A knowledge intensive implementation of an active collaborative space for concurrent CAD engineering purposes in an academic laboratory environment

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ABSTRACT: A knowledge intensive implementation is developed in the form of a social learning Web site for CAD concurrent engineering purposes in an academic laboratory environment. The implementation serves three main purposes: first, to provide a robust method of retrieving meaningful information assets from the Web, populating a sustainable CAD oriented knowledge base; second, to utilise this knowledge base using an active academic laboratory organisation; and third, to optimise both the knowledge base and the collaborative CAD Web site utilising a manufacturing process ontology.

THEORETICAL BASE

Content Acquisition and Tagging

The present work aims at creating a semantic knowledge base in a way that is configurable to serve an academic CAD laboratory, which operates in a concurrent engineering environment and uses social and experiential e-learning techniques. The knowledge building implementation focuses not only on content creation (finding the assets on the Web and classifying them accordingly) but also on content delivery. Both dimensions should be taken into account from the start.

A typical process sequence for knowledge implementation comprises the following [1-5]:

1. *Building* a large collection of facts about entities, classes and relationships based on Web sources;
2. *Cleaning* the knowledge base by assessing the validity of facts, possibly removing invalid pieces or completing missing pieces by deduction;
3. *Querying* the fact collection to answer advanced questions by knowledge workers;
4. *Ranking* answers to complex queries or reasoning tasks, by means of statistics about informativeness, confidence, compactness and other criteria;
5. *Reasoning* about entities and relationships to derive additional knowledge that is not readily given in extensional form;
6. *Maintaining* and growing the knowledge base as the world evolves, with new facts coming into existence and being digitally expressed on the Internet.

In the process of the aforementioned steps, the content is tagged using a set of keywords that come from two discrete entities: a) an engineering ontology, to assure orthological domain targeting; and b) the Sharable Content Object Reference Model (SCORM) metadata schema, for basic compliance with the core e-learning procedures.

Cognitive Models of Team Collaboration

Several models of team collaboration have been proposed. Warner, Letsky and Cowen [6] propose 16 distinct cognitive processes for successful team collaboration that are listed below (as they appear in Reference [6]), covering almost all aspects of the meaningful use of team effective collaboration. Being in tabular form, these distinct processes can be correlated with the features of the Web service supporting a team for on-line team collaboration (Table 1):

1. *Individual mental model construction:* Individual team members use available information and knowledge to develop their mental picture of the problem situation.
2. *Knowledge interoperability:* The act of exchanging useful, actionable knowledge among team members.
3. *Individual task knowledge development:* Individual team members ask for clarification of data or information or respond to clarification requested by other team members.
4. *Team knowledge development:* All team members participate in clarifying information to build team knowledge.
5. *Individual knowledge object development:* Pictures, icons or standard text are developed by an individual team member or the whole team to represent a standard meaning.
6. *Individual visualisation and representation of meaning:* Visualisations (e.g. graphs, pictures) are used by individual team members to transfer meaning to other team members. Representations are methods (e.g. note pads) used by individual team members to sort data and information into meaningful chunks.
7. *Iterative information collection and analysis:* Collecting and analysing information to come up with a solution with no specific solution mentioned.
8. *Team shared understanding:* The synthesis of essential data, information or knowledge, held collectively by some (complementary understanding) and/or all (congruent understanding) team members working together to achieve a common task.
9. *Develop, rationalise and visualise solution alternatives:* Using knowledge to justify a solution.
10. *Convergence of individual mental models to team mental model:* Convincing other team members to accept specific data, information or knowledge.
11. *Team negotiation:* Team negotiation of solution alternatives ending in a final solution option.
12. *Team pattern recognition:* The team as a whole identifies a pattern of data, information or knowledge.
13. *Critical thinking:* The team works together toward a common goal, whereby goal accomplishment requires an active exchange of ideas, self-regulatory judgment and systematic consideration of evidence, counterevidence and context in an environment where judgments are made under uncertainty, limited knowledge and time constraints.
14. *Shared hidden knowledge:* Individual team members share their knowledge through prompting by other team members.
15. *Compare problem solution against goals:* Team members discuss solution options against the goal.
16. *Analyse and revise solution options:* Team members analyse final solution options and revise them if necessary [6].

