#Easy" />
<lom-edu:interactivityType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
educational#Expositive" />
<lom-edu:learningResourceType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
educational#Lecture" />
<ns0:creator rdf:resource="#Prof.Angélica" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
Content.daml# Matematicas" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
Content.daml# Engenharia" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
Content.daml# Computacao" />
<lom-tech:requirement rdf:resource="#fast" />
</rdf:Description>

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- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
  daml# Biblioteca do Maple-S1-T2.2.1-D1">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
    d/Content.daml#Complementary" />
</rdf:type>
- <lom-tech:location>
  <xsd:string rdf:value="Bib_MGauss.html" />
</lom-tech:location>
<ns0:supportsTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Método de Gauss" />
- <dc:description>
  <xsd:string xml:lang="pt-BR" rdf:value="Biblioteca do Maple" />
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  metadata#LOMv1.0" />
<lom-edu:interactivityType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Expositive" />
<lom-edu:learningResourceType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Lecture" />
<ns0:creator rdf:resource="#Prof.Angélica" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Matematicas" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Engenharia" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Computacao" />
<lom-tech:requirement rdf:resource="#fast" />
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
  daml# Recursos do Maple para programar o Método de Gauss-S2-T2.2.1-D1">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
    d/Content.daml#Complementary" />
</rdf:type>
- <lom-tech:location>
  <xsd:string rdf:value="Teoria_Gauss.mws" />
</lom-tech:location>
<ns0:supportsTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Método de Gauss" />
- <dc:description>
  <xsd:string xml:lang="pt-BR" rdf:value="Recursos do Maple para
  programar o Método de Gauss" />
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  metadata#LOMv1.0" />
<lom-edu:interactivityType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Expositive" />
<lom-edu:learningResourceType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Lecture" />
<ns0:creator rdf:resource="#Prof.Angélica" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Matematicas" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Engenharia" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Computacao" />

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<lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
  daml# Recursos do Maple para programar o Método de Gauss-S3-T2.2.1-D1">
  - <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
      d/Content.daml#Complementary" />
  </rdf:type>
  - <lom-tech:location>
    <xsd:string rdf:value="Teoria_Gauss.html" />
  </lom-tech:location>
  <ns0:supportsTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Método de Gauss" />
  - <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Recursos do Maple para
      programar o Método de Gauss" />
  </dc:description>
  <dc:language rdf:resource="#pt-BR" />
  <lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metamodeldata#LOMv1.0" />
  <lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Expositive" />
  <lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Lecture" />
  <ns0:creator rdf:resource="#Prof.Angélica" />
  <ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Matematicas" />
  <ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Engenharia" />
  <ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Computacao" />
  <lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
  daml# Programas usando Maple-S4-T2.2.1-D1">
  - <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
      d/Content.daml#Complementary" />
  </rdf:type>
  - <lom-tech:location>
    <xsd:string rdf:value="Elim_Gauss.html" />
  </lom-tech:location>
  <ns0:supportsTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Método de Gauss" />
  - <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Programas usando Maple"
      />
  </dc:description>
  <dc:language rdf:resource="#pt-BR" />
  <lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metamodeldata#LOMv1.0" />
  <lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Expositive" />
  <lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Lecture" />
  <ns0:creator rdf:resource="#Prof.Angélica" />
  <ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Matematicas" />
  <ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Engenharia" />

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<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Computacao" />
<lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
    daml# Programas usando Maple (Para download)-S5-T2.2.1-D1">
- <rdf:type>
    <daml:Class
        rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
        d/Content.daml#Complementary" />
</rdf:type>
- <lom-tech:location>
    <xsd:string rdf:value="Elim_Gauss.mws" />
</lom-tech:location>
<ns0:supportsTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Método de Gauss" />
- <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Programas usando Maple
    (Para download)" />
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metametadata#LOMv1.0" />
<lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Expositive" />
<lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Lecture" />
<ns0:creator rdf:resource="#Prof.Angélica" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Matematicas" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Engenharia" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Computacao" />
<lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
    daml# Programas usando Maple (Filme)-S6-T2.2.1-D1">
- <rdf:type>
    <daml:Class
        rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
        d/Content.daml#Complementary" />
</rdf:type>
- <lom-tech:location>
    <xsd:string rdf:value="Elim_Gauss.avi" />
</lom-tech:location>
<ns0:supportsTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Método de Gauss" />
- <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Programas usando Maple
    (Filme)" />
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metametadata#LOMv1.0" />
<lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Expositive" />
<lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Lecture" />
<ns0:creator rdf:resource="#Prof.Angélica" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Matematicas" />

```

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<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Engenharia" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Computacao" />
<lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
<rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
  daml# Programas usando Maple (Filme para download) -S7-T2.2.1-D1">
  <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
      d/Content.daml#Complementary" />
  </rdf:type>
  <lom-tech:location>
    <xsd:string rdf:value="Elim_Gauss.exe" />
  </lom-tech:location>
  <ns0:supportsTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Método de Gauss" />
  <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Programas usando Maple
    (Filme para download)" />
  </dc:description>
  <dc:language rdf:resource="#pt-BR" />
  <lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metametadata#LOMv1.0" />
  <lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Expositive" />
  <lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Lecture" />
  <ns0:creator rdf:resource="#Prof. Angélica" />
  <ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Matematicas" />
  <ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Engenharia" />
  <ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Computacao" />
    <lom-tech:requirement rdf:resource="#dial-up" />
  </rdf:Description>
  <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
    daml# Programas em PHP-S8-T2.2.1-D1">
    <rdf:type>
      <daml:Class
        rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
        d/Content.daml#Complementary" />
    </rdf:type>
    <lom-tech:location>
      <xsd:string rdf:value="ProgPHP_Gauss.php" />
    </lom-tech:location>
    <ns0:supportsTo
      rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
      Content.daml# Método de Gauss" />
    <dc:description>
      <xsd:string xml:lang="pt-BR" rdf:value="Programas em PHP" />
    </dc:description>
    <dc:language rdf:resource="#pt-BR" />
    <lom-meta:metadataScheme
      rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
      metametadata#LOMv1.0" />
    <lom-edu:interactivityType
      rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#Expositive" />
    <lom-edu:learningResourceType
      rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
      educational#Lecture" />
    <ns0:creator rdf:resource="#Prof. Angélica" />
  
