

Integration of Hyperbooks into the Semantic Web

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Abstract

A crucial aspect in the Semantic Web is the capacity to add meaning to information, such as it can be processed by non-human actors. The creation of ontologies is a common solution. But it does not seem realistic to represent this information on a central server, as this model would not reflect the characteristics of presently used, non-centralized networks like the current Web. Therefore we are confronted with a huge number of locally developed and stored ontologies, and we need some kind of integration techniques to connect ontologies developed for the Semantic Web. In this article, we describe our experience with ontology-based e-learning systems and we propose a mechanism to integrate such systems into a Semantic Web context. We concretely present our hyperbook model and show how these books can be integrated into digital libraries by an ontology mapping procedure.

1 Introduction

Most of the digital libraries available on the Web are collections of documents stored on a document server where users can for instance use full-text search engines. Results are then presented in title lists with annotated, small informational fragments of the (perhaps) most relevant documents. By clicking on these references, users can see the whole text or information, which is stored in the form of a PDF-file or in a similar format. Such systems are simple to build, but have their drawbacks. From the semantic point of view, they are in fact static hypertext systems. There is no semantic representation of the content, and different systems and servers are not interrelated.

Even if most Web sites have a dynamic part, it is normally limited to information, which is semantically poor and which can be easily stored in a common database management system. For instance, most e-commerce shops have such functionalities. A virtual bookstore has information about titles, authors, page-numbers and prices, but the con-

tent of the books is often not formally represented. Systems including formal concept representation give for instance the ability of a non-linear reading or the presentation of narratives in multiple forms. Therefore, we propose an approach that allows fragmenting text sources and linking these fragments to domain ontologies. This is the main idea of what we call a hyperbook.

Such a dynamic hyperbook model results in a local, non-centralized and heterogeneous system. Heterogeneity is one of the characteristics of the Web and we anticipate it to be a permanent one. We even believe that one of the major keys to the success of the Internet is the heterogeneity of the systems where all users may create the pages in their own way. When building semantic web applications, we should not restrict authors by building the content. We furthermore should try to find solutions that involve a great flexibility. But to avoid the risk that users create isolated systems, we propose to assemble many hyperbooks into a digital library. The main task of this process is the integration of different domain ontologies.

The ontology integration problem is one of the most challenging tasks in the Semantic Web. The integration procedure for digital libraries we present uses specific properties of hyperbooks or similar e-learning systems like fragments, documents and personalization elements. But we can imagine that the approach could be extended to other domains, to the extent that there is a good information base or a document repository available.

The paper is organized as follows: Section 2 describes the existing research in the domain of hyperbooks and presents our model. Section 3 includes the step from hyperbooks to a digital library, and section 4 concludes the article with an outlook about future research questions.

2 Hyperbooks

There is presently no consensus on a common virtual document or hyperbook model. Nevertheless, most of the proposed models are comprised of (at least) a domain ontology and a fragment base. These models generally differ on the user interface part, i.e. how to specify the production of

user-readable documents (with declarative languages, through specific ontologies, with inference rules, etc.). Crampes and Ranwez [Crampes and Ranwez, 2000] propose two models of virtual documents. Both of them use domain ontologies for indexing informational fragments (the resources). In the first case, a “conceptual backward chaining” strategy can construct reading paths corresponding to the user objectives (described in terms of conceptual graphs). In the second case, a pedagogical ontology defines teaching rules, which guide the assembling of fragments to produce documents with respect to a predefined pedagogical approach. These rules, in particular, force the order of appearance of information in the documents. An inference engine generates documents that satisfy these rules.

Iksal and Garlatti [Iksal and al., 2001] propose a comprehensive and detailed model of virtual documents. It is based on four ontologies for modeling the domain, the metadata, the applications and the user. These ontologies allow a fully declarative approach to document composition.

The InterBook adaptative hyperbook project [Brusilovsky et al., 1998a] is based on two models: The domain model and the student model. The domain model is represented by a network whose nodes correspond to domain concepts and links to their relationships. In fact, the domain model corresponds to wath is named ontology in many research paper. The student model describes the student knowledge as well as the student learning goals, both expressed in terms of the concepts of the domain model. A glossary is used to describe the navigational paths in an InterBook hyperbook. Several books can be integrated in a bookshelf. They are connected by sharing the same set of domain concepts.

