The 2004 IEEE/WIC/ACM International Joint Conference on Web Intelligence (WI’04) and Intelligent Agent Technology (IAT'04)

Proceedings of the First International Workshop on Advanced Technologies for E-Learning and E-Science (ATELS’04)

King Wing Hot Spring Hotel, Beijing, China 20 September, 2004

Edited by

Hongxue Wang, Larbi Esmahi, Jing Long Wu
Athabasca University, Canada

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Preface

With the wide spread of the World Wide Web, e-learning and e-science have become hot and even fascinating topics for both researchers and practitioners, and Web-based systems for e-learning and e-science have found their ways to both educational and research organizations.

In general, e-learning refers to the development and delivery of teaching and learning activities by electronic means. E-learning covers a wide set of applications and processes such as web-based learning, computer-based learning, virtual classrooms, and even delivery of content via satellite, CD-ROM, audio and videotape. In the last few years, e-learning tend to be limited to a network-enabled transfer of skills and knowledge.

On the other hand, e-science refers to the large scale science carried out through distributed global collaborations enabled by the Internet. Services provided to scientists and researchers by e-science range from simple online lab for college students to complex systems for e-health or Military and defence grids.

The purpose of this workshop is to bring together researchers and experts in these two closely areas to share their findings and experiences, and to discuss and identify research areas of e-learning and e-science where advanced technologies such as Web agents, AI theories, Web services, distributed systems, mobile computing and Web technologies can be used.

The papers in the proceedings cover a range of topics that we have grouped under four main sections:
- Agent based E-learning systems
- Adaptive E-learning/E-Science
- Learning objects and collaborative learning
- Cognitive perception mechanisms

The organizers and the chairs of the program committee would like to thank all the authors for their contribution, and to thank all the PC members for their time and efforts in reviewing the papers.

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Dr. Larbi Esmahi
Dr. Jinglong Wu

September 20, 2004
Beijing, CHINA
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Session 1: Agent based e-learning systems

Chaired by: Dr. Hongxue Wang
A Web-Based Interactive Teaching-Learning System for E-Learning

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Abstract

To learn effectively a professional course, the teaching and learning interaction in classroom is still a necessary element in most universities. To overcome the problem of short time space in classroom, the WWW technology may be embedded in an interactive teaching-learning (ITL) system to improve and evaluate the teaching-learning effectiveness in classroom environment. In this paper, we present a practical ITL system, which has being experimented and supported for some professional courses in Electrical Engineering during past five years in Yuan Ze University. The capabilities of the proposed ITL system include: complete course materials, examinations and history preservation, real-time teaching progress and in-class audio/video materials, real-time individual and whole evaluations, convenient re-learning and feedback, easy maintenance and response, and a good trade-off among classroom, distance, and asynchronous learning. Our research concludes that a good ITL system can link closely teacher and students to participate and cooperate fully a course from both time and space viewpoints to increase learning effectiveness and evaluate whole teaching-learning performance.

1. Introduction

Many distance and asynchronous learning systems have been widely discussed due to the popularity of World Wide Web systems [1]. Intuitively, they can provide a possibly unlimited time and space merit for teacher’s teaching and student’s learning, even though students may express dissatisfaction with the communication tools due to a huge growth in the web-based education and training market [2]. However, despite the continued growth and popularity, distance education suffers from a number of problems such as a much higher course ‘dropout’ rate in online courses compared to traditional campus-based education. King [3] listed a number of negative factors that contribute to course noncompletion in web-based distance education: feelings of isolation, frustrations with the technology, anxiety, and confusion. He also suggested a tool to mitigate these negative factors, such as the use of electronic office hours.

Another question on distance education is ‘whether or not students are still engaged and actually learning when not actively involved in online discourse with other students and faculty’ [4]. This may include about how much learning actually occurs, how it does or why it does not, and what factors most influence learning outcomes in online formats. Even though there are many arguments on distance learning, one conclusion made by Beaudoin [4] is that essentially the same ‘witness learning’ phenomenon occurs in both formats: classroom and online. Accordingly, since the teaching and learning interaction in classroom-based education is still a necessary element in most universities to learn effectively a professional course in Engineering, in this paper an interactive teaching-learning (ITL) system based on web technology is presented for overcoming the problem of short time space in classroom and for improving the teaching-learning effectiveness in classroom environment.

Liber, Olivier, and Britain [5] presented a TOOMOL (Toolkit for the Management of Learning) system, which can be used in both local and distance learning contexts, and is designed to be able to support those engaged in lifelong learning programmers. This system includes two main theories: conversation theory and organizational cybernetics. The former is concerned with the interactions that take place between participants in the learning and teaching process, whereas the latter with the organizational constraints under which learning and teaching takes place. These theories support us for developing our ITL system. In addition, as pointed by Tuckman [6], web-based instruction should not become more mainstream in campus courses, not merely as an occasional alternative for convenience purposes, but as an integral part of the instructional design. He presented a hybrid instructional model, called ADAPT (Active Discovery And Participation through Technology) system combining the important features of traditional classroom instruction with those of computer-mediated instruction, which can be employed in campus labs. He noted that the important features of traditional classroom instruction include required attendance, a printed textbook, and presence of an instructor; whereas those of computer-based instruction include class time spent doing computer-mediated
activities rather than listening to lectures, a large number of performance activities rather than just two or three exams, and self-pacing with milestones rather than a lockstep pattern. In our ITL system, the principles of ADAPT model are also involved to enhance the performance of classroom instruction, especially for a professional course which is not easily instructed by merely in computer labs or distance learning environments.

The practical ITL system presented in this paper has being experimented and supported for some professional courses in Electrical Engineering during past five years in Yuan Ze University. The capabilities of the proposed ITL system include (1) complete course materials, examinations and history preservation, (2) real-time teaching progress and in-class audio/video materials, (3) real-time individual and whole class evaluations, (4) convenient re-learning and feedback, (5) easy maintenance and response, and (6) a good trade-off among classroom, distance, and asynchronous learning. In the following, the modules and functions of the proposed ITL system will be detailed. The teaching-learning behaviors including teaching quality, learning quality, student’s participation degree, individual and whole student’s quality, are then illustrated and discussed. Our research concludes that a good ITL system can link closely teacher and students to participate and cooperate fully a course from both time and space viewpoints to increase learning effectiveness and evaluate whole teaching-learning performance.

2. ITL system

The main components of classroom-based instruction include: instructor teaching the key contents in a textbook, students paying attention to follow the instructor’s guidance, and examinations for evaluating the learning performance of students. Some issues of the traditional classroom-based instruction are usually faced with:

- **Short time space.** The time space for teaching-learning activities in classroom is usually short (1~3 hours/week), which may lead in many questions to be solved for a student. For example, since students may not always pay attention to the instructor’s teaching, many key contents of the course may be lost in classroom-based instruction.
- **Uncertain learning motivation and responsibility.** Not only the required attendance in class but also the self-learning after class of a student are important. The learning motivation and responsibility for a student may be uncertain if both the factors are not tracked as mentioned in [3, 4].
- **Less real-time instructor’s monitoring.** Except for a good teaching skill for an instructor, a continuously monitoring on the learning performance of students is necessary for improving the performance of classroom-based learning. The effect of teaching-learning for a course may be unfairly evaluated if there is not a continuously monitoring, which is hardly done with a traditional classroom-based learning. This monitoring may include attendance recording, a variety of evaluations, real-time grade statistics for individual student and whole class.

![Figure 1. The Interactive Teaching-Learning (ITL) system.](image)

Based on the mentioned three issues of the traditional classroom-based instruction and the theories used in TOOMOL system [5] as well as features presented in ADAPT system [6], the details of our ITL system can be illustrated in Figure 1 and described as the following three parts.

- **Teaching-learning activities.** The time space of teaching-learning activities has been extended from classroom to the web site, which can be accessed anywhere and anytime as long as a personal computer is connected to an internet. Teacher provides his/her course materials for teaching activities, evaluates
grades for students, and monitors the performance for learning activities.

- **Teacher.** Teacher plays a key role for managing the ITL system. The system is designed to be easily manipulated based on the need of the continuous monitoring on the teaching-learning activities. The related course materials can be accessed. Once an in-class is finished, the in-class audio/video for teaching activities is manually or automatically transformed into the ITL system for network streaming and downloading after class. Once an examination is evaluated, the grades of students are statistically calculated for individual student and whole class population, and will be acknowledged to students automatically via e-mail. Teacher can communicate or discuss with students via the ITL system. The teaching history is also recorded. Because the teaching and learning activities are updated in real-time, teacher can monitor them and make his/her teaching more adaptive and much improvement. In our system, teacher is regarded as a self-organization.

- **Students.** Students play the role for learning a specified knowledge. The learning performance is evaluated by grades, which are examined by a variety of tests given from teacher. In class, students follow the guidance of teacher to learn or skill some key topics from a textbook or a course material. The discussion may also be presented in class but little due to the short time space. Hence the discussion between teacher and students can be moved to the ITL system, which can be presented at anytime and anywhere via the internet. Since the course progress, grades of examinations, and related information including discussion as well as communication are acknowledged to students real-time, students will be pushed to pay attention to this course after class. Therefore the performance of teaching-learning activities of the course assisted by ITL system can be improved. In our system, students are regarded as a self-organization as mentioned in [5].

Based on the main parts described above, our system has the following potential properties.

- The ITL system enhances the interaction between teacher and students.
- Student can understand and learn the most recent course information including highlighted key topics, in-class media, teaching progress, etc, provided from teacher.
- Student can understand his/her recent learning performance from the real-time grading information provided from teacher, and push him/her to pay attention to the course.
- The ITL system can shorten the distance between teacher and students, thus the discussion as well as communication become easy.

- Teacher can easily maintain his/her course material using this system. This convenience is very important for most teachers who teach in class.
- The most important thing is that the proposed ITL system can link teacher and students to participate and cooperate fully a course from both time and space viewpoints to increase learning effectiveness and evaluate whole teaching-learning performance. All the teaching-learning activities can be recorded completely.

**Table 1. Accessible contents of the ITL system.**

<table>
<thead>
<tr>
<th>Access by Any One Without Password</th>
<th>Access by Students With Password</th>
<th>Access by Teacher With Password</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Teaching project</td>
<td>1. Inquire individual grades</td>
<td>1. Edit the related basic courses for a semester</td>
</tr>
<tr>
<td>2. Teacher information</td>
<td>2. Answer the questions given from teacher</td>
<td>2. Edit key topics and their related contents for a course</td>
</tr>
<tr>
<td>3. Teaching assistant information</td>
<td>3. Write a letter or propose a problem to teacher (or teaching assistant)</td>
<td>3. Print a desired form listing students’ names</td>
</tr>
<tr>
<td>4. Key topics and their related contents of the course</td>
<td>4. Read the response from teacher (or teaching assistant)</td>
<td>4. Input grades for an examination</td>
</tr>
<tr>
<td>5. History of teaching progress</td>
<td></td>
<td>5. Calculate and preview the grades for individual and the statistics for whole class</td>
</tr>
<tr>
<td>6. Media for streaming or downloading</td>
<td></td>
<td>6. Import the course’s media for streaming and downloading</td>
</tr>
<tr>
<td>7. Discussion between teacher and students</td>
<td></td>
<td>7. Post the contents taught in class</td>
</tr>
<tr>
<td>8. Accessing status by student</td>
<td></td>
<td>8. Edit questions for examinations</td>
</tr>
<tr>
<td>9. Accumulative statistic grades of whole class</td>
<td></td>
<td>9. Reply an answer for the problem proposed by a student or write a letter to students</td>
</tr>
</tbody>
</table>

The accessible contents of the ITL system are divided into three categories as listed in Table 1. They are ‘access by any one without password’, ‘access by students with password’, and ‘access by teacher with password’.

For the category of access by any one without password, any one can browse the contents displayed in the web site (http://www-zion.eed.yzu.edu.tw/). The information including course project, teacher information, teaching assistant information, and the key topics as well as their related contents can be browsed basically. The media (especially recorded in class) for streaming and downloading may help students to re-learn after class, and thus extend the learning time space. It is also noted here that the accessing status of students is displayed. This can help teacher to track the student’s attention on the course.
The message of discussion between teacher and students hints that communication is presenting. In addition, the accumulative statistics grades of whole class are displayed following history. This may also help teacher to monitor the performance of teaching-learning activities for this/her course.

For the category of access by students with password, this prevents personal information from others access. When a student logins this system using his/her password, his/her access will be recorded. He/She can see his/her learning performance, answer questions, propose problems, and give a communication with teacher (or teaching assistant).

For the category of access by teacher with password, the security of course management is highly prevented by password and IP addresses. The entry of hyperlink for teacher editing will not appear in web site if the used IP address is different from those specified by teacher. In our system, at most four IP addresses can be specified, thus teacher can manage his/her course information in his/her personal computers at office or at home. For a new semester, a teacher can use the ITL system to create the related course’s links and databases, specify the evaluation terms as well as scoring percentages for a course, input teacher and teaching assistant information, import the name list of students selecting this course, and create the related tables based on the name list for database manipulation. In the teacher’s category, teacher can edit in advance the key topics and their related contents for a course, this will help him/her to easily post the contents taught in class. The media recorded in-class or a learn-by-doing media can be easily imported. A desired form listing students’ names for the use of roll call or examination is readily produced. In this category, when the grades for an examination is input, the individual and whole class learning performance from beginning to right now can be statistically calculated. This is an important property of this system for monitoring the effectiveness of teaching-learning activities. The communication between teacher and students can be performed by editing questions for examinations via an internet, writing a letter to students, and replying an answer for the problem proposed by a student.

