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An intelligent semantic e-learning framework using context-aware Semantic Web technologies

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Abstract

Recent developments of e-learning specifications such as Learning Object Metadata (LOM), Sharable Content Object Reference Model (SCORM), Learning Design and other pedagogy research in semantic e-learning have shown a trend of applying innovative computational techniques, especially Semantic Web technologies, to promote existing content-focused learning services to semantic-aware and personalised learning services. To facilitate this transforming process, this paper presents a novel context-aware semantic e-learning approach to integrate content provision, learning process and learner personality in an integrated semantic e-learning framework. As the basis of the computational framework, a scalable and extensible generic context model is proposed to structure the semantics of contextual relations and concepts in various contexts, such as learning content description, learning model, knowledge object representation and learner personality. Corresponding technical and pedagogical developments of this framework also consider compatibility issues with existing technologies (eg, XML/Resource Description Framework) and specifications (eg, IEEE LOM) in order to achieve the best interoperability.

Introduction

Internet-based e-learning revolutionarily changed the training and education industry for its uninterrupted online service for 24/7 access anywhere. Since the concept was formally introduced at the 'Internet-based training' workshop at the American Society for Training and Development 1996 international conference, the e-learning industry has gone through a boom-and-bust cycle of development (Kruse, 2002). Recent critical analysis revealed the reasons behind the scenes from various perspectives. Woodill (2004) and Bunis (2003) point out that in addition to business and marketing reasons, there are several other important issues related to e-learning solution developments, such as the lack of learner-centric usability and interactive involvement and the lack of understanding of multimedia-aided learning and teaching. There is a demand for shifting e-learning solutions from pure web-based content provision to instructional and learner-centric learning and teaching environments.

With the fast development of XML-based technologies on the Internet, the next generation of the World Wide Web (WWW)—the Semantic Web (Berners-Lee, Hendler & Lassila, 2001)—is starting to shape up. Ontology-based technologies and intelligent agents are expected to assist semantic information processing on the future Semantic Web. With more semantic-aware computing technologies, e-learning is expected to be more intelligent in the new era of Educational Semantic Web (Anderson & Whitelock, 2004).

To facilitate the transforming process towards the Educational Semantic Web vision, this paper presents a novel context-aware semantic e-learning approach, to integrate content provision, learning process, and learner personality in an integrated semantic e-learning framework. The proposed e-learning framework supports intelligent semantic e-learning by (1) bringing semantic context awareness into multimedia learning information processing and learning practices, and (2) bringing awareness of learner personality in support of personalised learning.

As the computational basis of the semantic e-learning framework, a scalable and extensible generic context model is proposed to structure semantics of contextual relations and concepts in various contexts such as learning content description, learning model, knowledge object representation, and learner personality traits. This context model aims to lower the knowledge barrier of semantic annotation of learning resources, which improves the usability of semantic e-Leaning systems. To achieve a high level of interoperability, compatibility of this context model with other existing technologies (eg, XML/ Resource Description Framework [RDF] [http://www.w3.org/RDF]) and specifications (eg, IEEE Learning Object Metadata [LOM] [http://ieeeltsc.org/wg12LOM/]) is considered in implementation. Hence common instructors and learners are not required to understand complicated concepts of ontology and reasoning with the existing Semantic Web technologies as a prerequisite before using knowledge-oriented services. Although this paper mainly focuses on providing a computational semantic e-learning solution, both technical and pedagogical issues related to the semantic e-learning are considered in the development process.

Related work

Learning content description

In recent years, there has been a lot of effort put into learning content description standardisation. Among these specifications, IEEE LOM is the most popular one adopted in most learning management systems (LMS). LOM aims at enabling learners or instructors to search, evaluate, acquire, share, exchange and utilise Learning Objects across technology platforms and systems. It specifies a set of metadata elements to guide the description and operation of learning objects at the conceptual level. However, from a user's point of view, with such a big set of 47 elements in 9 categories, it is not easy to use the complete set, or just part of it, correctly in real content annotation practices. There are a number of dedicated LOM editors in research and development, which include the LOM Java Editor from Darmstadt University of Technology, Germany (http://www.multibook.de/lom/), the TreeLOM from Cukurova University in Adana, Turkey (Cebeci & Erdoðan, 2005), the ImseVimse from the Royal Institute of Technology (http://kmr.nada.kth.se/imsevimse/), Sweden and the LOM Metadata Editor embedded in Authorware from Macromedia.

In the current e-learning industry, most LMSs work in a closed-system manner. Some systems still use their own framework for learning content description rather than adopting LOM as the main standard. These minority frameworks include TArgeted Reuse and GEneration of TEAching Materials (TargeTeam) (http://www.targeteam.net/), Tutorial Markup Language (TML) (http://www.ilrt.bris.ac.uk/netquest/about/lang/) and Procedural Markup Language (PML) for multimedia presentations (Ram, Catrambone, Guzdial, Kehoe, McCrickard & Stasko 1999). Given such a situation, even the same learning content (eg, an open access resource on the Web) could end up with a number of incompatible descriptions in different LMSs. Without a properly designed semantic interoperation interface, resolving the heterogeneity problem will take extra effort in practice.

In addition to plain learning metadata, more complex semantics of multimedia resources are to be represented and managed in modern e-learning solutions. In the field of semantic description, the most important work is known to be the RDF—the basic information encoding language of the new Semantic Web. Other high-level languages such as DARPA Agent Markup Language (DAML) (http://www.daml.org/) are developed based on RDF, and most ontologies on the Web are now encoded in RDF as well. As a matter of fact, most recent research into applying Semantic Web technologies in e-learning are involved with RDF and ontology (Sampson, Lytras, Wagner & Diaz, 2004). However, RDF only provides a fundamental language for semantic description, and further developments of semantics capture and management are to be carried out beyond RDF. Sheth, Ramakrishnan and Thomas (2005) categorised three kinds of semantics to be captured for the Semantic Web: the implicit semantics, the formal semantics and the powerful (soft) semantics. However, working with semantics and knowledge needs awareness of context in application, for example, user context and working context (Hadrich & Priebe, 2005). To bring Semantic Web technologies into e-learning, a lot of interesting work has been done recently. For example, Nilsson (2001) explores the potential impacts of Semantic Web on e-learning; Henze, Dolog and Nejdl (2004) present a logic-based approach for resource representation and reasoning based on RDF annotations; Simic, Gasevic and Devedzic (2004) discuss how Semantic Web technologies, especially ontologies, could be used to present semantics of course content and student information.

