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Computational Intelligence in Web-based Education

A Tutorial

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Abstract

The paper explains the basics of the current technology applied in Web-based education and how developments in computational intelligence can contribute to that technology. Web-based education is a popular research and development domain in educational technology. In recent years, a number of research groups have put a lot of efforts in developing suitable methodologies, approaches, tools, and practical systems to support Web-based education. There were also several introductory and survey papers covering the domain. However, there has been comparatively little research in applying the principles and achievements in computational intelligence – fuzzy systems, neural networks, granular computing, and evolutionary computing – to Web-based educational applications. To complement such a situation, this paper suggests a number of potential benefits that can stem from applying various techniques of computational intelligence to Web-based education. It also pays special attention to intelligent Web-based educational systems and tools for their development.

1. Introduction

Web-based education (*WBE*) has become a very important branch of educational technology. For learners, it provides access to information and knowledge sources that are practically unlimited, enabling a number of opportunities for personalized learning, tele-learning, distance-learning, and collaboration, with clear advantages of classroom independence and platform independence. On the other hand, teachers and authors of educational material can use numerous possibilities for Web-based course offering and tele-teaching, availability of authoring tools for developing Web-based courseware, and cheap and efficient storage and distribution of course materials, hyperlinks to suggested readings, digital libraries, and other sources of references relevant for the course.

On the other hand, abundant developments in the field of *Computational Intelligence* (*CI*) during the 1990s have made the CI technologies potentially comprehensive and effective algorithmic platform for supporting education processes. CI encompasses several important technologies aimed at the development of intelligent systems, that is fuzzy systems, granular computing, neural networks and evolutionary optimization. What is also very characteristic for CI today is a broad array of hybrid systems, such as neuro-fuzzy systems, neuro-evolutionary systems, and genetic fuzzy systems. They emerge as a result of an in-depth understanding of the benefits of individual technologies and their genuine complementarity. When applied to the development of WBE systems, CI technologies bring about important improvements that make the resulting WBE systems more flexible, more user-friendly, and better understood intuitively.

The purpose of this paper is to introduce the synergy of WBE and CI for the benefit of the learners, teachers, and authors of educational material on the Web. The next section covers the basics of CI and its issues relevant for WBE. Section 3 surveys important components of intelligent WBE technology in the context of knowledge representation, knowledge processing, and ontological support for the learning, teaching, and authoring processes. In Sections 4 and 5, the principles of applying CI to developing WBE applications and tools are discussed, and examples of successful CI-supported WBE systems are indicated.

2. Computational Intelligence (CI)

The development framework considered in the context of this study is Computational Intelligence (CI). CI [Pedrycz 1997,2000]is a well-established paradigm that seamlessly combines three main technologies aimed at the development of intelligent systems, that is granular computing, neural networks and evolutionary optimization. As in the design of such systems, we have to address various challenging issues such as knowledge representation, adaptive properties and learning abilities and structural developments, CI has to a cope with each of them. With regard to the properties of intelligent systems being supported by CI, we can envision two general points of view. These properties can be sought as *intrinsic* to any intelligent systems or they can be *extrinsic* to them. In the first case, we are concerned with the features that are crucial to the design of the systems, which usually do not manifest externally so by analyzing the performance of the system we cannot say whether a specific technology has been utilized. Essentially, we are not concerned about that. The extrinsic properties are dominant and become of a paramount relevance when dealing with communication of intelligent systems with others or facilitating an effective interaction with human users. This aspect is extremely relevant in providing the user a sense of intelligent and user-friendly capabilities of the systems. Here we can stress that these capabilities are very diversified and could cover a vast territory. For instance, one can envision several interesting scenarios

- Coping with heterogeneous information. Quite often, in intelligent systems we may encounter information coming not only from sensors (in which case these are numeric readings) but also from users (in the form of linguistic evaluations) or being a result of some initial aggregation or summarization. Interestingly, these inputs are essential to the functioning of a system and cannot be ignored or downplayed. The heterogeneity of information requires special attention in the sense of the use of more advanced mechanisms of processing and representing such a mix of various pieces of evidence
- Establishing an effective, transparent, and customized communication with the end user when presenting the results of processing completed by a system. Here the notion of generality (abstraction) or granulation of information plays a pivotal role. A suitable level of granulation of information is essential to the effective communication and acceptance of a system (in whichever role we can envision the system to be utilized). This immediately leads us to the concept of adaptive and user-driven interfaces which become an essence to most interactive and human centric systems including tutoring architectures, decision-support systems, and knowledge-based architectures (including expert-like systems and their more advanced topologies).

The term of CI being coined in the 1990s (quite commonly viewed as a synonym of soft computing) helps us establish a sound mapping between the technologies and their dominant role in meeting some specific requests of the domain. What is also very characteristic for CI today is a broad array of hybrid systems (called neurofuzzy systems, neuro-evolutionary systems, genetic fuzzy systems). They emerge as a result of an in-depth understanding of the benefits of individual technologies and their genuine complementarity.