The implementation of our ITL system is illustrated in Figure 2. The main server includes a web site, a SQL database, an e-mail system, and a FTP site. The media server imports the course’s media, and converts them to a file format such as ‘.asf’, ‘.wma’, or ‘.mp3’, etc, for streaming and downloading. The workstation is used to prepare other materials for the use of teaching-learning activities. This system has being experimented and supported for some professional courses, e.g., logic circuit design, microcomputer system, electronics, in Electrical Engineering during past five years in Yuan Ze University.

The responses of teachers and students are positively encouraged for using this system. The teaching-learning behaviors including teaching quality, learning quality, student’s participation degree, individual and whole student’s quality, can be easily analyzed and visualized using our system. As a result, our ITL system can link closely teacher and students to participate and cooperate fully a course from both time and space viewpoints to increase learning effectiveness and evaluate whole teaching-learning performance.

### Figure 2. Implementation of our ITL system.

#### 3. An illustration

In order to illustrate the behaviors of the ITL system, we present a performance chart to evaluate the teaching and learning quality as shown in Figure 3 and Figure 4. The history of grading an examination is listed at the right of the performance chart. The performance chart includes one ‘yellow-double-bars’ pattern for recording the percentage of teaching (scoring) progress, one ‘white-with-number’ pattern for recording the average learning score of whole class in history. The distributions of different grades are rated with ‘color-bars’ for fast visual evaluation. Here grade A (score ≥ 80) is represented by blue color-bar, grade B (70 ≤ score < 80) is represented by green color-bar, grade C (60 ≤ score < 70) is represented by black color-bar, grade D (50 ≤ score < 60) is represented by magenta color-bar, grade E (score < 50) is represented by red color-bar, respectively. Grade D is used to wake up the students for improving his/her study. Grade E provides a strong message to the students who may fail for this course. All information are normalized to 100%.

In usual, at the beginning of a course, the most of students may be rated to grade A (top of the performance chart). After progressing the course and evaluating with many examinations (and attendance is noted in our system), the distribution of different grades will be formed and toward to the bottom of the performance chart. From the trends of performance chart, the student’s learning quality is easily observed and compared. For example, the learning performance of class (A) is better than that of class (B) in
Figure 3. Accumulative statistic grades of whole class. (a) 69 students, (b) 68 students in different classes of the course ‘Logic Circuit Design’ taught in spring, 2002, in Electrical Engineering Department of Yuan Ze University.

Figure 3 even though the final average score is near. The reason is that the number of students with higher grades in class (A) is greater than that in class (B) and the number of students with lower grades in class (A) is less than that in class (B). The same phenomenon can also be observed in Figure 4. Note here that, the attendance of students is very important in the ITL system since the system is designed to enhance the classroom-based education. Furthermore, the recording history may also be used to compare the student’s learning quality with different datasets (see Figure 3 and Figure 4 for comparison). In the same teaching environment, the student’s learning quality in 2003 is lower than that in 2002. This may provide a useful cue for further exploring and improving the education for the students. Since the performance chart is updated in real-time, the teacher will attend to the learning status of his/her students and adapt properly for his/her teaching activities, whereas the student will pay more attention to his/her learning activities. Accordingly, the continuous improvement of the teaching-learning activities can be achieved using this ITL system.
4. Conclusion

To learn effectively a professional course in Engineering, the teaching and learning interaction in classroom is still a necessary element in most universities. To enhance the performance of classroom-based education, based on the theories used in TOOMOL system [5] as well as the features presented in ADAPT system [6], an interactive teaching-learning (ITL) system has been presented. The main parts, potential properties, accessible contents, and implementation of the ITL system have been described in detail. The system has being experimented and supported for some professional courses in Electrical Engineering Department during past five years in Yuan Ze University. In our realizations, we confirm that the teaching-learning behaviors including teaching quality, learning quality, student’s participation degree, individual and whole student’s quality, can be easily analyzed and investigated using our system. In this paper, we use a performance chart to analyze the teaching and learning quality, and therefore to illustrate the behaviors of the ITL system. From the discussion of the performance chart, the continuous improvement of the teaching-learning activities can be achieved using the proposed ITL system. Our research concludes that a good ITL system can link closely teacher and students to participate and cooperate fully a course from both time and space viewpoints to increase learning effectiveness and evaluate whole teaching-learning performance.

References


Toward an Agent-Based System for Mobile Learning

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ABSTRACT:
Mobile learning requires an enormous heterogeneity in terms of types and capacities of access devices, network bandwidth and the needs or preferences of users. The M-learning system is supposed to deliver the requested services even if the terminal being used (WebTV, PDAs or mobile telephones) cannot access the content due to various limitations (e.g. display, storage capacity, and processing or network access). The service should be adapted according to user’s preferences. To tackle these problems, different solutions were proposed for individual issues. Some applications that try to deal with many of these issues have also been developed, but most of them according to the client/server architecture.

In this paper we describe a multi-agent framework for delivering adaptive M-learning. First, we will discuss the advantages and limitations of used architectures for implementing E-learning systems. Then, we will present a detailed description of the architecture and components of the proposed multi-agent framework.

1. Introduction
Web-based learning systems development has taken two different but complementary directions. On one hand research-based systems: Intelligent Tutoring Systems (ITS) [1] and Adaptive Hypermedia Systems (AHS) [2]. These systems focus on the problem of adapting the instructional process (course content adaptation, course navigation adaptation, problem-solving support, etc). They are always underused and don’t go beyond their research environment. On the other hand industrial-based Learning Management Systems [3] whose primary focus is the management of the learning process (Registration and tracking of students, Content creation and delivery capability, Skill Assessment and development planning and Organizational resource management).

These systems are largely adopted in the education and training market.

In this work we are interested to the first group of systems (ITS and AHS) that deal with the course content delivery process and the learning services. Most of the systems developed in this context are based on a centralized architecture [4, 5, 6, 7] and can’t be deployed in large-scale environment of E-learning.

The basis context for this work is a university e-learning environment (i.e., Athabasca University) where learners are taking courses in an asynchronous mode (grouped or individual). In this context, most learners are working and have a personal need to enhance their careers. As well, these learners often have a long-term learning plan and prefer a flexible and individualized learning environment. A significant percentage of these learners are always mobile and need to have access to their courses from everywhere, anytime and by using different devices. Thus, the developers of this project must consider the following factors:

- Asynchronous E-learning.
- Mobile users.
- Multi-devices environment.
- Adapted courses.
- Personalized interfaces that offer the same look and feel.

2. Discussion and Motivations
2.1. Client/Server architecture
Most e-learning systems are implemented by using client/server architecture. Because of the nature of the application, client/server architecture seems to be the natural fit. In fact, one e-learning system needs to have a kind of centralized server for course management and authoring, while the clients are heavily distributed. The e-learning service or content can be distributed from a
server to more clients through a network through the use of three relevant architectures:

1. Thin client architecture: a centralized managed system with applications executed on a server.
2. Proprietary client architecture: a stand-alone client application developed to support a specific service.
3. Internet client architecture: a web-, wap-, or I-mode-browsers system.

Because of different device capabilities, different learners’ profiles and preferences and different learning strategies, an adaptation of the content and presentation is needed before they can be presented to the user. This adaptation can be done on the server (PHP, ASP, XSP), on a proxy (i.e., AvantGO) or on the client (XML/XSL or XHTML / CSS) [8]. The main weaknesses of these solutions are

- Not all browsers support content-control negotiation, so that the server must make assumptions about the browser’s ability to present the content.
- Heavy server-side applications may slow down the server
- Often the content is made to utilize one browser’s technological facilities application.
- The lack of care given to the content/presentation layer causes problems for different-sized browsers.
- The adaptation cannot be a dynamic adaptation according to the user’s profile.

2.2. Web Services architecture

Web services represent a new architectural paradigm for applications’ development. They have become a significant technology in the evolution of the Web and distributed computing.

Web services operate using open standards, unlike DCOM and CORBA. This means that Web services can, theoretically speaking, enable any two software components residing in any two hardware platforms to communicate – regardless of differences in programming languages or platforms.

The main architecture of Web services is currently based on the triad of functionalities [9]: Publish, Find and Bind.

- **Publish** - The Web Services Description Language (WSDL) describes the services in a machine-readable form, where the names of functions, their required parameters, and their results can be specified.
- **Find** - Universal Description, Discovery, and Integration (UDDI) gives clients — users and businesses — a way to find needed services by specifying a registry or “yellow pages” of services.
- **Bind** – Finally, the simple object access protocol (SOAP) provides the common protocol systems need to communicate with each other so that they can request services, such as to schedule appointments, order parts, and deliver information.

**Advantages:** Web services offer the advantage of incremental implementation, rather than all at once. This lessens the cost of adopting Web services and can reduce organizational disruption resulting from the process of switching to a new technology. But, the most important advantage of Web services over previous distribute-computing technologies is their interoperability based on open standards. The fact that Web services facilitate communications among disparate applications and platforms makes standardization and interoperability crucial aspects for them. The World Wide Web Consortium (W3C) - an organization that defines Web technologies - and other standards bodies are committed to ensuring that Web services protocols and specifications remain open and interoperable across vendor implementations.

**Limitations:** Despite their openness and interoperability, Web services are still based on client server architecture. So, they suffer from the same problems cited here above for client server. Especially, the following problems:

- Scalability problem, which is a crucial factor for e-learning environments,
- Heavy workload and central role of the server,
- Network dependence for getting a personalized service.

2.3. Motivations for agent-based architecture

The main objective of e-learning systems is to enable individually subscribed-to learning services to be delivered to their associated users whenever they request them, and wherever the users are, in a customized form that matches their profile. Thus, intelligent mobile agents have been introduced to provide this kind of dynamic service provisioning and management. The agents’ technology has several advantages for implementing new services on distributed systems. In fact, this technology enables these systems to distribute the functionalities in small, reproducible and distributed software entities. It also allows for a clear and easy separation between their internal, private knowledge, and their interface towards the external world and other agents.

The E-learning services provisioning and management fits well for exploiting the agents’ properties.

**Agents’ autonomy:**

- Allows for making decisions on service access, the interfaces’ configuration, and service provisioning without human assistance.
- Allows for automating the control and management tasks, hence reducing the operator’s workload.
• Allows for automating the service deployment and provision, thus reducing the effort and time required for the installation and the maintenance of services.

Agents’ intelligence:
• Allows for the dynamic customisation and configuration of services. The agents can learn and adapt to the preferences of their users and detect and update old versions of services.
• Allows for the service intelligence to be downloaded dynamically from the providers and for collaboration between different providers.

Agents’ mobility:
• Supports the dynamic topological of service provisioning.
• Enables e-learning services to be provided instantly and customized directly at the locations where a service is needed.
• Enables dynamic provision of customized services by downloading service agents from the service-provider system to the network nodes or user terminals.

Agents’ sociability:
• Offers the potential to distribute service-related processing and also offers a mechanism for the nodes in different networks to co-operate in order to provide a service to the user.
• Allows for negotiation for service features.
• Provides multi-services interaction and co-ordination.
• Allows for the asynchronous and co-operative processing of tasks.

The agents’ technology fits well for E-learning, since it supports the following requirements:

Dynamic scalability:
• Mobile intelligent agents (MIAs) support huge distributed systems such as the Internet. In fact, each service is modelled as a collection of agents, each agent occupying different places at different times since it can move from one place to another.
• MIAs support on-demand provisioning of services. In fact, when servers are implemented with an MIAs, the agents’ mobility allows them to deploy new replicas when the demand arises or to migrate to the location where the demand is high.
• MIAs enable the provision of flexible solutions, in which services are partitioned into mobile service agents achieving multiple functions that can be spread across the network.

Distribution of services:
• MIAs fit well for modelling the ideal situation for a mobile user, for mobile agents can provide the ubiquitous availability of applications, data files, and user profiles by using the concepts of mobility and cloning.
• MIAs enable control tasks to be performed in a distributed manner by using the concept of remote programming [10] instead of the client/server programming concept used currently in most Web-based learning systems.
• The possibility of bringing control or management agents as close as possible to the resources allows for a more decentralised realisation of service control and management software than could be achieved otherwise.

Reduction of traffic:
• MIAs decrease pressure on centralized network-management systems and network bandwidth by using both spatial distribution and temporal distribution.
• MIAs’ autonomous and asynchronous operation reduces the requirements regarding traffic load and the availability of the underlying networks.
• Independence regarding failures:
• MIAs reduce the influence of signalling network faults during service processing, since once a service agent has migrated, the processing will be performed locally.
• The agents’ migration to the required data reduces dependence regarding network availability, so more robustness is achieved in the distributed system.

Finally, agent technology offers a number of very interesting advantages, but it should not be seen as the only solution for all Web-services. Rather, it should be seen as a technology that can resolve some problems. Furthermore, we have to consider some of MIAs’ disadvantages.
• Require a specific run-time environment (agent execution environment) to be present in all nodes to be visited.
• Create a security problem. The platforms have to be protected from malicious agents and vice versa.
• May increase the network load in some situations. One of the mobile agents’ goals is to reduce the network traffic, but it does not seem useful for every agent to migrate in every situation; doing so would probably increase the network traffic. Therefore, new strategies have to be developed to establish under which circumstances an agent will migrate.
• Do not provide location transparency. Each agent must be aware of the location to be visited.

The MIAs technology is relatively new, and its suitability for solving Web-based services problems needs to be demonstrated by implementing more systems using this technology.

3. Multi-Agent framework for M-learning

3.1. System architecture
In this work, we are proposing a multi-agent architecture for implementing an e-learning system that offers course personalization and supports mobile users connecting from different devices. The detailed architecture of the system is articulated around five main components:

1. User profile repository: for each user, the system maintains a profile that has two components, the learner’s model and the user’s preferences regarding learning style, interfaces, and content display.

