Web Intelligence and Artificial Intelligence in Education

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Abstract

The paper provides a survey of Web Intelligence (WI) within the context of Artificial Intelligence in Education (AIED) research. The focus is on exploring the potential benefits of WI for AIED, with key components like ontologies, adaptivity, and personalization briefly mentioned. The paper primarily addresses other WI issues, including intelligent web services, semantic markup, and web mining, proposing their utilization as a foundation for addressing new and challenging research problems in AIED.

Introduction

The scope of Web Intelligence (WI) as a research field, as proposed by Zhong et al. (2002), includes Web information systems environments, ontological engineering, human-media interaction, and more. It aims to deepen understanding across various foundations and technologies for developing and applying Web-based intelligence and autonomous agent systems.

WI can be studied on four conceptual levels (Zhong et al., 2002):

- **Network level**: Internet-level communication, infrastructure, and security protocols, where intelligence comes from the Web adaptivity to the user's surfing process.
- **Interface level**: intelligent human-Internet interaction (e.g., personalized multimedia representation).
- **Knowledge level**: representing and processing the semantics of Web data.
- **Social level:** studying social interactions and behavior of Web users and finding user communities and interaction patterns.

Semantic Web

The Semantic Web allows information to be expressed in a precise, machine-interpretable form, facilitating processing, sharing, and reuse by software agents. The Semantic Web enables interoperability among web-based applications at both syntactic and semantic levels (Hendler, 2001).
Key components of Semantic Web technology are (Preece and Decker, 2002):

- A unifying data model, with RDF (Resource Description Framework) being the most frequently used.
- Ontologies for standardized terminology to represent domain theories.
- Languages based on RDF, such as DAML+OIL, for developing ontologies and marking up web resources.

Ontologies and semantic markup are the core of the network of knowledge on the Semantic Web, because marked up Web pages point to ontologies and ontologies point to each other, Figure 1.

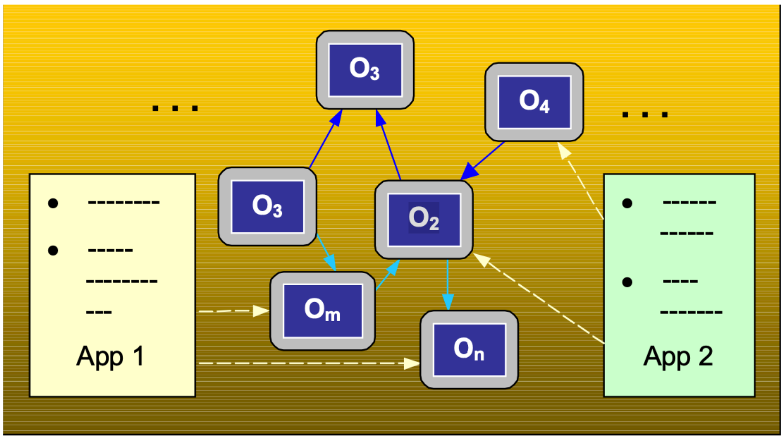

Figure 1. Semantic markup provides mappings between Web pages and ontologies (Oi - ontologies)

Languages

There are a lot of languages for developing ontologies and semantically annotating Web pages:

- One way or another, most of them are based on XML (eXtensible Markup Language), XML Schemas, RDF (Resource Description Framework), and RDF Schemas.
- Another important branch of languages is that for supporting WI-infrastructure issues, such as WSDL (Web Services Description Language) and WSFL (Web Services Flow Language)
- Recent developments include the Web Ontology Language (OWL), developed by W3C for representing ontologies on the web in an XML-based syntax.

WI-related Work in AIED

The AIED community is actively exploring issues relevant to Web Intelligence (WI) in the context of teaching and learning theories and systems. Autonomous software entities designed to support human learning through interaction with students, teachers, and other agents, are a focus of research and development.

Web-based intelligent tutoring systems (ITS) have a long tradition in AIED. They showcase how intelligent techniques can be deployed to address key learning and teaching processes on the web, including personalization, adaptivity, and collaboration.