In what follows, we briefly highlight the essence of the contributing technologies of CI, discuss their synergies and elaborate on the resulting architectures

<u>Granular Computing</u> Granular information is everywhere. We granulate information all the time. We rarely reason on a basis of numbers. Our judgment is often triggered by some aggregates which in a nutshell are a result of abstraction: a process in which we

Originally, CI embraced fuzzy sets as the key vehicle of information granulation. It is worth stressing that the other fundamental environments for describing granular information are readily available and a suitable choice depends upon a specific problem at hand. Figure 1 visualized the main developments in granular computing; it could help gain a better view as to their possible linkages.

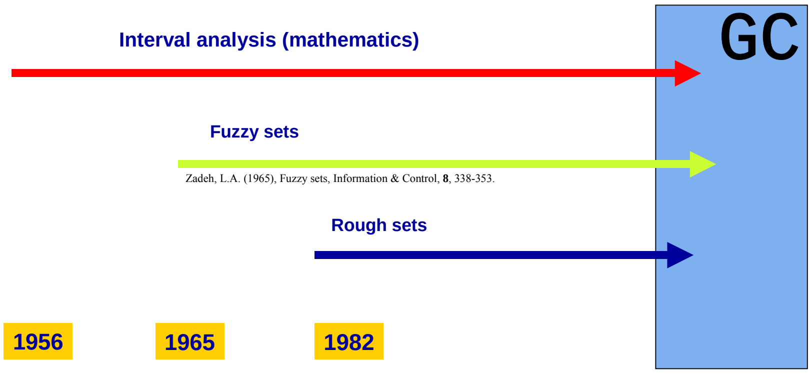


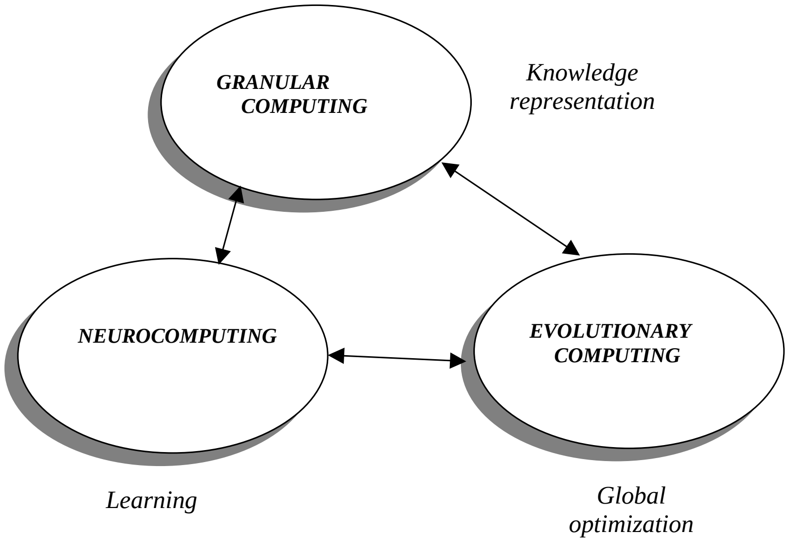
Figure 1. Main developments of granular computing

Neurocomputing is inherently associated with adaptive and highly flexible systems – neural networks. The learning abilities of the networks (either through supervised or unsupervised learning) are in the heart of networks. The learning is exploited when building systems that can learn from data, adapt to the nonstationary environment 9including preferences of users) and help generalize to new, unknown situations. The spectrum of learning models, network architectures is impressive. Neural networks are highly distributed which make them fault tolerant and What has been said so far, it is definitely very encouraging. The drawback is with the lack of transparency of the networks. The distributed character of processing can be pointed at as the most prominent reason of this deficiency. Similarly, as no prior domain knowledge could be "downloaded" onto the network, its learning is carried ouf from scratch which by itself is not the most encouraging.

Evolutionary Computing The principle of evolutionary computing cast in the setting of CI becomes a synonym of structural optimization, reconfigurability, combinatorial optimization, and variant selection usually completed in large and complicated search spaces. From its inception in the 1970s, evolutionary computing with all its variations of genetic algorithms, evolutionary strategies, genetioc programming, etc is aimed at the global, structural system optimization that is carried out in presence of a very limited and general information about the optimality criterion. With the growth of the topologies discussed in CI (and the growth being both present in terms of the plain dimensionality of the ensuing architectures as well as their increasing complexity).

From the above summary, it becomes apparent that the main agendas of these technologies are different yet highly complementary leading to the scenarios in which the advantages and limitations of each of them could be strengthened and compensated, respectively. This compensation effect is in essence a crux of the resulting synergy and helps develop interesting and useful linkages. Table 1 highlights the main tendencies and identifies the ways in which the synergies have been triggered.

Table 1. Main synergistic links in Computational Intelligence



As stressed, there are a significant number of possible interactions between the contributing technologies in the realm of CI. Bearing in mind the main objectives of granular computing and neural networks, we can envision a general layered type of the model in which any interaction with the external world (including users) is dome through the granular interface (external layers) whereas the core computing part is implemented as a neural network or a neuro-fuzzy structure (in which case we may be emphasizing the logic facet of ongoing processing faculties).