2. Device profile repository: for each device, the system maintains a profile of, the features and capabilities useful for providing the e-learning service (screen size, bandwidth limit, colors, resolution, etc.). Some features that can be automatically detected by the system (Operating System, Browser, Plug-ins) are not stored in the repository but integrated with the profile when initializing the terminal agent.

3. Learning object repository: contains the course’s teaching material defined as learning objects [11].

4. Course database: for each course, the system maintains two knowledge structures: the course study guide and the course study plan.

5. Multi-agent system composed of stationary and mobile agents.

The following figure presents the main components of the system:

**Profile Manager Agent**: the profile manager is implemented as a stationary agent. It manages the knowledge related to the learners and all defined devices (terminals). The main tasks of the profile manager are:

- Performing user authentication
- Acting as a central register, where each new learner must be registered.
- Managing and assuring the consistency of the databases containing the learner and device profiles.
- Receiving service requests from terminals and giving access to the user profile data.
- Initiating and sending the user agent and terminal agent to the remote device.

![System Architecture](image)

**Figure 1: System Architecture.**
• Checking the version of the user agent and the terminal agent that resides on remote terminals and automatically downloading any necessary updates.

**Course provider Agent:** A stationary agent that manages the knowledge about courses and teaching strategies. The main tasks of the course provider are
• Providing an interface for defining learning objects and course knowledge (study guide and study plan).
• Receiving service requests from terminals and giving access to course data.
• Generating the course study guide and study plan based on the user profile and the teaching strategy.
• Packaging the course teaching material according to the user profile and device profile.
• Initiating and sending the tutor agent and terminal agent to the remote device.

**User Agent:** A mobile agent that carries and manages a local copy of the user profile (user’s preferences and learner’s model) to the remote terminal. The main tasks of the course provider are
• Providing the tutor agent and terminal agent with the user information (profile, identification).
• Managing and synchronizing the user profile duplication with the central server.
• Providing the local personalization of the course material. In collaboration with the terminal agent and the tutor agents, the user agent insures the display of the course material according to the user’s preferences and the terminal’s capabilities.

**Tutor Agent:** A mobile agent that manages the course delivery to the roaming user. The main tasks of the course provider are
• Carrying and managing the course material and study plan.
• Providing a personalized learning service to the learner based on his or her model and learning style.
• Insuring the adaptation and packaging of external course content. Since the system is open to third-party providers, external course material will need to be converted to the required format and adapted to the user and device profiles. In collaboration with the user agent and the terminal agent, the tutor agent insures the necessary adaptation and conversion.
• Synchronizing the course content with the server.

**Terminal Agent:** A mobile agent that maintains the terminal profile of the corresponding device and insures the display of services according to the user’s preferences and terminal’s capabilities.

### 3.2. Knowledge structures for adaptive course delivery

**Course’s study guide:** The course content is organized around a set of concepts. Each concept has teaching material associated with it that comes from either an external source or a learning object. The course study guide defines the relationships among these concepts. The relationships consist of prerequisite, similar and substitute relationships.

**Course’s study plan:** The course material is organized in terms of units and sections, and in each section a set of concepts is learned by using different tasks: readings, labs and tests. The study plan defines the sequencing of the course content and the time constraints and deadlines for the different tasks of the learning process.

**Learner’s model:** A fuzzy overlay model [12] based on the course concepts. It represents static beliefs about the learner and in some cases is able to simulate the learner’s reasoning. Each concept in the model is associated a fuzzy value representing the assessment of the learner’s knowledge regarding this concept.

The system uses two different versions of the learner’s model: a global model and a local model. The global learner’s model is stored within the user profile repository and represents concepts reported to the system about the learner or learned from the learner’s past experience with different courses. As well as representing the concepts and associated fuzzy values, this model represents the relationships among concepts (prerequisite, similar and substitute). The local learner’s model is managed by the user agent within the user’s terminal and is related to a specific course. This model represents only the course concepts and associated values.

The local learner’s model is refined based on the learner’s interaction with the system when reading the course material and doing the assessment exercises. The local model is also used to update the global learner’s model and is initialized from the global model.

**Teaching Strategy:** A set of rules that control the adaptation of the course. The teaching strategy consists of rules for sequencing the course-material components, adding or dropping course-material components and selecting between similar or equivalent course material components.

### 3.3. Adaptation of third-party provider content

Unlike traditional systems, our system will be open to third-party providers. In fact, we aim in the future to implement an infrastructure (e-market place) to provide collaborative e-learning services. Thus, we need to
implement a process that provides user-side device independence for Web content. The main idea behind this process is to construct a basic generic page from the source and then to mark up that document with appropriate tags as determined by the user profile and the device profile.

A Web course’s content always involves different resources (files, database, learning objects… etc). Therefore, the adaptation process consists of creating a Java Servlets or JSP document that connects to data sources and objects and produces an XML document. The main idea here is to use a two-stage process that generates in the first step an XML document (model), and then translate the generated model to a rendering format (HTML, WML, etc.) that will be presented to the user.

The following figure describes the two stages of the services:

The first step in the content module is to create an XML document from the content resources. If we use the logic of Web services, this activity will correspond to the model creation service (Figure 2), which implements an XML generator by using JSP or Java Servlets, which generates an XML document of the Web content. The user profile is used here to personalize the content according to this profile. The second step in the content module is to create a rendering format for the XML document. This activity corresponds to the view transformation service (Figure 2), which implements an XML transformer by using XSLT or DSSSL, which generates a rendering format for the XML document. Since the rendering format depends on the devices’ features and the user’s preferences, the user profile and device profile will be used in this process. The two stages of the services will provide us with more flexibility and device independence than would be possible otherwise:

Figure 2: Adaptation of external course content
• The separation of the service model from the service view will provide us with device independence and facilitate the maintenance of the content-generation process.
• With browsers including a W3C-Compliant XSLT engine, more processing will occur on the client side and reduce the work done by the server.
• The services may be distributed over several machines if needed to balance the overall load.

4. Conclusion
The proposed multi-agent architecture offers the advantage of being more flexible and scalable than other architectures. The course adaptation may be done either in the server or the client, depending on the user’s needs. This architecture offers also a dynamic adaptation either for the course content or the interface since the tutor agent is in permanent communication with the user agent and the terminal agent. Furthermore, for the course content, the system is open to third-party providers.

References
Session 2: Adaptive E-learning and E-science

Chaired by: Dr. Larbi Esmahi
Adaptive User Interfaces Modeling by Means of Rough Classification Methods and Consistency Measures

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Abstract
The adaptive user interfaces are becoming very attractive for many web-based information systems providers. Quite often however they lack mechanisms for their analysis. This paper presents a method for user classification in adaptive systems based on rough classification and knowledge inconsistency analysis. The goal of rough user classification is to select the user profile attributes and their values that group together the users with similar interface settings. Additionally, knowledge inconsistency analysis enables to investigate differences between opinions of users in their user data, usage data and relevance assignments. In this paper we define some measures of quality of that kind of data. Finally some postulates for knowledge inconsistency are presented and analyzed.

1. Introduction

The recommender systems [6] delivering customized information for web-based system users are getting increasing popularity. Such systems concerning user interfaces are usually called adaptive or personalized user interfaces [4]. The general idea of collaborative user interfaces, presented in work [12], is rather simple. First we gather some information about the user in form of the his profile that according to [4] contains user data and usage data. As mentioned earlier, in recommender systems the user profile could be represented by many different forms: binary vectors, feature vectors, trees, decision trees, semantic networks. In our paper we propose to describe the user profile in the following way. Let us assume that we have a finite set \( A^u \) of attributes describing each user and a set \( V^u \) of attribute elementary values, where \( V^u = \bigcup_{a \in A^u} V^u_a \) (\( V^u_a \) is the domain of attribute \( a \)). A user profile is represented by a tuple that is a function \( p: A^u \rightarrow V^u \) where \( (\forall a \in A^u)(p(a) \in V^u_a) \).

In this paper we will consider an alternative approach to the collaborative adaptation presented in work [12]. Instead of user clustering applied in the beginning we propose to apply the rough classification [13] of user profiles based on the clustering of interface profiles. Then with rough classification methods we determine the minimal set of the user profile attributes and their values that lead to the same partition of the set of users as that created by the interface profiles. The main advantage of this approach is the possibility for reduction of the number of attributes that are necessary to generate actual user classification what causes reduction of user’s efforts in filling-in registration forms. In this paper we will also present a solution to the problem of determining the consistency and inconsistency level in adaptive systems.

2. Architecture of Adaptive User Interfaces Using Rough Classification of Users

2.1 User Profile and Interface Profile

User profile should contain all necessary data to model the user in adaptive systems. Usually the user profile contains two types of data: user data and usage data [4]. As mentioned earlier, in recommender systems the user profile could be represented by many different forms: binary vectors, feature vectors, trees, decision trees, semantic networks. In our paper we propose to describe the user profile in the following way. Let us assume that we have a finite set \( A^u \) of attributes describing each user and a set \( V^u \) of attribute elementary values, where \( V^u = \bigcup_{a \in A^u} V^u_a \) (\( V^u_a \) is the domain of attribute \( a \)). A user profile is represented by a tuple that is a function \( p: A^u \rightarrow V^u \) where \( (\forall a \in A^u)(p(a) \in V^u_a) \).

For the adaptive system purposes, however, we should use only a subset of the set of attributes \( B \subseteq A^u \), for example such attributes as user login, user password and
user name is not very useful. Thus as the user profile we will have a tuple \( p' : \mathcal{B} \rightarrow \mathcal{V}_u^a \) where \((\forall b \in \mathcal{B})(p'(b) \in \mathcal{V}_u^a)\).

The interface profile models the actual user interface together with its evaluation. Like in the interface personalization [4] the interface profile contains the following information: the interface layout, the information content and its structure. In order to know whether these settings are appropriate for a particular user the interface profile also contains the usability value associated with this profile [12].

The interface profile should be easily implemented for example in one the following technologies: HTML, CSS, XHTML or XML [15]. Quite many web-based system interfaces are also implemented in Macromedia Flash. In this case we can download appropriate movies according to the interface profile values.

The interface profile formal description reflects its complexity. For many cases a tuple is sufficient for the interface representation. However, for more complex systems also other structures, for example trees [15], may be considered. In the interface profile represented as a tuple, \( A' \) denotes the finite set of attributes describing the interface instance for the particular user and a set \( \mathcal{V}' \) of attribute elementary values, where \( \mathcal{V}' = \bigcup_{a \in A'} (\mathcal{V}_a^u) \) is the domain of attribute \( a \).

The interface profile is represented by a tuple that is a function \( r: A' \rightarrow \mathcal{V}' \) where \((\forall a \in A')(r(a) \in \mathcal{V}_a^u)\). This type of representation is also called as a single-valued information system. It is also possible to consider multi-valued information system. In this case we introduce \( \Pi(\mathcal{V}_a^u) \) that denotes the set of subsets of set \( \mathcal{V}_a^u \) and let \( \Pi(\mathcal{V}) = \bigcup_{a \in A'} \Pi(\mathcal{V}_a^u) \). The interface profile is represented by a tuple that is a function \( r': A' \rightarrow \Pi(\mathcal{V}') \) where \((\forall a \in A')(r(a) \in \Pi(\mathcal{V}_a^u))\).

The quality of the interface system is very important, but very difficult to measure. The domain of the Human Computer Interaction has worked out many methods for the interface evaluation, but all of them are not straightforward and could not be measured by a simple function [8]. Usability is also a concept addressed by the international standard ISO 9241 (Part 11) [2] and is defined in the following way: ‘Usability of a product is the extent to which the product can be used by specific users to achieve specific goals with effectiveness, efficiency, and satisfaction in a specific context of use’. Effectiveness expresses: ‘the accuracy and completeness with which users achieve specified goals’, while efficiency considers: ‘the resources expended in relation to the accuracy and completeness with which users achieve goals’ and finally satisfaction reveals the users: ‘comfort and acceptability of use’.

### 2.2 Distance between Interface Profiles and their Clustering

The distance function between values of each attribute of the interface profiles is defined as a function \( \delta^a: \mathcal{V}_a^u \times \mathcal{V}_a^u \rightarrow [0,1] \) for all \( a \in A' \). This function should be given by the system interface designer and fulfill all the distance function conditions but not especially all the metrics conditions. The values of the distance function should be determined for each attribute and its every pair of atom values. The distance function values could be enumerated or given in any procedural form.

The distance between interface profiles could be defined in many different ways. First, the distance between tuples \( i \) and \( j \) could be defined as a simple sum of distances between values of each attribute: \( \delta(r_i,r_j) = \sum_{a \in A'} \delta^a(r_{i}(a),r_{j}(a)) \). Second, the root of the sum of squares of these distances, or finally third, we also can indicate the importance of each attribute \( a \) by multiplying the distance by appropriate factor defined as a function \( c: A' \rightarrow [0,1] \): \( \delta(r_i,r_j) = \sum_{a \in A'} [c(a) \cdot \delta^a(r_{i}(a),r_{j}(a))] \).