Another approach is the Scholarly Ontologies (ScholOnto) project [Buckingham Shum et al., 2000]. It defines a digital library server that supports multiple and possible conflicting interpretations of a research document. Essential parts are the formalized encoding of interpretations of a scholarly document and the compilation to create semantic hypertexts. Objects (concepts or data) are connected by multi-typed links defining the properties of the objects. Reading a document is defined as going through a set of *claims*. Claims are the basics of formalized interpretations, which are considered as two connected objects and a (optional) typed link. The result is a set of semantic annotations about the document's contributions like citations to other key literature. As we will see, this approach is similar to our hyperbook model in the way in which links are typed.

[Dicheva et al., 2004] present a framework for standards-based, ontology-aware course libraries and an environment for building, maintaining, and using such libraries. The aim is to provide a system build of (existing) learning resources to assist students. The system is topic-map based that allows authors to describe the metadata of their learning material according to Dublin Core (DCMI) or IEEE LOM. The model is close to our approach in the way relationships were represented. Each relationship has a type and authors can use a pool of predefined relationship types.

Bocconi [Bocconi, 2003] describes a hypertext generation system to automatically select and compose scholarly hypermedia. The presented content is generated through a domain ontology containing the concepts and their relations and a discourse ontology containing different roles and narrative units describing different genres. The discourse ontology holds a very detailed and highly formalized description of the points of interest that a user can have about a domain. By integrating hyperbooks into digital libraries, we should also consider the question how to integrate elements stored apart of the domain ontology like essentials for hypertext personalization purposes. For this task, the above-mentioned model seems to be very interesting and might be a good base.

In general, the hypertext personalization problem [Brusilovsky, 1998b] seems essential for developing hyperbook systems in the domain of e-learning. In [Wu and al., 2001], the authors propose a model of adaptive hypertext which includes a domain model, a user model and adaptation rules. The domain model is a semantic network consisting of domain concepts and relations between concepts. This model serves essentially to define adaptation rules, depending, for instance, on the concepts known or appropriated by the user. We have included in a similar way some adaptive mechanisms like points of view into our system [Falquet and al., 2004].

A new research field has emerged in the last years that concentrates on the concept of personalizable virtual documents [Crampes, 1999; Garlatti and Iksal, 2001]. Personalizable virtual documents are defined as sets of elements (often called fragments) associated with filtering, organization and assembling mechanisms. According to a user profile or user intensions, these mechanisms will produce different documents adapted to the user needs. The model we will present is based on this approach.

Our hyperbook model is build upon a *fragment repository*, a *domain ontology*, and an *interface specification* [Falquet and Ziswiler, 2003]. The fragments and the ontology including their interconnecting links form the structural part of the hyperbook (Figure 1).

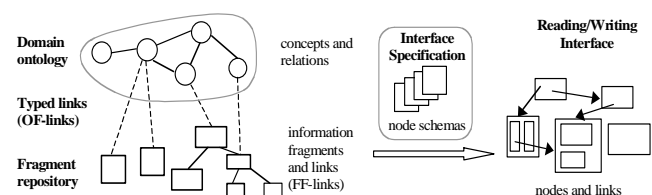


Figure 1. The hyperbook structure

The basic informational contents of the hyperbook are made of reusable fragments. These fragments can be small texts, or even illustrations or programming code, but we want to avoid that authors write large fragments. They have to divide the content sources like documents and to place the created fragments around concepts. Fragments are con-

nected by structural links, for instance from fragments to sub-fragments. These typed links indicate the roles they played in a group of fragments (compound fragments). For instance an exercise could be made up of a question fragment, one or more answer fragments, and a discussion.

The semantic structure is described by a domain ontology. It is intended to hold a formal representation of the domain's concepts and used for indexing or qualifying the fragments.

By establishing typed links between fragments and concepts, the information content stored in the fragments is referenced by the concepts of the domain ontology. This shows relations between the fragments and the concepts, but also put the fragment into a context or a semantic environment. Typical link types are *Definition*, *Property*, *Example*, *Illustration*, *Exercise*, *Instance*, or *Reference*. Link types should be predefined, such as authors of a hyperbook can choose of a limited number of unambiguous defined link types.

