Domain Ontology as a Resource Providing Adaptivity in eLearning

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Abstract. This paper presents a knowledge-based approach to eLearning, where the domain ontology plays central role as a resource structuring the learning content and supporting flexible adaptive strategies for navigation through it. The content is oriented to computer aided language learning of English financial terminology. Domain knowledge is acquired to cover the conceptualisation of basic notions about financial markets. The learning objects are annotated according to the type labels of a precisely elaborated type hierarchy and associated first-order logic propositions. The learner model and adaptivity decisions exploit the hierarchy of concepts. We claim that the well-organised domain knowledge might be a prerequisite which provides interoperability of learning objects, at least in a significant number of learning applications. Unfortunately, exchange between ontologies is difficult, as there is no much knowledge available (in the Semantic Web). But our approach shows clear paths to the development of shareable learning objects, assuming that some new ontologies will appear with the evolution of semantic-based web content.

1 Introduction

The present expectations are that the emerging Semantic Web will develop a solid basis for future progress in eLearning. As [1] points out, "none of these technologies has reached full maturity as yet or been deployed widely so it is hard to gauge their success or failure". Nevertheless the potential importance and impact of semantic-based technologies in eLearning are easy to estimate. The inspiring idea to develop reusable atomic learning components and to capture their characteristics in widely-accepted, formal metadata descriptions will most probably attract learning object providers to annotate their products with the accepted standards. The architecture of the learning objects seems to be generic enough to make use of any properly annotated www-content. The standardised metadata descriptions will enable a more unified approach to adaptivity. Initial developments of this kind already appear and illustrate the use of ontologies for educational services [2].

This paper reports some results of the Lasrflats project[1] and their ongoing elaboration. The project was presented in several papers ([3–6]) which consider in detail the integration of advanced language technologies in computer-aided language learning (CALL). In contrast to these publications, here we focus on the domain ontology that is the backbone supporting the content structuring and an unified approach to adaptivity. Section 2 discusses the Larflast project and its approach to assign a central role to the domain ontology. Section 3 sketches ongoing work. Section 4 contains possible directions for future work and the conclusion.

2 An Approach to Knowledge-Based CALL

There are intelligent tutoring systems which contain no explicit domain model and no explicit type hierarchy. For instance, table 1 in [7] lists and classifies forty CALL systems. Many of them are considered "intelligent" because they integrate knowledge about typical language mistakes, learning strategies, questions and answers, or specific linguistic knowledge about e.g. correct spelling of verb forms. Such CALL systems are most often domain independent as they operate with the vocabulary included in the system lexicons. Similarly, adaptivity might be implemented without explicit encoding of domain knowledge as well. For instance, Knowledge Sea [8] applies a neural network-based mechanism to process pages from different Web-based tutorials along with a set of closed corpus documents (e.g. lecture notes) and groups them by similarity; as a result, a list of (hyperlinks to) relevant readings is offered to the user. In general, domain knowledge is not a typical resource in running eLearning applications as it is an expensive and sophisticated artifact, which requires much effort for acquisition, integration and tuning. On the other hand, almost all CALL systems, which check the semantics of free learner's utterances, need domain/world knowledge to perform formal analysis and interpretations of the learner's answers. These CALL prototypes contain "knowledge base" from some sort. For instance, knowledge can be encoded as "lexical conceptual structures" (BRIDGE/MILT [9]) or as "facts and propositions in a knowledge base" (as chosen in one of the recent CALL systems Why2-Atlas that checks the correctness of students essays in physics [10]). Our understanding, however, is that the "facts and propositions" in general and the type hierarchy in particular might be a resource supporting almost all system activities and functions. Perhaps this is the most innovative aspect of the project reported below, as it applies the same knowledge base for semantic analysis of free natural language utterances, for annotation of the learning objects and for support of adaptive navigation facilities. In this section we present and discuss our results.

[1] Learning Foreign Language Scientific Terminology, a Copernicus'98 Joint Research Project, funded by the European Commission in 1998-2001, with partners CBLU Leeds, UK; UMIST Manchester, UK; LIRM Montpellier, France; Academy of Sciences, Romania; Simferopol University, Ukrain; Sofia University and Virtech Ltd., Bulgaria.)