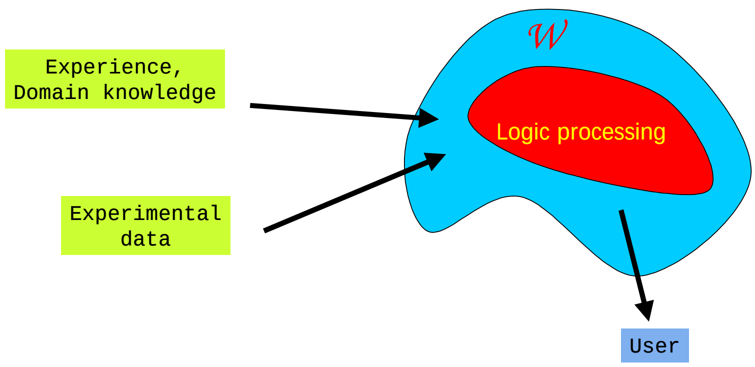


Figure 2. A layered style of CI constructs; see a detailed description in text

3. Components of Intelligent Web-Based Education (IWBE)

In the context of WBE, educational material is generally distributed over a number of *educational servers*, Figure 3 [Devedžić, 2003]. The authors (teachers) create, store, modify, and update the material working with an *authoring tool* on the client side. Likewise, learners use different *learning tools* to access, browse, read, and consult the material in completing their learning tasks.

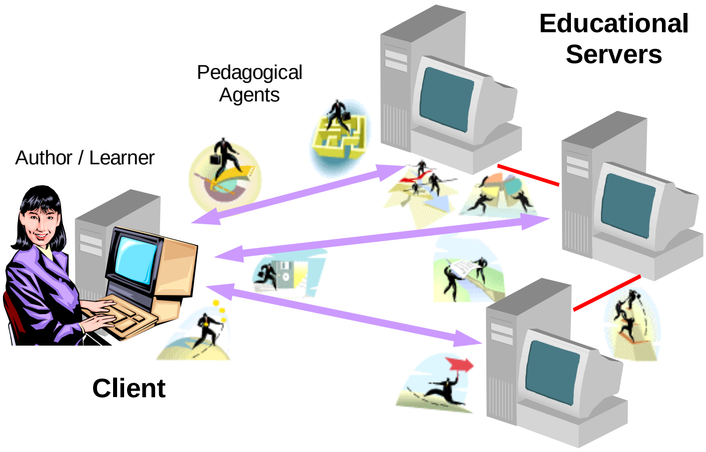


Figure 3. The setting for Web-based education

Intelligent Web-based education (*IWBE*) results from applying intelligent technologies to WBE. One important such a technology is that of intelligent *pedagogical agents*. Such agents provide the necessary infrastructure for knowledge and information flow between the clients and the servers in the context of Web-based education, Figure 1. They are autonomous software entities that support human learning by interacting with students/learners and authors/teachers and by collaborating with other similar agents, in the context of interactive learning environments [Johnson et al., 2000]. Pedagogical agents help very much in locating, browsing, selecting, arranging, integrating, and otherwise using educational material from different educational servers.
Many other intelligent technologies are popular in IWBE as well. They help complete the picture of the set of representational, processing, and technological components that constitute the IWBE framework nowadays.

3.1. Components

Figure 4 shows the components of IWBE. *Educational content* is any educational material pedagogically organized and structured in such a way that interested learners can use to get introduced to a knowledge domain, deepen their understanding of that domain, and practice the related problem-solving skills. Typically, educational content is represented on a server as a set of *learning objects* in a repository of such objects. A learning object is essentially a digitized entity that can be used to support learning process. Each educational *service* is a Web service designed specifically to support a learning or teaching goal. Table 2 presents a possible and incomplete classification of educational Web services. They are further elaborated in section 3.3.

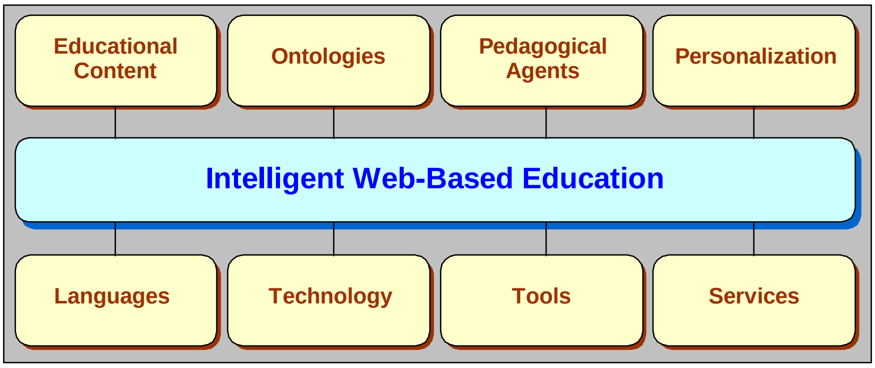


Figure 4. Components of intelligent Web-based education

Table 2. Partial classification of educational services

Service category	**Learning**	**Assessment**	**References**	**Collaboration**
Services	Course offering, integration of educational material, (creating lessons, merging contents from multiple sources, course sequencing), tutoring, presentation	On-line tests, performance tracking, grading	Browsing, search, libraries, repositories, portals	Group formation and matching, class monitoring

