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# Towards integrating semantics of multi-media resources and processes in e-Learning

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**Abstract** Internet-based e-Learning has experienced a boom and bust situation in the past 10 years [32]. To bring in new forces to knowledge-oriented e-Learning, this paper addresses the semantic integration issue of multi-media resources and learning processes with theoretical learning supports in an integrated framework. This paper proposes a context-mediated approach that aims to enable semantic-based inter-operations across knowledge domains, even across the WWW and the Semantic Web [8]. The proposed semantic e-Learning framework enables intelligent operations of heterogeneous multi-media contents based on a generic semantic context intermediation model. This framework supports intelligent e-Learning with a knowledge network for knowledge object visualization, an enhanced Kolb's learning cycle [31] to guide learning practices, and a learning health care framework for personalized learning.

**Keywords** Semantic integration · Context · Multi-media · Semantic e-Learning · Learning supports

## 1 Introduction

In the past 10 years, the Internet-based e-Learning market has gone through a boom and bust hyper cycle [32]. However, there is no doubt that e-Learning has become very popular in enterprises and education systems. Big companies such as Cisco Systems, DELL, Sun Microsystems commit to e-Learning solutions in order to reduce employee training cost and to facilitate knowledge sharing among employees. In this case, publishing multimedia learning resources online fulfills the basic requirements of work-related short-term learning. In contrast, e-Learning in schools and universities is different, where e-Learning is more widely used as an assistant or complementary approach to facilitate traditional learning or to enable distance learning. In higher education, there are several popular learning management systems (LMS) on the market such as Blackboard [10] and WebCT [52]. However, this does not imply that the whole e-Learning industry is fully back to a healthy development track. As Woodill pointed out in [54], the most critical problems of the current e-Learning industry are the lack of practical semantic multi-media learning support and pedagogical learner-centric learning support.

Nevertheless, there are some valuable efforts towards improving the quality of modern e-Learning, such as the Learning Object Metadata (LOM) standard [35] from IEEE and the Shareable Content Object Reference Model (SCORM) [47] from Advanced Distributed Learning (ADL) initiative. These standardization efforts aim at populating learning specifications in content description and content delivery in order to facilitate knowledge sharing and reuse across platforms and systems. However, the multi-media semantics issue has not been addressed in depth, neither have the pedagogy and learning theory issues in relation to learning processes.

In an attempt to address the two important issues in an integrated environment, this paper presents a context-based semantic integration framework for intelligent e-Learning. In contrast to the existing specifications that focus on content description and delivery, this paper looks into a more general solution in integrating the content of multi-media learning resources and learning processes at the semantic level in order to provide a learner-centric pedagogy-supported e-Learning environment. The proposed framework features a semantic context aware approach in intermediating semantics from heterogeneous sources. A context model is presented for the multi-media semantic integration in cooperation with a special learning service

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schema to guide e-Learning operations. Related multi-media resources semantics generation and retrieval issues are addressed with the support of a prototype system.

Based on the context model proposed, this framework enables further support of learner-centric intelligent learning (especially self-directed learning) from several different perspectives. The first is a multi-dimensional knowledge network for knowledge-object visualization in order to facilitate content coordination across the modules and learning processes; the second is an enhanced e-Learning model of Kolb's famous learning cycle [31] to guide learning practices; and the third is a learning health care framework with the support of intelligent Agents to enable user-friendly learning problem diagnosing processes.

The rest of this paper is organized as follows. Section 2 reviews related work of semantic integration and multimedia content management in the context of computing and e-Learning, respectively. Section 3 details the new context-mediated approach on multi-media semantic integration. Section 4 presents some new approaches to support intelligent e-Learning. Section 5 summarizes the paper and points out future work directions.

## 2 Related work

### 2.1 Semantic integration in computing context

Semantic integration has become an inevitable issue in distributed computing environments [15], especially on the WWW and the emerging Semantic Web (SW) [8]. Semantic-oriented web applications often use information referring to the multiple ontologies and schemas. Interoperability among those intelligent applications critically depends on the ontology and schema mapping between them, which is still a very labour-intensive manual process. Consequently semantic integration has been recognised as a bottleneck in the deployment of a wide variety of information management applications [15].

Research in semantic integration spans many computing fields such as Databases, Artificial Intelligence and Web Intelligence. Proposed typical approaches include ontology mapping and integration [2, 48], schema manipulation [9, 17], and interpretation [23]. Nevertheless, there is no good generic and intelligent ontology mapping solution working across domains and applications over the Web at this moment [16]. On the other hand, it also indicates the significance and complexity of common sense knowledge formalization work of McCarthy [36] in context research. His continuous work towards machine understanding and logic reasoning for the SW still features the context awareness [22], which reemphasizes the importance of taking context into consideration in semantics processing.

To address the semantic integration issue from another perspective, there have been some interesting efforts in semantic interoperation from academia using algebra [29] and information flow theories [46]. Most industrial and business efforts focus on semantic interoperability issues in standardization, for example ISO/IEC 11179 Metadata Registries [27], ISO 12620 Computer applications in terminology—Data categories [28].

### 2.2 Multimedia content management

In the field of multimedia computing, content management research on solo medium content processing has made some significant progresses in recent years. Zhu et al. present a video content summarization approach using hierarchical content structures and unified semantic and visual similarity [57]. In [57], Zhu et al. also give a good overview of related video summarization technologies in terms of video summary style in pictorial summary, video skimming, and data distribution map. Most related work in this area essentially focuses on visual content, which will be helpful to work with high level annotations and descriptions interfacing with video and image/visual retrieval [1, 4–6, 30].

