

Towards an Adaptive Learning Environment Supported by Ontologies

Erika Handa Nozawa¹, Elaine Harada Teixeira de Oliveira², Maria Luciana Ferreira da Costa³, Elder Rizzon Santos⁴, Seiji Isotani⁵ and Alberto Nogueira de Castro Júnior²

¹ Programa de Pós-Graduação em Informática, Universidade Federal do Amazonas (UFAM), Brazil

² Departamento de Ciência da Computação – Universidade Federal do Amazonas (UFAM), Brazil

³ Instituto Ambiental e Tecnológico da Amazônia (IATECAM), Brazil

⁴ Programa de Pós-Graduação em Computação, Universidade Federal do Rio Grande do Sul (UFRGS), Brazil

⁵ Department of Knowledge Systems, ISIR, Osaka University, Japan

erika.handa@gmail.com, elaine@dcc.ufam.edu.br, m.luciana.costa@gmail.com,
ersantos@inf.ufrgs.br, isotani@acm.org, alberto@ufam.edu.br

Abstract: Being proficient in a foreign language is an important differential for people who aim better position on nowadays world. This work addresses the issue of modeling the Japanese Language Proficiency Test (JLPT) domain through an ontology. The ontology was developed in the attempt to provide options for personalized learning oriented to the context, based on some relevance principles. The presented ontology was submitted to evaluators to assure its consistency.

Keywords: Ontology, JLPT, Adaptive learning environment

1. Introduction

Learning a foreign language is an essential requirement for nowadays world. Globalization, business and information without frontiers make world-wide communication much more difficult due to the necessity to understand different languages and cultures. Thus, to be proficient in a foreign language is the basic condition to have the best opportunities. Foreign languages proficiency tests require different levels of fluency in different areas like orthography, vocabulary, grammar and text and listening comprehension. Usually, there is a list of requirements to be fulfilled for each level. These requirements help students to

guide their studies and also help teachers to elaborate their course content and structure their classes.

There are many preparatory courses for the Japanese Language Proficiency Test (JLPT). The majority of these courses are offered in a traditional paper-based form and only a few of them are available online. In order to solve this problem Nozawa (2006) proposed the eJLPT¹ simulator, an educational hypermedia tool for students willing to practice their skills/knowledge about Japanese language through an online simulation of the JLPT.

Because eJLPT system has been utilized by a community of users interested in the JLPT, the need for improvements and new functionalities such as automatic scenarios has become necessary. Following are some examples of the questions posted by the users:

1. How is my learning evolution towards approval on the JLPT? May I have parameters to “measure” my learning in the JLPT context?
2. Which resources are available in the system to adapt my learning needs in the JLPT context?
3. Can the teacher guide me so I do not need to put unnecessary effort on certain subjects which may not be important to pass in the JLPT? Are there automatic tools for teachers? And for students?

To address these and other difficulties a new architecture for eJLPT is proposed. The existing system should not be presented as a unique hypermedia document for every user. It should be as flexible as an adaptive learning environment. In order to provide adaptability of content/interface, one of the necessary issues to be considered is having an adaptation model which supports the user model. In this work, the user model is based on a cognitive perspective. The intention is to model the domain in a way that it should represent part of the cognitive context of an individual. Therefore, our approach aims to model the domain using an ontology based on a cognitive perspective, referred to as the Relevance Theory (Sperber, 1986). Another issue that needs to be considered is the adaptation mechanism. In our schema, this will be done by an intelligent pedagogical agent. Details of this mechanism will be treated in our future work.

The whole proposed schema is shown in Figure 2. Figure 2a presents the chosen model of adaptation and Figure 2b, shows the instantiation of the model with the components of our work. Further information on holistic characteristics can be verified at Nozawa (2008).