The fragment-ontology structure allows representing different elements of an e-learning system. Domain knowledge can be represented in different, sometimes contradictory ways according to pedagogical or narrative purposes. Besides, we can annotate concepts with examples, illustrations, exercises and solutions. Even a discussion is possible (*topic* and *message* fragments connected through *about* and *reply-to* links), and authors can give their opinion about a subject (arguments, opinions).

This hyperbook structure enables to generate different hypertext views. As the number of concepts in the ontology is generally much smaller than the number of information fragments, the user can browse the ontology and then go down to the connected fragments. Fig. 2 shows an extract of a hyperbook that we have used in a computer science course this year. Around a concept, we found links to other concepts (some of them are even automatically generated by link inference techniques) and annotated fragments like comments and examples.

The screenshot shows a web interface for a virtual hyperbook. At the top, there are navigation links: [New Fragment] [Enter] [Concepts] [Fragments] [My Fragments] [Upload]. The main content area is divided into several sections:

- Finite-state Machine** (ofsi): A Finite-state Machine is composed of
 1. An alphabet of symbols $A = \{s_1, s_2, \dots, s_n\}$
 2. A set of states $Q = \{q_1, q_2, \dots, q_n\}$
 3. A initial state q_1 included in Q
 4. A set of final states included in Q
 5. A transition function d of $Q \times A$ in Q
- Concepts**:
 - <- reference Regular Language
 - <- reference Accepting a string
 - <- [Equivalence] -> FSM non-deterministic
 - <- [Comparison] -> Turing Machine
- Fragments**:
 - Definition**: FSM – general remarque
 - Example**: Tennis and FSM
- Comment**: A finite-state Machine is deterministic, intuitively if there is only one way of resolution for a given word: being given a initial state and a character, there is not more than one final state.

At the bottom of the main content area, there are links: [Modify] [Delete] [Create].

Figure 2. An extract of a virtual hyperbook

This model seems more adequate to e-learning purposes than approaches that are based on large ontology repositories, sometimes also of several types of ontologies (top-level

ontology, application ontology). Our experience has shown that people are more used building small text fragments and annotating them with the most important concepts of the domain than creating complex ontology structures. The result will be small, but expressive domain ontologies. Of course, a more formal representation of the content might have advantages for the ontology integration process. In the next section, we show how we integrate such small ontologies by using the fragment repositories.

3 From the Hyperbook to a Digital Library by Ontology Alignment

As all the hyperbook models presented above are based on ontologies, the integration of them plays a major role in the domain of virtual books and *a fortiori* in the domain of virtual libraries. If we suppose that each virtual book has its own domain ontology, we need an integration technique to be able to create a semantically coherent virtual library. It is important to note here that it is not very realistic to suppose that all the books will be annotated to the same (global) ontology, because either such an ontology does currently not exist or even if it exists, it contains only stable and well-established concepts and will not have the desired level of specialization or diversity. Thus, it won't be convenient for books on new and advanced topics.

Our ontology integration approach consists in preserving the concepts and the links of the initial ontologies and to establish relations of equivalences between elements of the origin ontologies. This approach seems to be much more flexible beside a complete fusion of the hyperbook's ontologies. The original hyperbook ontology is still persistent that will allow further development of parts of it by his initial author. In the domain of e-learning with non-centralized, semantic information systems, we have to consider that content is under a permanent evolution process. New parts of documents will continuously arrive in the Digital Library.

We are focusing on work that is based on *alignment* techniques. This means to bring two ontologies into mutual agreement by extending the ontology with drawing links between concepts [Klein, 2001]. As subcategory, *mapping* ontologies means relating similar concepts or relations from different ontologies to each other by an equivalent relation. In both cases, the existing ontologies will persist.

Some heuristics for semi-automatic ontology integration can be found in different approaches, they are based either on identifying structural or naming similarities like it can be found in the SMART algorithm [Noy and Musen, 1999] (now integrated in the interactive ontology merging tool PROMPT) or on machine learning techniques, used for instance in the GLUE system [Doan and al., 2002]. Other approaches like OBSERVER [Mena and al., 2000] use semantic interrelations (limited to the analysis of taxonomic relations) to specify mappings between (not synonymous) concepts of two ontologies. It defines lower and upper bounds for the precision and recall of ontology-crossing queries that are based on manually defined subsumption relations.