In addition to semantic description, another important issue in semantics management is semantic integration. Heterogeneity is one of the characteristics of the information on the open Web, and this will by no means remain on the Semantic Web in the future. A similar situation exists in e-learning. Even if all learning content descriptions on the global network are in encoded in RDF, it still needs various levels of 'bridge' for semantic translation and interoperation, because from a pure computing point of view, semantic integration is an inevitable issue in distributed computing environments (Doan, Noy & Halevy, 2004). Because ontology is the most frequently used technique in semantic description, semantic services will have a challenge to face when the semantic integration issue emerges with multiple ontologies and schemas. Potential solutions from generic computing perspectives are normally adopted in specific application areas such as e-learning and e-business. Recent typical approaches include ontology mapping and integration (Akahani, Hiramatsu & Satoh, 2003; Silva & Rocha, 2003) schema manipulation (Bernstein, 2003; Embley, Xu & Ding, 2004) and semantic interpretation (Huang & Hacid, 2003). In the e-learning field, Gasevic and Hatala (2005) present an algorithm for ontology mapping in course description context.

Pedagogy and learning process in e-learning

In addition to learning content description and semantics management, another important field in semantic e-learning is the learning process and pedagogy support. Wikipedia (http://en.wikipedia.org/) defines pedagogy as 'the art or science of teaching'. There are many aspects covered in the concept such as instructional design and theory, learning theory, and other social–cultural, ethical elements. In the education field, pedagogy is a traditional research area that evolves all the time, but pedagogy research in e-learning context is a relatively new sub-area.

In recent studies on pedagogy in e-learning, Allert (2004) gives out a comprehensive survey of metadata models used to present learning concepts in contexts from the social perspectives. Sicilia and Lytras (2005) investigate ontological structures for generic constructivist and sociocultural learning. Lakkala, Lallimo and Hakkarainen (2005) study the issues of pedagogical design in the context of a collaborative learning environment, including the effects of utilising new technology in web-based learning and the application of an appropriate method in the design process. Azouaou and Desmoulins (2005) present an ontology-based conceptual model for pedagogy and document annotation for teachers. Lama, Sanchez, Amarim and Vila (2005) present an ontology for IMS Learning Design (LD) concepts and learning activities.

In terms of standardisation, LOM from IEEE and Sharable Content Object Reference Model (SCORM) from the Advanced Distributed Learning (ADL) Initiative (http://www.adlnet.org/), the most popular e-learning standards, have not taken pedagogy support as one of their core issues in specification. As a run-time infrastructure for e-learning, SCORM now only enables learning content packaging, organisation and delivery. However, a new specification is under development as LD from IMS (http://www.imsglobal.org/learningdesign/), based on a pedagogy-friendly Educational Modelling Language (EML) from the Open University of the Netherlands (http://eml.ou.nl/). LD addresses pedagogy issues in processes within 'units of learning' or whole tasks (such as a course). It also provides a pedagogical metamodel to support various didactical learning approaches (both objectivist and constructivist) (Hummel, Manderveld, Tattersall & Koper, 2004). Other than the LD specification, there is another research project that addresses the learning process issue—PALO from The Universidad Nacional de Educación a Distancia (UNED), Spain (http://sensei.lsi.uned.es/palo/). Whereas EML uses a metamodel approach to explicitly describe the pedagogical approach used, with PALO the pedagogy is implicit in the particular PALO template used. However, no matter which pedagogy framework is adopted in a LMS, it is vital to seamlessly integrate the pedagogy supports of learning processes and learning theories with learning semantics management and other components in the system.

Learner personality and personalised learning service

Personalised learning and teaching could be regarded as an ultimate level of instruction. Confucius, a great thinker, philosopher and educationist of China, presented a philosophical statement about 3 000 years ago. His philosophy in teaching is known as: 'teach students in accordance with their aptitude, adjust measures to local conditions' (Confucius, 1997). Recent studies in modern psychology also show similar results. For example, Heinström (2000) proves that learner personality influences learning strategies and learning outcomes in real practice. A study of student characteristics and computer-mediated communication from Wilson (2000) reveals that personality may influence academic success in unanticipated ways. Therefore, to achieve the best performance in learning and teaching, especially in self-directed or instructor-led e-learning, it is essential to be aware of the learner's aptitude and personality in context.

According to psychological studies on personality, there are five basic dimensions of personality traits that are stable across the lifespan and directly related to human behaviour (Revelle & Loftus, 1992). These dimensions are extraversion, neuroticism, agreeableness, conscientiousness and openness to experience—and are also known as the Five Factor Model of personality (Carver & Scheier, 2004). Personality traits are expressed in learning styles, which are in turn reflected in learning strategies, which eventually produce a certain learning outcome (De Raad & Schouwenburg, 1996). Personality traits serve as directors or blocks for motivation and learning strategies (Blickle, 1996).

To enable successful personalised e-learning, support from a learning service provision is also essential. From this point of view, personalised learning is understood as an adaptive learning service via learning portals in many personalised e-learning solutions (Brusilovsky & Nijhawan, 2002; Dolog, Henze, Nejdl & Sintek, 2004). The aim has been towards ensuring that learning content and process are tailored to meet the needs of individuals. In this process, user modelling and personal profiling are commonly used to enable personalisation. Munoz, Palazzo and Oliveira (2004) try to use domain and content knowledge ontologies and student models to improve personalisation. Keenoy *et al* (2004) provide personalisation service in e-learning via adaptive user personal profiles, which include a history of recent user activities in learning. Simon, Mikl'os, Nejdl, Sintek and Salvachua (2003) provide a mediation infrastructure for learning services, where its personalisation service is also delivered via dynamic learner profiling using 'personal learning assistants'. In addition to user profiling, Chen, Lee and Chen (2005) address the learner ability aspect in web-based learning in addition to traditional aspects such as learner preferences, interests and browsing behaviours.