Clustering problem is defined as partitioning the given set of interface profiles into subsets according to some optimization criterion. One of the most popular algorithms for solving this problem is so-called Lloyd’s algorithm [3] and is one of the most popular solutions to the k-means problem. A brief description of this algorithm may be presented as follows: First, select randomly \( k \) elements as the starting centers of the clusters (centroids). Second, assign each element of the set to a cluster according to the smallest distance to its centroid. Third, recompute the centroid of each cluster, for example the average of the cluster’s elements. Finally, repeat steps 2 and 3 until some convergence conditions have not been met (for example centroids do not change). The attractiveness of this algorithm lies in its simplicity and its ability to reach the end when using the above mentioned convergence condition and for configurations without equidistant elements to more than one centroid. There is, however, one important problem with k-means algorithm, namely the algorithm takes a long time to run. First, the step 2 that has to be performed in each iteration costs \( O(kdN) \), where \( d \) is the dimension of each element and \( N \) is the number of elements. Second, algorithm usually needs many iterations to terminate. There are however quite many modification of this algorithm that run faster, for example bisecting k-means, that begins with single cluster containing all the elements, then splits it in two clusters and replaces it by split clusters. Splitting a cluster consists of applying k-means algorithm some \( \alpha \) times with \( k=2 \), keeping the split that average distance between all the elements and the centroid is the smallest.
2.3 System Architecture.

The system designer should first determine the attributes and their values of the user profile and the interface profile. Then the designers should specify the classification patterns for the user profiles and assign appropriate interface profiles for these classes.

The adaptive system works in the two phases. Firstly the users must register to the system, what implies the appropriate interface profiles assignment. The register users may interact with the system using the predefined interface or personalize it according to their preferences. The personalization is reflected as changes in the interface profiles. At the end of each session users are also asked to assess the interface usability. The users’ assessments are stored also in the interface profiles.

In the following step, which is launched after sufficient number of users have been registered, interface profiles are clustered. However, only interface profiles that were assessed as sufficiently good ones are taken into consideration. This clustering is then taken as a basis for rough classification of user profiles (described precisely in the next section). The rough classification enables to select the subset of attributes of the user profile which generates such user partition that the distance to the users partition generated by the interface profile is minimal.

The second phase starts after obtaining the user classification. We can group the interface profiles according to classes of the users. Then we can apply the consensus methods to build the user interface that represents the settings of all the users belonging to this class (described below). Finally the consensus-based interface profile settings are offered to all the new users that after registration were assigned to the appropriate class.

To solve the problem of finding the representation in the set of interfaces we must have the values of usability measure \( u(j) \) assigned to each of the interface \( j \). Let assume that the usability measure falls in the [0,1] interval and the value 0 denotes completely useless interfaces and 1 denotes ideally useful interfaces. Then to find the consensus we must find the interface \( i \) that’s sum of the distances to all other interfaces \( j \) belonging to the same class \( C \) multiplied with their usability measure \( u(j) \) is minimal: \( \min(\Sigma_{j \in C} u(j) \cdot \delta(i,p,ip)) \) where \( ip \) denotes interface profile in form of the tuple \( r \) or tree \( tr \). This problem could be computationally difficult, but according to [9] we can reduce the computation by finding the minimal value for all attributes \( a \) of a tuple separately: \( \min(\Sigma_{j \in C} u(j) \cdot \delta(r(a)_i, r(a)_i)) \).

Both phases could be launched any time when there is a need for it. When the re-classification and consensus determination of interface profiles does not result in acceptable usability assessments of the user interfaces by made by new users the designers should consider the introduction of some changes in the user profile and/or in the interface profile by modifying the set of values and/or set of attributes.

3 Rough Classification of Users

The concept of rough classification was defined by Pawlak in work [13]. First we must define an information system that is an ordered quadruple \( S = (U, A, V, \rho) \), where \( U \) is a set of objects; \( A \) is a set of attributes which describe the objects; \( V \) is the set of attribute values and \( \rho: U \times A \rightarrow V \) is the information function, such that \( \rho(x,a) \in V_a \) for each \( x \in U \) and \( a \in A \). The object is characterized by a tuple in the information system. Objects can be now classified into classes such that objects belonging to the same class have the identical tuples in the information system.

Pawlak worked out a methodology which enables to determine the minimal set of attributes (that is the reduct) which generates the same classification as the whole set of attributes. Having a classification \( C \) of set \( U \) Pawlak proposes a rough classification as its approximation. Assume that classification \( C \) is generated by set \( Q \) of attributes. The approximation of \( C \) is relied on determining a set \( P \subset Q \) such that the classification defined by \( P \) differs “a little” from \( C \). The small difference between these classifications is illustrated by the difference of their accuracy measure, which should not be larger than a threshold \( \epsilon \), that is \( \mu_Q(X) - \mu_P(X) \leq \epsilon \), for each \( X \subset U \), where \( \mu_Q(X) = \text{card}(AX) / \text{card}(AX) \), where \( AX \) and \( AX \) are the upper approximation and lower approximation of set \( X \), respectively, in information system \( S \) reduced to set \( R \) of attributes.

In this paper we consider another aspect of rough classification. This aspect is relied on the assumption that there is known a classification of set of users \( U \), and one should determine the set \( B \) of attributes from \( A \) such that the distance between the classification generated by attributes from \( B \) and the given classification is minimal. The given classification is that one which arises on the basis of user interfaces and the attributes come from user profiles. If these attributes could be determined, they would enable to classify the new users properly and as the consequence, to assign good interfaces to them.

3.1 Basic Notions

In this section we define the following notions:

A. Partition: By a partition of set \( U \) we call a set of nonempty and disjoint classes which are subsets of \( U \), and whose union is equal \( U \). By \( \pi(U) \) we denote the set of all partitions of set \( U \). Let \( P, Q \in \pi(U) \), the product of \( P \) and
Q (written as $P \cap Q$) is defined as: $P \cap Q = \{p \cap q; p \in P$, $q \in Q$ and $p \cap q \neq \emptyset\}$. Thus product $P \cap Q$ is also a partition of U.

B. Distances between partitions: We define 2 distance functions ($\sigma$ and $\delta$) between partitions:

**Function $\sigma$:**
In this function the distance between partitions P and Q of set U is equal to the minimal number of elementary transformations needed to transform partition P into partition Q. These elementary transformations are defined as follows:

1. Removal of an element – transforms a partition P of set U into a partition Q of set $U \setminus \{x\}$ by deleting an element x from P.
2. Augmentation of an element – transforms a partition P of set $U \cup \{x\}$ into a partition Q of set U by including an element x in one of existing classes from P or by creating a new class with only one element x.

**Function $\delta$:**
For $P,Q \in \pi(U)$ let $M(P) = [p_{ij}]_{i,j=0}^n$ be such a matrix that

$$p_{ij} = \begin{cases} 0 & \text{if } x_i, x_j \text{ are in different classes of } P \\ 1 & \text{if } x_i, x_j \text{ are in the same class of } P \\ \end{cases}$$

and matrix $M(Q) = [q_{ij}]_{i,j=0}^n$ be defined in the similar way, where $n = \text{card}(U)$. The distance between partitions P and Q is defined as follows: $\delta(P,Q) = \frac{1}{2} \sum_{i,j=0}^{n} |p_{ij} - q_{ij}|$. Such defined distance function is also a metric. It is also easy to show that the algorithm for determining distance of this kind requires $O(n^2)$ time.

C. Inclusion relation of partitions: Let $P,Q \in \pi(U)$. We say partition P is included in Q (written as $P \subseteq Q$) if each class of P is included in a class of Q.

D. Partitions determined by attribute (or set of attributes): As stated earlier, each user from U is represented by a user profile p which assigns each attribute from A with some value. Then each attribute a from set A determines a partition $P_a$ of set U, as follows:

1. 2 elements from U belong to the same class in $P_a$ if and only if their user profiles assign attribute a with the same value.

More general, a set B of attributes determines $P_B$ of set U, as follows: 2 elements from U belong to the same class in $P_B$ if and only if for each attribute $a \in B$ their user profiles assign with the same value. It is not hard to show that $P_B = \bigcap_{a \in B} P_a$.

3.2 User Rough Classification on the Basis of Profiles and Interfaces

As we have assumed above, after registering each new user is classified by the system into an appropriate class of users, which is the basis for determining an interface for that user. All the register users are able to customize their interfaces by means of the interface layout, content and structure personalization [4]. These interface settings are stored in the corresponding interface profile.

In this concrete application let’s denote by U as the set of users of the system and A as the set of all potential attributes which may be used in user profiles. By a user interface (UI) classification we mean that one which is generated on the basis of user interfaces, and by a user profile (UP) classification we call that one which is generated on the basis of profile attributes. We may notice that in the system, at present, uses UP classifications to assign to a new user a preliminary user interface. During using the system this interface may be personalized by the user (adjusted to his or her needs). As the consequence, the final interface should be better for the given user than the initial one.

Let $P_B$ be the actual UP classification of U determined by means of attributes from set $B \subseteq A$ and let Q be the actual UI classification of U. If $P_B$ differs from Q (or their distance is greater than a given threshold) then we say that the system is weakly adaptive. The smaller is the difference between $P_B$ and Q the more adaptive is the system. A system is then full adaptive if $P_B = Q$.

To make the adaptation more efficient, one should solve the problem of determining $P_B$ on the basis of Q. Notice that $P_B$ is dependent on B, this means that a set B of attributes determines exactly one partition $P_B$. Besides we know that different sets of attributes may determine the same partition, thus problem is relied on selection of a minimal set B (that is a set with minimal number of elements) such that the distance between $P_B$ and Q is minimal.

Let $d \in \{\sigma, \delta\}$. The problems of rough classification (RC) can formally be defined as follows:

**Problem RC-1:** For given partition Q of set U one should determine set $B \subseteq A$ such that $P_B \subseteq Q$ and $d(P_B, Q)$ is minimal.

In this case set B represents such classification which is equal or minimally more exact than Q. This classification guarantees that two users for whom different interfaces are designed, should not belong to the same class in UP classification. In this case we have the “exact” classification.

**Problem RC-2:** For given partition Q of set U one should determine set $B \subseteq A$ such that $Q \subseteq P_B$ and $d(P_B, Q)$ is minimal.

In this problem set B represents such classification which is equal or minimally differs from Q. In this classification two users for whom different interfaces are designed, may belong to the same class in UP classification, but the number of users of this kind should be minimal. Thus we deal with a kind of rough classification. The only advantage of the solution of this problem is that the number of attributes needed for UP classification is often smaller than in the solutions of
problem CR-1. Similarly to CR-1 this problem also may have no solutions.

**Problem RC-3:** For given partition $Q$ of set $U$ one should determine set $B \subseteq A$ such that $d(P_b,Q)$ is minimal.

Solutions of this problem may be needed if solutions of problems RC-1 and RC-2 do not exist. Thus set $B$ represents a rough classification referring to $Q$. This problem should be solved in the majority of practical cases.

### 3.3 Solutions for Problems RC-1, RC-2 and RC-3

**Solution of RC-1:** Notice that if $P_b \subseteq P_a$ then $P_a \subseteq Q$ because $P_a = P_b \cap P_{A,B}$. Thus if $P_a \not\subseteq Q$ then the solution does not exist. If $P_a \subseteq Q$ then set $B$ may be equal $A$, but for the condition that $d(P_b,Q)$ should be minimal some attribute eliminations from $A$ should be done. This can be performed owing to the property which states that for $P \in \pi(U)$ and $d \in \{\sigma,\delta\}$ if $P \subseteq Q$ then $d(P,Q) \leq d(P \cap R,Q)$.

According to this property if for some attribute $a$ that we have $P_{a,a} \subseteq Q$ then after eliminating $a$ the distance should be improved, that is $d(P_{a,a}Q) \leq d(P_{a,a}Q)$ because $P_a = P_{a,a} \cap P_{a}$. The algorithm for RC-1 is following: first calculate $P_a$; then if $P_a \not\subseteq Q$ then $B := \emptyset$ and finish else $B := A$; and finally for each $a \in B$ do if $P_{a,a} \subseteq Q$ then $B := B \setminus a$.

**Solution of RC-2:** Notice that $Q \subseteq P_b$ if and only if $Q \subseteq P_a$ for each $a \in B$. We will use the following property: For any information system $(U, A)$, attributes $a, b \in A$ and partition $P \in \pi(U)$ the following properties are true:

a) If $P \subseteq P_{a,a}P_{a}$ then $d(P_{a,a}P_{a}) \leq d(P_{a,a}P_{a})$

b) If $P \subseteq P_{a,a}P_{a}$ then $d(P_{a,a}P_{a}) \leq d(P_{a,a}P_{a})$ and $d(P_{a,a}P_{a}) \leq d(P_{a,a}P_{a})$, where $d \in \{\sigma,\delta\}$.

From the property presented above we can see that value $d(P_b,Q)$ is minimal if $B$ contains all attributes $a \in A$ such that $Q \subseteq P_a$. Set $B$ may be minimized by eliminating dependent attributes, that is if there exist attributes $a, b \in B$ such that $P_{a,b}$ then $b$ should be eliminated.

The algorithm for RC-2 should consist of the following steps: first $B := \emptyset$; then For each $a \in A$ do if $Q \subseteq P_a$ then $B := B \cup \{a\}$ and finally For each $a, b \in A$ and $a \neq b$ do if $P_{a,b} \subseteq P_b$ then $B := B \cup \{b\}$. It can be proved that $d(P_b,Q)$ is minimal for $d \in \{\sigma,\delta\}$.

Because of limited space for the paper the proofs of presented properties are not given.

**Solution of RC-2:** It was proven that this problem is NP-complete for both distance functions $\sigma$ and $\delta$ [7]. The algorithm for RC-3 is following: First Choose $a \in A$ such that $d(P_a,a) = \min_{b \in A} d(P_b,a)$; Second $C := B$; Third

If there exists $c \in A \setminus B$ such that $d(P_{a+c},Q) = \min_{b \in A \setminus B} d(P_{b+c},Q)$ and $d(P_{b+c},Q) < d(P_{b+c},Q)$ then $B := B \cup \{c\}$; Finally if $B \neq C$ then GOTO the third step.