The arrival of the MPEG-7 standard was an important evolution in modelling and representing the audio-visual content. MPEG-7 has changed traditional feature-based audio/visual retrieval approaches that focus on low-level audio-visual features (e.g. colour, shape, etc.) to a high-level of content representation [12, 20]. However, one of the challenging problems in MPEG-7 based retrieval techniques is that MPEG-7 itself is quite limited in representing the semantics of multimedia resources, which is shown in Semantic Views Query Language [19]. MPEG-7 itself is still an infrastructure in media content structuring based on XML. To reach the semantic level representation and understanding, MPEG-7 needs external schema and ontologies supports. In this case, the problem in multimedia semantic content management goes back to the general semantic integration issue on the Webs.

### 2.3 Semantic integration in e-Learning context

IEEE LOM standard 1.0 specifies a set of over 47 elements in 9 categories in its schema to standardize learning object description. The nine categories are General, Life Cycle, Meta Metadata, Technical, Educational, Rights, Relation, Annotation, and Classification. It also specifies the XML and Resource Description Framework (RDF) [44] binding frameworks for LOM. From the information processing point of view, LOM framework emphasizes more on content packaging level rather than the semantic description of content.

In cooperation with LOM framework, SCORM provides a Content Aggregation Model (CAM) and a Runtime Environment (RTE) for learning objects in Web-based learning. The SCORM model aims to coordinate emerging technologies and commercial/public implementations by referencing a set of interrelated technical specifications and guidelines. The SCORM model defines the assets in learning, shared content objects, content packaging and sequencing, and the common mechanism of learning resource communication.

Under the framework of LOM and SCORM, users might be able to access different learning packages across platforms (if it is allowed), but the traditional semantic information retrieval problem still exists, which is similar to searching information on the WWW. However, unlike generic Web searching environments, e-Learning environments are supposed to be more organised and tailored for learners, as most learners have paid to be instructed. In this case, the semantic integration and management issue is of greater importance in e-Learning. It is the key to help the learners to get exactly the right knowledge access point to learning materials and indicate all relevant knowledge in context. This is an important issue to be addressed and resolved in modern e-Learning.

In terms of learning object description, there still exist many other content-focused markup languages besides of IEEE LOM. For example, TArgeted Reuse and GEneration of TEAching Materials (TargeTeam) [50], Tutorial Markup Language (TML) [51], and Procedural Markup Language (PML) for multimedia presentations [43]. This implies that the same learning resource could end up with different formats of description in different LMSs because of the variety of description languages. In some cases, ontology mapping and schema manipulation can contribute to semantic integration in cooperation with other supporting technologies for specific types of resources. As an example, Outline Processor Markup Language (OPML) [40] is good at dealing with the outline semantics of web pages. However, these techniques are usually domain-specific, which implies that semantic integration of multimedia contents and other textual contents is still an open issue in e-Learning.

Apart from the learning content issues, there is another concern in e-Learning: learning process and pedagogy [54]. There are three options for any learning technology when it comes to pedagogy: no pedagogy at all (also known as ‘pedagogy-neutral’), single pedagogy, and multiple pedagogies [53]. LOM and SCORM as e-Learning specifications have not taken the pedagogy support issue as one of the core issues in their specifications. SCORM only enables an infrastructure for learning content delivery and organisation. Other pedagogy-friendly e-Learning specifications include Educational Modelling Language (EML) from Open University of the Netherlands [18] and Learning Design (LD) from IMS [34] derived from EML. Education Modelling Language (EML) and LD address the pedagogy issues in processes within ‘units of learning’ or whole tasks (like a course). Education Modelling Language (EML) and LD also provide a pedagogical meta-model to support various didactical learning approaches (both objectivist and constructivist) [26]. Another important project addressing the learning process is PALO [41]. Whereas EML uses a meta-model approach to explicitly describe the pedagogical approach used with PALO the pedagogy is implicit in the particular PALO template used.

In terms of commercial development and support, both PALO and EML/LD have a long way to go. Nevertheless, to make an impact in the ultimate lifelong e-Learning experience, semantic integration and interoperation of learning experience (processes and activities) across learning management systems and specifications will play a significant role in intelligent e-Learning in the future.

## 3 A Context-mediated approach on semantic integration

In this paper, we present a novel context mediated approach to address the semantic integration issue in e-Learning. The proposed framework aims to enable semantic operations over heterogeneous multi-media learning resources across knowledge domains, even across the WWW and the SW, and consequently build a solid infrastructure for the application of learning theories for intelligent e-Learning in an integrated e-Learning environment.

### 3.1 Definition of context

Current research activities around *context* mainly come from two fields: context-aware pervasive computing [38], and contextual logical reasoning [3, 37] in Artificial Intelligence. Research on context-aware mobile computing mainly uses physical location context information collected from digital sensors. They define contexts as “(i.e. whether a person, place or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves. Context is typically the location, identity and state of people, groups and computational and physical objects” [14]. In Artificial Intelligence, context is interpreted as ‘a collection of relevant conditions and surrounding influences that make a situation unique and comprehensible’ [11]. This paper addresses the context issue from the knowledge engineering point of view in order to facilitate knowledge reuse and refinement in e-Learning environments. Proposed approach deals with semantic contextual knowledge more than low-level physical sensor information. Corresponding contextual knowledge manipulations focus on engineering issues such as knowledge representation, retrieval and reuse proposed, rather than abstract logical reasoning.

In this paper, we define the concept of *semantic context* as follows:

**Definition** *Context of an entity (i.e. an object, an event, or a process) is a collection of semantic situational information that characterizes the entity's internal features or operations and external relations under a specific situation.*

The notion of context in this paper is used to structure an intermediate layer above existing syntax-oriented information presentation for semantic-oriented integration and interoperation in the future. Typically considered static resource and dynamic process description elements include:

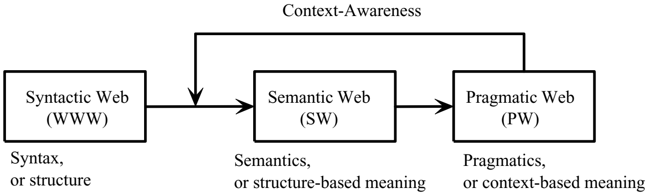


**Fig. 1** Evolution of the web

– general metadata of entities, such as title, author, key words, publish date, version, etc.;
– literal statements, such as free annotations of multimedia resources like images, audio, video, presentations, etc.;
– conceptual models, such as system models, learning processes, mind maps, etc.;
– hybrids of statements and conceptual models to represent contextual knowledge;
– descriptive interlinks between different knowledge domains, and interlinks between description elements across contexts.