```

```

<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
        Content.daml# Matematicas" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
        Content.daml# Engenharia" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
        Content.daml# Computacao" />
    <lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
        daml# Exemplo do Método de Gauss-S1-T2.2.2-D1">
- <rdf:type>
    <daml:Class
        rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
            d/Content.daml#Example" />
    </rdf:type>
- <lom-tech:location>
    <xsd:string rdf:value="Exp_Gauss_Pivot.html" />
</lom-tech:location>
<ns0:supportsTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
        Content.daml# Método de Gauss com Pivotamento" />
- <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Exemplo do Método de
        Gauss" />
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
        metatadata#LOMv1.0" />
<lom-edu:difficulty
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
        educational#Easy" />
<lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
        educational#Expositive" />
<lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
        educational#Lecture" />
<ns0:creator rdf:resource="#Prof.Angélica" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
        Content.daml# Matematicas" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
        Content.daml# Engenharia" />
    <lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
        daml# Programas do Maple em html-S1-T2.2.2-D1">
- <rdf:type>
    <daml:Class
        rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
            d/Content.daml#Complementary" />
    </rdf:type>
- <lom-tech:location>
    <xsd:string rdf:value="Gauss_Pivot.html" />
</lom-tech:location>
<ns0:supportsTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
        Content.daml# Método de Gauss com Pivotamento" />
- <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Programas do Maple em
        html" />
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
        metatadata#LOMv1.0" />
<lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
        educational#Expositive" />

```

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<lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
        educational#Lecture" />
<ns0:creator rdf:resource="#Prof.Angélica" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
        Content.daml# Matematicas" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
        Content.daml# Engenharia" />
<lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
        daml# Programas em Maple para download-S2-T2.2.2-D1">
    - <rdf:type>
        <daml:Class
            rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
                d/Content.daml#Complementary" />
        </rdf:type>
    - <lom-tech:location>
        <xsd:string rdf:value="Gauss_Pivot.mws" />
    </lom-tech:location>
    <ns0:supportsTo
        rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
            Content.daml# Método de Gauss com Pivotamento" />
    - <dc:description>
        <xsd:string xml:lang="pt-BR" rdf:value="Programas em Maple para
            download" />
    </dc:description>
    <dc:language rdf:resource="#pt-BR" />
    <lom-meta:metadataScheme
        rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
            metadata#LOMv1.0" />
    <lom-edu:interactivityType
        rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
            educational#Expositive" />
    <lom-edu:learningResourceType
        rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
            educational#Lecture" />
    <ns0:creator rdf:resource="#Prof.Angélica" />
    <ns0:isAvailableTo
        rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
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  metamodel#LOMv1.0" />
<lom-edu:interactivityType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Expositive" />
<lom-edu:learningResourceType
  rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
  educational#Lecture" />
<ns0:creator rdf:resource="#Prof. Angélica" />
<ns0:isAvailableTo
  rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
  Content.daml# Matematicas" />

```

```

<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Engenharia" />
<lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
    daml# Programas em PHP para demonstracao-S5-T2.2.3-D1">
- <rdf:type>
    <daml:Class
        rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
        d/Content.daml#Complementary" />
</rdf:type>
- <lom-tech:location>
    <xsd:string rdf:value="Ludecomp_p.php" />
</lom-tech:location>
<ns0:supportsTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Método da Decomposicao LU" />
- <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Programas em PHP para
    demonstracao" />
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metadata#LOMv1.0" />
<lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Expositive" />
<lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Lecture" />
<ns0:creator rdf:resource="#Prof. Angélica" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Matematicas" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Engenharia" />
<lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
- <rdf:Description
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/Content.
    daml# Programas em PHP para demonstracao-S6-T2.2.3-D1">
- <rdf:type>
    <daml:Class
        rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
        d/Content.daml#Complementary" />
</rdf:type>
- <lom-tech:location>
    <xsd:string rdf:value="Ludecomp2_pt.php" />
</lom-tech:location>
<ns0:supportsTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Método da Decomposicao LU" />
- <dc:description>
    <xsd:string xml:lang="pt-BR" rdf:value="Programas em PHP para
    demonstracao" />
</dc:description>
<dc:language rdf:resource="#pt-BR" />
<lom-meta:metadataScheme
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    metadata#LOMv1.0" />
<lom-edu:interactivityType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Expositive" />
<lom-edu:learningResourceType
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    educational#Lecture" />
<ns0:creator rdf:resource="#Prof. Angélica" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Matematicas" />
<ns0:isAvailableTo
    rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
    Content.daml# Engenharia" />

```

```
<lom-tech:requirement rdf:resource="#dial-up" />
</rdf:Description>
</rdf:RDF>
```

APPENDIX B DOMAIN ONTOLOGY