IMPLEMENTATION

An existing engineering ontology enrichment is proposed in order to serve the purposes of content tagging and knowledge building of assets that belong to the CAD domain [7]. The enrichment of the ontology refers to the purpose that the CAD assets are to be consumed in the particular educative environment of a CAD academic e-laboratory set up. The implementation uses the enriched ontology to model the way the e-laboratory populates and utilises its knowledge base. Extensive use of collaborative models supports the stakeholders roles from the concurrent engineering views [8].

Content Acquisition and Tagging

An e-laboratory CAD site is developed for the proof of concept of the proposed implementation. The features of this site follow the distinct processes of the cognitive models of team collaboration presented in the theoretical base above and are listed in Table 1. The experimental e-laboratory site is created to serve the present studies' implementation's purposes providing a proof of concept. The URL of this site: https://sites.google.com/site/aimscadcamsystems/

Table 1: Cognitive models/e-laboratory CAD features [6].

	Guidance	Tests	Calendar	Announcements	Forum	Chat	Ideas	Drawings	Blueprints	News	Blogs	Q & As	Mini library	Videos	3D CAD models	Help
1. Individual mental model construction		●	●		●		●	●	●			●		●	●	
2. Knowledge interoperability	●				●	●	●	●	●		●	●				
3. Individual task knowledge development	●	●	●				●	●	●		●	●	●	●	●	●
4. Team knowledge development	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

5. Individual knowledge object development				●	●		●	●	●		●	●				
6. Individual visualisation and representation of meaning				●	●		●	●	●		●	●				
7. Iterative information collection and analysis	●	●			●		●	●	●		●	●	●	●	●	
8. Team shared understanding	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
9. Develop, rationalise and visualise solution alternatives		●	●	●	●	●	●	●	●	●	●	●	●	●	●	
10. Convergence of individual mental models to team mental model			●	●	●	●	●	●			●					
11. Team negotiation	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
12. Team pattern recognition				●	●	●	●	●	●	●	●	●	●	●	●	
13. Critical thinking	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
14. Shared hidden knowledge	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
15. Compare problem solution against goals	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
16. Analyse and revise solution options	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	

It should be noted here that drawings and blueprints functionalities are essentially SaaS CAD software that can fully support 2D and 3D CAD designs reviewing and development giving the site a concrete experiential autonomy.

In the upper level system description, the logical architecture of the system is depicted in Figure 1, showing the *Data Circulation* amongst the stakeholders roles (here: *Processes*), as well as the *Data Repositories*.

These roles couple with the present studies' content acquisition and tagging theoretical base, described above, are as follows [1][8][9]:

1. Building (enriching the ontology and building up the knowledge base)

For simplicity purposes, all keywords/tags that come from SCORM are turned into ontology classes enriching the existing engineering ontology [7]. For the purposes of the present study the search for Web CAD assets is being directed in the network domain of a semi structured knowledge base called 3D Content Central **(**http://www.3dcontentcentral.com/Default.aspx).

The 3D Content Central Repository is the ideal place to extract actual 3D models of literally hundreds parts and assemblies that are easily reached by a central portal/repository and are categorised in convenient categories. These parts are certified by the 3D content central team to be representations of active, *real life* manufacturing parts and assemblies that are provided by a large number of industrial suppliers (full list: http://www.3dcontentcentral.com/parts/all-parts-suppliers.aspx). By utilising this site the interest of the present study is mainly focused on the next steps of the implementation.

First, the CAD assets are embedded in a Blog SaaS service that is powered by a robust tagging module, characterised by extended global use and also supports interoperability of its database assets (along with the tags) with other widely accepted and used platforms. For the purposes of the resent study, the Blogger platform by Google was chosen (http://aimscadcamsystems.blogspot.com/). Blogger was chosen also for compatibility reasons with the experimental e-laboratory site that is based on the Google sites platform.

