Learning Demography in a Web Classroom: Ontological Support

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Abstract. This paper describes steps taken towards introducing Web-based educational technology in teaching demography at the university level. Traditionally, demography is taught by giving lectures to the students, who are then expected to study from textbooks and exercise in demographic calculus. Some students find this way of learning monotonous and exhausting, hence their motivation gradually drops. Modern learning technology can help prevent such a situation, at least to an extent. Of course, using any technology to support teaching and learning requires representing essential parts of the domain knowledge with that technology first. The paper presents initial results in building such a knowledge infrastructure for Web-based education (WBE) in the domain of demography.

Keywords. Web-Based Education, Reusable Learning Objects and Standards, Ontologies, Teaching and Learning Technologies, Demography.

1. Introduction

The importance of demographic studies increases progressively in the last 50 years, and so does the interest in integrating quantitative and theoretic knowledge of human population [4], [8], [14]. Currently, demography as a scientific discipline is taught mostly at universities, since it requires a certain level of maturity and prerequisite knowledge higher than that at high-school level. On the other hand, learning demography requires mastering of a number of abstract concepts and specific skills are required in order to progress in learning effectively. Unfortunately, traditional textbook-and-exercise way of learning such a discipline is not always effective.

This results in the need to introduce other approaches in teaching and learning in this domain. WBE has proven to be effective as a teaching and learning approach in a number of other disciplines, and it can especially increase the students' motivation when learning abstract concepts. From the teachers' perspective, it requires keeping up with the progress of technology in their own studies, and supports avoiding staleness in their knowledge and pedagogical skills. From the learners' perspective, it supports pro-active studying and systematic adoption of the domain knowledge.

We have taken several steps in order to gradually introduce WBE in teaching and learning demography at our university. First, a team of software professionals has built a *Web classroom* – a network-based technological support for learners that will help them utilize current Web technologies to grasp domain concepts more easily. Initial practical experience with the Web classroom in learning topics from other domains is extremely encouraging [15]. Second, we want to introduce the technology of Web-based *intelligent tutoring systems* (ITS) [2] in the Web classroom, so that adaptive and personalized learning will be supported. Finally, we are in the process of building Web-based knowledge infrastructure to enable easy creation of teaching material, intelligent support for learning, and reuse of learning resources.

2. Web Classroom

Our Web classroom is a client-server learning environment designed as in Figure 1. Students and teachers work in a real or in a virtual classroom; in both cases, students learn individually and Web technology connects the server and the client sides. In the current design, interaction between the students and the teachers is not supported through the system. It is assumed that such an interaction can be rather direct in a real classroom, and that in a virtual classroom students exercise with the system individually (possibly only later reporting to the teacher the problems they run into).

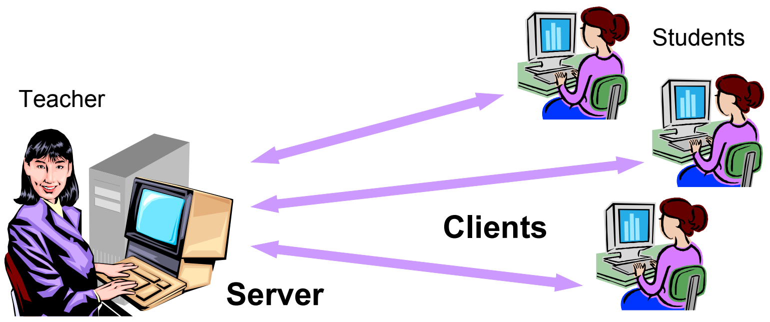

Figure 1 – A Web classroom

There are two major actors in this environment: the student on the client side, and the teacher on the server side. There are four modes of a student's interaction with the Web classroom: "Authentication" (logging in for a new session), "Learning" (selecting one of the material to learn from and reading the corresponding illustrated lessons; some of the lesson pages are filled with text and graphics, and some of them also have supporting audio and video clips), "Assessment" (answering questions the system asks after the learning of a lesson is completed), and "Validation" (the mode in which the system checks and updates the student model by estimating the student's knowledge about different topics from the material he/she was supposed to learn).

The teacher is on the server side. Her tasks include authentication, starting the server, monitoring the students' sessions, editing the domain knowledge (learning material) and stopping the server. Some of the tasks are very different from those on the student side - for example, editing the domain knowledge, which is allowed only to the teacher. In this mode, the teacher adds, edits or deletes the learning and assessment material. A specific server-side module, also accessible only by the teacher, is used for monitoring the students' sessions.