2.1 General description

The project Larflast developed an adaptive Web-based terminology learning environment with focus on the harmonic integration of advanced natural language processing (NLP) techniques and innovative learning solutions for system-student communication [3]. The users are students with background in economics, business or management who study English as a foreign language. From pedagogical perspective, the main objective was to elaborate and to test with actual users a distributed Web-based learning environment, which enhances learner performance, increases his/her autonomy and provides motivational and informational stimuli over and above what a traditional paper-based approach to learning terminology normally offers. The project aims to find some balance between innovative research and practical needs. Initially a user study was performed, which focused on paper-based teaching of foreign language terminology. Typical errors were analysed together with the user preferences regarding the desired feedback and diagnostics. It was also important to chose the proper subdomain for teaching representative core of English terminology. Some 150 terms in financial markets were initially selected for the prototypical implementation. More terms were added at later knowledge acquisition phases, to cover features of the basic notions and facts encoding their important interconnections. The ontology in OWL format can be seen at the project site[2].

Fig. 1 sketches the relevant aspects of the system architecture and shows resources and modules which deal with the domain knowledge. The ontology is the central static resource. The granularity of the concepts reflects the granularity of terms as the main application task is to provide self-tuition in terminology learning. The ontology contains:

- *a type hierarchy* - about 300 concepts in the area of finances, labeled by the actual English terms whenever possible, and
- *associated propositions* - about 150 statements in first-order logic (FOL), which encode facts that are relevant to the terminology learning task.

The ontology labels as well as the identifiers of the FOL propositions are inserted in the annotation of the pedagogical resources. There are two kinds of learning objects (LO):

- *static exercises* specially designed by a teaching expert to check user's comprehension of the domain. Some exercises require short answers in free English, the latter are checked by an original prover (details about the prover are given in [3, 6]);
- *relevant readings* dynamically collected from Internet and filtered according to their relevance to terms that might be "unknown" at particular learning situations [3].

The student reactions are reflected in the Learner Model (LM) and special cases of misconceptions are stored for later consideration. Elements of the LO

