Journal of the Korea Society of Mathematical Education Series D:
Research in Mathematical Education
Vol. 4, No. 1, May 2000, 45-55

韓國數學敎育學會誌 시리즈 D:
<數學敎育硏究>
제 4 권 제 1 호 2000. 5, 45-55

An Architecture for Mobile Instruction: Application to Mathematics Education through the Web[1]

Kim, Steven H.
Korea Advanced Institute of Science and Technology, Seoul, Korea;
E-mail: k@kgsm.kaist.ac.kr

Kwon, Oh Nam
Dept. of Mathematics Education, Ewha Womans University, 11-1 Daehyun-dong, Seodaemun-Gu, Seoul 120-750, Korea; E-mail: onkwon@mm.ewha.ac.kr

Kim, Eun Jung
Graduate School of Information Science, Ewha Womans University, 11-1 Daehyun-dong, Seodaemun-Gu, Seoul 120-750, Korea

(Received May 9, 2000)

The rapid proliferation of wireless networks provides a ubiquitous channel for delivering instructional materials at the convenience of the user. By delivering content through portable devices linked to the Internet, the full spectrum of multimedia capabilities is available for engaging the user's interest. This capability encompasses not only text but images, video, speech generation and voice recognition. Moreover, the incorporation of machine learning capabilities at the source provides the ability to tailor the material to the general level of expertise of the user as well as the immediate needs of the moment: for instance, a request for information regarding a particular city might be covered by a leisurely presentation if solicited from the home, but more tersely if the user happens to be driving a car. This paper presents system architecture to support mobile instruction in conjunction with knowledge-based tutoring capabilities. For concreteress, the general concepts are examined in the context of a system for mathematics education on the Web.
Key words: Mobile instruction, Internet education, Web-based ITS/CAI, Multimedia, Data Mining.

I. INTRODUCTION

The potential of communication networks to revolutionize education has been widely

[1] This work was partially supported by 1998 Ewha Womans University Research Fund and Texas Instruments Research Grant.

acclaimed. Unfortunately, much like the earlier technologies of television and movies, the envisioned promise of computer networks has remained largely unfulfilled (Solis, 1997).

In recent years, the rapid development of the Internet and multimedia capabilities have led to innovations in the fields of science, education, business, and other fields. One of the most promising applications of the infobahn lies in education. A widely recognized strength of the Internet is its vast arsenal of data and documents (Pea & Gomez, 1992).

The World Wide Web provides a colorful window into cyberspace through text, images, audio, and video. However, these formats have been poorly utilized in Web sites to date. Although the user can switch from one Web page to another through hypertext links, he or she remains largely a spectator. The experience is not much different from channel surfing on the television set.

The swift ascent of wireless networks provides a means for delivering instructional materials at the convenience of the user. By delivering content through portable devices linked to the Internet, the full spectrum of multimedia capabilities is available for engaging the user's interest.

In addition, the incorporation of machine learning capabilities at the source provides the ability to tailor the material to the general level of expertise of the user as well as the immediate needs of the moment: for instance, a request for information regarding a particular city might be covered by a leisurely presentation if solicited from the home, but more tersely if the user happens to be driving a car in heavy traffic.

This paper explores a number of background issues, presents a general architecture for intelligent mobile education, and introduces a novel Web site for mathematics instruction. Subsequently, the concluding section presents some final remarks and directions for the future.

II. BACKGROUND

All over the globe, increasing volumes of information are being created, captured, or converted into digital form. For instance, documents are first drafted on personal computers while sales data is captured through laser scanners at check-out counters, and works of art are transformed into electronic images. Further, the rapid interconnection of previously isolated computers has led to the accessibility of both public and private information through electronic networks.

To an increasing extent computer networks permeate everyday life at school, home, and office. For this reason, the information highway is an obvious tool for delivering educational programs.

The Internet allows for the fusion of multimedia files ranging from text to video. In addition, the technology offers a novel capability through its ability to present simulated

3-dimensional environments.

The ubiquitous format for presenting online information is the HyperText Markup Language (HTML), which specifies how information should be presented in a 2-D format on a computer screen. A complementary standard lies in the Java programming language. Java is a general-purpose language which can be used to depict objects within an HTML document or control other objects on a network. For instance, an applet is a small program written in Java which might be used for, say, providing an animation of a dog running across a 2-D scene whose overall structure is specified in HTML. In an analogous way, Java can be used to process information or specify complex relationships among objects in a 3-D world.

The technologies of HTML and Java provide a versatile vehicle for presenting information to students in multiple media formats. HTML can be used to lay out the 2-D presentation on the screen, while Java is used to control behaviors within and between the following interfaces: the 2-D screen, a simulated internal world, and complex interactions with the user.