### 4 Consistency Analysis

The notion of knowledge consistency can be applied in many different areas, where there are some kinds of divergences, the authors use terms consistency and inconsistency. In most cases the distinction of these two levels may be sufficient, however, there are some situations where we need to know exactly the level of consistency or inconsistency. So, we need some tools like the consistency functions, which will determine the value of consistency degree. They have been already presented in work [5]. In this paper, we want to present some results of their analysis.

#### 4.1 Postulates for Consistency Measures

Formally, let $U$ denote a finite universe of objects (alternatives), and $\Pi(U)$ denote the set of subsets with repetitions of set $U$. Each element of set $\Pi(U)$ is called a profile. The sum of sets with repetitions is denoted by the symbol $\cup$. In this paper we only assume that the macrostructure of the set $U$ is known and a distance is a function $d: U \times U \to [0,1]$ is nonnegative, reflexive and symmetrical. For normalization purposes we can assume that values of function $d$ belong to interval $[0,1]$.

A profile $X$ is called homogeneous if all its elements are identical, that is $X = \{n \times x\}$ for some $x \in U$. A profile is called distinguishable if it is not homogeneous. A profile is called heterogeneous if all its elements are different from each other. A profile $X$ is multiple referring to a profile $Y$ (or $X$ is a multiple of $Y$), if $X = \{n \times x_1, ..., n \times x_k\}$ and $Y = \{x_1, ..., x_k\}$. By symbol $C$ we denote the consistency function of profiles. This function has the following signature: $C: \Pi(U) \to [0,1]$ where $[0,1]$ is the closed interval of real numbers between 0 and 1. The idea of this function is relied on the measuring the consistency degree of profile’s elements. The requirements for consistency are expressed in the following intuitive postulates:

**P1a. Maximal consistency:** If $X$ is a homogeneous profile then $C(X) = 1$. 


**P1b. Extended maximal consistency:** For \( X^{(n)} = \{n \times x_1, k_1 \times x_1, \ldots, k_m \times x_n\} \) being a profile such that element \( x \) occurs \( n \) times, and element \( x_i \) occurs \( k_i \) times, where \( k_i \) is a constant for \( i=1,2,\ldots,m \). The following equation should be true: \( \lim_{n \to +\infty} C(X^{(n)}) = 1 \).

**P2a. Minimal consistency:** If \( X = \{a,b\} \) and
\[
d(a,b) = \max_{x,y \in U} d(x,y)
\]
then \( C(X) = 0 \).

**P2b. Extended minimal consistency:** For \( X^{(n)} = \{x_1, \ldots, x_n\} \) being a profile such that \( d(x_i,x_j) = \max_{x,y \in U} d(x,y) \) for \( i \neq j \). The following equation should be true: \( \lim_{n \to +\infty} C(X^{(n)}) = 0 \).

**P2c. Alternative minimal consistency:** If \( X = U \) then \( C(X) = 0 \).

**P3. Non-zero consistency:** If \( \exists_{a,b \in X} d(a,b) < \max_{x,y \in U} d(x,y) \) then \( C(X) > 0 \).

**P4. Heterogeneous profiles:** If \( X \) is a heterogeneous profile then \( C(X) < 1 \).

**P5. Multiple profiles:** If profile \( X \) is a multiple of profile \( Y \) then \( C(X) = C(Y) \).

**P6. Greater consistency:** Let \( d(x,X) = \sum_{y \in Y} d(x,y) \) denote the sum of distances between an element \( x \) of universe \( U \) and the elements of profile \( X \). Let \( D(X) = \{d(x,X) : x \in U\} \) be the set of all such sums. For any profiles \( X,Y \subseteq U \) the following dependency should be true:
\[
\left[ \frac{\min(D(X,Y))}{\text{card}(X,Y)} < \frac{\min(D(X,Y))}{\text{card}(X,Y)} \right] \Rightarrow [C(X) > C(Y)]
\]

**P7a. Consistency improvement:** Let \( a \) and \( b \) be such elements of profile \( X \) that \( d(a,X) - \min(D(X)) \) and \( d(b,X) = \max(D(X)) \), then \( C(X - \{a\}) \leq C(X) \leq C(X - \{b\}) \).

**P7b. Consistency improvement 2:** Let \( a \) and \( b \) be such elements of universe \( U \), that \( d(a,U) = \min(D(X)) \) and \( d(b,X) = \max(D(X)) \), then \( C(X \cup \{b\}) \leq C(X) \leq C(X \cup \{a\}) \).

### 4.2 Consistency Functions

Let \( X = \{x_1, \ldots, x_M\} \) be a profile. We introduce the following parameters:

**A.** The matrix of distances between the elements of profile \( X \): \( D^X = [d^X_{ij}] \) where \( d^X_{ij} \) is distance between \( x_i, x_j \) for \( i,j = 1,\ldots,M \).

**B.** The vector of average distances of knowledge states of each object to the rest:
\[
W^X = \left[ w^X_i \right] = \left( \frac{1}{M-1} \sum_{j=1}^{M} d^X_{1,j}, \ldots, \frac{1}{M-1} \sum_{j=1}^{M} d^X_{j,M} \right)
\]

**C.** Diameters of sets
\[
\text{Diam}(X) = \max_{x,y \in X} d(x,y), \quad \text{Diam}(W^X) = \max_{1 \leq i \leq M} w^X_i,
\]

**D.** The average distance of objects’ knowledge states:
\[
\bar{d}(X) = \frac{1}{M(M-1)} \sum_{j=1}^{M} \sum_{i=1}^{M} d^X_{i,j}
\]

**E.** The sum of distances between an element \( x \) of \( U \) and the elements of set \( X \):
\[
d(x,X) = \sum_{y \in X} d(x,y).
\]

**F.** The set of all sums of distances:
\[
D(X) = \{d(x,X) : x \in U\}.
\]

**G.** The minimal sum of distances from an object to the elements of profile \( X \):
\[
d_{\min}(X) = \min(D(X)).
\]

These parameters are now applied for the defining the following consistency functions:

\[
\begin{align*}
c_1(X) &= 1 - \text{Diam}(X), \\
c_2(X) &= 1 - \text{Diam}(W^X), \\
c_3(X) &= 1 - \bar{d}(X), \\
c_4(X) &= 1 - \frac{1}{M} d_{\min}(X), \\
c_5(X) &= 1 - \frac{1}{M} d_{\max}(X).
\end{align*}
\]

### 4.3 The Postulates’ Analysis

The table presented above shows result of analysing functions. The columns denote postulates and rows denote functions. Plus means that presented function complies the postulate and minus means that presented function doesn’t comply the postulate.

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5 Conclusions

In this paper a method for analysis of user profile data in adaptive user interface systems is presented. This method is based on user rough classification concept [13]. The difference between our approach and Pawlak’s approach to rough classification is that we do not use the upper and lower approximations of partitions, but we use the distance functions between partitions to determining the nearest partition to the given.

The application of the rough classification enables us to find the minimal set of the user profile attributes. The user must deliver to the system only the values of these attributes during the registration process in order to classify them and recommend them appropriate user profiles. In case when it is impossible to find such set that generates the acceptable partition the system designer should obtain the message that the set of the user profile attributes or their values are incomplete and there is a need to give the additional elements.

In this paper we also presented another tool for adaptive system analysis by means of consistency measures for reconciling knowledge. The authors propose a set of postulates which should be intuitive conditions for consistency functions. Some results of postulates’ analysis is given and 5 concrete consistency function are defined and analyzed.

References

Integrated Remote Experimentation

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Abstract

Embedded systems are an integral part of industrial and domestic electronics necessitating educational institutions and other training providers to offer advanced embedded systems courses. Experience has shown that effective teaching in this area requires an interdependent approach combining theoretical material underpinned by practical laboratory experiments and individualized tutoring. Increasingly the courses on offer include web-based distance education packages augmented by the provision of remote experimentation laboratories facilitating distant access to campus-based physical resources. The degree of functionality and level of user access to remote laboratories has evolved in recent years expedited by advances in web applications and technologies. This paper summarizes our recent experiences in this area focusing on the development of an architecture for an integrated remote experimentation laboratory designed to meet the unique requirements of a complex, dynamic learning environment.

1. Introduction

The proliferation of distance education courses in recent years poses unique challenges for disciplines involving a high level of practical work. For electronic and electrical disciplines hands-on experience is essential for effective student learning. Remote experimentation facilities offered as part of a web-based learning approach, affords a number of critical benefits and for engineering distance education courses it is the only realistic method of performing many experiments. This approach allows remotely located students to complete laboratory assignments unconstrained by time or geographical considerations facilitating the development of skills in the use of real systems and instrumentation.

This paper describes our recent experiences in the practical implementation of the DIESEL project (Distance Internet-Based Embedded System Experimental Laboratory) a three year distance learning project funded by the EPSRC under the Masters Training Program and located at the Intelligent Systems Engineering Laboratory on the Magee campus of the University of Ulster, Northern Ireland. The overall objective of the DIESEL project was to develop remote-access laboratories for Embedded Systems modules on a range of undergraduate and postgraduate courses. The facilities developed complement and extend existing courses by enabling students to conduct practical experiments in this area remotely via the Internet.

Section 2 of this paper summarizes our work in this area focusing on overcoming existing deficiencies in similar and related projects. An overview of individual DIESEL client components and their functionality is discussed and a typical user session is demonstrated. Section 3 discusses the .net client/server DIESEL implementation and each stage of the initialization and experimental process. Section 4 provides a summary of the paper and discusses future work currently under development.

2. Integrated Remote Environment

Previous surveys carried out by the authors identified key deficiencies in existing remote experimentation laboratories and a full review is provided in the following publications [1, 2]. The main conclusion arrived at following this review was that existing web-based remote laboratories were crude in nature with limited functionality and failed to fully utilize existing hardware and software resources [3, 4, 5, 6, 7, 8 and 9]. It was also apparent that the effort and redevelopment costs needed to redesign and adapt existing hardware and software tools with the extra functionality needed for online remote access was substantial and beyond the expertise and budget of most teaching institutions.
Learning support resources
- Lecture and laboratory notes (Audio/Video)
- Interactive multimedia user help (Macromedia flash demos)
- Discussion forum
- Laboratory reservation system

Remote experimentation facilities
- Remote desktop feature
- Circuit interface front ends (Circuit setup & manipulation)
- Virtual instrument interfaces (Labview)
- Webcams (Visual feedback)

Collaborative working and communication tools
- Video conferencing
- Whiteboard facilities
- Instant messaging
- Remote assistance

Figure 1. DIESEL advanced remote learning environment

Figure 2. Client and booking system overview
To overcome these shortcomings and address previous deficiencies a generic architecture and access-control methodology for remote laboratories was developed. This architecture efficiently integrates the instrumentation and experimental components of the system and is functionally comprised of three distinct but interconnected sections, learning support resources, remote experimentation facilities and collaborative working and communication tools (Figure 1).

The learning support resources include extensive lecture and laboratory notes complete with audio/visual content providing theoretical background material and guidance for experiments. A comprehensive interactive multimedia user help system is available outlining and demonstrating general laboratory operation and the conduction of experiments. A facility is also included to allow students to book laboratory access time (Figure 3). The remote experimentation facilities include the remote desktop feature which allows students to fully access all the resources of the distant workstations.

A series of Macromedia Flash based executables provide a user interface front end to the experiments which control the switching equipment on the remote workstations. This interface allows students to effectively wire up circuits and to connect test equipment for the taking of measurements or readings. Instrumentation control is provided by a series of virtual instrument interfaces built in Labview to closely resemble the physical characteristics of a range of test equipment e.g. oscilloscopes, digital multi-meters and function generators. The Labview interfaces allow the student full access and control of the test equipment and instrumentation connected to the remote workstation. To provide feedback to the students during experiments, a series of Labview interfaces have being designed to connect to data acquisition cards which take readings from a range of peripheral devices e.g. Stepper motors. This is augmented by the use of Web cams to provide visual feedback.

The collaborative working, support and communication tools were built using the Macromedia Flash communication server. This aspect of the environment allows advanced interaction between students or between students and course support staff via audio/video and text. A more detailed technical overview of this system is provided here (10,11 and 12).

### 2.2 DIESEL architecture

The DIESEL architecture is a distributed application comprised of three main components, the database, the client application and the server application (Figure 2). The database is used to store the list of authorized users, their passwords, the list of bookings made and a list of available experimental workstations. The client application is an executable which when installed on the student’s machine facilitates remote access to the experimental environment. The server application is a shell like framework which calls each of the individual components of the environment together and is located on the remote experimental workstation.

### 2.3 User session overview

To access the remote laboratory the user must first install the DIESEL client on the remote machine. The next step is the access process to reserve a time slot on the remote laboratory via the remote laboratory website (Figure 3).

![Figure 3. Remote environment booking system](image)

Once the booking process is completed the user is granted access to the Remote laboratory in a number of stages. The first stage of this process is to launch the DIESEL client (Figure 4).

![Figure 4. Student launches DIESEL client](image)
The next step in the process is to select an experimental range. In this case the user selects the Microcontroller based experiments and then a specific experiment in this range is selected (Figure 5-6).

As the student selects options at each stage of the DIESEL client startup, the workstation the student is accessing will begin to configure the laboratory to cater for the experiment selected. Lecture material and slides appropriate to the experiment will be loaded into the environment and the switching matrix will connect the chosen experimental board to the instrumentation. When the client is loaded the user can select which aspect of the environment to access using a tabbed menu navigation system (Figure 7).
Figures 8, 9, 10 and 11 show screenshots of components of the DIESEL client. Figure 8 shows the virtual circuit interface which allows the user to wire up circuits and connect instrumentation. Figure 9 is the Labview interface facilitating access and control of remote test equipment. Figure 10 shows the remote desktop approach central to overall operation. Figure 11 shows the communication tools.