### 3.2 Context intermediation

In terms of semiotics [39], the WWW can be regarded as a web of symbols and so can the next generation of the Web—the Semantic Web. There are three levels in information and knowledge representation: syntactic, semantic and pragmatic. Based on this theory, Singh presents a potential development track of the Web: syntactic WWW → the Semantic Web → the Pragmatic Web [49]. The Pragmatic Web distinguishes other Webs with its context-awareness, which is the closest to human nature in understanding. In [39] Morris points out that pragmatic contextual approaches always play important roles in understanding the real semantics. Reflection on this idea in Web evolution could be described as Fig. 1, which features an interesting loop of context-awareness coming back from the Pragmatic Web and merging into the process towards the Semantic Web.

The other side of the problem is: can the existing Web technologies solve the problems towards the SW without context awareness? RDF is the most widely accepted specification in WWW/SW research for machine-understanding of resources. But in reality, after six years, people still have not seen any outstanding, influential and popular applications of RDF-based technologies. Interestingly, existing specifications based on RDF such as DARPA Agent Markup Language with Ontology Inference Layer (DAML+OIL) [13] and Web Ontology Language (OWL) [33] try to operate simply based on RDF. Actually, RDF itself is very flexible and has nothing to do with context awareness because it is designed for representing generic semantics. Following the theory of signs [39], and also considering the importance of integrating or merging existing non-RDF-based application with those RDF-based SW applications, a pragmatic context-aware approach will be needed.

Considering that the open nature of the Web and the heterogeneous nature of the resources, which will remain the same in the future, this paper proposes a new approach of a 'context artifact' (CA) to address the semantic integration issue of the semantics-oriented applications along with the evolution of the Web technologies. As shown in Fig. 2, on one hand, the CA approach inherits the traditional and widely accepted metadata description method on the WWW; on the other hand, it aims to converge with the emerging SW information architectures. By applying the CA approach in existing applications on the current WWW, it will contribute to semantic integration and interoperation across the WWW and the SW in the future.

The CA layer operates as an intermediate layer between content descriptions of static resources and dynamic processes and those intelligent applications featuring logic reasoning and proof. In contrast to the SW cake stack [8], content descriptions are more WWW friendly, which could be based on either XHTML/XML or even RDF, while intelligent operations are more SW-friendly, which involves Agents, Logic Reasoning, Decision Making and Multi-Agent Cooperation. Another important component in the context-based approach is the vertical access/security/trust module, which is dedicated to enable measurable trustworthiness management of resources or services in different contexts.

Based on our previous work in context-based RSS (RDF Site Summary/ Really Simple Syndication) [42] news aggregation using Agents [25], this paper presents a new context mediated e-Learning semantic integration framework as shown in Fig. 3. The framework architecture is designed based on the service-oriented approach,

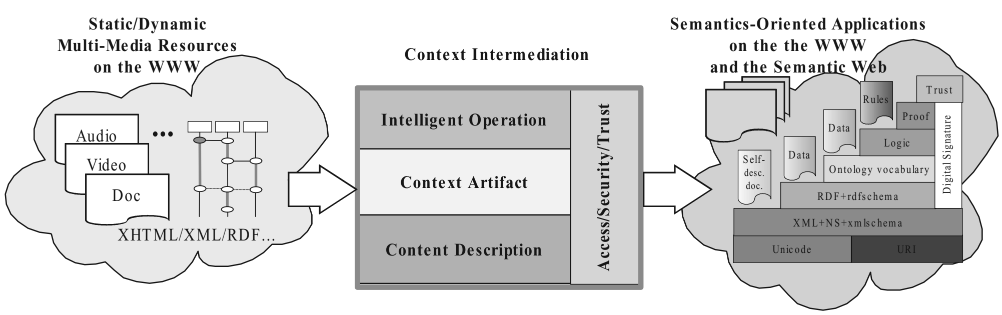


**Fig. 2** Context mediated semantic integration approach across the WWW and the SW

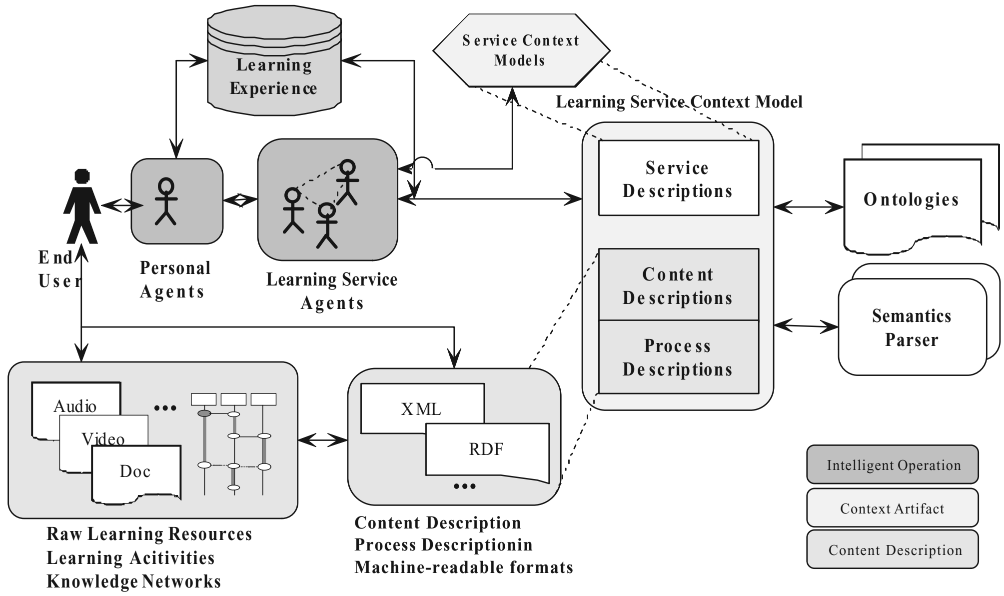


**Fig. 3** Context-based learning semantic integration and interoperation architecture

which addresses many issues using one generic context-aware methodology and under a single architecture for content description, process management, and pervasive access, interoperation and reuse. The proposed framework also features the use of intelligent personal and service Agents, the concept of context mediation, and an e-Learning orientation.