¹ <http://www.ejlpt.web.br.com>

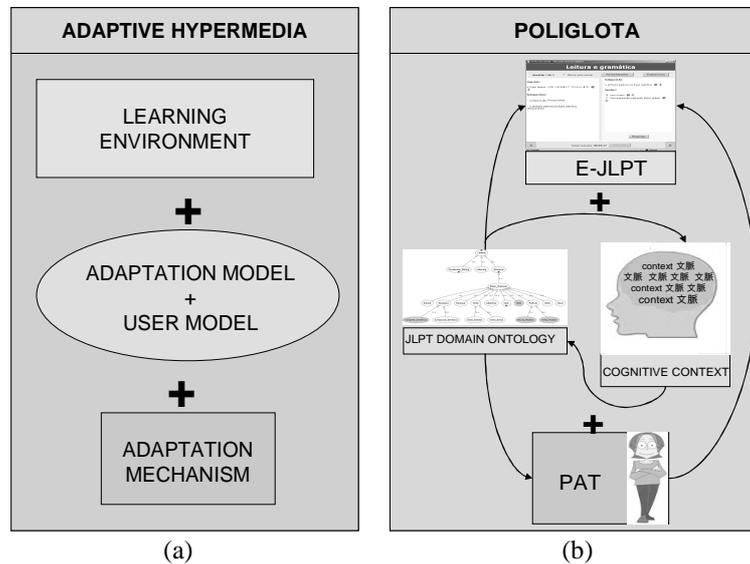


Figure 1 (a) Proposed schema of integration of adaptive learning environments and (b) a instantiation of this schema

To achieve our goals, this work concentrates on developing and describing the domain ontology for JLPT. The ontology has been developed based on a design process method and aims to be a tool for future reuse. To assure its validity, the ontology was submitted to evaluators who evaluated it according to a validation model (see section 4.1). The focus of this paper is the presentation of a possible valid solution for the problem of creating an adaptable online course that will help students during their preparation for the Japanese proficiency tests.

The paper is structured as follows. Section 2 will present a brief introduction and contextualization of the cognitive perspective adopted in this work. Section 3, introduces the ontology fundamentals as well as the JLPT ontology. Section 4 presents the design process methodology phases and gives special attention to the validation phase. Finally, section 5 presents some intended future work and some final considerations.

2. Cognitive Context

One of the first challenges of this work is the attempt to model a knowledge domain to reflect, in some way, the representation of the cognitive context of a person over such domain. For cognitive context, we mean the set of assumptions used to interpret a statement and, for cognitive context of a person over a particular domain, we mean the person's subset of assumptions on such domain.

It is not the intention of this work to represent the entire cognitive context of an individual, which would probably be impossible, but only those relevant to the domain of Japanese proficiency tests. An ontology was developed to represent this domain of JLPT. It consists of a class that represents the major context and subclasses representing subordinated contexts. In this case, the ontology plays both the role of representing the general area, acting as an agenda of a course, as something more specific, such as the representation of the knowledge already acquired by a particular individual. In this case, the ontology of the individual is a subset of the general ontology of the domain.

Besides the representation of the concepts, the ontology should allow navigation in a context from the perspective of the Relevance Theory (Sperber, 1986). According to this theory, for any assumption to be relevant in a context, there should be connections among new assumptions and existing ones, which are already part of the context.

Relevance can be characterized in terms of contextual effects. To modify and improve a context is to have some effect in that context. There is no change in the context where the information is completely duplicated or when it is not related to any old information. There must be an interaction between old and new information. "The context used to process new assumptions is a subset of the old assumptions of an individual, with the new assumptions which combine to generate a variety of contextual effects" (Sperber, 1995).

To ensure relevance, certain conditions must be met, which leads us to a comparative definition:

1. An assumption is relevant in a context in the proportion of the increase of the contextual effects;
2. An assumption is relevant in a context in the proportion of the decrease of the effort required to process it in that context.

One of the main goals of this work is to serve the principle of maximum relevance by assessing the relationship of best cost-benefit between the contextual effect and processing effort.

Considering the graphical representation of ontology, assuming that we are in the original node, the more we move towards the children nodes, the greater the contextual effect obtained. To have this move forward, and consequently, the contextual effect, the move should occur by the links between nodes. Each move is valued in accordance to the specified value in each link in the ontology modeling.

The processing effort, similarly, also increases as we move through the graph. As the value of contextual effect, the value of the effort of processing is not an absolute value, does not have a unit of measure, but is a relative value, for comparative purposes, given by experts who, based on domain principles and parameters, can identify topics with greater weight and importance to the learning of subsequent topics.

Currently, the values for each move for both contextual effect and processing effort are unit values. In future, we intend to attach values to the links in accordance to principles and parameters of second language learning.

Next section will present the fundamentals of ontology, specially the application of this concept in education and the concepts of the JLPT ontology.

3. JLPT Ontology

The idea of using ontologies on the educational domain is not new, as we can see in Mohammed (2007) and Bittencourt (2008). In this work ontologies are applied to model the application domain and to support the pedagogical agent's decisions. The practical utilization of the ontological model and its relation to the user model are also studied on this paper.

In our work, we view an ontology as an explicit specification of a shared conceptualization that holds in a particular context (Schreiber, 2008). Our context is the Japanese language proficiency test domain. In this case, the shared conceptualization models the necessary definitions and relations to enable people working in that domain to clearly communicate and exchange knowledge.