As conclusion of this introduction part into ontology integration, we will remain the following points:

- Ontology integration is essential for building Digital Libraries or semantic web applications, because it seems not realistic to assume that there exists one common ontology that covers all the domains and subjects. Using local domain ontologies allow users to express concepts in a higher explicitness.
- Automatic ontology mapping for building Digital Libraries is a *multi-level* task. We should take advantage of the larger information base of the hyperbooks (taxonomic relations between concepts, but also other *attributes* of the concepts and especially *instances* and annotated *fragments* or *documents*). Involving all this information will allow automatic procedure in contrary to other applications in the Semantic Web where automatic ontology mapping seems more difficult.

3.1 Ontology Mapping by measuring the semantic similarity

For mapping ontologies, we propose to calculate semantic similarities between the concepts. Studying the research in the domain of comparing concepts for determining semantic similarity, we have noticed that in most of them, ontology mapping is a assumption for the similarity measure, so, we can't take such work for our purposes – even less because most of these approaches carry out ontology mapping manually and just focus on how to represent them. This shows that developing algorithms for ontology integration is a crucial, but also a critical task, this might serve not only to research in the domain of semantic similarity measurement, but also to the whole Semantic Web community.

[Weinstein and Birmingham, 1999] present an overview about semantic similarity measures. They have identified three groups:

The first category are *filter functions* and are presented as inexpensive, universally applicable, and appropriate for identifying initial sets of candidate recommendations. A first subcategory concerns measures based on path distance, but they are labelled fragile due to their sensitive character of the degree of detail in the ontological structure. When classifying new concepts, the measures can change although the compared concepts have not changed. Other filter measures leverage the assumption of measures based on path distance that local concepts in differentiated ontologies inherit definitional structure from concepts in shared ontologies, they use inheritance links to identify concepts and both the definitions of the source and target concepts.

The *matching-based functions* build and evaluate (maximal) one-to-one correspondence between elements of concept definitions represented as graphs. They enable analysis of similarities and differences between the concepts.

The *probabilistic functions* require domain-specific knowledge of the joint distribution of primitives. To model the joint distribution, Bayesian Networks are necessary.

The identified groups cross a spectrum with respect to the *degree of required knowledge specification*. Filter functions do not involve role semantics, the matching-based functions use knowledge of roles considered independently, and the probabilistic functions exploit knowledge of the interactions among roles.

3.2 Similarity measure in Digital Libraries

For the integration of hyperbooks with their domain ontologies into a Digital Library, we are focusing on techniques that try to establish one-to-one correspondences between ontologies of two hyperbooks. We first carry out the computation of the semantic similarity to decide if two concepts belong to the same semantic field or not. Using string similarity measurement approaches might be the first and simplest task for this computation, but considering only the syntax of the concepts in question is too basic. In the domain of Digital Libraries, we first can assume that there are not a lot of words with the same spelling in the different ontologies, and second that there exists terms with the same spelling, but without being semantically similarity (polysemy). Figure 3 shows extracts from four sample-ontologies, each speaking about Football. As we can see, the word "Football" does not stand all the time for the same meaning.

Using the WordNet ontology or another available top-level ontology for word disambiguation and resolving the meanings of polysemous words might be a solution. But in such kind of ontologies, we usually can't find specific concepts, only more general terms are represented. Looking at the ontologies in Figure 3, we can assume that there are at least some words in the upper-class level that can be found in the WordNet ontology.

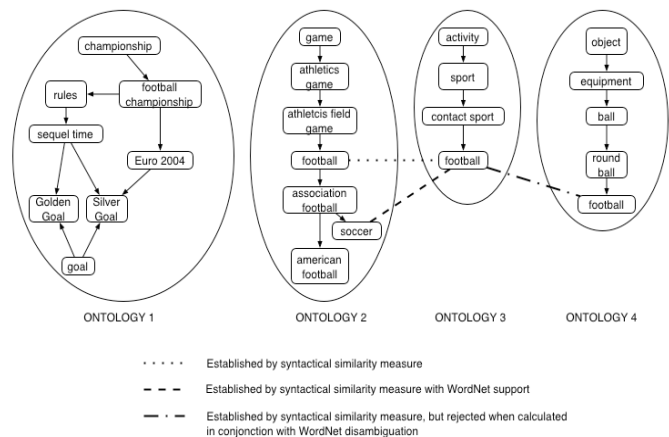


Figure 3. String similarity measurement with word disambiguation by WordNet

This would allow introducing some links between the different ontologies. But as our experiences with e-learning systems have shown, authors normally do not model the upper level part of their ontologies. Another question is also

if time needed to calculate word disambiguation with WordNet is reasonable.