The semantic integration architecture also shows how the proposed context intermediation model works in real practice. Interacting with users, personal Agents are expected to adapt the preferences of individual users and profiling user information for personalized services. Personal Agents co-operate with learning service agents, who directly access the service context model to understand the operation environment and related schemas. In the understanding process, semantics parsers act as interpretors for Agents to understand information encoding formats/languages, whilst ontologies act as the vocabularies, grammars, and rules for referencing and inferencing. These operations of personal and service Agents could be regarded as examples of 'Intelligent Operations' in Fig. 2. If we regard those content and process information packages from various sources as 'Content Descriptions' in the context intermediation model, the learning context service model then could be seen as an instance of the 'Context Artifact' accordingly.

The content description and process description part of the context model is always referred to or transformed from the original descriptions in XML/RDF from various sources (e.g. LOM, SCORM, EML, LD, etc.). However the service description part integrates contextual descriptions at a higher level to summarize the semantics of service (either content context or process context). When semantic interoperations are necessary, related schema manipulation or ontology mapping information will be given in the service context model. In this way, the whole context model acts like a lightweight middleware in content and process description in learning practices.

## 3.3 Multi-media semantic integration context model

### *3.3.1 Context formalization*

In order to integrate the semantics of multi-media resources, we propose a generic context mediation model as follows:

Let $x$ represent a multi-media object.

Let $s$ represent semantically isolated segments in media (i.e. shot/track in video/audio, parts in image or text).

If $KS$ represents a non-empty set ($KS \neq \emptyset$) of all contextual or Knowledge Sources of Object $x$;

and $ASD$ represents a set of Annotators' Semantic Descriptions of Object $x$ (could be empty).

The semantic Description Scheme (DS) of Object $x$ represents a combination of $KS$ and $ASD$ in context, which could be described as Eq. (1):

$$DS_s(x) = KS_s \cup ASD_s \tag{1}$$

If let $RD$ represent a non-empty set ($RD \neq \emptyset$) of all Resource Descriptors of Object $x$.

Let $EP$ represent a non-empty set of all Extracted Properties (EP) from Object $x$, where $EP \subset RD$, $EP \neq \emptyset$.

Let $ARD$ represent a non-empty set of all Annotators' Resource Description of Object $x$, where $ARD \subset RD$, $ARD \neq \emptyset$. (Note that $EP$ and $ARD$ are disjoint subsets of $RD$.)

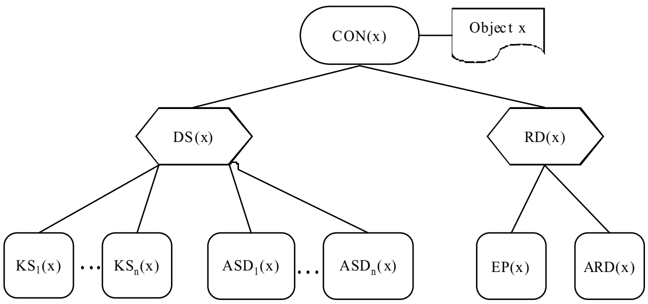


**Fig. 4** Context model for multi-media semantic representation

Therefore, the semantics of multi-media object $x$ in context as $CON(x)$ can be represented as Eq. (2):

$$\begin{aligned} CON(x) &= RD(x) \cup DS(x) \\ &= EP(x) \cup ARD(x) \cup \sum_{s=1}^{n} DS_s(x) \end{aligned} \tag{2}$$

where $n$ = total number of $s$.

The whole context description model could be illustrated as Fig. 4.

The XML/RDF schema of the context model is described as follows (part):

```
<?xml version='1.0' encoding='UTF-8'?>
<!DOCTYPE rdf:RDF [
     <!ENTITY rdf 'http://www.w3.org/
        1999/02/22-rdf-syntax-ns#'>
     <!ENTITY rdfs 'http://www.w3.org/
        2000/01/rdf-schema#'>
     <!ENTITY mmcontext 'http://
        www.cic.hull.ac.uk/
     research/mmcontext.rdfs#'>
]>
<rdf:RDF xmlns:rdf="&rdf;"  xmlns:
      rdfs="&rdfs;"
         xmlns:mmcontext=
            "&mmcontext;"   >
<rdfs:Class rdf:about=
     "&mmcontext;Entity"
    rdfs:label="Entity">
    <rdfs:subClassOf rdf:resource=
       "&rdfs; Resource"/>
</rdfs:Class>
<rdfs:Class rdf:about="&mmcontext;
     ContextFocus"
    rdfs:label="Object">
    <rdfs:subClassOf rdf:resource="
      &mmcontext;Entity"/>
</rdfs:Class>
<rdfs:Class rdf:about="&mmcontext;
    DescriptionScheme"
    rdfs:label="DS">
    <rdfs:subClassOf rdf:resource="
      &mmcontext;
       Entity"/>
</rdfs:Class>
<rdfs:Class rdf:about="&mmcontext;
   KnowledgeSource"
    rdfs:label="KS">
    <rdfs:subClassOf rdf:resource="
       &mmcontext;
       DescriptionScheme"/>
</rdfs:Class>
<rdfs:Class rdf:about="&mmcontext;
      AnnotatorSemanticDescription"
    rdfs:label="ASD">
    <rdfs:subClassOf rdf:resource="
      &mmcontext;
      DescriptionScheme"/>
</rdfs:Class>
<rdfs:Class rdf:about="&mmcontext;
   ResourceDescriptor"
    rdfs:label="RD">
    <rdfs:subClassOf rdf:resource="
      &mmcontext;
      Entity"/>
</rdfs:Class>
<rdfs:Class rdf:about="&mmcontext;
    AnnotatorResourceDescription"
    rdfs:label="ARD">
    <rdfs:subClassOf rdf:resource="
       &mmcontext;
      ResourceDescriptor"/>
</rdfs:Class>
<rdfs:Class rdf:about="&mmcontext;
     ExtactedProperty"
    rdfs:label="EP">
    <rdfs:subClassOf rdf:resource="
       &mmcontext;
       ResourceDescriptor"/>
</rdfs:Class>
</rdf:RDF>
```