First-wave Web-based ITS like ELM-ART (Brusilovsky et al., 1996) and PAT Online (Ritter, 1997), were followed by others learning environments that used Web technology as means of delivering instruction. More recent Web-based ITS address other important issues, such as integration with standalone, external, domain-service Web systems (Melis et al., 2001).

A growing branch of AIED research focuses on teaching and learning ontologies and ontology-aware authoring tools, emphasizing the development of reusable web content, services, and applications.

Educational gateways and portals, exemplified by GEM (the Gateway to Educational Materials), serve as important components in justifying WI-related issues. GEM, initiated by the U.S. Department of Education, acts as a teacher-oriented educational portal, providing access educational resources related to various fields of study. GEM, however, does not use ontologies but use metadata.

Setting for WI-AIED systems

Figure 2 depicts a web-based educational environment supported by Web Intelligence (WI), covering teaching, learning, collaboration, and assessment. Educational material is distributed among servers, with agents facilitating knowledge flow between clients and servers. To enhance personalization, intelligent educational servers act as tutors during learning sessions.

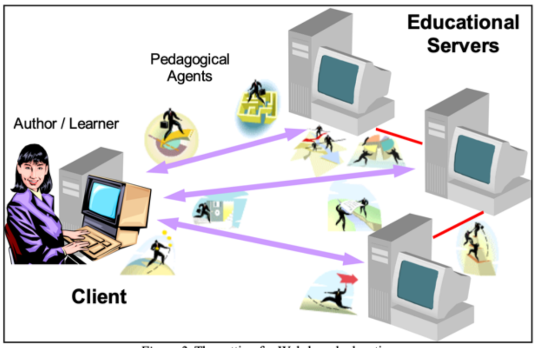

Figure 2. The setting for Web-based education

Mapping Figure 1 onto the setting in Figure 2 is straightforward. In the context of Web-based educational applications and services on the Semantic Web, these can exist on various educational servers. The key lies in their easy interconnection and semantic integration facilitated by a network of ontologies.

WI and Personalization of Learning

Adaptivity is crucial in Web Intelligence (WI), particularly in Web-based systems, as emphasized by Liu et al. (2003). In the context of Figure 2, the adaptivity of educational servers is centered around personalization, such as tracking learners' recent visits. Intelligent educational servers actively assist and interact with learners, and, as they are interconnected, a server can personalize a session by fetching needed material from other servers based on the learner's observed behavior.

Notably, Trausan-Matu et al. proposed an ontology-based approach to enhance network- and interface-level WI within the EU INCO Copernicus project in computer-aided language learning (Trausan-Matu et al., 2002). Since the Web information change constantly, new information can be integrated with the old ones in the domain ontology and combine with the student model to personalize learning sessions.

Ontological Engineering

Developing and deploying ontologies to support Web-based educational applications is an engineering discipline. Ontological engineering comprises the conceptualization, design, implementation and deployment of ontologies.

The ontological engineering of AIED (Artificial Intelligence in Education) systems has been influenced by a strong theoretical foundation provided by Mizoguchi and Bourdeau in 2000. Additionally, the Mizoguchi Lab at Osaka University, Japan, has contributed significantly to this field not only by advancing AIED systems but also by spurring the development of ontological engineering in other Web-based AIED applications.

Intelligent Web Services

Web services, in a broad sense, are activities that can be directly invoked by end users and software agents (Preece and Decker, 2002). In the traditional web model, users manually follow hypertext links while in the Web services model, as illustrated in Figure 2, users invoke tasks that enable various useful activities. From a technical standpoint, Web services are independent, which facilitates the development of highly distributed interoperable applications.

In WI-enhanced Web-based Intelligent Tutoring Systems (ITS), the aim is to utilize intelligent Web services. With Web Intelligence (WI), learners, teachers, and authors can find a collection of educational resources through the web with a clearly defined interface for invoking services (Vinoski, 2002).