It's important to evidence that there is no official and available public property neither from Japan Foundation nor Japan Educational Exchanges and Services, entities responsible for the administration, organization and dissemination of JLPT. Then, the concepts for the development of this ontology were obtained through the consulting on the grammar adopted by Japanese school books, available preparatory courses and interviews with an expert, a Japanese language professor for JLPT certification. The presented ontology is, then, an agenda, result of the compilation of several materials related to the Japanese language grammar because it expresses and defines the rules for a language as well as for the vocabulary. The Figure 2 represents the *is-a* relations and the some main classes of this ontology.

In this case, the ontology plays both the role of representing the general domain, as acting like a course agenda, as something more specific, such as the representation of the knowledge already acquired by a particular individual. In this case, the ontology of the individual is a subset of the general ontology of the domain. The shared attribute of the conceptualization also lead to a validation process which is explained on Section 4.1.

Finally, we refer to explicit specification as the formal language used to develop the ontology computationally. We adopted OWL² (Web Ontology Language) as the formal language, since it is developed by the World Wide Web Consortium and is a de-facto standard for building web ontologies. Research on OWL and its inference properties lead to several implementations of fast and

² <http://www.w3.org/Submission/owl111-tractable/>

reliable reasoners. The availability of this kind of tool is important since the ontology is the base to our adaptive learning environment.

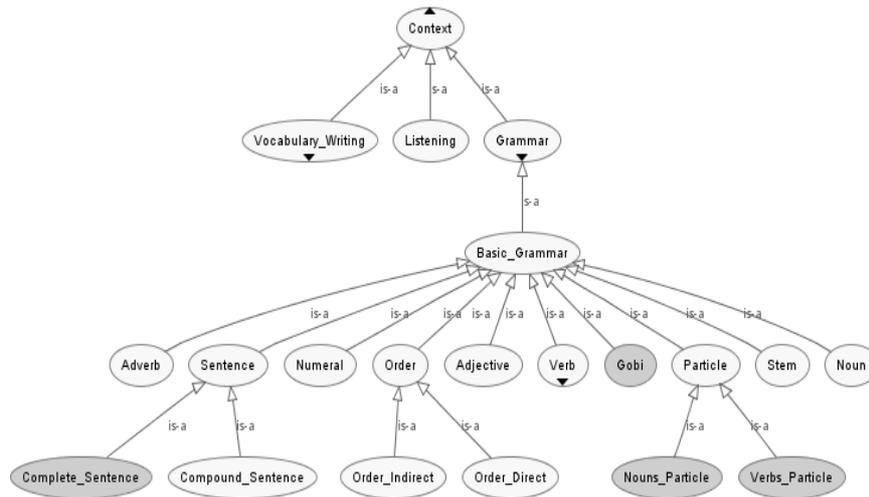


Figure 2 Basic Grammar class of JLPT ontology

4. Ontology design process

It is important to have an appropriate methodology for ontologies development, since it facilitates their process of construction and development. There are three generations of approaches of ontologies development (Ribeiro, 2006). The second generation seeks relevant concepts that support the development of ontologies, such as: specification, conceptualization, integration and implementation. The METHONTOLOGY methodology (Fernández, 1997) belongs to this second generation.

According to Silva (2005), the lack of standards for building ontologies hinders the development process, since ontologies are generated to be reused.

In this work we used the METHONTOLOGY methodology because its construction process is aligned to the software development process and the details this methodology provides to the structure of ontology. METHONTOLOGY has the following activities:

Planning: The JLPT ontology was developed by some Japanese teachers and Computer and Education students. The tools used were: a text editor and Protégé (including its plugins for taxonomy visualization).

Specification: JLPT ontology domain should represent elements, terms and properties related to the context of the Japanese language in JLPT domain. This ontology will allow a possible structure for a course in Japanese language directed

to the achievement of proficiency in the language. It will be used in a hypermedia environment for education and preparation for JLPT certification.

Conceptualization: The definition of JLPT ontology is based on grammar adopted by Japanese schools, books, available preparatory courses and interviews with an expert, a teacher of Japanese language for JLPT certification. This was the way chosen as there is not an official public domain agenda available from Japan Foundation and not by Japan Educational Exchanges and Services, entities responsible for the administration, organization and dissemination of JLPT. The proposed ontology is then an agenda, result of a compilation of several materials related to Japanese language grammar because it expresses and defines the rules for a language and its vocabulary. These data were developed by competence questions which the ontology proposes to answer.