Between the different kinds of ontologies, we want to remain that the domain ontology of a Digital Library is not just a terminological ontology where the collection of concepts are organized by a partial order. Moreover, it is an axiomatized ontology whose concepts are distinguished by different kinds of relations to other concepts. We have mentioned above the importance of link typing in a hyperbook structure, and we can now take advantage of this formalized representation for the ontology integration process. Thus, we need a similarity measure approach that considers more elements as just terminological relations. For this, we propose to use an extension of the technique of [Rodríguez and Egenhofer, 2003]. The approach is based on entity classes that are groups of equivalent or very similar words. The similarity between two entity classes is the weighted sum of three measurements: similarity of the terms (set of synonyms), similarity of the semantic neighbourhood (set of concepts close to the entity class in the graph) and similarity of the attributes (characteristics and properties, so called distinguished features like set of values). The similarity function takes into account the depth of the entity classes relative to their respective ontologies. The approach considers also cognitive properties of similarity by introducing asymmetric measure of semantic similarity. The authors argue that according to people's judgement, the base and the target concept can have different roles. For instance, the perceived similarity from a concept to its super-concept is greater than the perceived similarity from the super-concept to the concept. Finally, comparing not only sets of synonyms, but involving also distinguished features into the similarity measures means introducing grades of similarity. The result is no longer a simple binary expression (same or different word), it allows to detect also similar words.

As we have mentioned, most of the known techniques for semantic similarity measurement need a primarily integrated ontology. As we want to turn the process (integrating ontologies by first determining the semantic similarity measurement), we profit of the above-described approach because it can process the measures in not yet related ontologies. This is done by simply establishing a relation to an imaginary and more general entity class "anything" from the two root-concepts of the ontologies in question. This allows the calculation of the distance from two entity classes to the immediate super-class even if there is no "natural" common super-class.

3.3 Discussion

A first problem of the algorithm of Rodríguez and Egenhofer that is to mention is the fact that the assigned weights of each specification component depend on the characteristics of the ontologies. The authors mentioned, that for instance when a lot of polysemous terms occur within the ontologies, the synonym set component might not be a good indication of similarity. In consequence, the relative weight assigned to this component should be reduced. But it seems

critical when we have to analyze first the occurrence of polysemy. If we want to decide how the weights have to be assigned, we have to look in detail the three components.

First, comparing different synonym sets by a word matching process is a very basic level of similarity measure. When checking the number of common and different words in the synonym sets, there is a gradual similarity measure, but polysemy will not be detected.

Second, the semantic neighbourhood is determined by analyzing related super-concepts of an entity class. The links to them were labelled with types like "is-a" (hyponymy) or "part-whole" (meronymy). The authors use path distance (with a preliminary defined upper-bound) to define the semantic neighbourhood of an entity class. In a hyperbook, we can assume that the semantic neighbourhood is a priori of "good quality" for similarity measures, how should we determine the boundary of this distance?

But the most important problems can be found in the third component, by introducing distinguished feature. This might be quite astonishing in the first moment, because they provide a more formal description of a domain. But Rodríguez and Egenhofer have mentioned in their evaluation section, that feature matching alone is insufficient for detecting the most similar entity classes as many entity classes share common features or have a common super-class from which they inherit common features. And also in combination with the other two components, the *recall* is even lower for finding the *most equivalent* concepts than without using distinguished features.

The approach detects equivalences between concepts of two ontologies, but by using distinguished features, it also returns similar concepts. This is an important fact. In contrary to the ontologies that Rodríguez and Egenhofer have used for the evaluation of their approach (top-level ontologies like WordNet), we primarily are confronted with small domain ontologies. This means that we can't be sure that there are a lot of equivalent concepts. To get a stronger mapping between the two ontologies, we need an approach that at least can detect some similar concepts.