[2] http://www.larflast.bas.bg

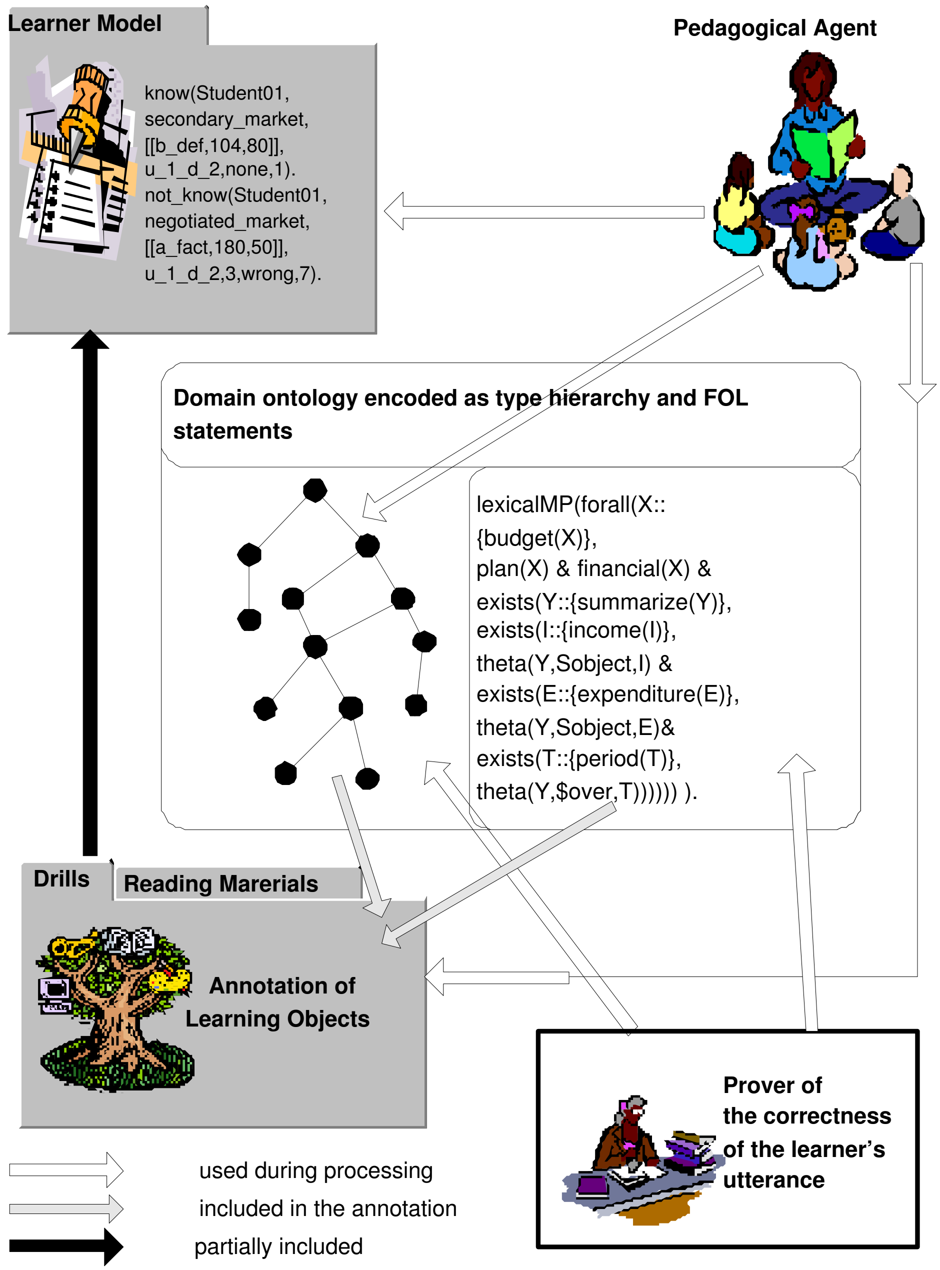

Fig. 1. Domain ontology and its usage in system resources and processing modules

annotation are repeated in the learner model, to facilitate the Pedagogical Agent (PA) and other modules at remote servers to track the learner's performance. According to the learner model content, the pedagogical agent plans the next learner's step and shows some drill or relevant reading. A sophisticated prover checks the correctness and appropriateness of the learner's utterances [3]. Please note that the pedagogical agent treats the FOL statements as "Identifiers" as long as they are included in the LO annotation, while the prover really employs them in the reasoning process.

2.2 Tagging the Learning Objects

The learning object is an atomic pedagogical content. Its annotation contains:

- `course identifier`,
- `topic identifier`,
- `unit identifier`,
- `Kind of LO` ("exercise" or "reading"),
- `List_of_TestedAspects` - empty for "reading" LO and list of triples for an "exercise"LO: `[Aspect, Proposition_Id, Weight]`, where
  - `Aspect` represents major types of aspects: *(i)* `b_def`: basic definition, *(ii)* `a_fact`: additional fact, `(iii) rel`: encodes possible relations i.e. object, agent, attribute, characteristic, instrument and etc.
  - `PropositionId` is a Id-number of an ontology statement and
  - `Weight` is a predefined number between 1 and 100, which reflects the importance of the tested information regarding domain understanding while teaching foreign language terminology.

  Sometimes there are more than one aspects of a concept that can be tested for an exercise entry which are encoded in separate triples.
- `ConceptLabels` - one concept (one term) for "exercise entry" and a list of pairs [*concept*, *relevance score*] for "reading" (because one text can be relevant to several terms),
- `Autorship`,
- `CreationDate`.

Annotations of the exercises are manually encoded when the object is created. They link the LO to the ontology items and indicate which domain concepts and facts are described or tested by every learning object. The FOL prepositions are used as references and enable system's reactions by pre-defined feedback. The concept weights for exercises are assigned by the teaching expert. In contrast to exercises, the readings are automatically annotated by concept labels that are English terms. The phrasal terms are assigned to readings with corresponding relevance score which is automatically calculated by a supervised information retrieval technique called Latent Semantic Analysis. It would be good to have a deeper annotation at the level of the FOL statements, i.e. to know the facts discussed in each text, but unfortunately the methods for "similarity" calculation cannot distinguish finer facts in the same domain (this is how the information retrieval works today especially with the most popular bag-of-words models).

2.3 Learner Model

The learner model keeps clauses to describe learners' familiarity with the terminology which is closely related to domain knowledge:

- **know** - the learner knows a term; the clause is inserted for correct answers;
- **not_know** - the learner doesn't know a term; the clause is inserted for wrong answers;
- **self_not_know** - inserted when the learner chooses the "don't know" answer to certain LO, if such answer exists; and
- **know_wrongly** - the learner's knowledge is considered wrong (eventually, might need corrections); the clause is inserted for partially correct answer to a certain LO.