The server exhibits enough intelligence to arrange for *personalization* of the learning tasks it supports. In fact, from the learner's perspective the server appears to act as an intelligent tutor with both *domain* and *pedagogical* knowledge to conduct a learning session. It uses a *presentation planner* to select, prepare, and adapt the domain material to show to the student. It also gradually builds the *student model* during the session, in order to keep track of the student's actions and learning progress, detect and correct his/her errors and misconceptions, and possibly redirect the session accordingly. Domain knowledge is structured in two levels: the basic and the advanced level. A novice student has to learn the basic concepts first. Only if the student passes the assessment of the basic knowledge without negative marks, he/she can study the corresponding advanced-level lessons. We have developed a number of question sets per lesson. This means that the student who gets at least one negative mark will be asked a new set of questions when repeating the same lesson. This forces the student to read and learn the lessons with attention. After evaluating the student's performance, the server (the tutor) can suggest the student to read a certain lesson again. This recommendation is based on the results of the assessment. There are separate knowledge-base modules (separate files) for this purpose. The system takes the assessment results and searches for the worst mark. If there are two or more marks with the same value, the system uses the first one it finds. Then it takes the worst mark's lesson-name and finds the mapped reference to the HTML page (paragraph). The final result of this reasoning process is a servlet-generated link which is the reference to a certain HTML page (or paragraph). The student can click the recommendation link and the session is continued by reading the referenced chapter/lesson. Otherwise, if the student is satisfied then submitting the results ends the session. See [15] for technical details on the design implementation of these techniques.

3. Web-Based ITS

Research and development in the area of Web-based ITS have a long tradition. First-wave Web-based ITS like ELM-ART [3] and PAT Online [13], to name but a few, were followed by a number of other learning environments that used Web technology as means of delivering instruction. Our initial design of Web classroom was pretty much the same.

More recent Web-based ITS address other important issues, such as integration with standalone, external, domain-service Web systems [9], using standards and practices from international standardization bodies in designing Web-based learning environments [12], and architectural design of systems for Web-based teaching and learning [1], [5], [10]. These were the main guidelines we took in the improvement of our initial Web classroom design. For example, we want to make possible for students of demography using our Web classroom to access electronic maps showing population distribution coming from an external Web-based geographic information system, as well as to browse an electronic atlas if they need to. Also, we want the Web classroom to provide intelligent reference-service to the students, such as when-needed appearance of a glossary of demographic terms (e.g., the one provided by The Commission on Population, http://www.popcom.gov.ph/Glossary.htm). Current architecture of our Web classroom is based on the centralized model explained in [10] – the server side performs all tutoring functions. XML technology is used to generate files that the server uses to provide recommendations to the students, as in [9], and several ITS-architecture design patterns [5] are applied in structuring the server.

Rebai and de la Passardiere try to capture educational metadata for Web-based learning environments [11]. We are aware of the importance of such efforts, and have taken some steps in redefining some modules in the Web classroom accordingly.

4. Ontological Support for WBE of Demography

In order to enable authoring of learning material to support intelligent teaching and learning of demography in the Web classroom through a Web-based ITS, it is necessary to provide a substrate of essential domain knowledge for the ITS to be based on. Likewise, it is also important to develop such educational content on the server in accordance with important pedagogical issues such as instructional design and human learning theories, to ensure educational justification of learning, assessment, and possible collaboration among the students. Moreover, the core of both the domain (demographic) and instructional (pedagogical) knowledge should be made available in machine-understandable and machine-processable form for different courseware in the Web classroom to reuse them.

4.1 Ontological infrastructure

The way to provide all that is to develop a number of shareable and reusable *ontologies*, as machine representation of the core-knowledge infrastructure around which knowledge bases of a demographic Web-based ITS can be built. Each such an ontology should provide a set of knowledge terms, including the vocabulary, the semantic interconnections, and some simple rules of inference and logic for some particular topic or service [7]. Once a number domain and instructional ontologies are developed, the author of learning material can rely on them in developing, representing and structuring the body of knowledge in the courseware she creates. With the appropriate authoring tool, the learning material gets automatically annotated with pointers to a number of shareable domain (as well as instructional) ontologies.