This section of the paper presented the components of an integrated environment for remote experimentation. A structured environment for remote experimentation was introduced which included comprehensive teaching and support material and integrated the ability to complete advanced embedded system experiments remotely. The next section provides more detail on the implementation of the DIESEL environment as a distributed communications application using a client/server web services/.NET Remoting framework.

3. Web service .NET/Remoting framework

The DIESEL distributed architecture is based on a four-layered communication model, the presentation, data, business and physical layers (Figure 13). The DIESEL client encompasses the presentation layer and provides the user-interface to the laboratory, allowing the configuration and manipulation of embedded systems and instruments remotely. The data layer allows access to user data stored in the web server database and provides secure internet communications for passing control data between the client and the business layer.

The DIESEL server, hosted on the remote workstation, utilizes the business and physical layers. The business layer responds to all client user requests by executing the appropriate control programs on the hardware architecture to configure the embedded circuits, signal routers, instruments while sending commands to the circuit under test. The physical layer represents the communication process between all physical lab equipment. The system operation is based around the use of web services and .Net Remoting.

During a remote session both the DIESEL client and server need to retrieve data from the database. A web service is used a gateway between the presentation, business and data layers to allow the client and server to access the database. This approach is used as it allows the separation of the client and server applications from the data storage process. In addition this approach circumvents any problems that could arise with access through firewalls and avoids cross platform issues. A .Net remoting approach is also used as it allows ease of application development and deployment with good performance and internet readiness. However a third party security solution was necessary as this is not included by default in the software.

3.1 Remote experimental session

During a typical experimental session the user would initialize the entire process by making a booking on the DIESEL website reserving a workstation for a remote session (typically one hour duration). At the chosen time the remote user launches the DIESEL client to initiate the remote session. A remote session has two distinct stages, initialization and experimental working. (Figure 14). During the initialization stages (1 – 6) the DIESEL client attempts to access the remote workstation. User name and passwords are passed to both the DIESEL web server and DIESEL workstation server for validation. If a valid user name, password and reserved time slot is entered the user is granted access to the remote workstation through the DIESEL workstation client. In stages 7 – 8 the experimental environment is configured, loading the appropriate lecture and support material and experimental boards as selected by the user during the log on process.
Figure 13. DIESEL client/server web service .NET/Remoting framework

Figure 14. DIESEL client/server operation
This completes the initialization stage. During the experimental working mode stage (8 – 13) the user is in experimental working mode. The DIESEL client passes requests to the DIESEL workstation server configuring equipment and switching between instruments and development boards as required.

4. Discussion and conclusion

A review and discussion of recent work undertaken by the authors in addressing issues related to the implementation of remote access experimental laboratories has been presented. The approach and architectures described offers considerable benefits in terms of full access to remote resources and cost redevelopment saving. The .net client/server architecture presented provides a flexible framework for the integration of a diverse range of components integral to the flexible and functional operation of the DIESEL remote experimentation environment.

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References


Measurement and Analysis of Human Characteristic on the Self-Rotation with Vision Stimulus

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ABSTRACT: The use of Virtual Reality (VR) is essential to entertainment, architecture, education, and other industry. So, it is important to develop the cost-effective VR with the superior feeling of “Reality”. To accomplish the requirement, we have to provide human the appropriate sensory stimuli to enhance the sense of reality and immersion. In human, the most part of sensory information are owing to vision, and it is sure to play an important role in VR environments. One of the important psycho-physiological effects in VR is visually induced perception of self-motion, called vection. In this study, we investigated circular vection to specify the optimal parameters for the visual stimulus, such as spatial frequency, temporal frequency, and stimulus speed. We revealed that the induction of circular vection depended on the multiple parameters of visual stimulus. Our results are suggested that selecting fundamental parameters of visual stimuli is important to improve the human experience of reality and reduce the side effects, such as motion sickness.

Keywords: Circular vection, Visual-vestibular interaction, Human, Temporal frequency

1. Introduction

Today, Virtual Reality is utilized not only in the amusement but also in various situations, in particularly, for the purpose of Traffic Safety and skill training under the dangerous circumstance such as a nuclear power plant though e-learning. Under the Virtual Reality environment, the feeling of the reality is the most important. However, on the contrary, such feelings cause to the some problem, such as motion sickness [1] [2]. So, we have to find the effective methods, which can avoid such problems but make human sense the reality. In order to realize the feeling of reality, we need to provide human the appropriate somatosensory and/or visual information. Among them, since the visual information can be occupied the most part of the sensory information of human, and hence, refining the presentation methods of the visual information could improve the feeling of reality.

Visual stimulation induces the perception of self-motion as well as the perceptual experience, such as color, shape and visual motion under particular conditions. Generally speaking, we perceive the self-motion during the active movement such as walking, running and swimming or the passive moving by means of train, ship plane and so on. As for the formation of the self-motion, various information arise from sensory receptor of muscle and joints, vestibular organ such as semicircular canal and otolith, vision and their interaction have to be integrated. On the contrary, visually induced self-motion is caused by only visual stimulation. The visually induced self-motion is a kind of illusion, during which human sense that he is moving in spite of no explicit movements. There are two different forms; Linear Vection (LV) and Circular Vection (CV). Using CV and/or LV would enable us to effectively realize the feeling of reality. Previous reports suggested that the generation of vection depended on the selection and combination of the parameters of visual stimuli [3] [4] [5]. One reason for this is that the experimental setup is different between researchers, and furthermore there are some technical limitations of the experimental equipments [5] [6]. To overcome this limitation, we newly constructed the wide view cylindrical screen with the extended field of view to the horizontal visual angle of 120 degrees and the vertical angle of 70
degrees. And then, using this screen, we investigated the dependence of CV on the spatial frequency, temporal frequency, and velocity of visual stimulus.

2. The design of experiment equipment

2.1 wide view cylindrical screens

The visual field is a very important factor of virtual reality environment, and, at least, the extent of 120 degrees was required to improve the sense of reality. These equipments have been developed, but were sometimes very expensive and unnecessarily large ones. So, we make a more economical and compact equipment, “wide view cylindrical screens”. However, there are two obstacles to make the wide view cylindrical screen. First, we have the problem when we project an image to a curved screen. Since the screen surface as shown in fig.1 is curved, the projected image is inevitably deformed with the direct linear projection using LCD projector. In order to compensate the deformation, we used the adjustments proposed by Nagumo et al., (1999) [7]. PC and the observed one about the nonlinear relationship between the theoretical luminance specify second problem being to be solved. In order to correct this, we performed the direct measurements of the luminance of stimuli generated by PC with RGB unit.

\[ m = \frac{L_{\text{max}} - L_{\text{min}}}{L_{\text{max}} + L_{\text{min}}} \]  

Where \( A(t) \) is spatial sine wave stimulus, \( x \) is position on the screen, \( A_0 \) is average luminosity, \( m \) is contrast, \( a \) is spatial frequency, \( L_{\text{max}} \) is maximum luminance, \( L_{\text{min}} \) is minimum luminance. In this experiment, the average luminance \( A_0 \) is set to 45cd/m² and the contrast \( m \) is 0.90.

In this experiment, the blue sine wave stimulus was used for the better penetration characteristic to the wide view cylindrical screen. The blue sine wave stimulus (of Fig.3) is projected to the wide view cylindrical screen using the projector (shown in Fig.1). When rotating the blue sine wave grating stimulus in the clockwise direction, the subject can experience the feeling of self-rotation in the opposite direction.

2.2 The stimulus of visually induced self-rotation

As a stimulus which generates CV, monochrome rectangle wave stimulus has been used in the previous research [4]. Since the experiment stimulus was generated with PC and was shown using a projector, as shown in Fig.2, it is possible to use an exact sine wave stimulus in our study. Spatial sine wave stimulus was generated using the following formulas.

\[ A(t) = A_0 (1 + m\cos 2\pi ax) \]  

In this experiment, the blue sine wave stimulus was project for the better penetration characteristic to the wide view cylindrical screen. The blue sine wave grating stimulus in the clockwise direction, the subject can experience the feeling of self-rotation in the opposite direction.

2.3 Compensation of the spatial deformation in projecting an image

When projected on a curved surface by the LCD projector, an image is inevitably deformed without any correction. Although this deformation can be corrected...
with modifying the projectors lens system, however, it would greatly cost. So, we use the Nagmo’s correction of deformation in projecting the curved screen. In this technique, the original image is appropriately deformed on PC in advance so that the projected image could be the unreformed and normal image. These spatial transformations to the original image are specified by the following set of equation:

\[ m = \frac{-f + \sqrt{f^2 - 4eg}}{2e} \]  
(3)

\[ n = r \left( \frac{1 - \cos \theta}{\cos \theta} + \frac{L_0}{L} \right) \left( \frac{L}{r(1 - \cos \theta_0) + L} \right)^y \]  
(4)

\[ L_0 = r \cos \left( \frac{\theta_0}{2} \right) \]  
(5)

\[ L_i = L + r - L_0 \]  
(6)

\[ \theta = \tan^{-1} \left( \frac{m}{L_0} \right) \]  
(7)

\[ e = r^2L_i^2 - x^2(L_0 + L_i)^2 \]  
(8)

\[ f = 2r^2xL_0L_i \]  
(9)

\[ g = x^2L_0^2 \left\{ y^2 - \left( L_0 + L_i \right)^2 \right\} \]  
(10)

Where \((x,y)\) is the Cartesian coordinates on the original image, \((m,n)\) is the Cartesian coordinates on the cylindrical screens, \(r\) is the radius of cylinder, \(L\) is the distance of the projector and the cylinder, and \(f\) is the visual angle. In this study, we specified them as follows: \(L=1500\,\text{mm}, \, R=500\,\text{mm}\) and \(\theta_0=120\,\text{deg}\). The sample images before and after the spatial transformation based on the above formulas are presented in figure 4 and 5, respectively.

2.4 Specifying the relationship between the luminance of the original image and the projected image

The characteristic of blue luminance sine wave generated by the experiment equipment of Fig.1 is shown in Fig.6. The horizontal axis of Fig.6 is luminance value with the specified value from a computer, and the vertical axis is the luminance measured from the color luminosity mater (TOPCON BM-7Fast).

![Fig.6 Nonlinear relationship between luminance code and the blue on the screen](image)

Fig.6 shows that the between a blue luminance with a particular value and an actual luminance measured value is nonlinear (The solid line is obtained by method of least-squares). In following experiment, we use this relationship to generate luminance-corrected images.

3. Experimental setup

The experimental setup is shown in Fig.7, which includes the wide view cylindrical screen, a PC (W9 866/128/of COMPAQ DESKPROENSF P), a projector (SANYO LP-SU30), and a reaction key.
The spatial compensation of the experimental stimulus was carried out on PC at real time, and rear-projected to the wide view cylindrical screen.

4. Method

Ten healthy subjects (all men from 20 years old to 24) participated in our study. The experiment was conducted at a quiet and dark laboratory. Subjects' head was fixed on a shelf to ensure the stability of the head during the experiment. Subjects' eyes were required to fix on a fixed point and not to wink as much as possible during the experiment. The fixation point was a small light-emitting tape with the size of 10mm × 10mm on the center of the screen. Subjects were directed to push a reaction key when they experienced CV. We also evaluated the perceived CV velocity using the Magnitude Estimation method [9]. First, we presented the subject a standard stimulus: the sine wave pattern of a standard stimulus was made of 0.125 cycle/deg spatial frequency and stimulus rotation speed was 42.0 deg/sec for 1.5 seconds, whose speed of rotation was assumed to 10. The subjects rated the experienced speed of CV by a natural number comparing with that of the standard stimulus. The time chart of experiment is shown in Fig.8.

As shown in Fig.8, the time between an experiment stimulus starting point and the experience of CV was defined as the latency of CV. Subjects rated the perceived CV at 30 seconds after stimulus onset. If CV did not occur during the 30 seconds, we regarded that the subject did not experience CV. Spatial frequency of the sine wave pattern were set to 0.050, 0.075, 0.100, 0.125, 0.150, 0.175, and 0.200 cycle/deg, and stimulus rotation speed were set to 31.5, 42.0, 52.5 deg/sec. There were 21 combinations the spatial frequency of the stimulus and rotation speed. Each condition was performed five times. The produce of spatial frequency (cycle/deg) and stimulus rotation speed (deg/sec) was defined as temporal frequency (cycle/sec).

5. Results

The results of the perceived CV velocity and the latency of CV are shown in figure 9(A) to (B), respectively. The horizontal axis of Fig.9 represented spatial frequency and the vertical axis of (A) is the magnitude estimates of the perceived CV velocity and (B) is the latency time. The stimulus rotation speed of 31.5, 42.0, and 52.5 deg/sec was denoted by, •, ■, and ▲ mark, respectively. In several conditions, subjects do not always perceived CV (†: three subjects, ††: seven subjects, †††: eight subjects).

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Repeated-measures ANOVAs were performed and revealed that there are significant difference in the perceived CV velocity for spatial frequency conditions ($F = 59.36$, $p < 0.001$) and rotation speed ($F = 18.23$, $p < 0.001$) (Fig. 9(A)). There was no significant interaction in spatial frequency and stimulus rotation speed ($F = 0.975$, $p = 0.481$). In Fig. 9(B), there was significant difference in The latency of CV for temporal frequency condition ($F = 18.23$, $p < 0.001$), and no significant difference in stimulus rotation speed condition ($F = 0.400$, $p = 0.680$). In addition, no significant interaction existed between temporal frequency and stimulus rotation speed ($F = 0.359$, $p = 0.973$).