Each of the learner model clauses has seven arguments:

- *user name*, logging identifier of a user;
- *ontology concept*, the tag `ConceptLabels` from the LO annotation;
- *tested facts*, the tag `List_of_TestedAspects` from the LO annotation;
- *exercise identifier* (an unique Id corresponding to the tags `cource identifier`, `topic identifier` and `unit identifier` from the LO annotation);
- *counter* how many times the user passes trough the tested learning object;
- *indication of linguistic and conceptual mistakes* (more details in [3]) and
- *unique index* for tracking the whole dialog history.

There are two sample LM clauses at Fig.1: that 'student01' knows the basic definition of secondary market (at the 1st pass through the exercise) and does not know an additional definition of negotiated market (at the 3rd pass through the same testing object). It is worth to emphasize that references to ontology enter the learner model and the pedagogical agent via the LO annotation and thus both the learner model and the pedagogical agent are domain independent. Manual efforts need to be invested only for the ontology acquisition and the LO annotation; afterwards the labels of ontology items are propagated through all other resources and components at no cost. The learner model is also used by system modules which are not presented here (see [3] for discussion of the dynamically generated explanatory www-pages which contain term definitions and concordancers of term contextual usages for wrongly-known terms).

2.4 Pedagogical Agent

The learning environment presented here is a self-tuition framework, which compliments the classroom activities. The prototype supports the student to accomplish drills and to read suggested training materials on relevant subjects. There is a default sequencing of performing drills (passive sequencing) but the pedagogical agent offers an alternative presentation which is tailored to the learner's competence as it is recorded in the learner model (active sequencing). The dynamic archive of updated readings enables choices within a growing corpus of relevant texts that may be suggested to the student.

The pedagogical agent has two main strategies for active sequencing: local and global. The local strategy plans the movement between drills testing different characteristics of one concept. Its main goal is to create a complete view about learner's knowledge concerning this concept. This strategy chooses exercises with increasing complexity when the learner answers correctly and it gives again previously completed drills if the learner has performed poorly. For instance, if a student does not know some fact related to the tested concept (term) which is encoded in the exercise annotation with low weight, the pedagogical agent will suggest a reading. The global strategy plans the movement between exercises testing different concepts, according to their place in the financial ontology. For instance, if the student does not know the basic definition of a concept and its major additional facts, the pedagogical agent will choose to test first whether the student knows at all the super-concepts and only afterwards to suggest basic readings for the unknown concept.

As shown at Figure 1, the pedagogical agent chooses the next learner's movement depending on:

- the annotations of available learning objects,
- the position of the tested concept in the type hierarchy, and
- the current LM user's status: history and quality of learner's performance.

2.5 Discussion

Today there is no cognitive theory of human learning which is elaborated enough to support the development of standardised models of the eLearning activities. Rather, there are partial solutions to separate tasks in particular implementations. We claim that without explicit domain knowledge, the semantics of the learning objects can be described in general terms only. In our view the domain ontology is an inevitable part of advanced learning solutions as it:

- structures in a natural way the learning content and provides a backbone for unification of the granularity of all kinds of learning objects;
- enables knowledge-based solutions to complex tasks (e.g. checking the correctness of learner's utterances in natural language);
- allows for clearer diagnostics of the student misconceptions and supports a consistent, domain independent strategy for planning the adaptive behavior of the system;
- provides annotation markers that might facilitate the interoperability and exchange of learning resources.

To support these claims, let us have a closer look to the Larflast ontology and the gains of its central place in the prototype. Acquiring the ontology and integrating all the processing components was an effort-consuming task which took almost three person years. The main difficulty was to harmonise the exercises allowing answers in free English and the mechanisms to generate consistent feedback and proper error diagnostics. In other words, the user expects some consistency in the interface appearance and the system reactions, so much efforts were invested to assure "fluent" diagnostic dialogs after semantic errors are encountered and to design the consequent moves. So proving the correctness of the learner's utterance is a complex tasks and its integration in CALL turned to be complicated as well. Fortunately we discovered simpler solutions which are also very beneficial for the user and facilitate his/her training performance.