Intelligent semantic e-learning framework

In this paper, an intelligent semantic e-learning framework is presented to address semantic information processing, learning process support and personalised learning support issues in an integrated environment. The contrast between semantic e-learning and traditional e-learning information flow is illustrated in Figure 1.

Traditional web-based e-learning systems use a web browser as the interface. Through run-time learning environments (either compatible or incompatible with SCORM), users could access the learning objects, which are directly linked to multimedia learning resources such as lecture video/audio, presentation slides and reference documents. In the proposed semantic e-learning framework, in addition to the existing learning information flow, three new components are introduced to bring in more intelligence in e-learning. These components are a semantic context model, intelligent personal agents and conceptual learning theories.

By using intelligent personal agents, the framework could perform adequate personal trait information profiling and deliver personalised learning services according to the individual's personality and interests. By applying a new semantic context model, semantic information for static resource and dynamic process description could be more easily encoded and retrieved across the current WWW and the future Semantic Web, referring to ontologies or knowledge bases if necessary. The context model also enables

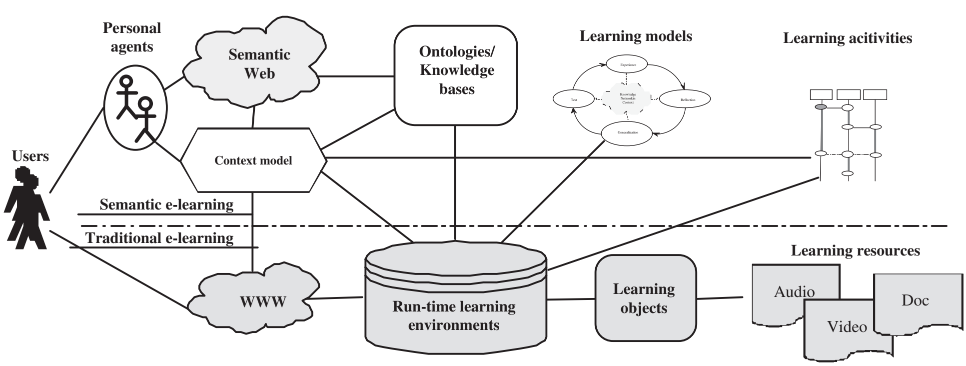

Figure 1: Architecture of a semantic e-learning framework in context

process-oriented learning activity description. By integrating dynamic and static learning-related semantic information in the same run-time learning environment, learning theories are to be properly supported in practice. Because the context model is designed to be generic enough, the current generation of e-learning systems with basic XML support are expected to interoperate with it seamlessly. Furthermore, the framework also opens the knowledge gate via the scalable context model to external XML-based knowledge communities, no matter which Web they are on. In this way, semantic integration across the two Webs will be feasible.

On the educational research side, the framework is designed to support various learning models and theories such as scenario-based learning (Kindley, 2002). Based on the analysis of semantic information aggregated in individual learning processes, more personalised learning service could be delivered. Within the framework, instructors are to be provided with practice templates of each learning model or a new teaching approach in learning context (eg, level, student group, subject, nature) practised by colleagues. New improvements could be added and shared among peers as well.

An intelligent e-learning scenario

There are three stages in a typical intelligent semantic e-learning scenario (either self-directed or instructor-led). The first stage is the *prelearning process*, which involves preparation work from both the learners and the instructors. Instructors are to prepare online multimedia learning resources, provide contextual descriptions of learning objects and learning environments, design learning paths for different types of learners, and design learning activities and assessments for individual sessions and whole courses. All the information will be parsed and stored into the knowledge base for future use. On the learners' side, the intelligent agent assists learner profiling, which involves identifying learner personality and learning style by doing a series of questionnaire tests, defining learning goals and learning preferences, and clarifying personal learning responsibilities in context.

The second stage is the *learning process*, which involves various kinds of learning activities such as locating learning materials, reading materials, writing reflections, discussing with peers, self-evaluation and revision, and so on. Each complex learning activity could be regarded as a sequence or combination of simple activities. Basic knowledge retrieval service is carried out based on the context model, which provides an integrated and universal semantic-based interface for all multimedia resources. Throughout the learning process, the intelligent agent of the learner collects real time learning data to monitor the learning progress. It uses learning signals to communicate with peer agents of other learners or with the system knowledge base against learning theories and paths in order to get adequate learning advice. Based on the learning theories and personality study results, learners with different personalities, learning styles and backgrounds are to be treated differently in different contexts; guidance will be given on an individual basis. For example, neuroticism is linked to surface learning style, therefore, extra guidance will be needed when a deep understanding is necessary in a specific knowledge point of a module.

The final stage is the *postlearning process*, which involves reporting and evaluation of learning outcomes on both the learner and instructor sides. After each learning session or at certain checkpoints, agents could generate a learning progress report against the predefined goals and outcomes. Learning efficiency as well as the effort (ie, time) spent on the learning activities are to be shown in the report. Further guidance for future learning path and adjustments on certain learning activities could be given if required. From the instructor's perspective, a progress report of all involved learners from the system will provide a holistic view of the learning and teaching effectiveness in contexts, which provide concrete evidence and decision-making basis for further improvement or adjustment in learning and teaching.

Semantic context-aware information service

The first contribution of the framework to semantic e-learning is the semantic context-aware information service. It differs from existing web-based information retrieval and database application in its awareness of semantic context in description, processing and retrieval. Huang (2005) defines the notion of 'semantic context' as 'a collection of semantic situational information that characterizes the entity (context focus)'s internal features or operations and external relations under a specific situation'. Both static content descriptions and dynamic process descriptions are to be captured by the context model. Typical contextual elements include:

- general metadata of entities (eg, title, author, keywords, publication date, version);
- literal statements (eg, free annotations of multimedia resources such as images, audio, video, presentations);
- conceptual models (eg, system models, learning processes, mind maps);
- hybrids of statements and conceptual models to represent contextual knowledge; and
- interlinks with other knowledge descriptions, links between description elements across contexts.