Next, we investigate the effects of temporal frequency on the perceived CV velocity and The latency of CV. The temporal frequency is defined by the following formulas:

$$SF\left(\frac{\text{cycle}}{\text{sec}}\right) = TF\left(\frac{\text{cycle}}{\text{deg}}\right) \times SRS\left(\frac{\text{deg}}{\text{sec}}\right) \quad (11),$$

Where TF is Temporal Frequency, SF is Spatial Frequency SRS is Stimulus Rotation Speed. The relation between spatial frequency, stimulus rotation speed, and temporal frequency is shown in Fig.10.

![Fig.10 Relation between spatial frequency, temporal frequency and stimulus rotation speed](image)

The relationship between temporal frequency and the perceived CV velocity or the latency of CV is shown in figure 11(A) to (B), respectively. The horizontal axis of Fig.11 is temporal frequency. The definition of axis and, the makers of †, ††, ††† are the same as Fig.9.

6. Discussion

6.1 CV velocity
An experience of CV velocity shows a significant difference among the conditions of spatial frequency and rotation speed as shown in Fig.9 (A). It suggests that the vividness of CV depends on parameters of visual stimulus. In the previous research, Dichgans et al. [4], and Graaf et al. [6] reported that the spatial frequency had influence on the perceived CV velocity. In our research, the perceived CV velocity was dependent on spatial frequency (Fig. 9 (A)), which supports Graaf’s results [6]. However, it notes that there are differences in experimental setup between our study and others. Dichgans and Brandt. used the rectangle wave form stimuli projected on the cylindrical drum, which cannot represent the correct spatial frequency [4]. Graaf et al. used the filtered rectangle wave form to approximate the sine wave on the cylindrical drum. In our experiment, using the wide view cylindrical screen and the sine wave stimulus, we can realize the more exact spatial frequency than previous experiments.

![Fig.11 Experimental results of temporal frequency](image)
The perceived CV velocity showed a significant difference between different stimulus rotation speeds (Fig. 9 (A)). This result supports the result of Wong et al. [5] [8], which showed that CV velocity was proportional to the rotation speed of the drum.

Fig. 11 (A) shows that the perceived CV velocity closely depends on temporal frequency. However, Graaf et al. reported that the perceived CV velocity is proportional to drum velocity and not to temporal frequency [6]. This discrepancy may result from the difference in the stimulus and/or the stimulus presentation instrument. Since the parameter of visual stimulus is well controlled rather than previous study, we are certain about our results of dependence of CV velocity on temporal frequency.

6.2 CV latency

The latency of CV shows a significant difference among the conditions of spatial frequency (Fig.11 (B)). In addition, there is no interaction in the spatial frequency and the stimulus speed, and hence, we conclude that CV latency depends on spatial frequency. There is no dependence of the latency of CV on stimulus rotation speed, which reconfirmed Wong’s results [5] [8]. And we also reveal that CV latency depends on temporal frequency, which is a novel finding in our study.

7. Conclusion

We investigate the dependence of CV on the spatial frequency, temporal frequency, and velocity of visual stimulus using the wide view cylindrical screen. We revealed that the induction of circular vection depended on the multiple parameter of visual stimulus such as spatial frequency, temporal frequency, and stimulus speed. In particular, the perceived speed and CV latency can be explained by only one parameter, temporal frequency. Controlling these parameters, we can effectively provide human the sense of reality and immersion without any side effects, such as motion sickness. These results will provide the useful information for Virtual Reality application including e-learning and e-science.

References

Session 3: Learning Objects and Collaborative Learning

Chaired by: Dr. Jinglong Wu
Abstract

This paper proposes a data-model for the standardized representation of both synchronous and asynchronous text-based and other communications. Such communications are widely used in e-learning practice today, and have been studied under the rubrics of "computer conferencing," "Computer-Mediated Communication" (CMC), "Computer Supported Collaborative Learning" (CSCL), and many other names and titles. This paper begins with an overview of this rich research tradition to date, and of its relation to metadata and relevant standardization activities. It then considers the use of these communication and collaboration technologies in educational settings and software systems. It identifies specifiable uniformities in the structural and behavioural characteristics of these systems, and then uses these uniformities as a basis for its proposed data model. This paper then concludes by considering the advantages presented by such a standardized model, which extend from data portability and system independence to new possibilities for automated evaluation or analysis of communication data, and performance.

1. Introduction

Computer Supported Collaborative Learning (CSCL) involves the creation of a networked collaborative learning environment. It can be understood as a subset of collaborative learning [1], and it has been the subject of significant research efforts for two decades or more. Canadian contributions to this work have been prominent, being made under the rubrics of "global" or "learning networks" [2] and more recently, as "knowledge building" and "knowledge technologies" [3]. Connected with the latter is an international group of researchers that has identified its work using the rubric of "CSCL" generally, holding conferences [4; 5] and publishing in a wide variety of forums [6; 7; 8]. As a further example, at this site [5] there are 16 papers for CSCL, which are classified into topics of learner model, role and group, strategy and process, and agent or companion. These researches focus on essential elements for CSCL, but a comprehensive framework of CSCL does not yet appear to have been set forward.

Metadata, or "data about data," that is specifically relevant to collaborative and other forms of learning first appeared in standardized form with the IEEE Learning Object Metadata (LOM) standard [9]. This standard has been developed to facilitate "the sharing and exchange of learning objects, by enabling the development of catalogs and inventories." The apparent tacit assumption behind this approach is that curriculum and learning units will first be designed and developed by different organizations and professionals, and then provided to learners in managed, networked contexts. In order to be used and re-used in such contexts, each digital, educational resource needs to be identified and described in its various attributes in systematic and consistent ways. The LOM claims to provide such systematic means of identification and description.

However, collaborative learning incorporates very different types of learning activities: it provides an environment in which many learners are able to exchange their opinions and information. In theory, "learning" activities occur while reading others’ comments and opinions, and while articulating one’s own. In this case, learning materials are not necessarily provided by e-
learning experts or organizations --as would likely be the case with LOM metadata. Instead, these learning resources are created by learners themselves, and the creation of these resources is itself part of a learning process. Finally, in further contradistinction to the LOM metadata approach, the act of creating these discursive, conversational learning resources necessarily involves the creation of corresponding metadata. Messages exchanged between learners typically contain titles, times and dates of composition, an author name and much more "metadata" information. This already-existing metadata should be captured and structured in the form of standardized metadata, in order to allow for the portability, analysis and even reuse of the data generated in the course of collaborative learning activities.

2. Relevant Researches and Standardizations

Friesen [10] proposes just such an abstract representation scheme for asynchronous collaborative learning activity. He summarizes four top level schemata of “Forum”, “Message”, “Participant”, and “Body”. The “Forum” schema represents a learner group and includes messages generated in the group. The “Message” schema describes the detail of each message. The “Body” schema is linked from “Message” in order to specify the detail of the message. The “Participant” schema gives various attributes for each learner. It also specifies functions that participants can perform on messages and forums. A similar, but further developed set of schemata is proposed in this document.

The IMS Global Learning Consortium has released a specification for a type of metadata relevant to this effort titled "IMS Learning Design" [11], in order to provide interoperability for various products of asynchronous e-learning environment. This specification is based on Educational Modeling Language (EML), developed at the Open University of the Netherlands. This Learning Design specification is based on a very different understanding than that implied in the LOM standard. Learning Design represents an integrated view of learning materials, participants, processes and outcomes, all of which are connected at the highest level of the hierarchical structure underlying this specification. However, on lower levels of this same hierarchical structure, the interrelationship between these central elements is lost. As a result, it is difficult to describe collaborative learning processes, participants and materials together and in significant detail generated using this descriptive framework.

ISO/IEC JTC1 SC36 (Learning Technology) began the data standardization of learning materials, learner information and learning environments of synchronous and asynchronous learning support systems in 2000. Now in 2004, there are seven working groups. There are currently two projects underway in the second of these groups, mandated to develop standards in the area of "collaborative learning"; one is named “collaborative Workplace”, the other “Learner to Learner Interaction Scheme” [12]. In both projects, discussion has just started in the context of the development of preliminary documents called "committee drafts."

The Collaborative Workplace project [13] represents an information scheme to register, archive and acquire a range of information related to collaborative learning. The Learner to Learner Interaction Scheme project focuses on the representation of dynamics within collaborative learning activities. [13] It enumerates five attributes for a collaborative workplace (CW) metadata:

- “CW ID”
- “CW Name”
- “Group ID”
- “Resource ID” and
- “CW Log ID”.

It also clarifies six attributes for CW log metadata:

- “Time Stamp”
- “CW ID”
- “Group ID”
- “Trigger ID”
- “Resource ID” and
- “Description”.

These attributes of metadata are mostly general purpose and specific options or values are expected to be identified in each implementation.

The Learner-to-learner Interaction Scheme project [12] specifically targets "interaction" between learners in collaborative learning. In the Committee Draft document, it proposes twelve attributes:

- “Learner ID”,
- “Comment on Learner”,
- “Learning Objectives”,
- “Expected Results”,
- “Learning Activities”,
- “Evaluation Methods”,
- “Expected Group Size”,
- “Group Structure”,
- “Environment”,
- “Duration of Learning”,
- “Facilitators”, and
- “Members”.

Kim [14] has more recently introduced metadata for collaborative work and learning specific to video editing and authoring activities. These activities are represented in a variety of media (video clips, audio, captions, annotations etc.) and roles (creator, editor, contributor etc.). Tamura et al. [15] have also very recently proposed their metadata, namely CLEM (Collaborative Learning
3. CSCL Related Environments and Tools

Internet technologies that support the interchange of messages, remarks or other forms of written or audio (or even multimedia) expressions are typically divided into two types: synchronous and asynchronous. Both are used in a wide variety of collaborative learning contexts, and are described using a broad range of terms, platforms and theoretical frameworks. Asynchronous systems have been labeled "bulletin boards"[17]"computer conferences" [18], "learning networks" and "discussion" [19] or "knowledge forums." They have been understood in terms of "distributed decision-making"[20] "knowledge construction" [21] and "communities of inquiry" [22], to name just a few theoretical frameworks. Systems supporting synchronous communication have been labeled "ICQ" [I seek you] and "IRC" [Internet Relay Chat]. These “messaging technologies” support communication activity that is referred to also as "texting" when it occurs on mobile phones. Although this messaging is more frequently associated with informal communication, it is becoming increasingly important in m-learning, and as an adjunct to video or audio communication.

These communication technologies, and the turnkey instructional management systems in which they are frequently integrated, are widely used in a variety of educational settings and organizations today. WebCT, for example, includes multiple, asynchronous "discussion" forums and a synchronous "chat" application. It is available in 14 languages, and is used by "thousands of institutions in more than 80 countries worldwide" [23]. Similarly, Blackboard, has a "discussion board," and combines its "chat room" with a shared "whiteboard," and a "question and answer panel" component. Blackboard has been adopted "at 3,000 Institutions in 140 Countries" [24]. First Class has a similarly international customer base, and provides a highly customizable discussion tool, along with "real-time" chat. Edutools (http://www.edutools.info) ranks dozens of other commercial and open source systems that incorporate "discussion forums" and "chat" technology, and there are also many more stand-alone tools available [25].

4. Collaborative Learning Metadata

Despite the variety of software and ways in which their educational efficacy is understood, these systems manifest specifiable uniformities in their underlying structural and behavioral characteristics. The most basic of these commonalities is represented by "messages" (textual, multimedia or otherwise) possessing titles, which are both arranged systematically (e.g., sequentially or thematically), and are associated with contributor names (e.g., actual or pseudonymous). Further shared characteristics are:

- Expressions that are composed, shared and organized over specifiable periods of time: usually minutes or hours for asynchronous communication, usually days, weeks or months for synchronous forms;
- Participants/authors who are identified in some manner, have permissions associated with them (e.g., defining them as moderators, or in groups/subgroups), and can undertake specifiable actions (e.g., viewing and composing expressions, composing and viewing expressions);
- Expressions that can identify new topics, reply (recursively) to previous expressions, and be thus hierarchically organized or structured;
- An organizational hierarchy or structure that can be extended, either to a higher level of generality (to include, for example, forums and sub-forums), or a lower level of specificity (attachment, link, elaboration, counter-argument); and
- Expressions that can also be organized by date, author, title and through the use of a variety of other labels and criteria, chosen by the
participants, or the moderator and/or enforced by the system.

The data-structures underlying these commonalities can form the basis of a common, generalized and abstract model. Such a model, when further refined and tested, has the potential to describe the structures and actions arising in these communication systems, and could also be adaptable, extensible, and capable of simplification. Together, the data elements that make up this abstract data model can be said to represent structured data or "metadata." They take the form of attribute/value pairs, with multiple and semantically rich interrelationships. (Such metadata is, of course, much sought after in recent work on learning objects, repositories and the semantic Web in general.) The data-structures underlying these commonalities can be expressed as a UML (Uniform Modeling Language) static structure. Such a common, generalized and abstract model, when further refined and tested, has the potential to describe the structures and actions arising in these communication systems.

The proposed model in Figure 1 is composed of four classes --environment, participant, expression and (expression) body. The class "expression" lies at the center, linking the others together. Its salient attributes include title, time sent, identifiers for associated expressions, and for assigned participant, body and environment.

The environment is listed as a metaclass, meaning that it is capable of being instantiated in the form classes and sub-classes, with (for example) a general environment containing a number of rooms, and with each room, in turn, containing multiple areas for separate communication groups or processes.

The participant component lists attributes that would be typically included in user log-in information in a turnkey system such as WebCT, and that would constitute a subset of data elements defined or permitted by a learner record system or specification, such as the IMS Learner Information Package.

An expression body, finally, allows for the expression content (which could, for example, be text, audio or multimedia), and links and attachment identifiers associated with the expression.