The accelerating pace of online content highlights the need for intelligent agents to assist in presentation and instruction. Ideally, a software agent should possess greater functionality than merely fetch data or broadcast simple information. More specifically, an intelligent agent should be able to perform routine tasks autonomously, glean new knowledge from disparate databases, and improve its own performance through experience. This section examines a number of critical issues behind the development of such an agent, formulates a general architecture, and presents the key modules for implementation.

The objective of knowledge discovery and data mining is to support decision making through the effective use of information. The practical aspect of knowledge mining lies in the development of learning software to discover patterns, trends, or relations in databases (Fayyad et al., 1996).

Agents on networks.

One way to classify agents is in terms of mobility. A sedentary agent resides permanently on a particular machine and handles local tasks such as serving as a user-friendly interface to a complex application package (Lieberman, 1999). On the other hand, a mobile agent travels across a network to pursue high-bandwidth tasks such as protracted negotiations (Coen, 1996).

An intelligent agent is a flexible program characterized by adaptability and autonomy (Franklin et al. 1996). The more a user comes to depend on a particular agent, the greater is the need for adaptation to his habits and needs (1995).

In a network system, security is a paramount concern for both agents and servers

(Chess et al. 1995). Agents must be protected against accidental damage or deliberate attempts to extract private information. In a similar way, servers must be made secure against deliberate intrusions or accidental calamities caused by welcoming unknown visitors through the network.

To work in a distributed environment, an agent must be able to accommodate a diverse set of knowledge representation formats and database structures. Such an agent has to recognize common standards such as Knowledge Query and Manipulation Language (Finin et al., 1992; Mckay et al., 1996).

The preceding issues represent a number of key considerations in the design and implementation of agents on electronic networks. The general architecture presented in the next section reflects the preceding concerns as well as other important issues in intelligent system design (Kim, 1990).

III. PRIOR WORK

After reviewing a large number of Web sites for mathematics instruction, a handful of superior examples was selected for further scrutiny. Subsequently, a variety of programs or software packages for mathematics education was examined.

Many of the Web sites and programs displayed innovative features. However, each had its limitations and offered potential for improvement.

Our objective during the research has been to create a Web site which would emulate the best features of extant examples while minimizing their drawbacks. Even more importantly, the goal is to embody the full promise of multimedia capabilities for online mathematics education.

In this task, our main considerations lay in the promise of a particular technology to implement interesting features and creative content. On the other hand, a technology which is too new to be stable can be cumbersome to deploy for both the developer and end user. In that case it would be better to wait for the maturation of the technology before incorporating it into a Web site for all levels of visitors – both novice and experienced users.

In our work, we have attempted to strike a balance between innovation and maturity in various technologies. The Web site described below represents our initial step in this direction.

IV. ARCHITECTURE

An intelligent agent must be able to work in a distributed environment characterized by diverse hardware platforms, database structures, and application packages. To this end, an adaptive agent must function purposively in a heterogeneous network and interact effectively with other agents.

Figure 1 shows the activation cycle for an interactive agent. The agent first procures data, processes it, and implements the outcome of the decision, as exemplified by dispatching a purchase order.

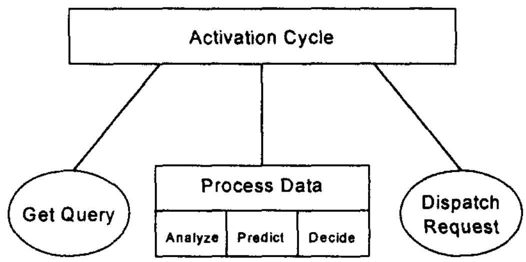

Figure 1. Schematic of a processing cycle for an interactive agent.

The agents are collectively identified as the Edbot family and the discussion is tailored to the domain of mathematics for illustrative purposes. However, the same architecture and agent personalities may be cloned for other domains such as scientific education, marketing information systems, and so on. Figures 2 through 6 depict respectively the primary functions of the Zeus, Athena, Odysseus, Hermes, and Helen agents in the Edbot clan.

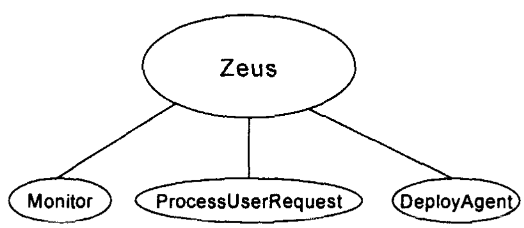

Figure 2. Application server agent: Zeus.