```

<?xml version="1.0" encoding="ISO-8859-1" ?>
<rdf:RDF xmlns:daml="http://www.daml.org/2001/03/daml+oil#"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  xmlns:dc="http://purl.org/dc/elements/1.1/#"
  xmlns:dom="http://www.inf.ufrgs.br/~tapejara/Ontology/Domain.daml#">
  <daml:Ontology rdf:about="">
    <dc:title>AdaptWeb Domain Ontology</dc:title>
    <dc:date>November of 2003</dc:date>
    <dc:creator>Lydia Silva Muñoz, José Palazzo Moreira de Oliveira.</dc:creator>
    <dc:description>Taxonomy of subjects for the Domain to be taught in the AdaptWeb Project.</dc:description>
    <dc:subject>Taxonomy of subjects of Algebra discipline</dc:subject>
    <daml:versionInfo>2.0</daml:versionInfo>
  </daml:Ontology>
  <daml:ObjectProperty rdf:about="http://purl.org/dc/terms/#isPartOf">
    <rdfs:comment xml:lang="en-US" />
  </daml:ObjectProperty>
  <daml:ObjectProperty rdf:about="http://purl.org/dc/terms/#hasPart">
    <rdfs:comment xml:lang="en-US" />
  </daml:ObjectProperty>
  <daml:ObjectProperty rdf:about="#isPartOf">
    <rdfs:comment xml:lang="en-US">Represents that the element is part of a whole. It can be a Topic being part of the educative material explaining a Discipline, or a Topic being part of the educative material explaining another Topic.</rdfs:comment>
    <rdfs:subPropertyOf rdf:resource="http://purl.org/dc/terms/#isPartOf" />
    <rdfs:domain>
      <daml:Class rdf:about="#Taxon" />
    </rdfs:domain>
  </daml:ObjectProperty>
  <daml:TransitiveProperty rdf:about="#isPartOf" />
  <daml:ObjectProperty rdf:about="#hasPart">
    <rdfs:comment xml:lang="en-US">Represents which topics form a discipline or other topic.</rdfs:comment>
    <rdfs:subPropertyOf rdf:resource="http://purl.org/dc/terms/#hasPart" />
    <daml:inverseOf rdf:resource="#isPartOf" />
  </daml:ObjectProperty>
  <daml:ObjectProperty rdf:about="#includedIn">
    <rdfs:comment xml:lang="en-US">Represents that the taxon is included in a particular taxonomy</rdfs:comment>
    <rdfs:subPropertyOf rdf:resource="http://purl.org/dc/terms/#isPartOf" />
    <rdfs:domain>
      <daml:Class rdf:about="#Taxon" />
    </rdfs:domain>
    <rdfs:range>
      <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-classification#Taxonomy" />
    </rdfs:range>
  </daml:ObjectProperty>
  <daml:TransitiveProperty rdf:about="#isPartOf" />
  <daml:Class rdf:about="#Taxon">
    <rdfs:comment xml:lang="en-US">Subject in the taxonomy.</rdfs:comment>
  </daml:Class>
  <rdf:Description rdf:about="#Algebra">
    <rdf:type>

```

```

        <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
            classification#Taxonomy" />
        </rdf:type>
    </rdf:Description>
    - <rdf:Description rdf:about="#Linear Algebra">
        - <rdf:type>
            <daml:Class rdf:about="#Taxon" />
            </rdf:type>
            <dom:isPartOf rdf:resource="#Algebra" />
        </rdf:Description>
    - <rdf:Description rdf:about="#Abstract Algebra">
        - <rdf:type>
            <daml:Class rdf:about="#Taxon" />
            </rdf:type>
            <dom:isPartOf rdf:resource="#Algebra" />
        </rdf:Description>
    - <rdf:Description rdf:about="#Linear Dependency">
        - <rdf:type>
            <daml:Class rdf:about="#Taxon" />
            </rdf:type>
            <dom:isPartOf rdf:resource="#Linear Algebra" />
        </rdf:Description>
    - <rdf:Description rdf:about="#Linear Transformations">
        - <rdf:type>
            <daml:Class rdf:about="#Taxon" />
            </rdf:type>
            <dom:isPartOf rdf:resource="#Linear Algebra" />
        </rdf:Description>
    - <rdf:Description rdf:about="#Linear Systems">
        - <rdf:type>
            <daml:Class rdf:about="#Taxon" />
            </rdf:type>
            <dom:isPartOf rdf:resource="#Linear Transformations" />
        </rdf:Description>
    - <rdf:Description rdf:about="#Canonical Forms">
        - <rdf:type>
            <daml:Class rdf:about="#Taxon" />
            </rdf:type>
            <dom:isPartOf rdf:resource="#Linear Transformations" />
        </rdf:Description>
    - <rdf:Description rdf:about="#Linear Systems Direct Solution Methods">
        - <rdf:type>
            <daml:Class rdf:about="#Taxon" />
            </rdf:type>
            <dom:isPartOf rdf:resource="#Linear Systems" />
        </rdf:Description>
    - <rdf:Description rdf:about="#Linear Systems Iterative Solution Methods">
        - <rdf:type>
            <daml:Class rdf:about="#Taxon" />
            </rdf:type>
            <dom:isPartOf rdf:resource="#Linear Systems" />
        </rdf:Description>
    - <rdf:Description rdf:about="#Gauss Method">
        - <rdf:type>
            <daml:Class rdf:about="#Taxon" />
            </rdf:type>
            <dom:isPartOf rdf:resource="#Linear Systems Direct Solution Methods"
                />
        </rdf:Description>
    - <rdf:Description rdf:about="#Gauss Method with Pivoting">
        - <rdf:type>
            <daml:Class rdf:about="#Taxon" />
            </rdf:type>
            <dom:isPartOf rdf:resource="#Linear Systems Direct Solution Methods"
                />
        </rdf:Description>
    - <rdf:Description rdf:about="#LU Factorization">
        - <rdf:type>
            <daml:Class rdf:about="#Taxon" />
            </rdf:type>
            <dom:isPartOf rdf:resource="#Linear Systems Direct Solution Methods"
                />
        </rdf:Description>
    - <rdf:Description rdf:about="#Cholesky Factorization">
        - <rdf:type>
            <daml:Class rdf:about="#Taxon" />
            </rdf:type>

```