At this moment, it seems important to remark that this approach is adapted to hyperbooks and Digital Libraries and most probably can't be used in other Semantic Web applications as such. A high degree of domain formalization and a strong explicitness of concept representation are important assumptions.

Before we explain how we use an extended concept of distinguished features to improve semantic similarity, we want to mention another unresolved problem of this approach. In fact, there probably is no single root in each of the ontology to compare. But our model presented in section 2 explicitly allows a flat hierarchical ontology structure, where a single root might not appear very often. Such a hyperbook model might be much closer to e-learning purposes. So, the question remains how to build a common virtual root if there is even no one in the domain ontologies in concern? We could try applying the approach of Rodríguez iteratively, but applying the process to an even smaller

part of the ontology might not yet represent the best solution.

The above-mentioned approach of [Doan and al., 2002] is particularly interesting because they deal with taxonomical relations and instances to establish links between two ontologies. In contrary to Rodríguez, they don't establish an artificial top-level root concept to measure the semantic similarity, they furthermore match primarily the instances with machine-learning technique to be able to define the semantic similarity of two concepts. Then, they define distributions over the concepts to determine the final semantic similarity by a user-supported approach. Finally, they determine which of the derived relations will be considered into the ontology mapping according to given *domain constraints* and *relaxation labelling* (taking into account the neighbourhood of a concept).

In our case of virtual documents, we furthermore make use of additional information to evaluate the similarity between concepts. We also consider the annotated fragments and we take advantage of the fact that links between fragments and concepts are typed links. As we have seen above, the fragments were annotated according to a predefined list of link types. If two concepts A and B are bound by links of the *same* type t to sets of fragments $t(A)$ and $t(B)$ respectively, the “documentary” similarity between $t(A)$ and $t(B)$ will be taken into account in the definition of the similarity between A and B . To define the similarity between $t(A)$ and $t(B)$, we will use a traditional technique of information retrieval (for instance, the cosine between the *tf-idf* vectors representing the documents in the space of terms [Salton, 1989]). Then, we define the similarity between $t(A)$ and $t(B)$ based on the similarities between documents (for example by taking the maximum similarity found between all the fragments of $t(A)$ and $t(B)$). The similarities obtained for all types of links will then be added up to the similarity measure computed at the conceptual level.

It is important to remark that link typing is crucial here. Indeed, the comparison makes sense only if the compared fragments play the same role with respect to a concept. If, for instance, fragment a is an *example* of concept A whereas b is a *counterexample* of B , a strong similarity between a and b does not imply a strong similarity between A and B , on the contrary.

4 Future Research Questions and Conclusion

In this article, we have presented our hyperbook model, which is based on domain ontologies and fragment repositories and an integration process into a Digital Library, which is an extended version of the approach of Rodríguez and Egenhofer. We have applied their algorithm to Domain ontologies by involved typed relations between fragments and the domain ontology. In future research, we will work on the integration process, especially about the validation of matched links between concepts of the domain ontology, but also about the integration of hypertext personalization elements like points of view. This seems also an interesting approach for validating the established relations because

points of view help to describe the concept of an ontology more precisely.