An important issue in IWB is interoperability and knowledge sharing between different educational applications. They can be achieved by using appropriate *languages* for representing educational content and services. Current trends in Web technology suggest that appropriate representation languages include *XML*, *XML Schema*, *RDF*, and *RDF Schema* languages [Decker et al., 2000], all developed under the auspices of WWW Consortium (http://www.w3.org/XML, http://www.w3.org/RDF), as well as other languages built on top of those four. An important emerging topic related to representational languages and WBE technologies is that of *Educational Markup Languages* that represent educational *metadata*, possibly but not necessarily together with content for learning [Koper, 2003].. There are many kinds of metadata used in educational systems and settings. These kinds often differ substantially in their application. For example, metadata may be related to the learning method, the complexity, technical format, human language or pedagogical intention of the content, the curriculum, the authoring process, usage conditions, an abstract or summary or the kind of intended learner.
The other components depicted in Figure 2 are explained in the following sections.

3.2. Knowledge Representation

All IWBE systems use various knowledge representation and reasoning techniques from AI. The *domain* or *instructional* knowledge/content of an IWBE (specifying what to teach) is traditionally referred to as *expert module*, while different teaching strategies (specifying how to teach) from the *pedagogical module* drive instructional sessions. The system's knowledge of the student's mastery of the topics being taught, in order to dynamically adapt the process of instruction to the student (learner), is represented in the *student* (*learner*) *model*.

The knowledge represented in the pedagogical module of an IWBE is that of *instructional design*. It encompasses the theory and practice of design, development, utilization, management and evaluation of processes and resources for learning, as well as building them into IWBE. This kind of knowledge is either implicitly built into the IWBE, or explicitly represented in its knowledge base (for the latter, see [Mizoguchi and Bourdeau, 2000]). The ultimate goal of instructional design in IWBE is to achieve a desired level of the learner's performance. The performance should be measurable. For a good starting point in looking for comprehensive theoretical sources of instructional design, see http://carbon.cudenver.edu/~mryder/itc_data/theory.html. A good glossary of instructional design can be found at http://garnet.acns.fsu.edu/~www6982/glossary.html.

3.3. Knowledge Processing

Intelligent knowledge processing of an IWBE system is the capability of demonstrating some form of knowledge-based reasoning in curriculum sequencing, in analysis of the student's solutions, and in providing interactive problem-solving support (possibly example-based) to the student, all adapted to the Web technology. In order to be useful to individual learners, intelligent knowledge processing in an IWBE system must be *adaptive*, since when a student is learning from a Web-tutor there is often no colleague or a teacher around to provide assistance as in a normal classroom situation. Minimum adaptivity of an intelligent Web-based educational application includes collecting some data about the student working with the system and creating the student model [Brusilovsky, 1999]. It can be then used to adapt the presentation of the course material, navigation through it, its sequencing, and its annotation, to the student. Further levels of adaptivity are achieved by using models of different students to form a matching group of students for different kinds of collaboration, as well as to identify the students who have learning records essentially different from those of their peers (e.g., the students progressing too slow or too fast) and act accordingly (e.g., show additional explanations, or present more advanced material).

Further levels of intelligent knowledge processing in IWBE are achieved using educational services, such as those shown in Table 1, and making them autonomous and capable of communicating with pedagogical agents. Roughly speaking, all Web services are activities allowing both end users and, under appropriate circumstances, software agents to invoke them directly [Preece and Decker, 2002]. A *service-oriented architecture* of IWBE, elaborated after [Vinoski, 2002], is shown in Figure 5. Educational services, described using WSDL (Web Service Description Language, see http://www.webservices.org for details), advertise themselves in the registry, allowing the learners' agents to query the registry for service details and interact with the service using those details. Pedagogical agents will continue to facilitate automatic service discovery, invocation and composition, but as educational Web services evolve, they too will acquire standard interaction models [McIlraith et al., 2001].

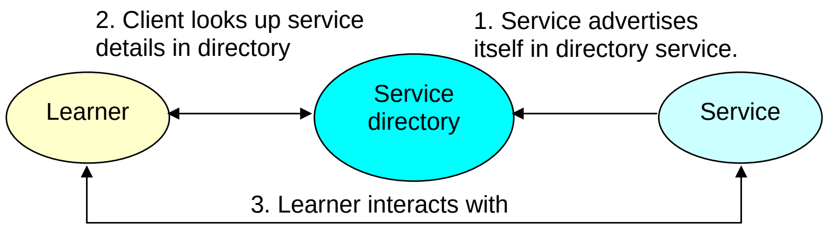


Figure 5. Service-oriented architecture of educational Web servers

Using service-oriented architecture from Figure 5 in IWBE systems development can greatly enhance the traditional process of developing learning applications, since the client-side system can be built based on educational Web services even if these services are not yet available or they are not known by the developers. This due to the fact that each Web service is described through a service description language such as WSDL, dynamically discovered by applications that need to use it, and invoked through the communication protocol defined in its interface. The central component of an educational Web server is the service directory – dynamically organized, but highly structured (e.g., as a tree, or as a table/database) information pool pertaining to different educational services. The underlying assumption is that at each point in time the directory lists those services that are ready to be invoked by the learner; those are supposed to advertise their readiness and availability to the directory. Hence a pedagogical agent can find out about the available services by looking up the directory. Then it can decide whether to automatically invoke a suitable service on the learner's behalf, or merely to suggest the learner to interact with the service directly.