```
<dom:isPartOf rdf:resource="#Linear Systems Iterative Solution
    Methods" />
</rdf:Description>
- <rdf:Description rdf:about="#Jacobi Method">
  - <rdf:type>
    <daml:Class rdf:about="#Taxon" />
  </rdf:type>
  <dom:isPartOf rdf:resource="#Linear Systems Iterative Solution
    Methods" />
</rdf:Description>
- <rdf:Description rdf:about="#Gauss-Seidel Method">
  - <rdf:type>
    <daml:Class rdf:about="#Taxon" />
  </rdf:type>
  <dom:isPartOf rdf:resource="#Linear Systems Iterative Solution
    Methods" />
</rdf:Description>
</rdf:RDF>
```

APPENDIX C STUDENT ONTOLOGY

```

<?xml version="1.0" encoding="ISO-8859-1" ?>
<rdf:RDF xmlns:daml="http://www.daml.org/2001/03/daml+oil#"
           xmlns:dc="http://purl.org/dc/elements/1.1/#"
           xmlns:dcterms="http://purl.org/dc/terms/#"
           xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
           xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#" xmlns:lom-
           edu="http://kmr.nada.kth.se/el/ims/schemas/lom-educational#" xmlns:lom-
           tech="http://kmr.nada.kth.se/el/ims/schemas/lom-technical#" xmlns:lom-
           meta="http://kmr.nada.kth.se/el/ims/schemas/lom-metametadata#" xmlns:lom-
           lom="http://kmr.nada.kth.se/el/ims/schemas/lom-base#" xmlns:lom-
           life="http://kmr.nada.kth.se/el/ims/schemas/lom-lifecycle#" xmlns:vcard="http://www.w3.org/2001/vcard-rdf/3.0#"
           xmlns:ns0="http://www.inf.ufrgs.br/~tapejara/Ontology/Student.daml#"
           xmlns:xsd="http://www.w3.org/2000/10/XMLSchema#">
  <daml:Ontology rdf:about="">
    <dc:title>Student Knowledge Ontology</dc:title>
    <dc:date>November of 2003</dc:date>
    <dc:creator>Lydia Silva Muñoz, José Palazzo Moreira de Oliveira.</dc:creator>
    <dc:description>Student Profile Repository of the Adaptive Hypermedia System AdaptWeb.</dc:description>
    <dc:subject>Student Profile</dc:subject>
    <daml:versionInfo>2.0</daml:versionInfo>
  </daml:Ontology>
  <daml:ObjectProperty rdf:about="#hasLearningStyle">
    <rdfs:comment xml:lang="en-US">Indicates the Cognitive Style of Learning the student has.</rdfs:comment>
    <rdfs:domain>
      <daml:Class rdf:about="#Student" />
    </rdfs:domain>
    <rdfs:range>
      <daml:Class rdf:about="#CognitiveLearningStyle" />
    </rdfs:range>
  </daml:ObjectProperty>
  <daml:UniqueProperty rdf:about="#hasLearningStyle" />
  <daml:ObjectProperty rdf:about="#hasLearningGoal">
    <rdfs:comment xml:lang="en-US">Indicates a Course the student is taking.</rdfs:comment>
    <rdfs:domain>
      <daml:Class rdf:about="#Student" />
    </rdfs:domain>
    <rdfs:range>
      <daml:Class
        rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
                  d/AWOntology.daml#Course" />
    </rdfs:range>
  </daml:ObjectProperty>
  <daml:ObjectProperty rdf:about="#hasKnowledgeOn">
    <rdfs:comment xml:lang="en-US">Indicates a topic the student has knowledge about.</rdfs:comment>
    <rdfs:domain>
      <daml:Class rdf:about="#Student" />
    </rdfs:domain>
    <rdfs:range>
      <daml:Class
        rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
                  d/AWOntology.daml#Topic" />
    </rdfs:range>
  </daml:ObjectProperty>
  <daml:ObjectProperty rdf:about="#hasNetworkConnection">

```