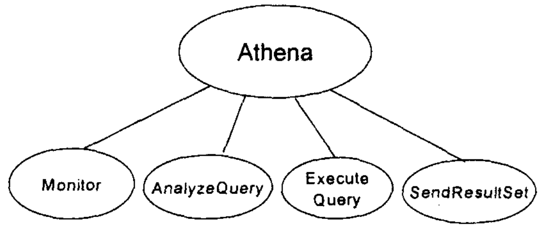

Figure 3. Database server agent: Athena.

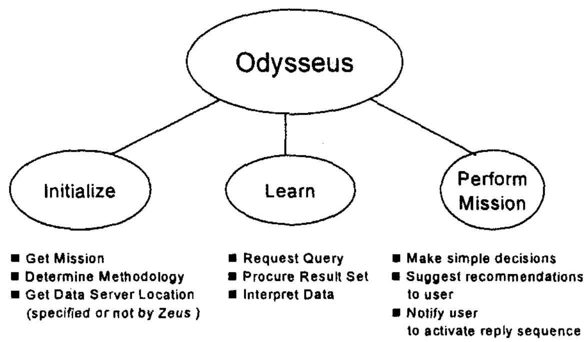

Figure 4. Ad hoc mission agent: Odysseus.

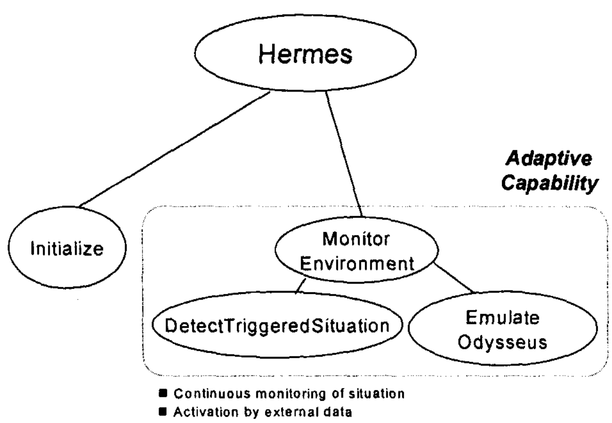

Figure 5. Residential (permanent task oriented) agent: Hermes

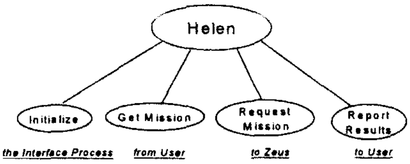

Figure 6. Client environment agent: Helen.

To fully realize the promise of software agents, the entities must be able to procure new knowledge and improve their performance over time. For this purpose, an agent should employ adaptive techniques such as case based reasoning and neural networks. The adaptive functionality is described further below.

The past few decades have witnessed increasing interest in the development of software for knowledge mining. The tools have been applied widely to practical domains especially since the late 1980s.

Learning Methods.

A neural network (NN) offers many advantages such as robustness and graceful degradation (Hopfield, 1982). Perhaps the perception structure employing the back propagation (BPN) algorithm is more popular than all other neural techniques combined. However, most neural nets suffer form a number of limitations such as the need for long learning times. Another drawback lies in the implicit nature of the acquired knowledge, which cannot be explicitly communicated to a human.

Another useful technique is found in case based reasoning (CBR). A key advantage of case based reasoning lies in the ability to work with data in their original format. Often the methodology is effective even when applied to an incomplete or partially faulty database. One drawback, however, lies in the tendency of conventional CBR tools to identify similarities based on superficial rather than substantive features of two cases. Another limitation is found in the ability to perform well – such as in predicting stock markets – without yielding an explicit explanation of the underlying causative factors. However, this is a limitation applicable to the entire gamut of learning tools.

The overall architecture for a mobile Web-based education system is depicted in Figure 7. The architecture embodies various aspects of the Web-based system for education and instruction. The approach incorporates software technologies such as the Wireless Application Protocol (WAP) for messaging with mobile devices such as cellular phones; Extended Markup Language (XML) for intelligent document processing; and Jini for automatic recognition and communication among hardware devices.