3.4. Ontological Support for IWBE

As the technology advances, the Web of today is likely to get gradually transformed into the *Semantic Web*, a huge network of machine-understandable and machine-processable human knowledge, not just ordinary information [Decker et al., 2000], [Fensel et al., 2001], [N. Friedman-Noy et al., 2001], [Hendler, 2001], [McIlraithh et al., 2001]. The Semantic Web (http://www.semanticweb.org/) is expected to provide explicit representation of the semantics of data in the form of various domain theories stored on many Web-servers as a myriad of shareable ontologies, as well as advanced, automated, ontology-supported, and agent-ready reasoning services. That way, ontologies will provide the necessary armature around which knowledge bases will be built [Swartout and Tate, 1999].

For true, semantic interoperability of educational contents and applications on the Web, it is necessary to root them in the Semantic Web, which sets grounds for developing reusable educational Web-contents, Web-services, and applications [Devedžić, 2001].

Standard educational ontologies must cover a number of areas and aspects of teaching and learning, such as curriculum sequencing, student modeling, pedagogical issues, grading, and many more [Devedžić, 2003]. However, work in that direction is still at the beginning and many ontologies are still missing.

For developing and representing ontologies, higher-level languages built on top of XML(S) and RDF(S) are a good choice. Although there are several frequently used, general-purpose ontology development languages (such as KIF, SHOE, XOL, Topic Maps, DAML, OIL, DAML+OIL; see [Fensel et al., 2001]), IWBE systems developers recently turn more and more to OWL, the latest Web Ontology language

proposed by WWW Consortium (http://www.w3.org/TR/2003/WD-owl-guide-20030331/).
It is up to the developers of IWBE authoring tools to provide support for creating Web pages with educational content that points to appropriate ontologies and with educational services that ensure easy and automatic access of the content by means of pedagogical agents. This requires requires the corresponding educational Web pages to contain a) *semantic markup* [McIlraith et al., 2001], i.e. descriptions which use the terminology that one or more ontologies define, and b) pointers to the network of ontologies, Figure 6. Using ontologies as references in marking-up educational pages and services on the Semantic Web enables knowledge-based indexing and retrieval of services by pedagogical agents, agent brokers and humans alike, as well as automated reasoning about the services, such as how to use them, what parameters to supply, what results to expect, and so on.

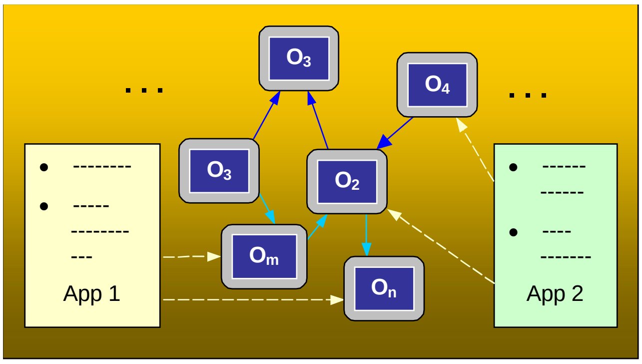


Figure 6. Semantic markup provides mappings between educational Web pages and ontologies (Oi - ontologies)

Summarizing the ideas from the previous sections, Figure 7 depicts a service-based architecture of educational Web servers. The services shown in Figure 7 are those from Table 2. The server can offer teachers, learners, and authors service-oriented access to educational content in (a) specific domain(s) of interest. Through presentation services, the content can be adaptively organized and shown in numerous ways.

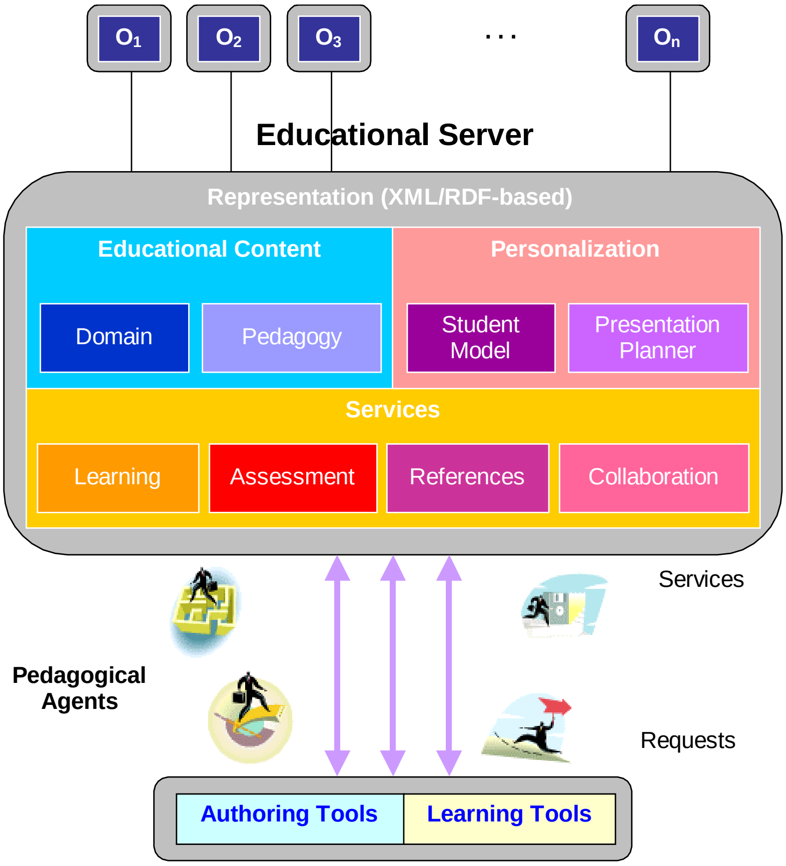


Figure 7. INES architecture: inside an intelligent educational server (Oi - ontologies)