2. Cleaning

Key entries of the upper level SCORM description and the experiential perspective are embodied in the existing **[7]** engineering ontology to serve the academic e-learning purposes of the formulating knowledge base. The new classes are illustrated in Figure 2 and Figure 3 that are following:

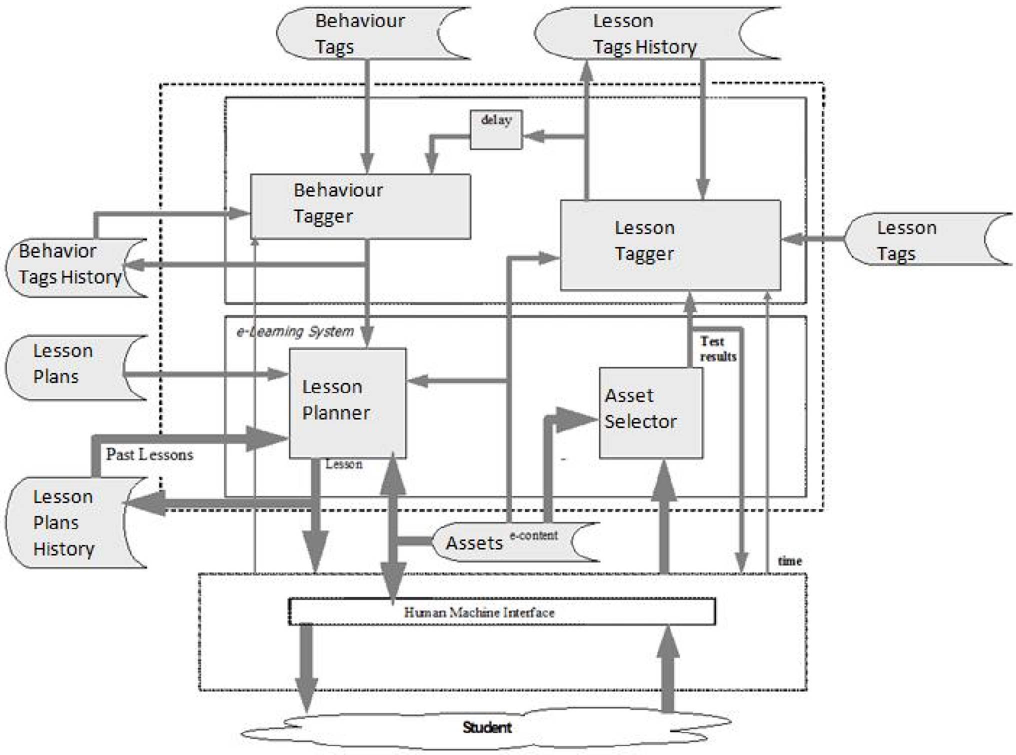

Figure 1: Upper level system description with stakeholders' roles and high-level processes.

3. Ranking

Ranking is performed by means of tagging by the lesson tagger role:

Lesson Tagger: *The lesson tagger classifies (tags) the assets using all the ontology class names as tags. The lesson tagger uses all the class names described above* (it is compulsory for the lesson tagger to use all the available tags/class names depicted in Figure 2 and Figure 3) and as many from the pure/non-educative CAD entries as possible/available.

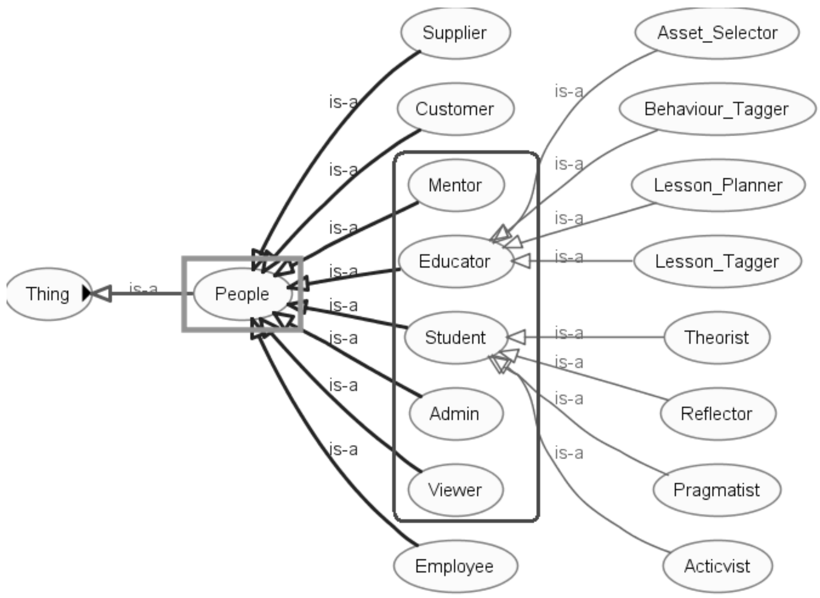

Figure 2: New classes for the *people* main class.