```

<rdfs:comment xml:lang="en-US">Indicates the current network
connection of the student.</rdfs:comment>
- <rdfs:domain>
  <daml:Class rdf:about="#Student" />
</rdfs:domain>
- <rdfs:range>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
    d/AWOntology.daml#NetworkConnection" />
</rdfs:range>
</daml:ObjectProperty>
<daml:UniqueProperty rdf:about="#hasNetworkConnection" />
- <daml:DatatypeProperty rdf:about="#locationLearningTrajectoryWF">
  <rdfs:comment xml:lang="en-US">Indicates the location of a learning
  trajectory tailored to the student profile.</rdfs:comment>
- <rdfs:domain>
  <daml:Class rdf:about="#Student" />
</rdfs:domain>
</daml:DatatypeProperty>
<daml:UniqueProperty rdf:about="#locationLearningTrajectoryWF" />
- <daml:DatatypeProperty rdf:about="#wantsTutorial">
  <rdfs:comment xml:lang="en-US">Indicates if the student currently
  wants to work in a tutorial mode.</rdfs:comment>
- <rdfs:domain>
  <daml:Class rdf:about="#Student" />
</rdfs:domain>
</daml:DatatypeProperty>
- <daml:DatatypeProperty rdf:about="http://www.w3.org/2001/vcard-rdf/3.0#FN">
  <rdfs:comment xml:lang="en-US">Formal Name.</rdfs:comment>
</daml:DatatypeProperty>
- <daml:Class rdf:about="#Student">
  <rdfs:comment xml:lang="en-US">A registered student.</rdfs:comment>
  <rdfs:subClassOf
    rdf:resource="http://kmr.nada.kth.se/el/ims/schemas/lom-
    base#Entity" />
</daml:Class>
- <daml:Class rdf:about="http://kmr.nada.kth.se/el/ims/schemas/lom-
  base#Entity">
  <rdfs:comment xml:lang="en-US">Instances of this class are persons or
  organizations, described by VCards.</rdfs:comment>
</daml:Class>
- <daml:Class rdf:about="#CognitiveLearningStyle">
  <rdfs:comment xml:lang="en-US">Its individuals are the possible
  Cognitive Style of Learning a student could have.</rdfs:comment>
</daml:Class>
- <rdf:Description rdf:about="#Analogue-Analitical">
  - <rdf:type>
    <daml:Class rdf:about="#CognitiveLearningStyle" />
  </rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="#Concrete-Generic">
  - <rdf:type>
    <daml:Class rdf:about="#CognitiveLearningStyle" />
  </rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="#Deductive-Evaluative">
  - <rdf:type>
    <daml:Class rdf:about="#CognitiveLearningStyle" />
  </rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="#Relational-Synthetic">
  - <rdf:type>
    <daml:Class rdf:about="#CognitiveLearningStyle" />
  </rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
  gy.daml# Matematicas">
  - <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
      d/AWOntology.daml#Course" />
  </rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
  gy.daml# Computacao">

```

```

- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
d/AWOntology.daml#Course" />
</rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
gy.daml# Engenharia">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
d/AWOntology.daml#Course" />
</rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
gy.daml#dial-up">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
d/AWOntology.daml#NetworkConnection" />
</rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
gy.daml#fast">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
d/AWOntology.daml#NetworkConnection" />
</rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
gy.daml# Contexto e Objetivos da Computação Algébrica e Numérica">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
d/AWOntology.daml#Topic" />
</rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
gy.daml# Sistemas Lineares de Equações Algébricas">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
d/AWOntology.daml#Topic" />
</rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
gy.daml# Introducao">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
d/AWOntology.daml#Topic" />
</rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
gy.daml# Métodos Diretos">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
d/AWOntology.daml#Topic" />
</rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
gy.daml# Métodos Iterativos">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
d/AWOntology.daml#Topic" />
</rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
gy.daml# Métodos Iterativos">
- <rdf:type>
  <daml:Class
    rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
d/AWOntology.daml#Topic" />
</rdf:type>

```

```

</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
  gy.daml# Método de Jacobi">
  - <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
      d/AWOntology.daml#Topic" />
  </rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
  gy.daml# Método de Gauss-Seidel">
  - <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
      d/AWOntology.daml#Topic" />
  </rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
  gy.daml# Método de Gauss">
  - <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
      d/AWOntology.daml#Topic" />
  </rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
  gy.daml# Método de Gauss com Pivotamento">
  - <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
      d/AWOntology.daml#Topic" />
  </rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
  gy.daml# Método da Decomposicao LU">
  - <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
      d/AWOntology.daml#Topic" />
  </rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
  gy.daml# Método de Cholesky">
  - <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
      d/AWOntology.daml#Topic" />
  </rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
  gy.daml# Condicionamento de Matrizes">
  - <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
      d/AWOntology.daml#Topic" />
  </rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
  gy.daml# Algoritmo Triangularizacao">
  - <rdf:type>
    <daml:Class
      rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generate
      d/AWOntology.daml#Topic" />
  </rdf:type>
</rdf:Description>
- <rdf:Description
  rdf:about="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/AWOntolo
  gy.daml# Algoritmo Retrosubstituicao">
  - <rdf:type>

```