3.5. Examples of IWBE Systems

First-wave IWBE systems like ELM-ART [Brusilovsky et al., 1996] and PAT Online [Ritter, 1997], to name but a few, used Web technology only as means of delivering instruction. More recent IWBE systems address other important issues, such as integration with standalone, external, domain-service Web systems [Melis et al., 2001], using standards and practices from international standardization bodies in designing Web-based learning environments [Retalis and Avgeriou, 2002], and architectural design of systems for Web-based teaching and learning [Alpert et al., 1999], [Mitrović and Hausler, 2000]. Rebai and de la Passardiere try to capture educational metadata for Web-based learning environments [Rebai and de la Passardiere, 2002].

The most notable classical work in the WBE community related to the development of educational ontologies comes from the Mizoguchi Lab at Osaka University, Japan, and from Tom Murray. Mizoguchi and Kitamura indicate that the ontology of an intelligent educational system as a whole consists of *domain ontology*, which characterizes the domain knowledge, and *task ontology*, which characterizes the computational architecture of knowledge-based systems [Mizoguchi and Kitamura, 2001]. They also make an important contribution to the hierarchy of ontologies in the domain of education, and study how the use of ontologies can contribute to the architecture of intelligent educational systems, shells, and authoring tools. Murray defines the important *topic ontology*, based on topic types (e.g., concept, fact, principle), topic link types (e.g., is-a, part-of, prerequisite, context-for), and topic properties (e.g., importance, difficulty) [Murray, 1998].

More recently, Abraham and Yacef experimented with their XML Tutor in delivering personalized instruction when domain ontology is represented in XML [Abraham and Yacef, 2002]. Cimolino and Kay present a system that supports students in creating concept mapping tasks intended to capture the student's understanding of the ontology of a small domain, as well as to infer his/her misconceptions in the learning process [Cimolino and Kay, 2002]. SITS (Scrutable Intelligent Teaching System) deals with the problem of different understandings (of different authors) of what is most important and how things are related within the domain, i.e. with the existence of different ontologies underlying the sets of teaching documents created by different authors [Kay and Holden, 2002]. The approach used to handle this problem is the automatic extraction of the ontology from teaching documents metadata, which are kept separate from the documents. Apted and Kay go one step further by building a system that automatically constructs an extensive ontology of computer science starting from FOLDOC, the Free On-Line Dictionary of Computing, and using it as a basis for making inferences about student models and other reasoning [Apted and Kay, 2002].
Kassist is a workbench for planning problem solving workflow [Seta and Umano, 2002]. It takes into account an important difference between the models of problem solving processes and learning processes, and is based on an ontology for enhancing the learners' meta-cognition of their work. Sicilia et al. introduce the concept of a learning link, as a context-independent, typed entity that can be used to represent (possibly imprecise) semantic relationships between learning resources on the Web [Sicilia et al., 2002]. Examples of good engineering design of ontological support for Web courseware authoring include the recently ontology-enhanced AIMS architecture [Aroyo et al., 2002] and the Ontology Editor [Bourdeau and Mizoguchi, 2002] that enables collaborative ontological engineering involving both a domain expert and an instructional-design expert. Mitrović and Devedžić have recently proposed M-OBLIGE, an ontology-based model and architecture for building multitutor learning environments [Mitrović and Devedžić, 2002].
More recently, the focus of intelligent web-based education has started to shift from integrated systems to personalized services. For example, Web F-SMILE by Kabassi and Virvou (2003) assigns agents to constantly observe the users and collect information about them. This information is maintained centrally on a Learner Modelling Server. In this way, each learner model is available to any client application that requests it. The agents of the client applications interact with the Learner Modelling Server through Web Services. The main characteristic of Web Services is that they interact with the applications that invoke them, using web standards. Sampson, Karagiannidis and Kinshuk (2002) provide many other examples and perspectives of such services.