The Figure 3 show an example of a service-oriented architecture of Web-based ITS:

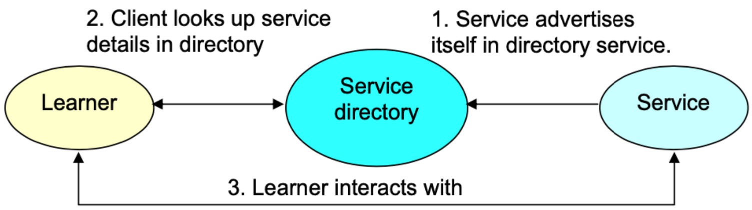

Figure 3. Service-oriented architecture of educational Web servers

Leveraging service-oriented architecture, as depicted in Figure 3, in the development of Web-based Intelligent Tutoring Systems (ITS) can significantly enhance the traditional ITS development process. Each Web service is described through a service description language like WSDL and invoked through the communication protocol defined in its interface. The central component in Figure 3 is the service directory within the educational Web server that lists ready-to-be-invoked services and agents can discover available services by consulting them.

Intelligent Educational Servers and Portals

The proposed architecture for Intelligent Educational Servers (INES) is outlined in Figure 4, accompanied by a description of associated services in Table 1. INES facilitates service-oriented access to educational content in specific domains for teachers, learners, and authors. INES also allows intelligent educational services to delegate roles to other services through agents and ontologies.

In a hypothetical scenario, a learner seeks to deepen knowledge of Greek mythology using an agent. The learner's agent contacts educational servers, queries learning services to identify the ontology of Greek mythology, and returns it to the learner. The learner refines the search to the concept of gods, and the agent invokes learning and reference services from the INES server to generate a multimedia HTML page with marked-up ontological information. Upon selecting Titans, the agent interacts with INES services to acquire, integrate, and arrange learning material, build the learner's model, and initiate a suitable tutor for the learning session. The agent monitors the session, assists the learner intelligently, and handles changes in the learner's focus and checks the availability of INES services.

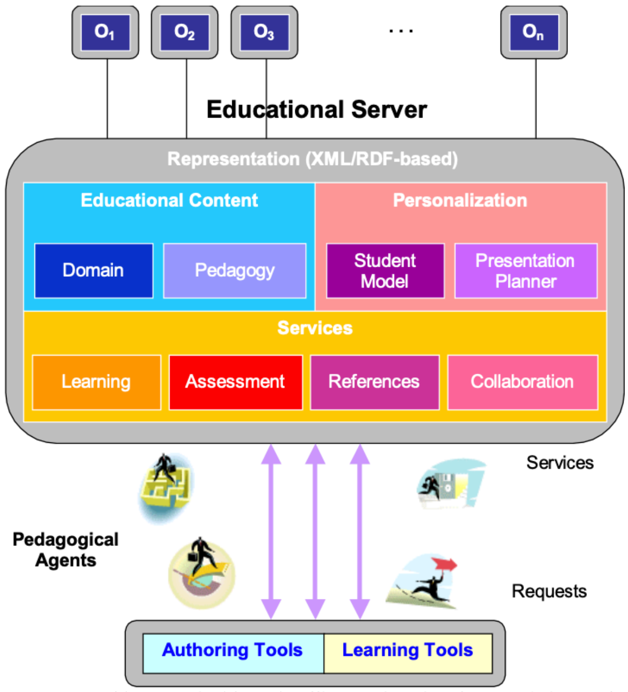

Figure 4. INES architecture: inside an intelligent educational server (Oi - ontologies)

Table 1. 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

To ensure that all services are influenced by pedagogy, pedagogical agents can be integrated within the architectural block of the educational server. Serving as an intermediate interface between requests and services, they can collaborate with external ones to provide comprehensive pedagogical support across all services.

Web Mining and Social Networks

Web mining is the process of discovering potentially useful and previously unknown information and knowledge from Web data (Cooley et al., 1997). This process involves tasks like automatic resource discovery (Chakrabarti et al., 1999). Figure 5 outlines the key categories of web mining.