At first we noticed that the acquisition of the type hierarchy itself is relatively easier, moreover updates and changes do not affect much the already elaborated components and resources. The type hierarchy in Larflast encodes partitioning perspectives which might look relatively complex to non-specialists but it is never shown completely to the learner, which would be the case of manual navigation through the conceptual content. The pedagogical agent, despite its simplicity, takes care to guide the student through the hierarchy. The sequence of moves was evaluated positively by the learners in the final user study. In addition, while planning further "readings", the pedagogical agent tries to offers materials containing *known terms* which is possible because of the unified backbone for annotation of all learning objects [11]. This fact pleased the students as well as the teaching experts who evaluated the prototype.

Another interesting resource is the dynamic archive of readings which is automatically annotated by the same ontological labels. Obviously, manual search in Internet (e.g. via google with the same phrases) would deliver the same documents but ordered in a different ranking. Moreover, the system deletes the documents that seem to contain much non-textual information. The supervised methods for calculating relevance are better than simple search by key words and allow for boolean requests that avoid the usage of unknown terms. In this way annotating the readings by the labels of the same type hierarchy enables personalised information retrieval. Integration of heterogeneous components via one simpler conceptual resource ensures a well-balanced functionality of the whole environment.

3 Towards Interoperability and Visualisation

Recently we align the Larflast prototype to the advanced research on Semantic Web and eLearning. The first step was to look more deeply to ontology interoperability from the Semantic Web perspective, moreover several components in our learning environment are independent from the particular ontology we use. However, there are serious obstacles to make further progress towards interoperability of learning objects, due to the lack of aligned ontologies in the domain of finances. Another recent development concerns the visualisation of domain knowledge to the learners. In this section we sketch the ongoing work in these directions.

3.1 Interoperability via Ontology Alignment

The LO content should be exchangeable between different providers and the exchange is to be ensured by the metadata annotations, which obligatory include descriptions of the LO semantics. For instance, the LOM standard [12] includes field for semantic description. The annotation presented in section 2.2 contains reference to semantic descriptions too (but is not encoded according to some of the existing standards, as the prototype was implemented before the appearance of the LO standards). So as a first guess, interoperability between learning objects might be achieved at the level of their semantic content in case that we find efficient methods to "compare" and align it.

We studied the publicly available ontologies, to find out some resource similar to the one we developed in finances, in order to make experiments with the content of our LO. We considered in depth the public financial "branch" of the MILO ontology [13] which contains all concepts mentioned at least three times in the Brown corpus and additionally, is relatively easy for people to understand and practical for computational use. MILO is integrated under SUMO [14] and its financial part covers 246 basic entities (terms). In Teknowledge's ontologies, terms belong to one of five basic types: class, relation, function, attribute, or individual. We manually mapped MILO to the financial ontology we developed for educational purposes in the Larflast project. Three quarters of the terms coincide, however the design decisions are quite different. For instance, in MILO *dividend* is a relation while for us it is a concept. It looks difficult even for knowledge engineers to formulate precise rules how to align the semantics of concepts to relations. Mapping of too different ontologies will require complex semantic resources, which define better the meanings, and in-depth inference. Additional study shows that the ontological design and choices differ drastically even for partitioning in simple taxonomies. The overview of existing public constructions displays primarily the multiple perspectives to classification of reality objects, relations and their attributes and features. The reader may consider as an example three taxonomies in computer science: *(i)* the ACM taxonomy of keywords, designed by the IEEE Computer Society [15], *(ii)* a taxonomy in Computer Graphics Interfaces, developed within a NSF-funded project as a searchable database index for a large part of the ASEC Digital Library [16] and *(iii)* the SeSDL Taxonomy of Educational Technology, which gives links to the British Educational Thesaurus BET [17]. These three hierarchies are built for different purposes and a careful study of their concepts shows that less than 5% of the nodes are common. As a rule, even for these "intersecting" concepts the classification into subconcepts is different. Similar variety exists concerning the emerging ontologies.

In this way, semantic interoperability of LO is not a trivial task and it will requite much efforts for the elaboration of agreements between the providers of semantic content.

3.2 Visualisation scenario

Another promising direction while learning foreign-language terminology is the visualisation of domain knowledge. This could be useful for second language learners or domain novices who read a document and do not grasp the meaning of unknown or specific terms.