As the core component of the context-aware information service, the context model needs to capture and represent various contextual features, including those that might already be in existing metadata formats, and those that are currently unstructured and to be structured in the meanwhile. This requires the model to be generic and scalable enough to work across the HTML-based WWW and the XML/RDF-based Semantic Web, and to interoperate with various learning content description specifications.

Context model

A scalable layered context model is designed for semantics representation as shown in Figure 2. There are three layers in the context model: element layer, structure layer and context layer. Inside each layer, there is a statement model, which is mathematically iterative. This means that any lengthy description is allowed and could be easily scaled further based on the same unitary representation model in that layer. As a result, the whole context model is scalable as well.

The context model also enables semantic weighting at each layer. This is used to represent and facilitate the semantic context similarity or distance computation in semantic

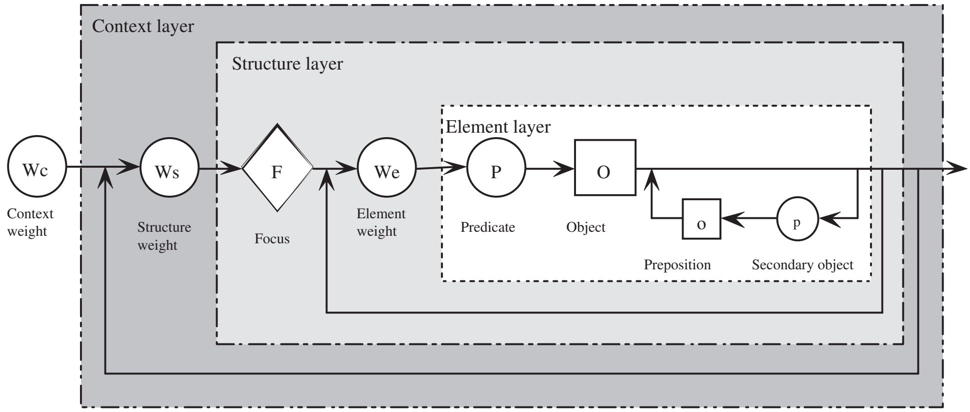

Figure 2: Scalable semantic context layer model

processing and retrieval. One, and only one, numerical weight between 0 and 1 (with a default value of 1) is assigned to each semantic statement to show its impact in that semantic context. Weights in different layers have different influences in the global context and could be influenced by user profile and personality as well.

The element layer statement model is a scalable tuple model, which contains a context *focus*, a *predicate* and an *object*, and any number of *prepositions* and *secondary objects*. The syntax of the context layer model could be formalised as follows:

$Statement_{element} = (Focus, We \cdot (<Predicate, Object>, \{<preposition, secondary\ object>\}))$
$Statement_{structure} = \{W_s \cdot Statement_{element}\}$
$Statement_{context} = \{W_c \cdot Statement_{structure}\}$

As shown in the syntax formula above, the basic element layer structure is very similar to the RDF triple model. On the one hand, this design enables a high level of interoperability with RDF—the Semantic Web content description specification, hence, benefits from the strength and support of the RDF community on the Semantic Web. On the other hand, the model itself is scalable and features context awareness, and that enables a more sophisticated presentation of contextual semantics than the RDF triple-based presentation. This context model aims not only at presenting the generic concepts, but also at capturing the semantic relations among concepts and statements, which could be used as a basis for computerisation.

As indicated in Figure 1, in the context of semantic e-learning, this context model plays an important role within the proposed framework. Following the well-known Semantic Web cake stack (Berners-Lee, Hendler & Lassila 2001), the existing information architecture in e-learning application could be described as a layered architecture in Figure 3. By introducing the contextualisation layer into the architecture, the context

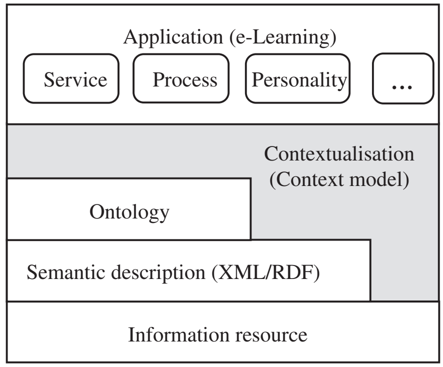

Figure 3: Context model in application context
RDF = Resource Description Framework

model interconnects with the four layers at different presentation levels and provides an integrated interface for the centralised processing of both static and dynamic information. Generally speaking, application of this context model in developments such as service description, personality description, and process description may vary in different contexts, but all these instances share the same underlying data model, which provides a high level of conformability within the framework.

On the user's side, application of this context model is supposed to be simple and natural, and does not require any prior knowledge of semantic description. However, there is a suggestion to describe the context with both predicates and object, which is slightly different from traditional keyword-based metadata descriptions. As an example, if the user applies this model onto the University of Hull Centre for Internet Computing (CIC) website for contextualisation, rather than inputting a group of keywords in the meta tags of the HTML page, real semantics of this website could be described as a set of statements, such as 'A website' that 'has a URL at http://www.cic.hull.ac.uk/', 'is a university website', 'has academia', 'has students', also 'provides forum'. In this case, the focus of description is the 'http://www.cic.hull.ac.uk/', and other information could be structured in four <predicate/object> pairs such as <isa, university website>, <has, students>, <has, academia> and <provides, forum>.

In application of the context model in e-learning practice, a learning service schema (see Figure 4) is presented for development. The context schema defines the generic terms used in context model description, and the learning service description schema contains necessary generic terms of content (static), process (dynamic) and personality (hybrid) descriptions in e-learning. Existing descriptions based on LOM and Dublin Core (DC) (http://dublincore.org/documents/dces/) could be imported and integrated into the framework automatically (see Figure 5).