As the context model is designed to be a conceptual model, there is no problem to bind context descriptions into XML rather than RDF. As shown in Fig. 3, the context model is not specifically content-oriented. Process description could also be integrated into the framework, which is addressed by the learning service schema across platforms.

### *3.3.2 Learning service schema for integration*

The generic context schema above is proposed to facilitate high level understanding of the context approach and related generic terms. Another important component of the model is its Learning Service Description Schema, which is outlined in Fig. 5.

The general terms defined in the schema are set to facilitate the general understanding of content and process in various learning environments and from various specification platforms. Concrete descriptions in content and processes

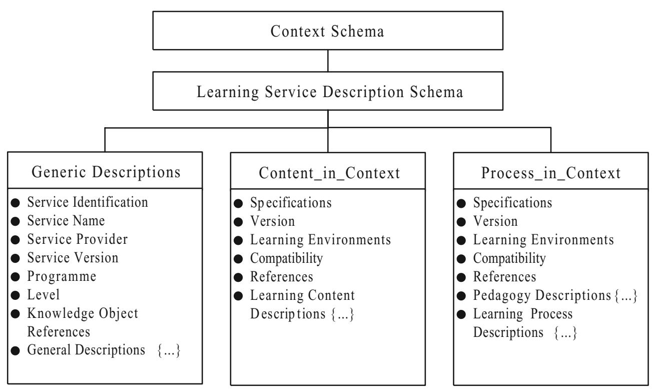


**Fig. 5** Learning service schema

will use the context mediated model in Fig. 4 for the purpose of storage and management. To the end users and intelligent Agents, semantic integration takes place at the context artifact level based on the understanding of the contextual information.

## 3.4 Multi-media semantics generation and retrieval

### *3.4.1 Multi-media semantics generation*

One of the challenging problems in multimedia content management is automatic semantics capturing of continuous media resources. Under the generic multi-media semantic integration framework and based on the context mediation model, we develop a prototype system—Context Manager (CONMAN) for multi-media semantics generation, integration and management. It aims at semi-automatic semantics generation and authoring for heterogeneous media resources in an integrated environment. The CONMAN system has four important components: media aggregator, semantic scrapper, semantic parser, and semantic matcher. The system work flow is described in Fig. 6.

The Media Aggregator is normally where the automatic annotation operation is initiated from. A base Universal Resource Identifier (URI) is passed to it and then it scans through looking for known media types. If a media object is found, the semantic scraper component is invoked on the URI before continuing with the annotation. For semi-automatic annotation, the URI of the media is simply supplied.

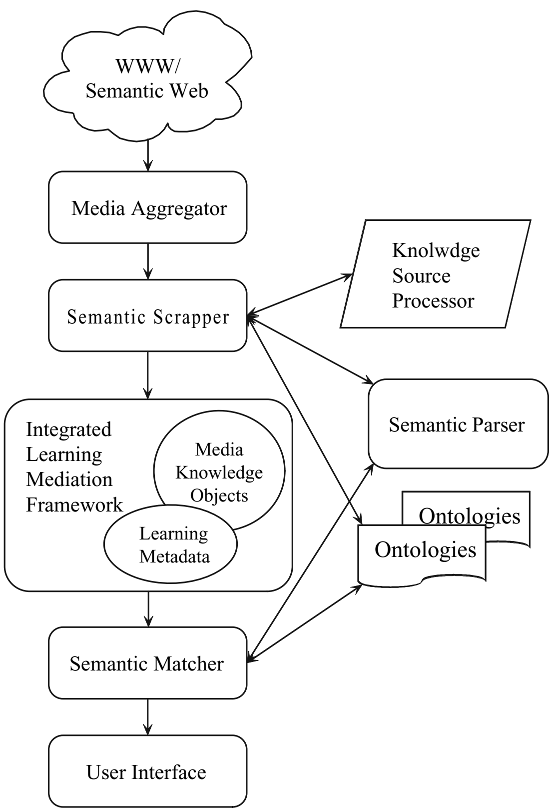


**Fig. 6** CONMAN system media semantics generation work flow

The Semantic Scrapper applies dedicated web scrapping techniques with the aid of taxonomies to gather additional information about the media object that could add to better semantic description of the media content.

The Semantic Parser detects content segments (e.g. video shots in video, tracks in audio) in the continuous media object. The detected segments are passed to the Semantic Matcher for matching against the media ontology knowledge base. Also, the Knowledge Source Processor is invoked depending on media type. The Knowledge Source Processor identifies and processes other possible semantic knowledge sources for media type. For example, in the case of video or audio, a possible knowledge source could be the transcription of audio to text.