Formalization: The formalism to be explored is directed to existing classes of objects in the domain, that is, formalism oriented to classes and relations, such as Description Logic. The importance of this formalism is to help the perception of the domain to be fully described, since relations among objects are allowed, especially in the inheritance relations. The table 1 shows the main classes of JLPT ontology, with the predicate logic;

Integration: The intention is to integrate JLPT ontology with other ontologies in order to complement the stored information and also to enlarge the chosen domain;

Implementation: The language chosen to represent the ontology is the OWL, which allows describing properties and classes, such as relations among classes and cardinality. This language has the following levels of expressiveness: Lite, DL and Full. OWL DL was used to the ontology in question.

Evaluation: tools will be used (Protégé³ and RACER⁴) to validate the design of ontologies (consistency checking).

Documentation: JLPT ontology was developed through Protégé tool, because it facilitates the documentation of each class, property and generated instances;

Maintenance: The maintenance of the ontology is being done by this paper authors, who will verify the existence of new concepts to be included in JLPT ontology.

³ <http://protege.stanford.edu>

⁴ <http://www.racer-systems.com/>

Table 1. Some main classes of JLPT ontology

CLASS	PROPERTY	INSTANCE	RULES	REPRESENTATION
Adjective	hasPart	i_Adjective	Adjective is part of at least one expression	$\forall x(\text{Expression}(x) \rightarrow (\exists y(\text{hasPart}(x,y) \wedge \text{Adjective}(y))))$
		Na_Adjective	Adjective is part of Grammar	$\forall x(\text{Essential_Grammar}(x) \rightarrow (\exists y(\text{hasPart}(x,y) \wedge \text{Adjective}(y))))$
Noun	hasPart	OTOKO_Noun	Noun is part of at least one expression	$\forall x(\text{Expression}(x) \rightarrow (\exists y(\text{hasPart}(x,y) \wedge \text{Noun}(y))))$
		isPartOf	SAKANA_NO	Noun has particle
Nouns_Particle	hasPart		Noun is part of Grammar	$\forall x(\text{Essential_Grammar}(x) \rightarrow (\exists y(\text{hasPart}(x,y) \wedge \text{Noun}(y))))$
		Expressing_a_sequence_of_verbs_with_TE_form	Is part of Noun	$\forall x(\text{Noun}(x) \rightarrow (\exists y(\text{hasPart}(x,y) \wedge \text{Nouns_Particle}(y))))$
	hasPart	Expressing_a_sequence_of_verbs_with_TE_form	Is part of Verb	$\forall x(\text{Verb}(x) \rightarrow (\exists y(\text{hasPart}(x,y) \wedge \text{Verbs_Particle}(y))))$
Numeral	hasContext	Hitotsu	Has context of vocabulary	$\forall x(\text{Vocabulary}(x) \rightarrow (\exists y(\text{hasContext}(x,y) \wedge \text{Numeral}(y))))$

4.1 Ontology validation process

The validation process followed three stages. First the ontology was evaluated by three experts of the field. Their field of expertise is on Japanese language teaching. This stage of the process helped to achieve the “shared” property of the ontology. It demonstrated that the ontology is reflecting the common body of knowledge from the Japanese proficiency domain.

We are aware that more experts must evaluate the ontology, but this is part of the work’s evolution. As the ontology and our adaptive system are made public, we will be able to gather more feedback and improve the conceptualization. This point is not covered by the methodology adopted on Section 3.

Secondly, we followed the work of Gangemi (2006) that is focused only on the validation stage. That work defines and formalizes several metrics to evaluate the ontology from quantitative and qualitative perspectives. The definition is represented with a meta-ontology and the formalization establishes the mathematical formulae to calculate the quantitative part.

We evaluated the JLPT ontology using the modularity, depth, breath and accuracy parameters. From this partial evaluation, the ontology is valid. Our next step is to evaluate the ontology against the full set of parameters defined in Gangemi (2006). At this point we used more quantitative aspects since we are more concerned with the practical utilization of the ontology. The pragmatics aspect is related to the fulfillment of the requirements established at the specification stage with support from the utilization scenarios (more end-user-related issues).

Finally, we validated the ontology from a computational perspective. Since used OWL for the development we were able to use two reasoners that logically verify OWL ontologies. The purpose of a reasoner is beyond this simple evaluation, but this is the part that better fits this paper. Logical consistency tests were performed with the Pellet⁵ and RACER reasoners. Both of them generated the same results confirming the validity of the ontology.