There are many concepts in demography that are used in other disciplines as well (e.g., population growth and migrations are important in political sciences as well). Hence different domains can share some ontologies or parts of them, and sometimes complex ontologies can be composed of several simpler ontologies. In other words, ontologies can be stored on different servers on the Web, can point to each other, and can be reused by educational applications and different courseware, Figure 2. For example, suppose a student uses a Web-based ITS to learn about population changes in a certain region during a specified time period. If the ITS is ontology-aware, and if it uses the ontology of population changes residing somewhere on the Web, it can dynamically generate and refresh the ontology tree (in a dedicated pane on the screen) as the student navigates through the learning material. It can also dynamically and adaptively highlight the terms from the ontology in the working window on the screen. Simultaneously, quite another intelligent Web-based tutor from the domain of war history can use the same ontology for explaining another learner the implications of war on population decrease.

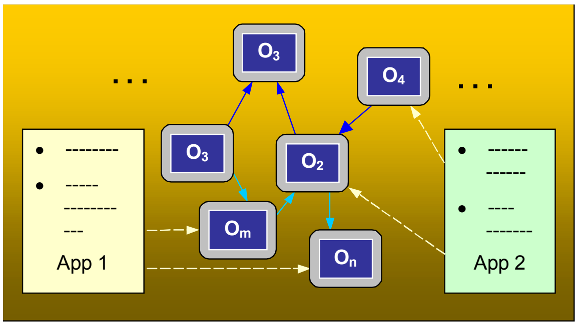

Figure 2 – Different Web-based ITS can share ontologies (O_i - ontologies)

Interoperability and knowledge sharing between different educational applications can be achieved by using appropriate *languages* for representing ontologies and educational content and services. Current trends in *Web technology* suggest that appropriate representation languages include *XML*, *XML Schema*, *RDF*, and *RDF Schema* languages, all developed under the auspices of WWW Consortium (http://www.w3.org/XML, http://www.w3.org/RDF). For developing domain ontologies, higher-level languages and graphical tools built on top of those four are a good choice.

4.2 Demographic ontologies

For a demographic Web-based ITS, two kinds of ontologies are needed – demographic (domain) and pedagogical. We have developed some pedagogical ontologies according to the GET-BITS framework for building ITS [6]. They are applicable in different Web-based ITS, and are beyond the scope of this paper. As for domain ontologies, we have started designing and developing them relying on domain knowledge represented in well-known textbooks such as [4], [8], and [14].

Figure 3 represents a part of the knowledge structure pertaining to some well known concepts in demography, according to [4]. We used it as the starting point for developing a set of demographic ontologies. Without going into more detailed explanations, it suffices to say that *population composition* denotes population structure based on the value or modality of a certain criterion. While the notion of the concepts from Figure 3 is intuitively clear, it should be noted that other authors may have a different categorization.

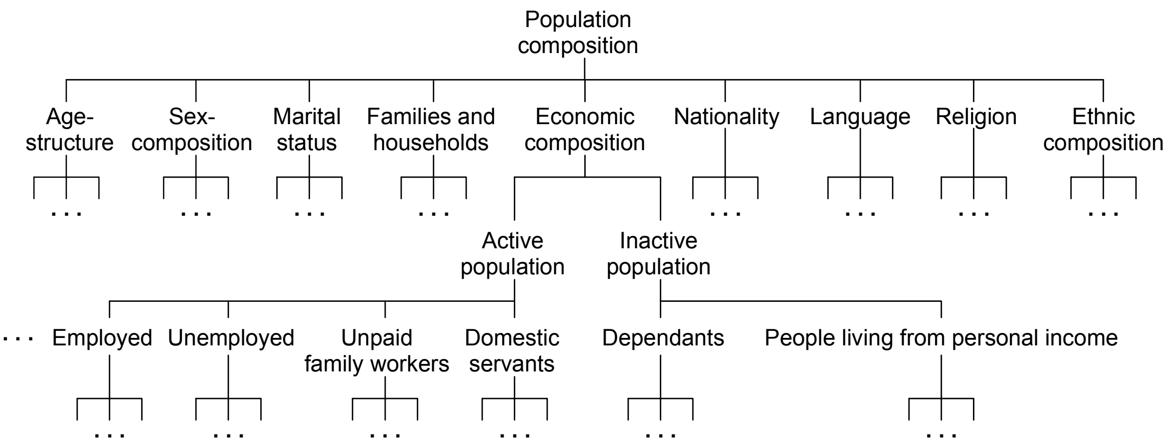

Figure 3 – Important concepts in demography

Starting from these concepts and a number of other demographic concepts, their relationships and attributes, as well as from formulae needed to calculate various quantitative demographic indicators, we have designed and developed a set of demographic ontologies. We used the Protégé-2000 ontology development environment (http://protege.stanford.edu/). The following section presents details.