The CONMAN prototype system for multi-media semantics management is developed in Java and its provisional user interface is shown in Fig. 7. In the system, external or internal context-related multiple media resources in different formats (e.g. lecture video/audio, image, presentation slides, text/html documents) could be opened on the Media Window panel. Content descriptions in context could be created and modified on the Resource Description panel. Temporal audio/video resources can also be browsed in Semantic Segments on the preview panel. With references to ontologies and schemas, integrated semantic descriptions of a knowledge objects could be saved in the centralized knowledge base, in the options of XML or RDF.

### *3.4.2 Semantic media retrieval*

In the Semantic Matcher, images are matched based on the colour, texture, and shape attributes, which uses traditional image retrieval techniques. Images are seldom identical, and therefore matching is based on a similarity-measuring function for the visual attributes and a set of weights for each attribute. The score is the relative distance between two images being compared. The score for each attribute is used to determine the degree of similarity when images are compared, with a smaller distance reflecting a closer match.

A media ontology knowledge base is stored in an Oracle database using Oracle interMedia features. When matching key frames in a video clip, a weight is attached to each of the visual attributes (shape, colour, and texture) and interMedia calculates a similarity measure for each visual attribute. Weight values can be between 0.0 and 1.0. The similarity measure for each visual attribute is calculated as the score between the two images with respect to that attribute. The score can range from 0.00 (no difference) to 100.0 (maximum possible difference).

Equation (3) shows how the weighted sum of elementary distances is calculated, for the purpose of determining the


**Fig. 7** GUI of CONMAN, a multi-media semantic context manager

degree of similarity between two images:

$$\text{Similarity} = \sum_{\text{attribute}:t} \text{Weight}_t \times \text{Score}_t \qquad (3)$$

where $t \in \{\text{colour, texture, shape}, \ldots\}$.

A threshold value $\Delta$ is normally given in the match process that if the weighted sum of the scores for the visual attributes is less than or equal to the threshold, the images match; otherwise, the images do not match.

Video content matching could also follow the image matching approach using the keyframes generated. In multimedia computing area, there is enough related work including content-based image retrieval (CBIR) and video summarization and MPEG-7 search. Therefore, this kind of physical feature based media retrieval function is not the core contribution of the framework and system in terms of semantics retrieval, but the generic context artifact level semantics retrieval is.

### 3.5 Context-based semantic information retrieval

Traditional search engines such as Google, Yahoo!, and Altavista normally use keyword based retrieval mechanism, which is hard to specify a context. For example, 'apple and computer' might stand for a scene of an apple besides a computer in the user's mind, but it is hard to represent it in traditional keywords-based information retrieval. On the other hand, the RDF Query language (RDQL) [45] is still in development. RDQL basically works in a traditional SQL-like 'Select-Where-' style. There is no generic RDF resource search engine influential on the Web at this moment, our developments follow the simplicity principle in HCI in terms of usability.

To address this issue, we propose a simple context-based retrieval approach, which features a simple predicate/object pair model. This model not only follows the most intuitive and primitive description and expression in natural languages, but also compatible with RDF-based query and search in the future.

As shown in Fig. 8, the user could either choose to use the basic query—traditional keyword interface to perform the search, or to use the simple query interface to generate predicate/object pairs to specify the context. In this example, the query could be described as 'is a university website, has academia, has students, also provides forum', and structured in four pairs as <isa, university website>, < ∗,students>, < ∗,academia>, <provides, forum>, more rows of pairs could be added if necessary. By giving the flexibility to user to specify the context in retrieval, the system has less of a semantic ambiguity problem than traditional information retrieval systems.

Once the query context is defined, the system will pass the context model to the search engine. The search engine works with XML query mechanisms (e.g. XQuery [56]) and RDF query mechanisms (e.g. RDQL). In the case of RDQL search execution, there might be duplicated results shown in 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 that happened in the same raw result object will be re-weighted and the ranking will be recalculated when the iterations of single context query or multiple

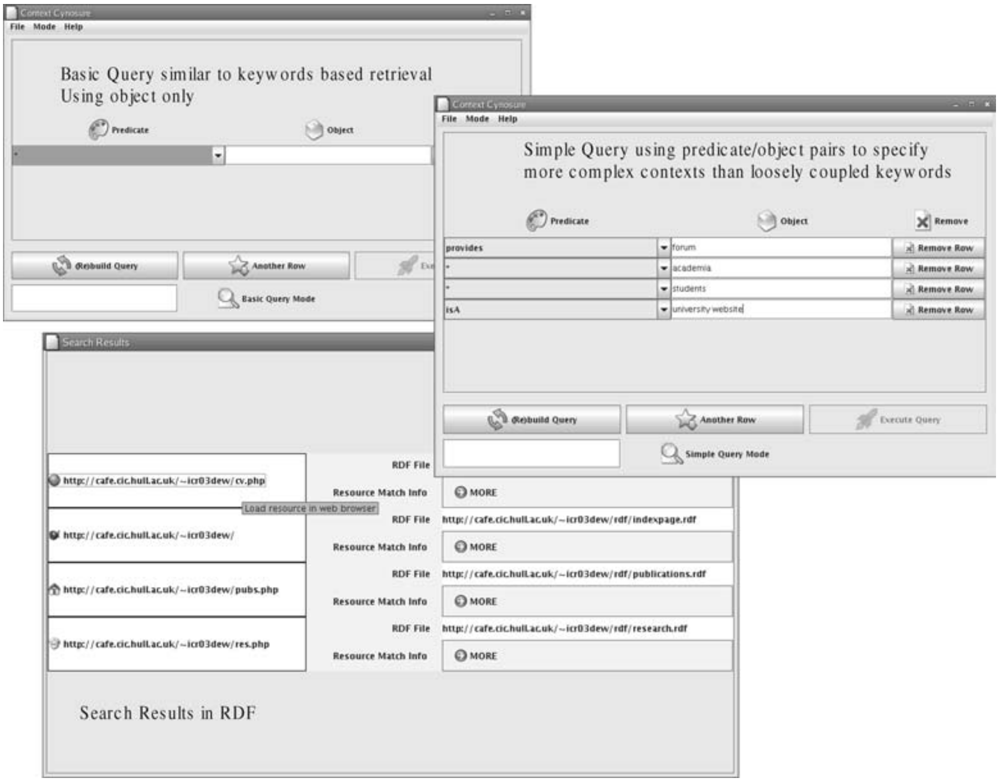


**Fig. 8** Semantics retrieval based on context

contexts query go on. An example of result list in RDF is shown in Fig. 8.