5. Conclusion

From an educational point of view, the main contribution of this work is the ontological model of the educational domain following the Relevance Theory's perspective. This was achieved with a domain ontology (JLPT) and the embodiment of the concepts and general guidelines from the relevance theory on the ontology and on the development of the adaptive system. Technically, we demonstrated our validation process achieving an effective evaluation of the model.

Considering the more general goal of the work, which is an adaptive computational learning environment, the results presented in this paper represent the foundation to achieve adaption. We already have an initial user model for adaptability and sufficient elements to feed the adaption mechanism, mainly from the domain ontology. Our next step is to integrate both models in one system, which will result on the end user learning environment.

Acknowledgments

This work was partially supported by FAPEAM and CNPQ, Brazil.

References

- Breitman, K.K. *Web Semântica - A Internet do Futuro*. LTC, Rio de Janeiro (2005).
- Fernández, M., Gomez-Perez, A., Juristo, N.: METHONTOLOGY: from Ontological Art towards Ontological Engineering. In: Proc. of the AAAI97 Spring Symposium Series on Ontological Engineering (1997).
- Gangemi, A., Catenacci, C., Ciaramita, M., Lehmann, J. Modeling Ontology Evaluation and Validation. Y. Sure (ed.), *Proceedings of the Third European Semantic Web Conference*, Springer (2006).
- Guarino, N. Understanding, Building and Using Ontologies: A Commentary to "Using Explicit Ontologies in KBS Development" by van Heijst, Schreiber, and Wielinga. *International Journal of Human and Computer Studies*, 293-310 (1997).

⁵ <http://www.racer-systems.com/>

- Guarino, N. Formal Ontology and information systems. In Proceedings of the FOIS'98. Available at: <<http://www.loa-cnr.it/Papers/FOIS98.pdf>>. Accessed 15 set. 2008.
- Schreiber, G. Knowledge Engineering. In: Handbook of Knowledge Representation, Elsevier. (2008).
- Bittencourt, I.I., Isotani, S., Costa, E., Mizoguchi, R. Research Directions on Semantic Web and Education. *Journal Scientia - Interdisciplinary Studies in Computer Science*, 19(1), 59–66 (2008).
- Nozawa, E.H. and Oliveira, E.H.T. Simulador e-JLPT: Um Software de Apoio Educacional com enfoque em Hipermídia Adaptativa. XVII SBIE - Simpósio Brasileiro de Informática na Educação, realizado de 8 a 10 de novembro de 2006, Brasília/DF, Volume I (2006).
- Nozawa, E.H., Oliveira, E.H.T., Castro Júnior, A.C., Vicari, R.M. Proposta de um esquema de integração de hipermídias adaptativas em ambientes virtuais de aprendizagem dentro de um contexto de arquiteturas pedagógicas. XIX SBIE - Simpósio Brasileiro de Informática na Educação, III Workshop de Arquiteturas Pedagógicas para Suporte à Educação à Distância mediada pela Internet, realizado de 12 a 14 de novembro de 2008, Fortaleza/CE (2008).
- Mohammed, P. and Mohan, P. Contextualizing Learning Objects Using Ontologies. In: *Computational Intelligence*, V. 23, N. 3, 339–355. Blackwell Publishing (2007).
- Ribeiro, R.D., Batista, F., Pardal, J.P., Mamede, N.J., Pinto, H.S. Cooking an Ontology, In The Twelfth International Conference on Artificial Intelligence: Methodology, Systems, Applications, Springer Berlin / Heidelberg, vol. 4183, pages 213-221, Varna, Bulgaria, September 2006.
- Silva, D. L., Souza, R.R., Almeida, M.B. Comparação de metodologias para construção de ontologias e vocabulários controlados. In: *Seminário de Pesquisa em Ontologia no Brasil*, 2008, Niterói/RJ.
- Sperber, D. and Wilson, D. *Relevance: Communication and Cognition*. Cambridge, MA: MIT Press (1986).
- Sperber, D. and Wilson, D. *Relevance. Communication and Cognition*. Oxford: Blackwell (1995).

Adaptive e-learning systems can be defined as systems offering personalized solutions to suit individual learners's needs. Thus personalized solutions are built with respect to different kinds of... Cite this paper as: Laroussi M. (2012) Ontology in Adaptive Learning Environment. In: Uden L., Corchado Rodríguez E., De Paz Santana J., De la Prieta F. (eds) Workshop on Learning Technology for Education in Cloud (LTEC'12). Advances in Intelligent Systems and Computing, vol 173.