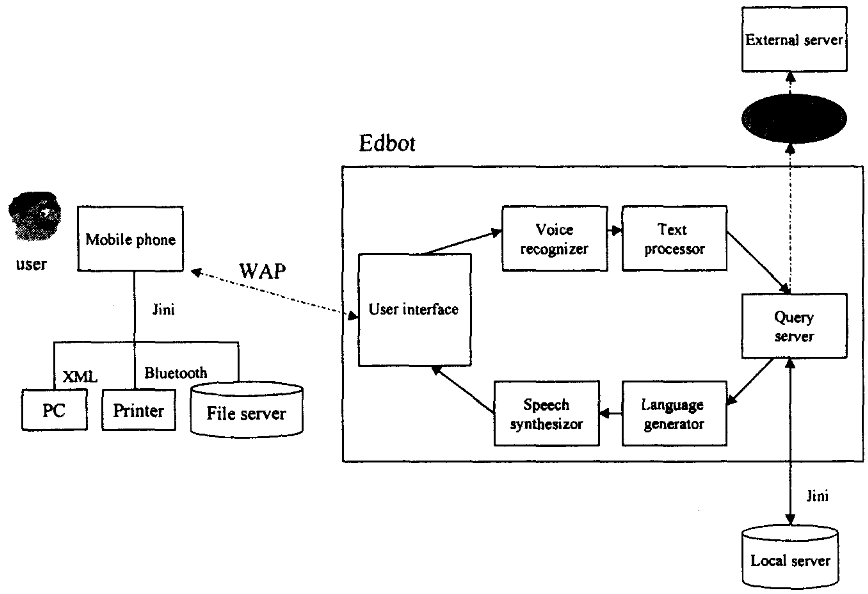

Figure 7. Overall architecture for a Mobile Web-based Education (MWE) system.

The user should be able to interact with the system in natural language, including speech. Examples of pertinent queries from the user are as follows.

"What is a quadratic function?"
"Show me a parabolic dish in 3-D format."
"Why is translation of an object a commutative operation, but rotation is not?"
"Explain Kepler's Law on sweeping equal areas of an ellipse in equal time."

The responses to such questions must be handled intelligently, depending on the expertise of the user as well as the needs of the moment. The period ahead will witness a variety of interesting developments in Web-based education. A sampling of these directions for the future is highlighted in Table 1. Our goal is to incorporate these capabilities into a Web site over the years ahead.

V. CASE STUDY

Our ideas on an interactive forum for mathematics education is found at the WebMath site, located at: www.webmath.org.

Table 1.
Emerging directions for Web-based education.

Capability	Strengths	Limitations	Suggestions
Multiple users in interaction.	Learning from other users. Socializing and informal community support.	Limited graphics and bandwidth make interactions cumbersome & slow.	Problems will vanish with next- generation wireless channels.
Representation of users by avatars.	"Personalization" of cyberspace. An avatar can take over simple behaviors when owner is offline.	Easy to hide behind a mask & engage in disruptive behavior.	Require greater authentication.
Engagement through edutainment, including games.	Learning is more compelling & memorable.	Not all instruction is amenable to a gaming format.	Develop new forms of edutainment.
Data mining & artificial life.	Smart tutors to guide students. Evolutionary software to challenge users.	Difficult to produce versatile intelligence.	Adapt additional concepts from neurology, biology, psychology, etc.
Web access on mobile phones.	Education anytime, anywhere.	Small screens.	Extensible and/or flexible screen.

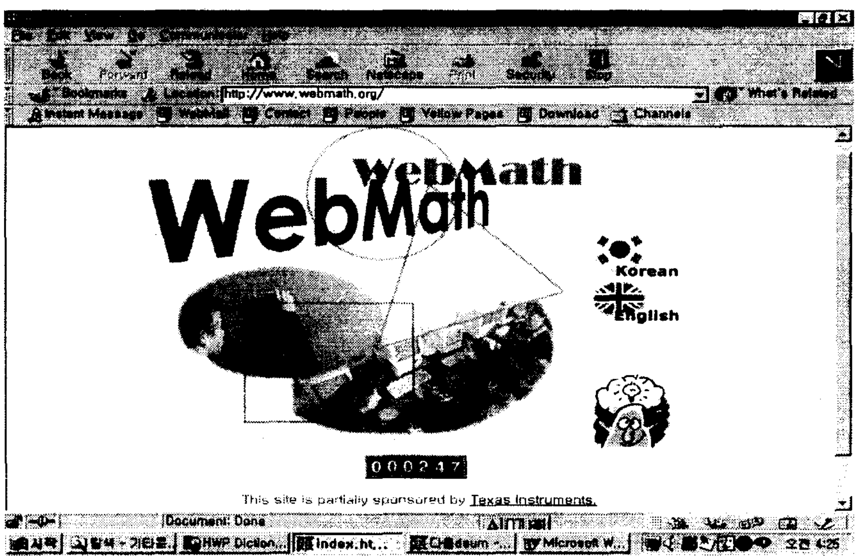

Figure 8. Homepage of the WebMath site

The homepage of the site is displayed in Figure 8. As apparent from the figure, the

Web site offers content in both Korean and English. Certain materials are available in both languages, while the majority of the content is in one or the other language.