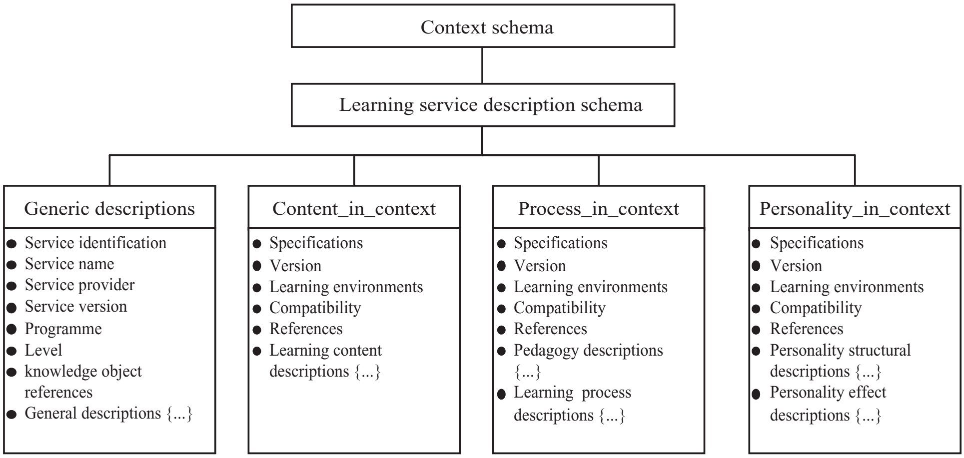

Figure 4: Learning service schema

Context-based semantic information retrieval

Traditional search engines such as Google, Yahoo! and Altavista normally use a keyword-based retrieval mechanism, in which it is hard to specify a context. For example, 'apple and computer' might stand for a scene of an apple beside a computer in the user's mind, but it is hard to represent it in traditional keyword-based information retrieval. Furthermore, existing solutions are all literal-based, and there is no sense of real semantics. Even in the same semantic context, two synonyms are normally considered separately for their literal difference. On the other hand, RDF-based search for the Semantic Web is still in its infancy. For example, the RDF Query language (RDQL) (http://www.w3.org/Submission/RDQL/) from the World Wide Web Consortium is still in early development stage. RDQL basically works in a traditional SQL-like 'Select-Where-' style, which is still not practical and mature enough to be widely used in practice.

To simplify the context-based query process, also based on the proposed context model, a very simple <predicate,object> search mechanism is provided to users. The pair query model could also be implemented in just a single text field search as the most common Web search interface. The intention of designing such a simple semantic query form close to natural language expression is to provide high system usability in semantic information retrieval by using existing knowledge to help the user specify context and find semantically related results in context as precisely as possible. The compatibility with RDF-based search is also considered for future development with the Semantic Web.

As shown in Figure 6, the user could choose to use either the basic query—traditional keyword interface—to perform the search, or the simple query interface to generate predicate/object pairs to specify the context. Following the example of the context model

Figure 5: Process of importing Dublin Core metadata into the context model (a) Select import source. (b) Input the source's uniform resource locator. (c) Metadata is extracted and imported into the context model.

of the university website above, the query pairs could be <isa, website>, <*, students>, <*, academia> and <*, forum>. By giving flexibility to the user to specify the context in retrieval, the system has fewer semantic ambiguity problems than traditional information retrieval systems.

Once the query context is specified, the system will pass the context information to the search engine to retrieve matched results. Basically, the designed information search engine works independently with the proposed context data model. It is different from pure Semantic Web search techniques such as RDQL, which is limited to triple-based information retrieval rather than contextual information retrieval. However, the framework still provides the interface with generic information retrieval techniques such as

Figure 6: Context-based information retrieval
(a) Basic query similar to keywords based retrieval Using object only. (b) Simple query using predicate/object pairs to specify more complex contexts than loosely coupled keywords. (c) Search results ranked by contextual distance.

XML Query Language (XQuery) (http://www.w3.org/TR/xquery/) and RDQL, and presents results in these generic formats. In the retrieval process, there might be duplicated results shown in relation to the same physical object. To resolve this problem, a group manger is created. When the first matched raw result comes up, the group manager will allocate a group for it, and the duplicated match results found in the same raw result object will be reweighted and the ranking will be recalculated when the iterations of the single context query or multiple contexts query go on. An example of a results list (in RDF) in groups with context distance is shown in Figure 6.

A more advanced feature of the system is the autocompletion of the pair based on the context of personal interest, personality and previous knowledge from the thesaurus/dictionary related to the input word. The system knowledge base will suggest the most frequently used predicates, including prepositions, to the user; the thesaurus also helps the user to find other potential semantically related results to the query but probably not literally matched by word. In the current implementation, WordNet (http://wordnet.princeton.edu/) is used as our generic dictionary and thesaurus, and simple rules for semantic inference between nouns and verbs/predicates are generated. For example, if a learning object uses the LOM and DC metadata element '*creator*' in description, its potential corresponding predicate could either be '*CreatedBy*' or '*AuthoredBy*' in retrieval. Instead of calculating the semantic distance between those words, a direct mapping table is designed to speed up the most commonly used keywords in generic electronic description and e-learning description.

This integrated semantic information processing mechanism not only works with the contextual e-learning knowledge within the framework, which is bound in XML or RDF based on the context model; it is also interoperable with any other generic XML/ RDF based semantic resources on the Web and the Semantic Web such as HTML/XHTML pages with DC metadata and XML/RDF-based Really Simple Syndication/Rich Site Summary (RSS) news items (Huang & Webster, 2004). This gives the proposed e-learning framework a great advantage in semantic integration and interoperation across domains.

Learning theory support for knowledge-oriented learning

Knowledge visualisation: knowledge network

Another important feature of this framework is integrating the learning theory into the knowledge flow process in daily e-learning activities. To facilitate knowledge communication process, especially the revision process when students are eager to revise all semantically related contents taught by instructors, a tactical knowledge network of visualisation is designed based on the programme and module specifications.