```
<daml:Class
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d/AWontology.daml#Topic" />
</rdf:type>
</rdf:Description>
- <rdf:Description rdf:about="#German">
-   <rdf:type>
-     <daml:Class rdf:about="#Student" />
-   </rdf:type>
-   <ns0:hasKnowledgeOn
      rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
      AWontology.daml# Contexto e Objetivos da Computação Algébrica e
      Numérica" />
-   <vcard:FN>
-     <xsd:string rdf:value="German Cuello" />
-   </vcard:FN>
-   <ns0:wantsTutorial>
-     <xsd:string rdf:value="false" />
-   </ns0:wantsTutorial>
-   <ns0:hasLearningStyle rdf:resource="#Relational-Synthetic" />
-   <ns0:hasNetworkConnection
      rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
      AWontology.daml#dial-up" />
-   <ns0:hasLearningGoal
      rdf:resource="http://www.inf.ufrgs.br/~tapejara/Ontology/Generated/
      AWontology.daml# Computacao" />
- </rdf:Description>
</rdf:RDF>
```

APPENDIX D METADADOS PARA CONTEÚDO EDUCATIVO COM BASE EM ONTOLOGIAS.

Introdução

A popularidade da Web tem motivado grandemente o desenvolvimento de Sistemas Hipermídia dedicados ao *e-learning*. A Web libera ao professor e ao aluno de restrições relacionadas com o espaço e o tempo, no entanto que fornece um veículo para disseminar conhecimento.

A respeito dos Sistemas Hipermídia dedicados ao *e-learning*, a adaptabilidade do conteúdo educativo ao perfil de cada aluno, e a possibilidade de interoperar na Web reutilizando o dito conteúdo entre diferentes aplicações de ensino a distância são assuntos de intensiva pesquisa.

O trabalho apresentado aqui envolve pesquisa relativa ao uso das tecnologias da *Web Semântica* para atingir interoperabilidade e melhorar a adaptabilidade de Sistemas Hipermídia dedicados ao *e-learning*.

Recentes esforços no desenvolvimento do RDF *framework* (Lassila, 1998; Lassila & Swick, 1999) e na linguagem RDF *schema* (Brickley & Guha, 2000) para a representação de estruturas que permitam transportar semântica na Web foram concebidos para fazer a realização do conceito da *Web Semântica* possível (Berners-Lee, 1999; 2000). Linguagens mais expressivas, como DAML+OIL (Connolly et al., 2001; 2001b) e OWL (Bechhofer et al., 2003) contribuem para este propósito.

O fundamento da *Web Semântica* é a explícita representação do conhecimento que descreve os recursos da Web de maneira que seja possível atingir não somente o processamento destes recursos, mas também o entendimento da sua semântica por agentes automáticos. Isto envolve metadados que descrevem a semântica das estruturas usadas para atingir interoperabilidade no nível semântico.

Por sua vez, os Sistemas Hipermídia Adaptativos (SHA) modelam o conhecimento relativo ao perfil do estudante e ao domínio que vai se ensinar, com o propósito de adaptar o conteúdo educativo ao perfil de cada estudante (Brusilovsky, 1998; Brusilovsky, 1999; Rousseau, Garcia-Macías, Valdeni & Duda, 1999; Brusilovsky, 2002; Souto et al., 2002). O conhecimento relativo ao perfil do estudante é composto de informações que descrevem as características mais relevantes do estudante para o propósito de atingir adaptabilidade. O conhecimento relativo ao domínio a ser ensinado é composto da descrição de cada sujeito elementar que conforma o dito espaço de conhecimento e das inter-relações existentes entre eles.

O objetivo deste trabalho é duplo. O primeiro objetivo é fazer uma análise dos fundamentos da Web Semântica e definir uma metodologia para usar as suas tecnologias para melhorar a adaptabilidade e atingir interoperabilidade no domínio dos SHA. O segundo objetivo é a aplicação da metodologia definida no sistema *AdaptWeb*. O *AdaptWeb* é um ambiente para ensino adaptativo na Web atualmente em desenvolvimento na Universidade Federal do Rio Grande do Sul.

Para atingir o primeiro objetivo foram estudados os resultados da pesquisa em Ontologias e também em representação de metadados para conteúdo educativo na Web. De acordo com o pesquisado, a proposta da figura 1 foi formulada para atingir interoperabilidade e fazer adaptação no Sistema *AdaptWeb* mediante o uso das tecnologias da Web Semântica.

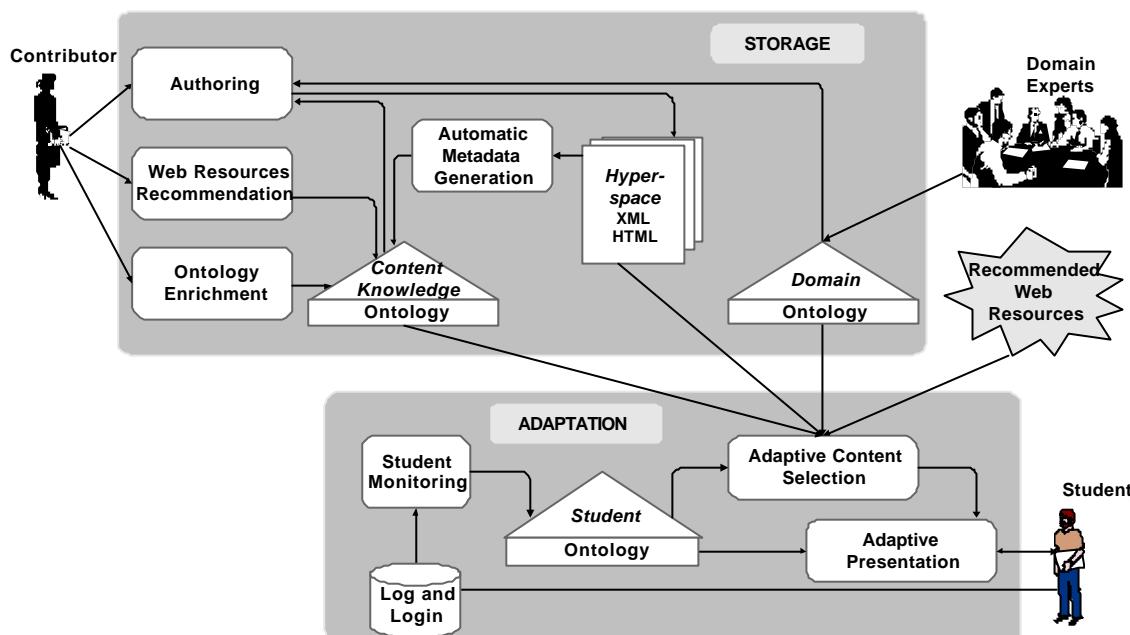