The end result of the lesson tagger is a learning activity. A *learning activity* can be defined as an interaction between a learner and an environment, leading to a planned outcome. It is the planned outcome, which makes learning a purposeful activity [10]**.** This particular ranking process happens having only the asset attributes in mind and not taking into account any lesson specifics - something carried out by the behaviour tagger and mainly the lesson planner as described below. This de-coupling parallel tagging from different tagging roles happens mainly for re-usability purposes of the learning activities (from other, future, unknown system implementations) that have to avoid being lesson plan specific.

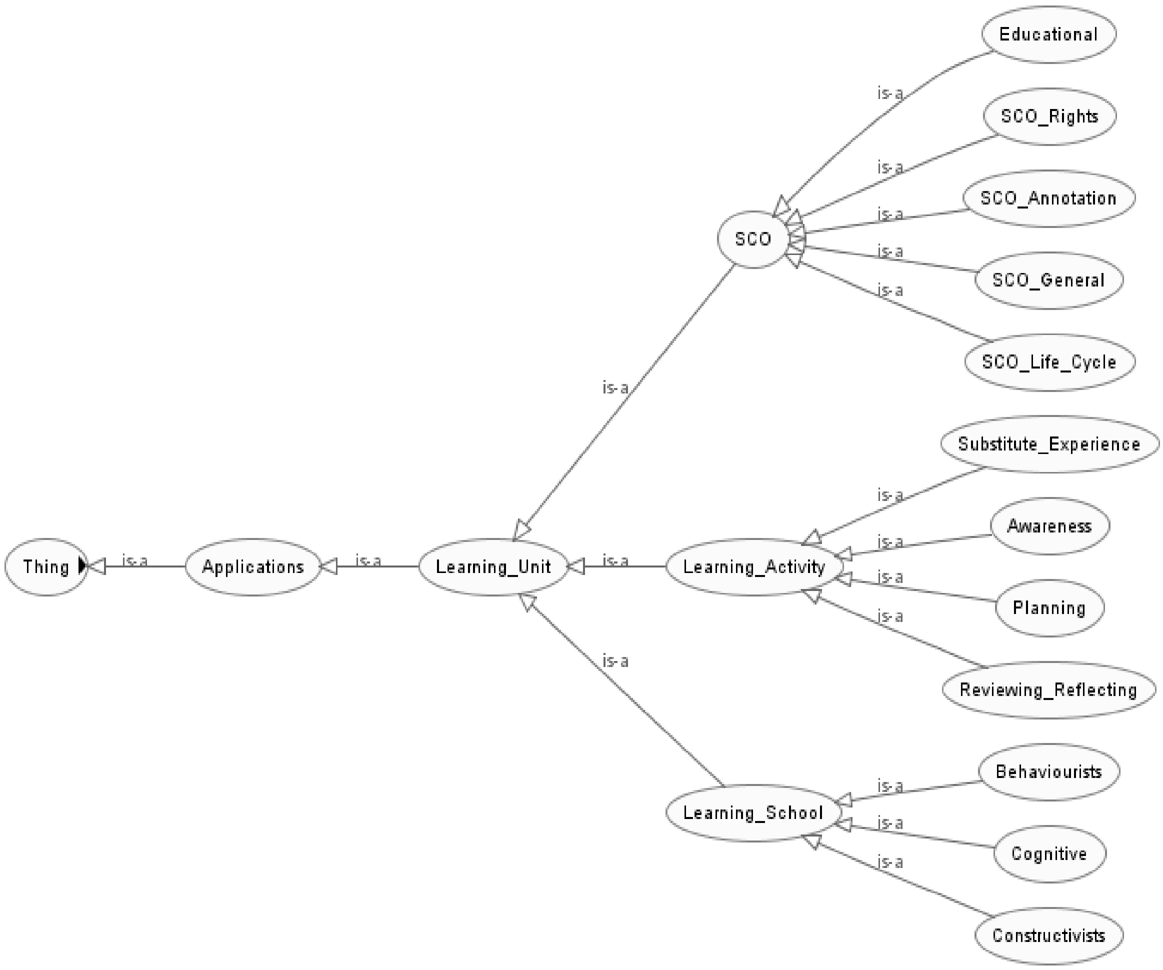

Figure 3: New classes for the *applications* main class.