In our case, at the presentation interface to the learners, the 'reading' LOs are displayed as html-pages which are semantically indexed by the terms - labels of the type hierarchy sketched in Fig. 1. Recently we implemented a tool supporting the hierarchy visualisation [4]. The hierarchy itself appears in a graphical window with the classification perspective displayed in different colors and associated comments. The logical statements attached to a chosen concept node can be seen by clicking the right mouse button. At present we have implemented the following visualisation functionality: Suppose a student is reading a page concerning financial instruments, but some of the domain specific terms are unknown to him/her and then s/he could 'load' the underlying ontology. At this stage the semantic index is visualised in the text and a special window appears, which contains the list of all terms anchored to ontology labels. By just clicking on a term from the list, the term is highlighted in the hierarchy and by right-clicking on the same list term, the user can view definition, properties, attributes and relations associated to this term. Although the FOL-format may be really discouraging for end users, it is beneficial to see the conceptual environments in the hierarchy - sister concepts, super- and sub-concepts, etc. Initial user evaluation suggests that simple visual hints please both teachers and users, who dislike complex drawings that focus their attention to activities which are not directly related to language learning and language comprehension. All in all by selecting an item from the list the user can see all the appearances of this term highlighted in the www-page (i.e the language context of its usage) and also its position in the hierarchy of ontology terms (i.e its ontological environment).

4 Conclusion

The Larflast project was long enough (3 years) to allow for two-three development iterations: knowledge acquisition and components design, implementation, and evaluation. Starting with the knowledged based approach from the very beginning, we gathered much experience how to acquire and tune domain ontologies to eLearning applications. As we already said above, the taxonomy as such is a very good conceptual resource, especially when it incorporates concept definitions for notions with different granularity and multiple perspectives [4]. Many components in our learning environment work with the taxonomy only because it turned out that this relatively "flat" conceptual resource can be successfully used as a unifying backbone across all the system resources and components. We believe that our approach to structuring and processing taxonomies opens the door to domain independent architectural solutions in eLearning. In this way the acquisition of sophisticated knowledge chunks (which is always domain-dependent) is not necessary for initial prototypical developments and it makes sense to start with simpler tasks and to carry out initial user studies with simpler prototypes. We encountered as well that the reasoning is not an obligatory instrument; sensible functionality can be achieved by simpler operations like type expansion, type contraction and projection without making proper inferences. We also learned that the whole is more important than the separate components and that both the students and the teaching experts need to see a broader operational context in order to evaluate relevantly the system functionality.

Regarding the interoperability of learning objects, it seems that the progress in this field depends on the progress in ontology development and alignment, which is one of the main challenges in the semantic web. Current educational standards look rather human-oriented to offer effective solutions for formal encoding of semantic content, e.g. LOM is originally designed as a platform for publishing and exchange of teaching programs of higher education institutions between human experts. New views to LO semantic interoperability will probably evolve, inspired by the expected evolution of ontology merging and alignment algorithms. On the other hand, the partial solutions are feasible as well, when sub-groups of LO content providers may agree to apply coherent conceptualisations. In our view the taxonomies might be important knowledge structures in this process as their relative simplicity and readability allow for easier negotiation. (In fact the taxonomies correspond to the thesauri in the paper-based world; it is much easier to agree on a thesaurus than on a holistic textbook content). Our future plans in this respect include more experiments with different ontologies and their taxonomies, to better estimate the hierarchies as a resource providing interoperability of LO as well as domain independence of eLearning implementations.

Regarding the visualisation, we assume that graphical representations are a necessary component of the advanced multimodal interfaces. The user-friendly and intuitive visualisation of conceptual contexts is very important because it facilitates domain comprehension not only in language learning but in any kind of getting acquainted with a new domain. At present we adopt an earlier tool for acquisition of knowledge bases [18] to the needs of visualisation in language comprehension and learning, as it was sketched in section 3.2. We plan to continue this activity together with the necessary user evaluation.

Current eLearning systems need increased abilities in quality, quantity, and interaction. We believe that the solid grounds of the knowledge based approaches will facilitate further implementations. Some very serious questions remain open, especially the discouraging mismatch between ontologies acquired for the same domain. Perhaps the application of simpler knowledge structures is a feasible alternative that is worth to be investigated, until we find some balance between the desired usefulness of our systems and the human abilities to define knowledge formally.

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