4. Computational Intelligence in Education

4.1. Fuzzy Systems in Educational Applications

Fuzzy sets play a pivotal role in two important and unique ways. First, these are essential constructs addressing an issue of information and knowledge abstraction and granulation. Let us recall that information granulation and abstraction go hand in hand. Information granules directly result from information granulation – a process within which we combine individual elements into some more general entities (information granules). The elements are collected together because of their similarity, closeness, or existing associations. They are a direct manifestation of processes of abstraction. By accepting a certain level of processing we either move up or down along the scale of abstraction and thus concentrating to a certain extent on the details we are interested in. Higher abstraction comes with higher generality, less details and more general view of the problem. Lower abstraction helps us target more details. The level of abstraction is easily manageable through choosing fuzzy sets. This naturally leads us to a hierarchy of concepts

The second important feature that is inherent to fuzzy sets deals with their human-centric nature. In contrast to set theory, rough sets and alike constructs, fuzzy sets link well to the linguistic framework typical for any communication processes between humans. Taking this account it is not surprising to see an important role being played by fuzzy sets in computerized education applications

- Fuzzy sets directly promote a variable cognitive perspective by helping focus on the most suitable level of detail. This level could vary depending upon the user and his/her level of confidence as to the subject area
- Fuzzy sets are essential in calibrating linguistic concepts. Membership functions help quantify notions that are inherently linguistic in their essence
- By admitting partial membership to concept we can easily model processes of learning where any accumulation of knowledge occurs in a gradual manner. By exploiting membership grades one can come up with a comprehensive instrument expressing the dynamics of learning. An interesting alternative arises: one starts with a high level of abstraction (conveying general ideas) and then refines them while controlling the process of learning. The underlying idea is portrayed in Figure 8.

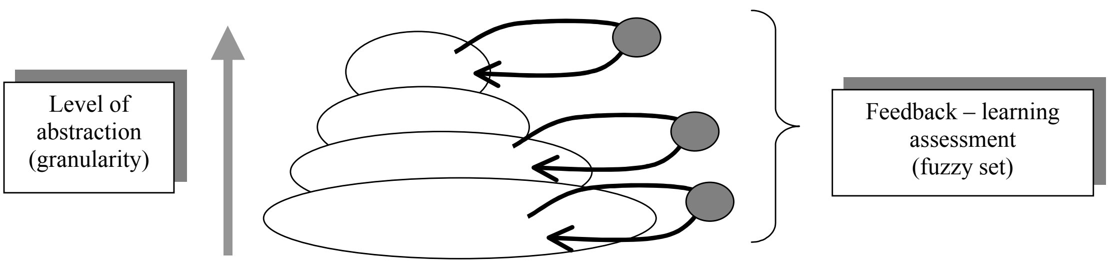


Figure 8. Refinement of concepts (level of abstraction of learning) through the feedback loop with the learner; note the use of fuzzy sets in assessment of learning and the level of specificity of acquired knowledge.

There is a number of potential issues, learning situations, and parts of IWBE systems where fuzzy sets and techniques can be used as a suitable modeling technique. For example, the model of the importance of a learning object for a certain learner may be quite realistically expressed in terms of several overlapping fuzzy sets (e.g., *not-so-important*, *important*, *very important*). Likewise, fuzzy sets can be used in expressing the suitability of a teaching strategy for a specific teaching goal (e.g., *low-efficiency*, *moderate-efficiency*, *high-efficiency*). The following two operational examples of using fuzzy sets in intelligent learning systems further illustrate this point.
Abou-Jaoude et al. have introduced a specific module in the architecture of their intelligent tutor, called Duffy, to model the role of the learner's emotions in the

learning process [Abou-Jaoude et al., 1999]. They called it the believable layer. The idea is to take into account both positive and negative emotions of the learner when she/he is dealing with a specific topic, and use them among the other parameters to drive the learning session more effectively. The learner's emotional status should always be "driven" in such a way to maximize the learning goals. In order to do that, the designers of Duffy have modeled a number of pairs expressing the learner's emotions during the learning session (such as Joy/Distress, Concentration/Disconcentration, and so on) using the fuzzy sets *low*, *medium*, and *high*. Each such an emotional couple *e* generates a reaction *r* from the learner, and there are several triplets of fuzzy rules in the system (of the form: if *e* is *high*, then *r* is *low*; if *e* is *low*, then *r* is *high*; if *e* is *medium*, then *r* is *medium*) responsible for handling the learner's emotional states.
Similar ideas in learner modeling are applied in the TADV architecture for Web Course Management Systems (WCMS) in distant learning [Kosba et al., 2003]. A TADV-based WCMS can track information generated about individual students and build fuzzy student, group, and class models. The models then provide teachers with appropriate advice to help them manage their distance courses.

4.2. Evolutionary Computing in Educational Applications

Many leading educational institutions are working to establish an online teaching and learning presence. The research in on line educational systems is focused in the computer-assisted personalized approach. We have two ever-growing pools of data: 1) educational resources such as web pages, demonstrators, simulations, homework assignments, examinations and 2) information about users who create, modify, assess and use these resources.
We studying data mining methods for extracting useful knowledge from these large databases of students using online educational resources and we try to answer the following questions:
1) Can we find classes of students? If so, can we identify that class for any individual student?
2) Can we classify the problems that have been used by students?

We then try to find similar patterns of use in the data and eventually be able to make predictions as to the most effective course of studies for each learner based on their present usage.

- Evolutionary mechanisms (i.e. Genetic Algorithms) become of paramount relevance when it comes to gathering information through intensive and directed Web search. We can envision situations in which an effective and flexible mechanism requires a substantial level of structural optimization. This feature is well handled by genetic algorithms and genetic optimization[Falkenauer98]
- Genetic Algorithms can be used to optimize a combination of classifiers (ie. Quadratic Bayesian classifier,1-nearest neighbour(1-NN),k-nearest neighbour(k-NN),multi-layer perceptron (MLP) and Decision Tree).We can also use GAs to classify the students and problems directly as well.