Figure 7 shows part of the knowledge network of the CIC undergraduate programme specification under the national (UK) Quality Assurance Agency for Higher Education framework. There are three dimensions in the knowledge network: modules, learning outcome-related skills and knowledge object (tactical). The nodes in the space indicate the key knowledge checkpoints in learning and teaching, and different colours indicate different levels of the programme (ie, BSc Year 1, Year 2 and Year 3). The edges between the nodes indicate the relation between the knowledge checkpoints. The vertex of the multidimensional knowledge network is the user, who could be the learner or instructor. Using common graph visualisation approaches, the whole network could be visualised for the users and could be interactive in zooming, focusing, node-information expanding, and so on. This knowledge network gives both the learners and the instructors a direct and general overview of what they are learning/teaching and what they need to know beforehand or afterwards. The knowledge network is also a visualised interface of the contextualised learning information generated using the proposed approaches mentioned earlier and stored in the learning knowledge base, which includes content descriptions and learning processes.

Enhanced Kolb's learning cycle and learning process description

In addition to providing basic support of knowledge navigation using knowledge network, this paper also looks into the possibility of supporting learning theories in practice. As an example, one of the most popular learning theories—D. A. Kolb's four-step learning cycle—is chosen for experiment. The four steps in the cycle are 'experience, reflection, generalisation, and test' (Kolb, 1984). In every step of the learning practice,

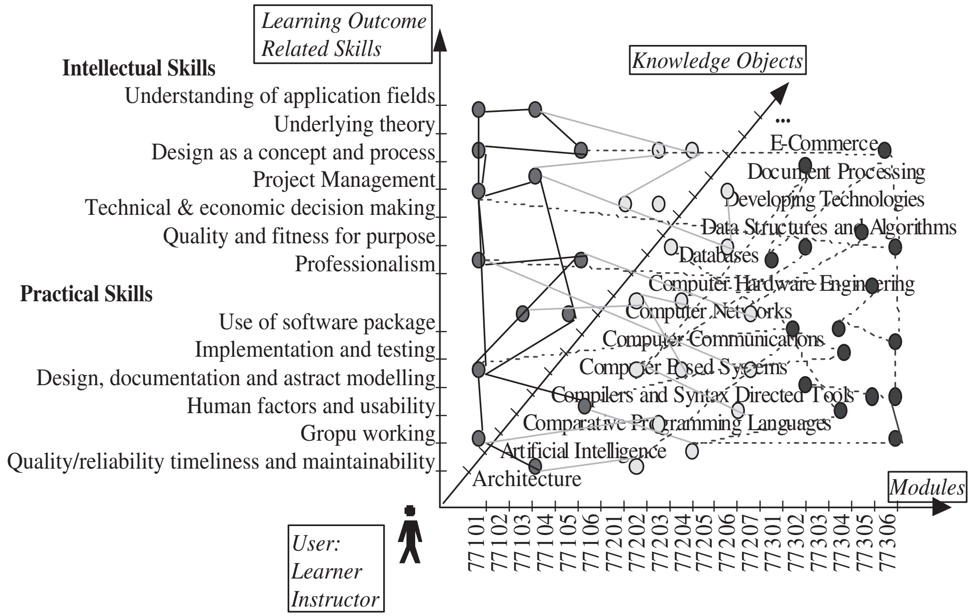

Figure 7: A part of the University of Hull Centre for Internet Computing undergraduate programme knowledge network

computational supports are provided from the knowledge network and the context-based semantic information processing for dynamic learning activities of individuals.

Figure 8 shows an enhanced e-learning cycle model with two levels and four generic steps. In practice, it cooperates with concrete concepts and activities in learning and teaching, such as content description, process description, knowledge network and other supporting technologies. This model is expected to guide various types of learning activities in practice in the learning support context.

As an important step towards intelligent semantic e-learning, learning processes in contexts need to be modelled and represented. Based on the underlying context model and the proposed learning service schema, the learning process is expected to present more information than the basic Learning Design metamodel of EML/LD, and more learner personality and profile and learning environment elements are to be captured.

To reflect the learning cycle and theories in practice, three important categories of elements are proposed to model the learning process in context: *learning activities*, *learning contexts* and *learning signals*.

- *Learning activities* are components performing specific learning functions. Complex learning activities could be regarded as the combination of simple and atomic learning activities. Typical activity types in self-directed learning include navigating,

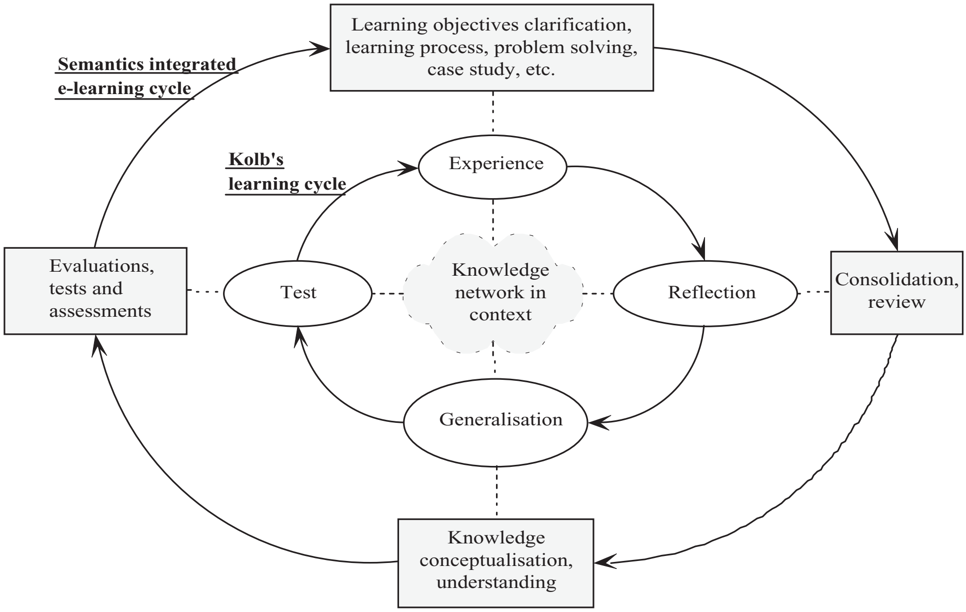

Figure 8: Semantic integrated e-learning cycle with knowledge network

searching, reading, writing, communication, discussion, watching and listening to learning material, assessment, coursework, games, and so on. As an example, a revision process could be regarded as a complex activity, which might involve many simple activities such as reading, discussion and self-assessment.