Figura 1: Arquitetura proposta para o sistema *AdaptWeb*.

Na arquitetura proposta um módulo de autoria fornece ao autor (*Contributor*) uma metodologia e uma ferramenta de edição para criar os elementos de conteúdo educativo do sistema: O *Hyperspace*.

Três ontologias foram implementadas, a *Domain Ontology* contém o conhecimento sobre a estrutura do domínio a ser ministrado, A *Student Ontology* contém o conhecimento sobre o perfil de cada estudante, e finalmente a *Content Knowledge Ontology* é capaz de fornecer regras de composição para a configuração de objetos de ensino complexos e adequados ao perfil do aluno a partir de outros mais simples. Seu vocabulário está baseado no padrão LOM (IEEE Learning Technology Standards Committee, 2002) para representação de metadados de conteúdo educativo.

Durante o processo de autoria, o autor pode consultar a ontologia do domínio (*Domain Ontology*) para estar ao tanto da estrutura do domínio de conhecimento que se planeja ensinar e indicar a qual elemento do domínio corresponde o conteúdo educativo que está sendo criado. Aliás, ele pode estar informado dos elementos do conteúdo

educativo que já existem no sistema e eventualmente reusar eles como parte do conteúdo que está sendo criado.

Toda vez que novo conteúdo educativo é colocado no *Hyperspace* do sistema, o *wrapper Automatic Metadata Generation* gera a metadata básica que descreve cada elemento do novo conteúdo em triplas RDF que coloca na ontologia *Content Knowledge Ontology*.

O enriquecimento da ontologia *Content Knowledge Ontology* por edição faz com que agentes humanos possam aumentá-la em qualquer momento. A recomendação de recursos da Web como adequados, para apoiar a representação de um tópico para um aluno (*Web Resources Recommendation*), é feita indicando as principais características do recurso e identificando ao professor que fez a recomendação.

Por sua vez, a ontologia do estudante (*Student Ontology*), que contém as características do aluno relevantes para adaptabilidade, é atualizada segundo as atividades do estudante no sistema. Finalmente, ela é levada em conta no momento em que o agente *Adaptive Content Selection* escolhe a melhor trajetória de aprendizado para o aluno.

O módulo *Adaptive Presentation* determina o estilo de apresentação, do conteúdo educativo levando em conta as preferências de apresentação do aluno que estão modeladas na *Student Ontology*.

No início deste trabalho o módulo de Autoria já tinha sua implementação feita, e o *Hyperspace* do sistema tinha um caso de prova relativo à disciplina *Computação Algébrica e Numérica*. Os elementos a seguir foram implementados como parte do trabalho em descrição.

- A *Domain Ontology*
- A *Content Knowledge Ontology*
- A *Student Ontology*
- O wrapper *Automatic Metadata Generation*
- O módulo *Web Resources Recommendation*

A seguir serão apresentados os tópicos tratados nos capítulos deste trabalho.

Sistemas Adaptativos

No primeiro capítulo são apresentados os fundamentos dos Sistemas Hipermídia Adaptativos (SHA). Os diferentes espaços de conhecimento de um SHA são descritos, isto é, o *Knowledge Space* e o *Hyperspace*, e as conexões entre eles caracterizadas. As considerações a levar em conta no momento de fazer o modelo do estudante também são apresentadas e exemplos de ditos modelos são fornecidos.

Metadados

O terceiro capítulo introduz metadados, dá uma explicação da sua utilidade, detalha as suas principais características e os classifica segundo diferentes critérios. O importante

papel dos metadados na Web, como parte da emergente *Web Semântica* é salientado, definindo conceitos como *Namespace Schemas*, *Application Profiles*, *Crosswalks* e *Metadata Registries*.

O *Dublin Core Metadata Element Set (DCMES)* é apresentado como um importante referencial para a semântica dos metadados na Web, e o *Resource Description Framework (RDF)* é introduzido como o atual padrão para intercâmbio de metadados na Web com alguns exemplos para mostrar o seu uso. O *RDF Schema* é apresentado como a linguagem que pode ser usada para definir vocabulários para usar em descrições RDF, e um completo exemplo do uso de RDF Schema é fornecido com a sua correspondente serialização em XML.