Another important issue involved in the context integration and retrieval process in the system is interfacing the context descriptions based on the model formalized in Sect. 3.3.1 to the predicate/object pairs in retrieval process. For example, a learning object could use LOM and Dublin Core metadata element 'creator' in descriptions, its potential corresponding predicate will be 'CreatedBy' or 'AuthoredBy' in retrieval. To make the system work, there needs to be a semantics mapping process between 'creator' and 'CreatedBy/AuthoredBy', which is not available with traditional search engines at this moment. From this example, we can see that a solution to this problem is to use simple inferencing rules between nouns and verbs/predicates generated from thesauri such as WordNet [55].

This integrated semantic retrieval approach is not only able to work with the context-based learning knowledge within the framework, but also to interoperate with other generic XML/RDF-based semantic e-Learning resources in other LMSs. This gives the context-based e-Learning framework a great advantage in semantic integration and interoperation across knowledge domains in learning practices.

## 4 New approaches to support intelligent e-Learning

In addition to enabling semantic-based information service in e-Learning, there is another important issue to be considered in modern e-Learning: learning theory application in relation to pedagogy. Existing solutions such as EML, LD, and PALO have shown a promising feature of supporting pedagogies in learning. It is also of great importance to manage knowledge and apply learning theories in practice in an integrated semantic e-Learning environment. Within the proposed context-aware learning framework, we look into the possibilities of enabling learner-centric knowledge-oriented e-Learning from different perspectives.

### 4.1 Knowledge object visualization with knowledge network

Both learning-by-doing and learning-by-teaching methods are all about processing of knowledge: from knowledge creation, to knowledge transfer and diffusion [21]. Comparing with learning objects, knowledge objects are more of a contextual sense. Effective knowledge management in education and learning enables better know-how creation and accumulation, which has become central to economic performance [21]. In the e-Learning context, we classify knowledge objects of knowledge communication in higher education e-Learning environments [24] into different levels. The three levels of knowledge objects are: tangible knowledge objects, tactical knowledge objects, and empirical knowledge objects (as shown in Table 1).

As a key to a knowledge-oriented learning framework, visualization of knowledge objects in contexts could help

**Table 1** Knowledge objects of knowledge communication in higher education

| Categories | Instances |
|---|---|
| Tangible objects | Textbooks, lecture slides and video, further readings, references, coursework, exam papers, experimental equipments |
| Tactical objects | Programme specifications, module syllabus, student handbooks |
| Empirical objects | Module questionnaires, feedbacks, PDP (Personal Development Planning) |

learners in self-directed revision and help instructors in content coordination across modules and programmes. In this paper, we present a new tactical knowledge network for visualization based on real learning programme and module specifications. Figure 9 describes part of the knowledge network of CIC (Centre for Internet Computing) undergraduate programme specification under the national (U.K.) Quality Assurance Agency for Higher Education (QAA) 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 check points in learning and teaching, and different colours indicate different levels of the programme (i.e. BSc Year 1, Year 2, and Year 3). The edges between the nodes indicate the relation between the knowledge check points. The vertex of the multi-dimensional knowledge network is the user, which could be learner or instructor. Using common graph visualization approaches, the whole network could be visualized 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, what they need to know before hand or afterwards. The knowledge network visualizes the contextualized learning information generated from the semi-automatic multimedia semantics generation and manual annotation based on the context model. A knowledge base stores the multi-media content descriptions and learning process descriptions based on the same semantic integration context model.

## 4.2 Enhanced Kolb's learning cycle in semantic e-Learning

To provide a learning environment with adequate scientific learning supports for learners, we look into related learning theories in education. Among the most popular theories, D.A. Kolb's learning cycle features 'experience, reflection, generalisation, and test' four steps [31]. To apply the generic learning theory in self-directed learning practice, we design a content and process integrated e-Learning cycle in conjunction with Kolb's cycle with the support of a knowledge network throughout.

As shown in Fig. 10, the enhanced e-Learning cycle model still has four generic steps, but apply in practice with concrete concepts and activities in learning and teaching practices, which could be implemented with the content description, process description, knowledge network, and other supporting technologies. This model is expected to guide various types of learning in practice in the learning support context.

By coordinating the abstract learning model (inner cycle) with concrete learning activities (outer cycle) in context, learners and instructors see how practices could be guided by the theories. In this process, personal Agents help individual learners to find out what have been done, what need to be done, and which methods are the most suitable in contexts. In terms of a human computer interface, similar to the knowledge network, this process could be also visualized in a Java 3D environment.