- *Learning contexts* define the environment for the execution of related learning activities and could be used for information exchange and activity execution coordination. There are three categories of elements included in learning contexts: *learning environment*, *learning profile* and *curriculum information*. Typical learning environment elements include signature, specification (both internal and external), links, tutor support and peer support. Typical learning profile presents individual personality traits, personal needs, prior experience, personal learning plan and management, and learning outcomes/results. Typical curriculum elements include course material, instruction, learning path, assessments and subject knowledge.
- *Learning signals* are signs and messages used to coordinate the execution of learning activities. It represents not only the status of learning activity in sequence (and corresponding to the four-step learning cycle if necessary), but also the status of synchronisation and collaboration status between different learning activities within a common context.

In terms of information serialisation, the learning process is based on the tuple context model in XML/RDF referring to a schema that defines the basic structure and vocabulary of the elements above. Existing learning activities described in the Learning Design metamodel are also considered to be imported in application.

Learner personality representation for personalised learning

The third contribution of this framework is learner personality representation. Personality representation plays an important role in personalised learning. Current development in e-learning has gone through the stages of generic content delivery, and on discovering how learning content could be tailored according to the learner's needs. However, to enable real personalised learning service, an individual learner's personality needs to be considered. Chamorro-Premuzic, Furnham, Dissou and Heaven (2005) identify strong correlations between the Five Factor Model (McCrae & Costa, 2003) and a student's assessment type preference. For example, students high in neuroticism were shown to dislike oral examinations, whereas those high in extraversion or agreeableness showed a strong preference for them. Based on the research result in learner personality in context, the most suitable learning model and pathway could be identified and suggested to the learner.

Representation of learner behavioural process

This section presents a new comprehensive computational model for representing learner behaviour in context. According to traditional personality study, behaviour is generally initiated by a motivation which is stimulated from three sources: environmental, physiological and psychological (Carver & Scheier, 2004). In the e-learning context, the environment becomes the most influential aspect among the three sources, and it is of most interest in terms of computerisation. Figure 9 shows the generic human behavioural process in the learning process. External environmental aspects, such as social, economic and political influences, around the learner motivate the learner to learn, and these aspects work together with the internal physiology and psychological aspects of the learner throughout the learning process. Once motivation is identified, cognitive processes formulate the motivation into goals and identify action plans and resource requirements in order to achieve the goals. In practice, these action plans turn into learning processes, which include internal (ie, knowledge conceptualisation, generalisation and understanding) and external learning behaviours (ie, learning activities in contexts).

In contrast to the enhanced Kolb's learning cycle discussed earlier, the behavioural flow from motivation to cognitive process and learning behaviour in Figure 9 actually reflects the basic steps of the 'experience→reflection→generalisation' process in the learning cycle as in Figure 8. Of particular interest, the learner's personality has significant impacts on both internal and external learning behaviours and consequently on learning outcome. Personality may also influence the type and level of motivation, limit the range within which goal development occurs, and change how the behaviour is expressed externally or how effective learning is internally. The central personality structure contains some aspects that are intrinsically linked to the other elements, and others that affect outcome only as personality effects.

Learner personality model

Current literature on personality in psychology follows several perspectives (Carver & Scheier, 2004), each with their own philosophical roots, assessment methods, and core

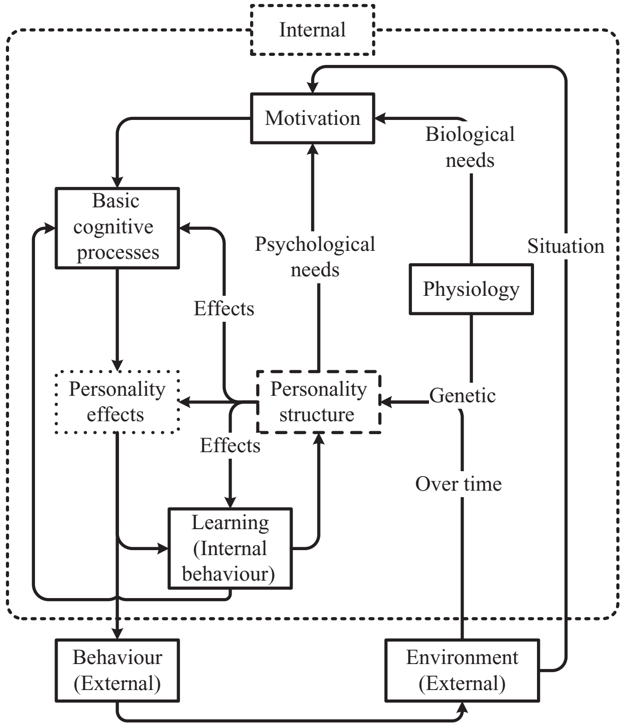

Figure 9: Human learning behavioural process

structures and processes. These were assessed against the criteria to ascertain those aspects that were computationally possible within a software system. From this it was identified that dispositional (trait and type) theories were most suited for computation. In particular, the Five Factor Model shows strong evidence of behaviour prediction across age, sex and multiple cultures. This was used as the foundation for the development of both models, with influence from other theories (Carver & Scheier, 2004).