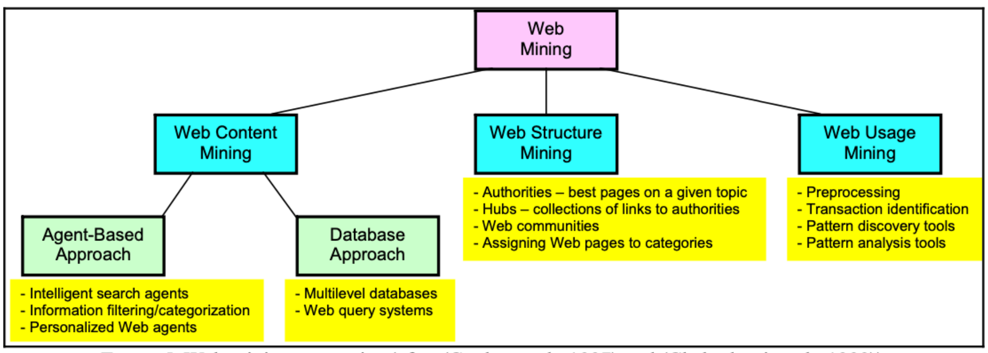

Figure 5. Web mining categories (after (Cooley et al., 1997) and (Chakrabarti et al., 1999))

All categories of Web mining are relevant to AIED. Personalized, ontology-enabled pedagogical agents can continuously perform web content mining and knowledge from large web data repositories. This information is organized into educational web servers, combining with locally operational knowledge to offer a centralized and adaptable set of intelligent web services for a dedicated community of learners. A pioneering effort in this direction, though not directly related to web services, is discussed in Trausan-Matu et al. (2002). For instance, in the context of learning about Greek mythology, if an agent discovers new content related to Zeus, it filters this information using the ontology of Greek mythology. The relevant data is inserted into a local database, and the server may run data mining to discover patterns among its contents, adapting the learning material sequencing based on the dynamic changes in available web resources. The new content then can be matched against the ontology and use to improve it through machine learning.

Further possibilities arise from implementing Web structure mining on the INES server side as a background process. The server can continually crawl the web to update its database with available external educational services. It can also reorganize its local hub of links to the most authoritative external pages and services. INES server reference services can dynamically use such hubs to help learners automatically discover their peers. This may create and maintain Web communities of human learners.

Web usage mining is a particularly attractive category for Web-based education, focusing on discovering typical patterns of user interactions with web pages and services. An INES server employing multiple pedagogical strategies can utilize web usage mining to identify patterns in learners' activities and issues faced during sessions. This can allow potential correlations with the employed teaching strategies.

In the context of Web-based AIED, the concept of social networks is crucial. These networks form a self-organizing structure involving users (learners), information, and expert communities (authors, teachers, educational institutions) (Raghavan, 2002). These networks serve as a strong foundation for integrating next-generation educational portals, ontologies, search agents, and functions like web mining and knowledge management.

Conclusion

The field of Web Intelligence (WI) provides a framework that encompasses various AIED (Artificial Intelligence in Education) efforts and offers insights into both established and emerging research and development challenges in AIED (Devedžić, 2003). While there is a trade-off between the benefits of integrating ideas from different fields into one's research, the intersection of Web Intelligence with AIED introduces numerous open issues and research challenges. These include areas like intelligent web services, social networks, and web mining. Overall, WI presents a highly stimulating context for AIED research. It also enables social-level WI for AIED systems, since it encompasses issues central to social network intelligence.

Key advantages of applying Web Intelligence (WI) techniques to AIED are enhanced adaptivity and improved learner comfort. WI facilitates course sequencing and material presentation based not only on the learner model but also on the most relevant content available on the web. Finally, ontology automatize a number of activities related to Web-based learning environments.

Certain issues discussed in the paper are expected to change in the near future. The rapid evolution of enabling web technologies is likely to address these challenges. The transition from XML and XML Schema to more abstract representational languages like OWL occurred in just a few years, indicating the potential for advancements in educational technologies.