4.3 Design and implementation

Figure 4 a screenshot from *Population composition* ontology, one of the demographic ontologies that we developed using the knowledge structure from Figure 3. In order to make our ontologies shareable and reusable, we converted them into RDF Schemata. Figure 5 shows an example.

We have also developed ontologies related to *population growth*. Population growth depends on two components, *natural increase* (expressed in terms of *fertility* and *mortality*) and *net migrations* (i.e., *immigration* and *emigration*). A quantitative indicator showing the rate of population change is the *population increase rate*. Simple formulae are used to compute population increase rate and other quantitative indicators to initialize instances of the corresponding ontologies.

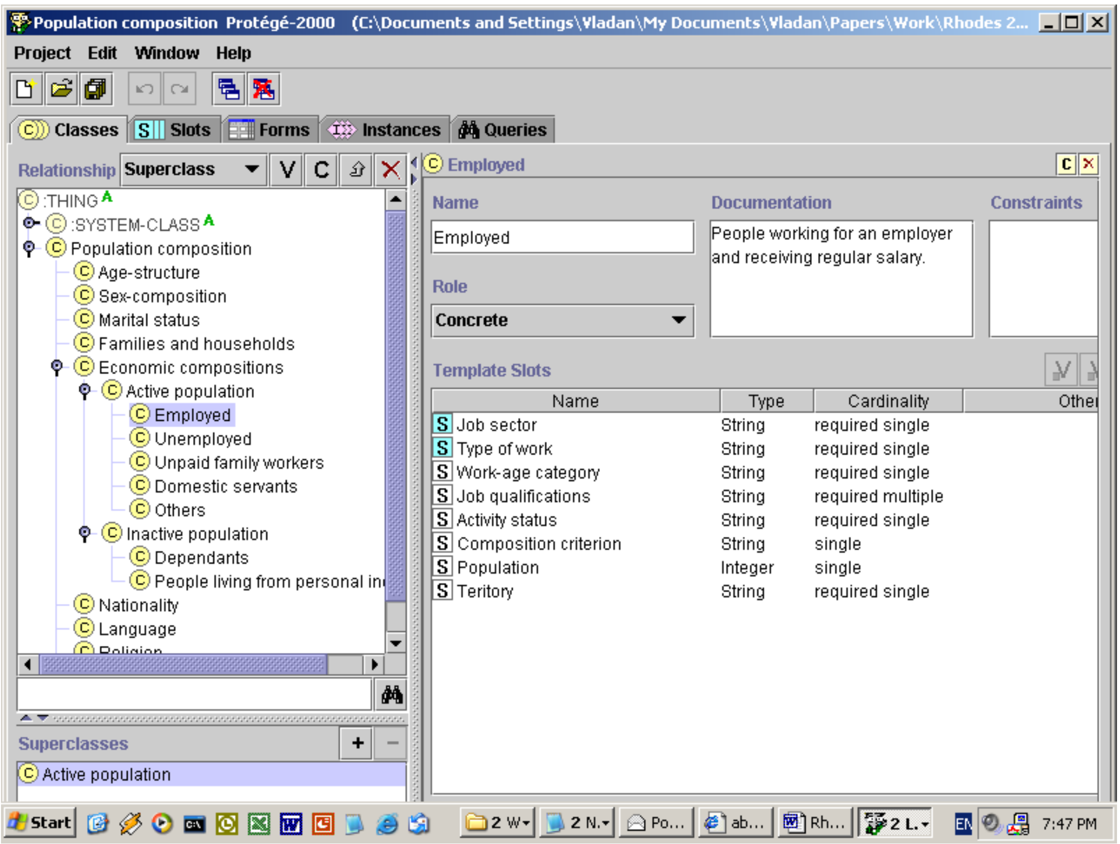

Figure 4 – Creating *Population composition* ontology in Protégé-2000

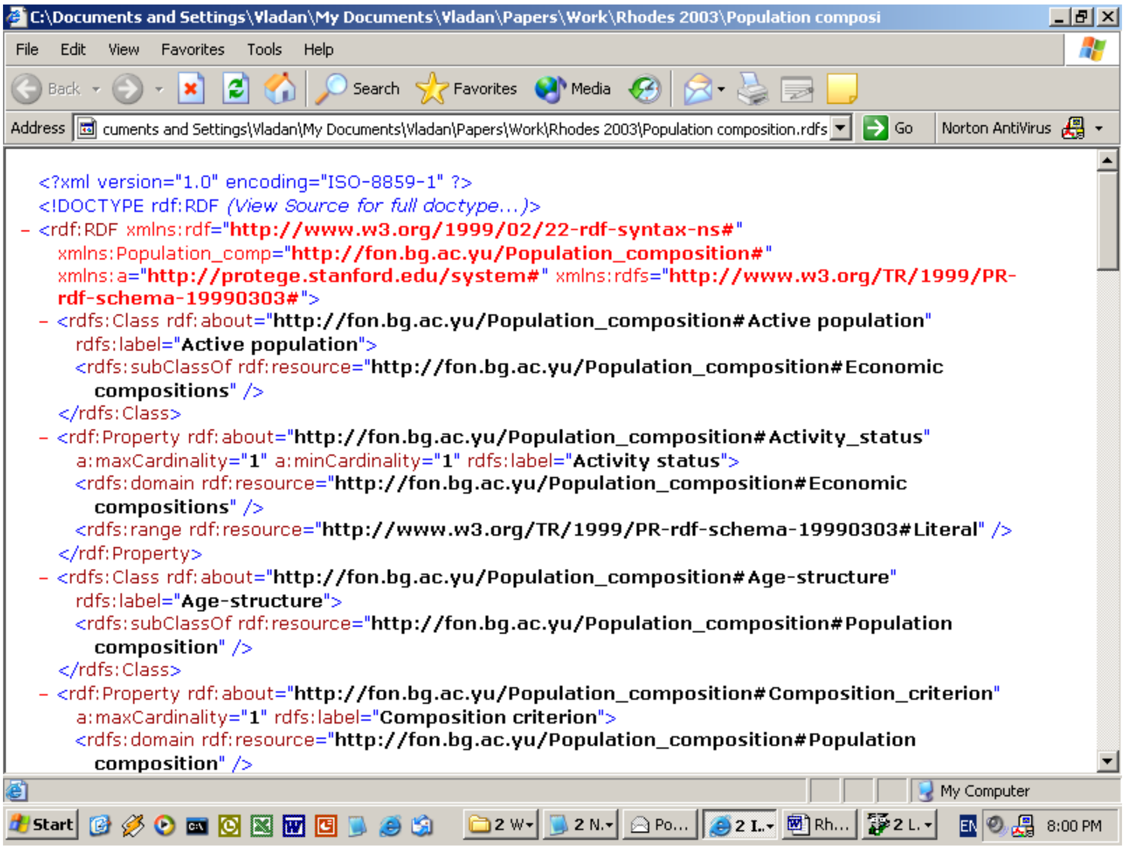

Figure 5 – The RDF Schema representation of the *Population composition* ontology

We are perfectly aware of the fact that our ontologies are not completed yet, neither individually, nor as an interrelated set of ontologies. It is now left to their users and domain experts to notify us of the usability and deficiencies of the ontologies we developed, and it is our responsibility to refine them in the future. As for the users, our intended users at the moment are Web courseware authors for our Web classroom. Indirectly, the students who are supposed to learn from the material the authors develop are also the users and potential critics of design of our ontologies. Once the design is refined to a satisfactory extent, we also hope for feedback from other institutions whose Web applications need demographic knowledge sharing and reuse, such as bureaus of statistics, electoral bodies, and other government organizations.

Meanwhile, we have conducted some informal rudimentary evaluation of the Web classroom (albeit not with the students of demography; we have prepared the courseware in the domain of radio-communication previously [15] and conducted an evaluation study within that domain). The evaluation was questionnaire-based and has revealed that the students want more diversity in material presentation than it is currently supported. In other words, the next steps in further developing the Web classroom should include more instructional design.

5. Conclusions

Since the GET-BITS view of both pedagogical and domain ontologies is that they should evolve, we started with a small set of ontologies that represent widely known demographic concepts. Although they are not highly elaborated yet, they still provide at least a limited initial semantic interoperability across pedagogical agents, courseware, tools, and educational servers. If over time these ontologies prove to be really useful for developing demographic Web-based ITS, it makes sense to believe that they will get upgraded and extended over time. If, on the other hand, they fade away, it is highly likely that some other, competing ontologies in the domain of demography, possibly published elsewhere on the Web, will gain more attention and will become more widely used for developing courseware for our Web classroom.

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