An example of a program available at the site lies in the Probability Concepts module, an interactive animated piece to teach the basics of probability theory and its applications. Another example is the Fractal Patterns program, designed to teach the geometry of chaotic processes; to enhance user interest, the material is presented in the form of a solitary game.

The Website will form the nucleus of the mobile system for mathematics instruction. Over the years ahead, the site will be enhanced by incorporating the types of capabilities identified in Table 1 and Figure 7.

VI. CONCLUSION

The Internet provides an integrated environment for accessing the wealth of information being digitized all over the globe. Not only is access possible, but multimedia offers a multisensory vehicle for presenting information in a compelling way. The active role of the user in navigating a virtual space and the instant response of the system provide an immersive experience.

The rapid growth of wireless communication and the explosion of knowledge highlight the need for mobile instruction and intelligent tutoring based on intelligent agents. A general architecture to support these functions has been presented, and the associated society of agents defined.

A key direction for the future lies in autonomous learning capabilities. The maturation of machine learning capabilities offers a means of developing intelligent tutoring systems which can tailor a presentation not only to the basic level of expertise for a particular student, but also to his or her changing level of knowledge. The learning capabilities may be implemented using techniques such as case based reasoning, neural networks, and induction.

Such intelligence may be implemented as a kernel of a smart system for multimedia presentations. A framework for such intelligent systems has already been developed (Bordegoni et al., 1997). The framework for intelligent presentations has been adapted to software agents and their embodiment as icons (Andre, 1997). The framework may also be tailored readily to the educational environment.

REFERENCES

André, E. (1997). WIP and PPP: A Comparison of two Multimedia Presentation Systems in Terms of the Standard Reference Model. *Computer Standards and Interfaces* **18(6-7)**, 555-564.

Bordegoni, M.; Faconti, G.; Maybury, M. T.; Rist, T.; Ruggieri, S.; Trahanias, P. & Wilson, M. A (1997). *Standard Reference Model for Intelligent Multimedia Presentation Systems.* http://www.dfki.de/imedia/lidos/papers/cis97.

Chess, D.; Grosof, B.; Harrison, C.; Levine, D.; Parris, C. and Tsudik, G. (1995). *Itinerant Agent for Mobile Computing*. IBM. http://www.cs.umbc.edu/ kqml/ papers/itinerent.ps.

Coen, H. M. (1996). *SodaBot: A Software Agent Construction System.* Boston, MA: MIT AI Lab. http://www.cs. umbc.edu/agents/papers/sodabit.ps.

Fayyad, U. M.; Shapiro, P. G.; Smyth, P. and Uthurusamy, R. (1996). *Advances in Knowledge Discovery and Data Mining*. AAAI Press; Boston, MA: The MIT Press.

Finin, T.; Fritzson, R. and McKay, D. (1992). *A Language and Protocol to Support Intelligent Agent Interoperability.* http://www.cs. umbc.edu/kqml/papers/cecals.ps.

Franklin, S. and Graesser, A. (1996). *Is it an Agent, or just a Program? A Taxonomy for Autonomous Agents.* Univ. of Memphis. ftp://ftp.msci.memphis.edu/comp/caat/agentprog.ps.z.

Hopfield, J. J. (1982). Neural Networks and Physical Systems with Emergent Collective Computational Abilities. *Proc. Nat. Acad. Sciences USA* **79(8)**, 2554-2558.

Kim, S. H. (1990). *Designing Intelligence*. New York: Oxford Univ. Press.

Lieberman, H. (1999). *Integrating User Interface Agents with Conventional Applications*. Boston, MA: MIT. http://lieber.www.media.mit.edu/people/lieber/Lieberary/Integrating-UI-Agents/ Intergrating -UI-Agents.html.

McKay, P. D.; Pastor, J.; McEntire, R.; Fininsheth, T. and D.B. (1994). *An Architecture for Information Agents*. UMBC. http://www.cs.umbc. edu/kqml/papers/arpi.ps.

Pea, R. D. & Gomez, L. M. (1992). *Distributed Multimedia Learning Environments: Why and How?* Evanston, IL: Institute for the Learning Sciences, Northwestern U.

Sheth, D. B. (1994). *A Learning Approach to Personalized Information Filtering.* Boston, MA: MIT. ftp://media.mit.edu/pub/agents/interface-gents/news-filter.ps.

Solis, C.R. (1997). Virtual Worlds as Constructivist Learning Tools in a Middle School Education Environment. In Khan, B. H. (Ed.), *Web-Based Instruction.* (pp. 393-398). Englewood Cliffs, NJ: Educational Technology Publications.