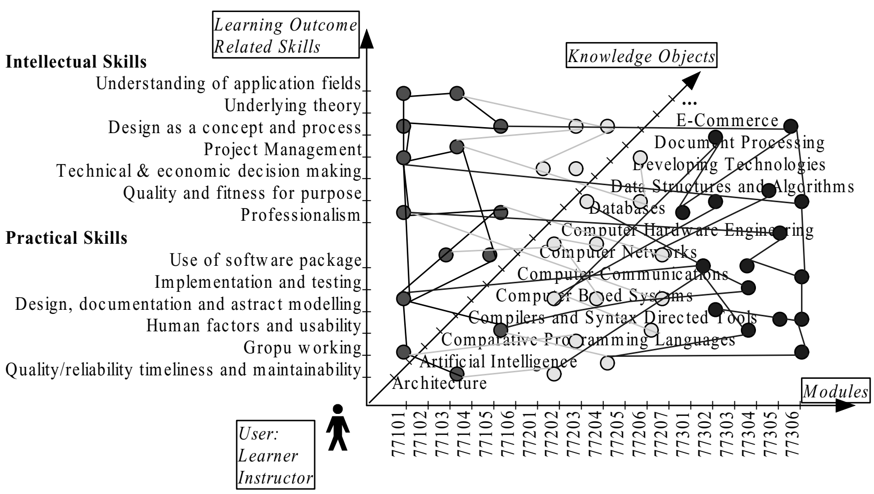


**Fig. 9** Undergraduate programme knowledge network (part), Centre for Internet Computing, University of Hull, UK

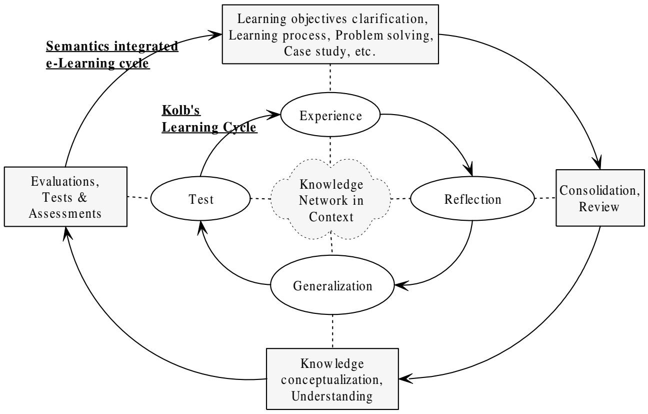


**Fig. 10** Enhanced Kolb's learning cycle with support of knowledge network and reflection on e-Learning activities

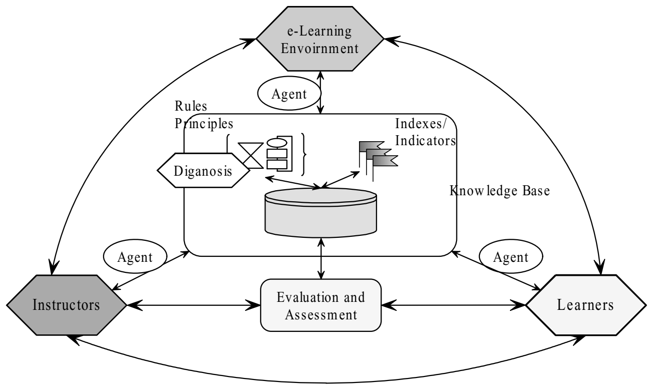


**Fig. 11** An integrated learning healthcare framework with support of intelligent agents and knowledge base

### 4.3 A learning healthcare framework towards intelligent e-Learning

To apply existing and enhanced learning models in real e-Learning practice, especially self-directed e-Learning, we propose a novel learning healthcare framework, which uses intelligent Agents to facilitate learning knowledge management. Agents can help us to collect, filter, and manage semantic information in learning activities (no matter which learning model/style in use). In our previous work in content syndication based on RSS [25], we used Java Agents developed on the JADE framework [7] to carry out semantic-based operations, which are similar to those in e-Learning practices.

The basic idea of this framework is to enable the close interaction between the learning activities and learning targets. The knowledge network can provide a graph of check points for the learners, but they might not be able to know where the problems are, and when the problems need to be solved in order to process to the next stage. Therefore, there is a great need to have a health-check framework to help the learners in practice. As the knowledge base stores the contextual learning process information in relation to the learning content of the learners, the diagnosis process could be carried out automatically based on certain rules and using indicators to notify learners. The whole framework structure is described in Fig. 11. The major contribution of this framework is to leverage the e-Learning environment context impact rather than traditional self-guided or instructor-guided learning. With the support of the knowledge network and learning healthcare framework, learners are expected to have a clearer view of the learning content and learning process through the learning cycle, while making use of all contextual related semantic information.

In terms of implementation, the knowledge base is expected to implemented in an XML database, which could improve the low level data retrieval of the encoded static and dynamic information. High level information processing, based on contexts, uses a context processing engine, which is dedicated to recording, retrieval, transformation, and communication oriented towards various services in applications such as e-Learning. The context processing engine operates like a middle-ware in the framework, which corresponds to the context artifact described in Fig. 2. To bring in personalized learning service, intelligent Agents help in recording down the learning activities and history, which could be used for user profiling and learning advice based on analysis of learning theories and learner case studies in similar contexts. This feature is expected to be accomplished using advanced natural language processing and logical reasoning techniques based on the contextual information provided by the knowledge base.

## 5 Conclusions and future work

In this paper, we present a context-based framework towards integrating semantics of multi-media resources and processes in e-Learning. The proposed context intermediation model aims to bring a pragmatic context artifact layer into traditional heterogeneous media content descriptions, and to work towards a more integrated service-oriented architecture. Related development issues such as semantics generation and retrieval are also discussed in the paper with an example of a prototype in media semantics management and in context-based semantics retrieval.

To support intelligent e-Learning services within the context-aware information service framework, we propose to integrate various types of knowledge objects into an integrated knowledge network to facilitate the coordination of contents for the instructors and assist the learning and revision process for the student. Based on the support of the knowledge network and intelligent agents, concrete learning activities of individuals are to be explicitly guided by learning theories such as Kolb's learning cycle [31]. Further development of a learning healthcare framework, with the aid of knowledge base and logical reasoning techniques, is expected to deliver more intelligent semantic understanding of learning processes, as well as learning contents, for learners, and consequently build a learner-centric intelligent e-Learning environment.

Future work involves further developments on multimedia semantics semi-automatic generation and management, personal Agents to support personalized learning in the learning healthcare framework, and pedagogy education theories application in practice.

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