Finalmente, o padrão para representação de metadados do domínio educativo *Learning Object Metadata (LOM)* é apresentado, o seu modelo, propósito e condições de uso explicados, assim como também um *RDF binding* que permite a sua implementação em RDF.

Ontologias

O capítulo quatro inicia dando algumas definições que introduzem o conceito de ontologia e uma detalhada caracterização dos seus componentes que é acompanhada por um exemplo. A seguir uma categorização por diversas dimensões é apresentada, e uma extensa lista de áreas onde as ontologias são usadas é fornecida.

Alguns critérios para apoiar o projeto de ontologias são apresentados e uma descrição detalhada dos principais tipos de linguagens que têm influencia nas ontologias a serem usadas na Web é fornecida. Isto é, *Description Logics* e *Frame-based systems* são explicados com ajuda de exemplos, para finalmente concluir na descrição detalhada da linguagem usada na implementação dos protótipos deste trabalho: DAML+OIL.

As últimas seções do capítulo estão dedicadas a apresentar recursos para editar e raciocinar sobre ontologias, com uma simples enumeração das possíveis operações que um *reasoner* pode fazer.

Repositório de Metadados do Sistema AdaptWeb

O capítulo final relata o trabalho realizado para a obtenção dos dois objetivos propostos. Em primeiro lugar o projeto de uma metodologia para aplicar as tecnologias da Web Semântica para atingir interoperabilidade e adaptabilidade é proposta. A continuação o resultado da aplicação de dita metodologia ao projeto AdaptWeb é apresentado.

Uma visão geral do trabalho feito pode se ver na figura 2, onde círculos indicam atividades e retângulos indicam resultados obtidos. Setas indicam a entrada ou saída de resultados de atividades.

Os resultados nomeados *Repositório Hipermídia*, *Padrão para metadados LOM* e *Student Workflow* não são resultados deste trabalho. As áreas brancas não são cobertas por este trabalho, mas são incluídas por claridade. Aliás os elementos pontilhados representam resultados a serem obtidos em tempo de execução.

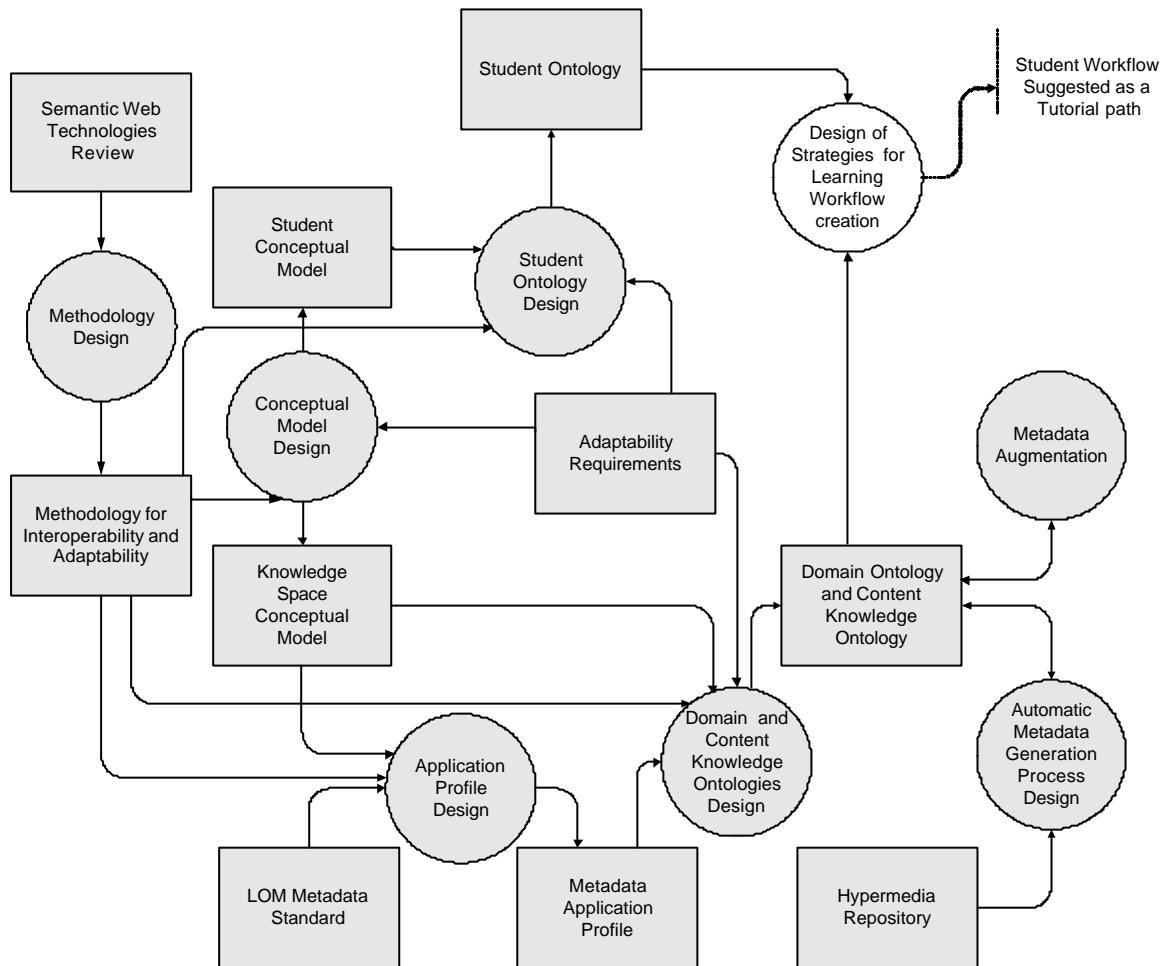


Figura 2: Visão Geral

Uma vez que as tecnologias da Web Semântica foram estudadas e uma metodologia para usá-las para atingir interoperabilidade e adaptabilidade projetada, os principais requerimentos de adaptabilidade do sistema no que a metodologia ia se provar (o AdaptWeb) foram identificados na etapa de análise. Com base nestes requerimentos, o Modelo Conceitual do sistema foi feito, consistindo do Modelo Conceitual do Estudante e do Modelo Conceitual do *Knowledge Space* do sistema.

Com base no Modelo Conceitual do Estudante a ontologia *Student Ontology* foi implementada.

A partir do Modelo Conceitual do *Knowledge Space* do sistema e da especificação do padrão para representação de metadados LOM foi desenvolvido um novo *application profile* do LOM adequado ao contexto educativo do projeto AdaptWeb.

Com base nos requerimentos de adaptabilidade e o vocabulário definido no *application profile* a *Content Knowledge Ontology* foi projetada e implementada para manter o conhecimento do sistema sobre cada pedaço de conteúdo educativo e as regras necessárias para construir complexos objetos de ensino a partir de outros mais simples. Aliás, a *Domain Ontology* foi implementada para conter o conhecimento sobre a estrutura do domínio a ser ministrado.

Para popular a *Content Knowledge Ontology* com instâncias que descrevem o *Hyperspace* do sistema foi implementado um *wrapper* que gera automaticamente descrições RDF de cada pedaço de conteúdo educativo existente no repositório Hipermídia (o *Hyperspace*).

Finalmente foi desenvolvido um procedimento para acrescentar o repositório de metadados com recomendações de conteúdo educativo da Web não criado no sistema, mas considerado de importância para apoiar a exposição de algum tópico a ser ministrado.

Conclusões e Trabalhos Futuros

O capítulo 6 está voltado a resumir os objetivos e logros do trabalho feito, a enumerar as contribuições dele, e aquele conjunto de trabalhos relacionados que poderiam ser feitos no futuro.