4. Reasoning

Behaviour Tagger: *The behaviour tagger audits the tags used by the lesson tagger by focusing on the compatibility of the tags related to the people class with all the remaining*. This audit is particularly important taking into account the social and experiential character of the e-laboratory site.

Lesson Planner: *The lesson planner queries the knowledge base for applicable/available learning activities comparing to the particular cases and the CAD laboratory configuration at hand that consists of the* real world *academic settings and the* virtual *one of the e-laboratory CAD site*. An optimal choice is made and the lesson is given a singular name and ID code. After that the lesson is made available on the site. It should be noted that *a lesson is different from a learning activity* in the sense that a lesson could include more than one learning activity. Also, classification is made at the learning activity level mainly for re-use purposes of the learning activities.

5. Maintaining

Even though the aforementioned roles are described in a framework of a continuous process of a learning activity, they work independent and not necessarily for a single/common learning activity at a given time. This organisation leaves room for maximum flexibility and continuous improvement of the learning activities and can be effective since a learning activity could be quite functional, although far from its end-product potential, from the moment the Asset Selector puts it together. Tagging by the lesson tagger, behaviour tagger and fine-tuning from the lesson planner (fine-tuning: putting the learning activity in a full lesson plan implementation) may happen in due time only to enhance efficacy of the learning activity at hand.

CONCLUSIONS

As a result, the stakeholders/users of the Web site being developed for the CAD academic laboratory are provided with both semantic knowledge assets ready to serve the site's learning purposes and a sustainable process oriented ontology aligned to serving academic purposes via social experiential learning techniques. The social experiential learning methods and tools (on the site) are used as a binding tool between the assets of the knowledge base and their use by the CAD laboratory members with a view to broader academic utilisation. Furthermore:

a) An ontology Web language (OWL) framework is presented and actively put in the service of an academic laboratory domain.
b) The ontology is enriched both at the class and devices levels. At the class level the ontology is enriched with additional classes in order to serve the e-learning schemes. This is done mainly with the use of SCORM descriptions and also with some significant proprietary entries concerning the experiential/social aspect of the work. At the physical files level the ontology is enriched with CAD drawings according to a specific pattern that involves active collaboration by all the laboratory stakeholders.
c) An active concurrent engineering ready Web site configured to support the knowledge harvesting implementation is created. The implementation use cases are embedded seamlessly into the Web site and the importance of enriching a knowledge database as an integral part of the educational process of the CAD e-laboratory is emphasised.

REFERENCES

1. Nichols, F., *The Knowledge in Knowledge Management*. In: Cortada, J.W. and Woods, J.A. (Eds), The Knowledge Management Yearbook 2000-2001. Boston: Butterworth-Heinemann, 12-21 (2000).
2. Takeuchi, H. and Nonaka, I., *Theory of Organizational Knowledge Creation*. In: Morey, D., Maybuny, M. and Thuraisingham, B. (Eds), Knowledge Management: Classic and Contemporary Works. Cambridge (Mass) and London: MIT Press, 139-182 (2000).
3. Wilson, T.D., The nonsense of *knowledge management*. *Infor. Research*, 8, **1** (2002).
4. Karsten, H., Constructing interdependencies with collaborative information technology. *Computer Supported Cooperative Work*, 12, **4**, 437-464 (2003).
5. Karsten, H. and Jones, M., The long and winding road: collaborative IT and organisational change. *Proc. 1998 ACM Conf. on Computer Supported Cooperative Work*, 14-18 November, Seattle, Washington, USA, 29-38, (1998).
6. Warner, N., Letsky, M. and Cowen, M., Cognitive model of team collaboration: macro-cognitive focus. *Proc. 49th Annual Meeting of the Human Factors and Ergonomics Society*, Orlando, USA (2005).
7. Kim, K-Y., Manley, D.G. and Yang, H., Ontology-based assembly design and information sharing for collaborative product development. *Computer-Aided Design*, 38, **12**, 1233-1250 (2006).
8. Blackmore, C., *Social Learning Systems and Communities of Practice*. Springer, 44-50 (2010).
9. Kolb, D.A., *Experiential Learning: Experience as the Source of Learning and Development*. New Jersey: Prentice-Hall (1984).
10. Anderson, T. and Elloumi, F., *Theory and Practice of Online Learning*. Athabaska University (2004).