References

- [Bocconi, 2003] S. Bocconi. *Automatic Presentation Generation for Scholarly Hypermedia*. In *Proceedings of the 1st International Workshop on Scholarly Hypertext at the Hypertext 2003 conference*, Nottingham U.K., 2003.
- [Brusilovsky et al., 1998a] P. Brusilovsky, J. Eklund, E. Schwarz. *Web-based Education for All: A Tool for Development Adaptive Courseware*. In *Computer Networks and ISDN Systems* (Proceedings of the Seventh International World Wide Web Conference), April 1998.
- [Brusilovsky, 1998b] P. Brusilovsky. *Methods and techniques of Adaptive Hypermedia*. *User Modeling and User-Adapted Interaction*. Adaptive Hypertext and Hypermedia, Kluwer, 1998, 1-43.
- [Buckingham Shum et al., 2000] S. Buckingham Shum, E. Motta, J. Domingue. *ScholOnto: An Ontology-Based Digital Library Server for Research Documents and Discourse*, In *International Journal on Digital Libraries*, vol. 3 (3), Springer-Verlag, Berlin, 2000.
- [Crampes, 1999] M. Crampes. *User Controlled Adaptivity versus System Controlled Adaptivity in Intelligent Tutoring Systems*. In *Proceedings of the Artificial Intelligence in Education Conference*, Le Mans, France, 1999
- [Crampes and Ranwez, 2000] M. Crampes, S. Ranwez. *Ontology-Supported and Ontology-Driven Conceptual Navigation on the World-Wide Web*. In *Proceedings of the ACM Hypertext 2000 Conf.*, San Antonio, 2000.
- [Dicheva et al., 2004] D. Dicheva, C. Dichev, Y. Sun, S. Nao. *Authoring Topic Maps-based Digital Course Libraries*. In *Proceedings of the Workshop on Applications of Semantic Web Technologies for Adaptive Educational Hypermedia (SW-EL@AH'04)*, in conjunction with AH 2004, Eindhoven, The Netherlands, August 23-26, 2004.
- [Doan and al., 2002] A. Doan, J. Madhavan, P. Domingos, A. Halevy. *Learning to Map between Ontologies on the Semantic Web*. In *Proceedings of the ACM World Wide Web Conference*, Honolulu, Hawaii, May 2002.
- [Falquet and Ziswiler, 2003] G. Falquet, J.-C. Ziswiler. *A Virtual Hyperbooks Model to Support Collaborative Learning*. In *AIED 2003 Supplemental Proceedings*, Sydney, Australia, July 2003.
- [Falquet and al., 2004] G. Falquet, L. Nerima, J.-C. Ziswiler. *Adaptive Mechanisms in a Virtual Hyperbook*. In *Proceedings of the 4th IEEE International Conference on Advanced Learning Technologies (ICALT2004)*, Joensuu, Finland, August 30 - September 1, 2004.
- [Garlatti and Iksal, 2001] S. Garlatti, S. Iksal. *Revisiting and Versioning in Virtual Special Reports*. In *Proceedings of the Hypertext 2001 conference*, Arhus, Denmark, 2001.

- [Iksal and al., 2001] S. Iksal, S. Garlatti, P. Tanguy, F. Gagnier. *Semantic Composition of Special Report on the Web: A Cognitive Approach*. In *Proceedings of the H2PTM'01 conference*, Valenciennes, France, 2001.
- [Klein, 2001] M. Klein. *Combining and relating ontologies: an analysis of problems and solutions*. IJCAI2001 workshop on Ontologies and Information Sharing, Seattle, 2001.
- [Mena and al., 2000] A. Mena, A. Illarramendi, V. Kashyap, A. Sheth. *OBSERVER: An Approach for Query Processing in Global Information Systems Based on Interoperation across Pre-existing Ontologies*. In *Distributed and Parallel Databases*, Vol. 8 (2), 2000. pp. 223-271.
- [Noy and Musen, 1999] N. F. Noy, M. A. Musen. *An Algorithm for Merging and Aligning Ontologies: Automation and Tool Support*. In *Proceedings of the Workshop on Ontology Management at the Sixteenth National Conference on Artificial Intelligence (AAAI-99)*, Orlando, Florida, AAAI Press, 1999.
- [Rodríguez and Egenhofer, 2003] M. A. Rodríguez, M. J. Egenhofer. *Determining Semantic Similarity among Entity Class from Different Ontologies*. In *IEEE Transactions on Knowledge and Data Engineering*, Vol. 15, No. 2, March/April 2003.
- [Salton, 1989] G. Salton. *Automatic Text Processing: The Transformation, Analysis, and Retrieval of Information by Computer*. Addison-Wesley, 1989.
- [Weinstein and Birmingham, 1999] P. C. Weinstein, W. P. Birmingham. *Comparing Concepts in Differentiated Ontologies*. 12th Workshop on Knowledge Acquisition, Modelling and Management, Banff, Canada, 1999.
- [Wu and al., 2001] H. Wu, E. de Kort, P. De Bra. *Design Issues for General-Propose Adaptive Hypermedia Systems*. In *Proceedings of the ACM Hypertext 2001 Conference*, Aarhus, Denmark, 2001, pp. 141-150.