Whereas the Five Factor Model defines the generic and common aspects of human personalities, there are other unique and dynamic aspects that contribute to the integral personality of an individual. A new learner personality model is designed to represent both the common static aspects (eg, traits, talents, orientations) and dynamic learning-specific aspects (eg, mood, emotions). Figure 10 shows the basic elements of the learner personality structure model, which provides a tangible basis for further computerisation.

The first part of Figure 10 constitutes those things that are genetically related and develop until early adulthood, where they become relatively stable. These contain the personality traits of the Five Factor Model (McCrae & Costa, 2003): extraversion, openness to experience, agreeableness, conscientiousness and neuroticism. The Five Factor

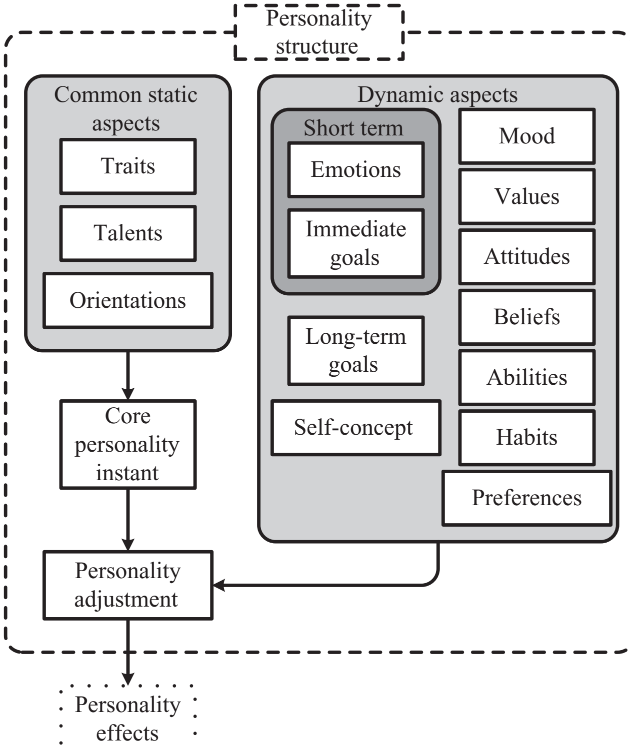

Figure 10: Structure of personality model in e-learning

Model can be identified using self-reporting and statistical methods via such tools as the Neuroticism Extraversion Openness Personality Inventory (NEO PI-R) 240-questionnaire measure (McCrae & Costa, 2003). This has been shown in previous studies, proving correlations between personality traits and educational activities such as academic assessment (Chamorro-Premuzic *et al*, 2005).

The second part of Figure 10 identifies those aspects that are unique to all individuals and are continually changing; they represent life history. Although not a complete life history, particular aspects have been identified by various theorists as more relevant, each having specific effects—which are already defined—on the behavioural process. These are as follows:

- Attitudes—negative or positive value towards an object, person or place
- Values—object, person or place that hold a more specific weight to an individual than an attitude
- Beliefs—statements that hold a true or false value for an individual
- Habits—repeating patterns of behaviour when performing a specific task
- Preferences—hierarchical order of objects people, places or behaviours

- Goals—both short and long term, and identified during the motivation–cognition process. Unachieved goals are stored and have an effect on subsequent goal generation
- Self-concept—an individual's view of both who they are and who they would like to be. Again, this affects goal generation as well as other aspects
- Mood and emotions—current aspects of an individual's disposition towards certain activities, moods being longer term than emotions
- Abilities—particular skills that affect both cognition and behaviour. Within e-learning, these can be represented by the contents of an ePortfolio as described in Ishaya and Wood (2005).

Each of these elements will hold data that applies the uniqueness of an individual to the profile. The population of data is intended to be generated by assessing student interactions, but it may be beneficial to allow user input to some aspects.

To help learners identify their personality, a traditional questionnaire approach is to be used. Common static aspects of personality such as traits could be identified by completing a set of questions within each of the five dimensions against the Big Five Inventory (John & Srivastava, 1999). Based on the predefined metrics, the test could identify the learner's personality based on a defined personality scale. Unlike the static elements, dynamic personality elements are more environmental and tangible. With a new inventory and evaluation metrics for learning dynamics, it is feasible to form a computational model for real time monitoring of learning efficiency by using intelligent agents. Once corresponding clinical experiments in real learning practices go through the proof stage, research results will definitely promote the existing content-tailored learning service up to a new level of intelligent personalised learning.

Conclusions and future work

Recent fast development of Semantic Web technologies such as XML/RDF and ontologies has enabled a possibility for semantic-based e-learning services in the future. However, learning is not only about content provision, it is also about pedagogy. Towards enabling intelligent semantic e-learning, this paper presents a novel semantic e-learning framework that considers both technical and pedagogical issues in an integrated environment. The proposed framework features context-aware semantic information management service, knowledge-enhanced learning model support and learner personality representation.

As a core contribution of this paper, a generic and scalable context model is developed to enable static and dynamic semantics representation and management in contexts. With full consideration of interoperation with underlying XML/RDF technologies and existing learning specifications such as LOM and LD, this model mediates the current generation of e-learning technologies on the WWW and new e-learning technologies on the future Semantic Web. With the assistance of thesaurus-based semantic mapping, existing metadata mark-up descriptions for learning contents are to be imported into the framework. Dynamic learning activity descriptions could be integrated in the framework as well, and a context-based information retrieval facility provides an integrated interface for both the two types of information.

From the pedagogy support perspective, this paper presents a new approach of knowledge visualisation and learning process modelling to cooperate with learning theories such as Kolb's learning cycle model. Furthermore, the paper presents a human learning behaviour process model and a new learner personality model towards personalised e-learning. The proposed personality structure represents both the common static aspects from traditional personality research and the dynamic learning-specific aspects in an integrated model. Based on the generic context model for semantic information management, these two models form a concrete computational foundation for intelligent personalised e-learning.

Future work on this framework includes further developments of the semantic context-aware information management service, interoperation with other learning specifications such as SCORM and LD, support of new learning models such as Scenario-based Learning and Problem-based Learning, and further development of agent-based learner personality modelling and management.

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