- We can also use Evolutionary Strategies(ES)[Back96] to evolve queries for concept modeling/user modeling (query expansion is the major problem to be solved in semantic search).

4.3 Neural Networks in Educational Applications

Systems that can communicate naturally and learn from interactions will power Web intelligence's long term success. The large number of problems requiring Web-specific solutions demand a sustained and complementary effort to advance fundamental machine learning research and incorporate a learning component into every internet interaction.

Learning by its very nature is a highly dynamic process. In order to capture its characteristics in an efficient manner and assure that the ensuing models are fully equipped with such abilities, we require mechanisms of learning. Neural Networks (NN) are an ideal vehicle to meet this goal and develop knowledge representation formalism for Intelligent Educational Systems. The superb learning models involved in neural architectures and this deals both with supervised and unsupervised learning.

Usually an Intelligent Educational System consists of the following components: i) the *domain knowledge,* containing the structure of the domain and the educational content, ii) the *user modelling component,* containing information concerning the user, iii) the *pedagogical model,* containing knowledge regarding the pedagogical decisions and iv) the *supervisor component.*

The domain model serves as a basis for structuring the content of an adaptive web-based course. A NN, with nodes corresponding to domain concepts and weighted connections reflecting relationships between concepts serves to model the domain knowledge component. A NN could also be used to model the user/learner model (which consists of the personal data, interaction parameters, and student characteristics) and the pedagogical model (which consists of the teaching method, the course selection method, and the evaluation module).

Recent efforts towards Web Intelligence will make the Web a richer, friendlier, and more intelligent resource that can all share and explore .Developing the Web Intelligence requires a systematic, computer-oriented world representation based on ontologies. NN technology could play a significant role in developing intelligent OntoLearn tools for intelligent educational systems.

5. Tools for IWBE Applications

The complex nature of IWBEs makes it difficult for typical educators to even customise them in many cases, not to mention about creating new applications. The process of developing IWBEs is generally so complicated that most research work in this area has not seen the light of real academic environment outside of the prototype stage. Once an application is developed, it becomes like a black box to any outsider (including the academics of the disciplines for whom that particular system is developed). There is generally very little possibility of customisation on the part of the implementing teacher (the one who is expected to use it in his/her curriculum) except perhaps few pedagogical rules and the chunks of knowledge (learning objects) (Kinshuk, 2002).

To circumvent the situation, various tools have been developed for creation/authoring and customisation of IWBEs, with two major purposes: reuse of typical components of the IWBEs to create new applications with very little or no programming experience (particularly useful for the teachers outside computer science domain), and customise existing applications to suit contextual requirements.

Murray (1999) classified the IWBE tools into two broad categories: pedagogy-oriented tools focusing on sequencing and teaching the content and performance-oriented tools focusing on providing rich learning environments that provide feedback on learner's actions.

The authoring part of these tools enables teachers to describe courses, construct teaching strategies, categorise students and assign different strategies and different material for them (Ainsworth, Underwood and Grimshaw, 1999). The delivery of the content is undertaken by the shell part of the tools. These shells enable adaptive delivery of the content to the learners according to the individual student profile. Examples of these tools include historic Demonstr8 (Blessing, 1997), REDEEM (Major, Ainsworth and Wood, 1997), and more recent VRCapture (Kinshuk, Lin, Yang and Patel, 2003) to name a few.

There are also hybrid tools available that allow teachers to provide tight integration between the domain content and the pedagogy as required in certain scenarios such as problem-based learning. For example, the web-based authoring tool for intelligent tutoring systems for algebra by Virvou and Moundridou (2000) enables the construction of exercises by the teachers, monitoring of students' progress while they are solving the exercises and providing appropriate feedback. This tool can be useful for any domains that apply algebraic equations such as chemistry, economics, medicine, physics and so on.

Recent developments in the ontology area have prompted its influences in the development of IWBE tools. For example, PERSEUS (Presentation ontology builder for custom lEarning sUpport Systems) is an interactive tool for designers to model the courses by defining and creating ontology of objects used to build adaptive presentations under educational context (Macias and Castells, 2001). Jin, Chen, Hayashi, Ikeda and Mizoguchi (1999) developed an ontology-aware authoring tool for intelligent training systems. They employed two kinds of ontologies: "task ontology", which is one for representing problem solving process domain-independently, and "domain ontology" which corresponds to ordinary one.

6. Conclusions

Whereas CI is certainly not the panacea that can improve all parts of current Web-based education, it definitely offers some tools and techniques quite suitable for improving the technology of Web-based learning, teaching, and authoring systems. For the benefit of the learners in the first place, developers of Web-based learning technology systems should pay more attention to CI techniques and further study the ways to apply them in education. This particularly holds for enabling CI-based modeling of domain and pedagogical knowledge, learning situations, learners' reactions and behavior, collaborative learning processes, and learning efficiency. Fortunately, there already exist a few pioneering CI-based educational systems that exemplify how to incorporate CI in educational systems effectively.

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