These four classes are related in the following ways:

- The attribute “ID” of class “Participant” links to the attribute “Participant_ID” of class “Expression”.
- The attribute “ID” of class “Environment” links to the attribute “Environ_ID” of class “Expression”.
- The attribute “Content” of class “Content” links to the attribute “Body_ID” of class “Expression”.

5. Benefits

Together, the data elements that make up this abstract model can be said to represent structured data or "metadata." They take the form of attribute/value pairs, with multiple and semantically rich interrelationships. (Such metadata is, of course, much sought after in recent work on learning objects, repositories, and the semantic Web in general.) As Barros and Verdejo [26] explain, "computer mediated collaborative learning [in general allows for] the recording of a large amount of data about the interaction processes and the task performance of a group of students. This, in turn, can provide empirical data [which] is a very rich source to mine for a variety of purposes."

Some purposes are of a pedagogical nature, such as the improvement of peer awareness on the on-going work. Other, more specific purposes and applications include pattern and network analyses [27], concept or "dialog" mapping [28], latent semantic analysis [29], and syndication [30]. Still further potential benefits include data preservation for legal and regulatory purposes, and the transfer of structural templates and other resources from one system to another. (In collaborative systems, such templates or structures can be specified in terms of forum/sub-forum structure, group memberships, participant permissions, etc.)

These benefits, however, can only be realized if the structured data generated by collaborative learning systems can be represented in a manner that is system-independent such that it can be extracted and made portable and reusable (See Figure 2).

The proposing metadata has two types of advantage to comparing with preceding researches and specifications. One is to provide detailed data of utterances and activities. The metadata in Figure 1 provides detailed
attributes of “Expression”. For example, the attribute “Environ_ID” specifies the type of target activity and media type of learner’s outcome. Also, “Reply_To_ID” helps to trace semantic relationship between learners’ utterances and activities. These attributes are implicitly provided in e-mail environment, but the proposing metadata has characteristics that these attributes, not only described above, are essential to describe collaborative learning activity. The other advantage is that the proposing metadata provides to record dynamics of the activity. In collaborative learning, many topics and threads are discussed concurrently in one learner group, and many topic branches are generated. In order to analyze this structure, just the attribute “Time_Sent” of class “Expression” is not enough. In this case, the additional attributes of “Reply To ID”, “Relation Attrib”, and “History” are useful. There are some preceding researches to generate topic tree from CSCL utterances, but they do not mention what attributes should be provided to generate the topic tree.

6. Conclusion

By simultaneously enabling a wide variety of functions and leveraging their common characteristics, the standardized model proposed in this paper has the significant potential to increase the interoperability, sharing and reuse of collaborative educational applications and resources. This model extends data portability while supporting system independence. And it facilitates the automated evaluation or analysis of communication data, and performance.

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**DIGOL—A System for Mining Learning Objects from the Web for E-Learning**

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**Abstract:** Learning objects are believed to be essential parts of e-learning systems. It is also believed that one day we can simply pick up learning objects from learning object repositories to make new courses. As such, over the years many people have invested huge amount of their time and money on developing standards for marking up learning objects and designing learning objects repositories. There is one big question unanswered: who is going to put learning objects in learning objects repositories and how? In this paper we present an elementary system that is designed to help discover learning objects from the Web, and generate entries of learning objects in a learning objects repository based on the discovery.

**Keywords:** data mining, Web mining, learning objects, e-learning

**Introduction**

The purpose of this project is to investigate ways in which data on the Internet can be mined and turned into learning objects according to some well established standards [1]. The most challenging part is analyzing and extracting the information the user wants. The volume of data (web pages) on the Internet makes this a very time consuming task due to the limitless ways information can be represented. If we have a system that can search the Internet and automatically build a learning objects repository then it would be valuable to learning institutions.

**1.1 Background**

Traditionally, textbooks have been used to represent a concept or set of concepts to be learned. One of the disadvantages of textbooks is that they often do not exist in digital form so that they can be searched and accessed for use in an online learning environment. A learning object is a component in an e-learning system. Similar to a textbook a learning object represents a concept or set of concepts to be learned. However, unlike a textbook, a learning object is designed to be reusable so that course authors can build courses from these objects.

The General Architecture for Text Engineering (GATE) [4] is one of the best-known tools for text analysis and includes a variety of features such as annotation and named-entity tagging. Although GATE was not particularly designed to classify documents it may be used for such purposes due to the integration of some of its machine learning algorithms with the Waikato Environment for Knowledge Analysis (WEKA) [5]. WEKA is a toolkit that implements machine algorithms that can be applied to text classification problems. WEKA was chosen for this project because of its classification algorithms (GATE was not used). This project uses only a small subset of the very basic and fundamental features in WEKA. There are many directions that may be taken with WEKA; we hope that our basic implementation sparks more interest in how this technology may be applied to mining learning objects.

**1.2 Scope of Mining Activity**

This system searches the Internet for web pages using a keyword (or phrase) the user supplies and a search engine (such as Google). These web pages (a.k.a documents or objects) are placed into a temporary location called "Unclassified". These objects are referred to as "Unclassified" because they have not been assigned a topic. Once a topic is assigned to an object it becomes known as a "Classified" object and is placed into a location called "Classified." There can be only one topic assigned to a particular object. The
user defines the topics in the system and they form a hierarchical (tree-like) structure.

The user can do one of two things with an "Unclassified" object. The user may either manually assign a topic to the object or ask the system to determine the topic. If the user asks the system to assign a topic to an object (i.e. classify the object) the system will compare the object to a predefined set of training objects to see which training object(s) it resembles the most. The training objects are flagged as if they have been pre-classified (assigned a topic) by the user. The training objects serve to train the system to recognize objects of a particular topic (class). The system uses the machine learning algorithms implemented in WEKA to assign probability for each topic for the object in question. The system then shows the user the top 5 topics and the user can then choose one to assign to the object. Once a topic has been assigned to an object it can be exported to XML for import into a learning objects repository.

2. The design of the system

2.1 Overview of Information Processing in Digol

In this section we will describe some important steps in which learning objects are discovered.

a) Building the Topic Map
A topic is a subject or category. In this paper, the terms topic and class mean the same thing. A topic map is a collection of topics organized in a hierarchical manner.

Before this system can be used a topic map must be built. The user creates the topic map using the interface. The topic map is shown to the user in a similar way that Windows's Explorer shows folders to a user in MS-Windows. Once the topic map is created, the user may modify (maintain) it at any time.

b)Searching the Internet
This process involves searching the Internet for links or URL's (Uniform Resource Locators). The user initiates this process by typing in a keyword or phrase to search for on the Internet and the system will use a specific Search Engine (like Google) to perform the search. The result of this search is a list of links. If the user chooses to search with Hotbot, for example, the results would be equivalent to navigating to http://www.hotbot.com in a web browser, typing in the search phrase and clicking on the "Hotbot" button to start the search.

c) Retrieving (saving) objects from the Internet
Once the Internet has been searched for links, the next step is to save the contents of the links locally on the file system. At this point the user is given the option of selecting the individual links that he/she wants to save. If a link points to a web page (which it most likely does) saving the link locally would save the contents of the complete web page to the user's hard drive.

d) Classifying the Objects
Once the objects have been retrieved from the Internet they need to be organized. After an object is saved it is unclassified by default so it does not have a topic assigned to it. An object may be classified in one of two ways. Either the user classifies the object or the user asks the system to classify it. The system can only be asked to classify objects that contain text. An image, for example, does not contain text per say so it cannot be automatically classified by the system. If asked to classify an object, the system will compare the text of the object to the text in each training object. It will use the machine learning algorithms in WEKA to perform this task. The system will determine how "similar" the object is to the objects in the training set and then present the user with the top 5 topics the system thinks the object may fall under. At this point the user can choose one of the topics and assign it to it. If there are no training objects in the system then the system cannot classify any new objects until the training set is created.

e) Training the System
To train the system the training set must be identified first. The user identifies the training set by flagging certain classified objects as training objects. If there are no classified objects in the system then the user must manually classify some first. After the training set has been identified, the system can be trained with this set by clicking on a button. The system will remember the knowledge it has "learned" from the training session.

f) Exporting the objects metadata to XML
Before exporting an object's metadata to XML language the user can manipulate the metadata. At the time of this writing the only metadata field that can be edited is General.Title.
system the General.Title field is referred to as the "Name" of the object. The metadata that is generated that can be exported from this system is limited. The purpose of providing an export to XML is so that the object can be imported into a learning objects repository.

Diagrams in Figure 1,2 and 3 show the activities of the system.

Figure 1: Search and Retrieval

Figure 2: Train System

3. The implementation of essential technologies and processes

3.1 Search and Retrieval

The Search Process

There are three search engines implemented in this system; Google, Hotbot, and WebCrawler.

The Google API uses SOAP to query Google and provides a simple interface for using the Google search engine in Java. The Google API is free for use but in order to use it one must obtain a key from http://www.google.ca/apis/. A key entitles you to run 1000 queries against Google everyday. Google pages the results out and one must run a query to obtain the results for each page. With the API, the maximum number of links that can be retrieved with one query is 10 so the maximum number of links that can be queried from Google on a daily basis is $1000 \times 10 = 10,000$.

Unlike Google, Hotbot and WebCrawler are queried directly without the aid of an API. Consequently, the number of links that can be retrieved from these search engines on a daily basis is not limited. The Java networking classes are used to formulate a HTTP GET request with all the criteria for the search encoded in the request. Each HTTP request (query) retrieves the results for one page. Each page is then parsed using custom classes and regular expressions (HTMLParser is not used). The same technique is used for querying Hotbot and WebCrawler. The major difference is that WebCrawler queries will take 10 times longer to run than Hotbot queries. The reason for this is that each WebCrawler link points to a web server that redirects the browser to the real link.
WebCrawler is implemented this way most likely to keep track of how many times a link is clicked in the browser. For this reason a HTTP HEAD request is required for each link retrieved from WebCrawler so that the real link can be noted. Consequently, for performance reasons, it is not recommended that WebCrawler be used in this system with a 56K dialup connection.

Retrieval Process
The output of the search process is a set of links (URLs). Retrieving the contents from these links involves saving the contents of the links to the local hard drive. If a link points to a web page then the entire web page would be saved. This includes any style sheets, JavaScript files, and images that may be used in the web page. The pages are saved with the aid of software developed by the Open Source community called HTMLParser. HTMLParser provides the means to parse HTML. Saving a page involves parsing the HTML, resolving all relative links to absolute links, saving external files linked in the page (such as images etc.), rewriting the HTML with the modified links, and then saving the modified HTML.

Only text/html and text/plain web pages can be saved. Images used in a web page that are more than 10K are treated as separate objects in the repository. That is, if a web page contains an image that is more than 10K in size the system would generate two entries in its repository, one for the web page and one for the image. In this manner images are brought into the repository.

3.2 Knowledge Modelling with Topic Maps
The topic map is represented in the system as a hierarchical structure. To the system, the only possible association a topic can have to another topic is a parent-child relationship and this is a one-to-many relationship. A topic cannot have, for example, two different parent topics. The topic map, in the formal sense according to the standard XTM (XML Topic Map) specification has not been implemented. This may be a feature for future expansion. The machine learning algorithms used in this system also have no knowledge of the topic map. To the algorithms, each topic is distinct and independent of every other topic. The fact that a topic is a sub-topic of another topic has no meaning to the classification algorithms.

3.3 Web Mining Strategies

a) Text Classification
Text classification \[6][11][12] has been an area of research for decades. It involves research areas including Machine Learning (ML) \[5][7][14], Natural Language Processing (NLP) \[13], data mining \[4][10] and even fuzzy theory \[15]. NLP takes a more semantics-based approach while ML takes a more statistics-based approach. A Machine Learning approach to text classification was chosen for this project due to the availability of the classification algorithms in the Waikato Environment for Knowledge Analysis (WEKA).

b) Training the System
In this system, the examples that the classification algorithms use to learn from are called the training objects. The training objects form the dataset that is used to "train" the system. The purpose of training the system is so that the system can be used to classify new objects. The training objects are fed into a classifier (i.e. a classification algorithm). Depending on the algorithm used, the classifier then learns or gains knowledge from the training objects so that it can recognize (classify) a new object based on what the classifier has learned from the training objects and how similar the object is to the training objects.

c) WEKA's Standard ARFF format
The WEKA classification algorithms handle structured data only (not free-form text). WEKA uses the terminology concept, attribute, and instance. A concept is what needs to be learned (it is the knowledge to be gained from the training data). The training data is organized in a table-like structure that contains attributes (columns) and instances (rows). The format of this structure is defined in WEKA's ARFF (Attribute-Relation File Format) specification. This system prepares the training objects so that they can be used in WEKA. This involves processing the training objects into the ARFF format. As mentioned earlier, only objects that contain text (such as a web page or text file) can be used as training data. The following is a typical ARFF file (also known as a relation):

```plaintext
@relation foodtypes
@attribute doc string
@attribute class {junkfood, goodfood}
@data
```
"these potato chips are fattening chips", junkfood
"this hamburger is greasy", junkfood
"fatty foods are really really", junkfood
"blimpie sells low-fat subs", goodfood

The name of this relation is "foodtypes". It contains two attributes, one called "doc" and the other called "class". The "doc" attribute is a string and the "class" attribute is a list of values (it is nominal).

d) Getting the Text from the Training Objects
Before the training objects can be processed into WEKA's ARFF format the text from the objects must be extracted. The text from web pages is extracted with the help of software developed by the Open Source community called HTMLParser. The text from text files is extracted as is. Once the text is extracted it is filtered. This process (referring to as "pruning" in this system) involves removing stop words (such as "a", "the" etc...) and stemming words to their roots. For example the words "call", "calling", "called", and "calls" would be reduced to "call". This system is currently limited to English language. The text is filtered using software developed by the Apache Software Foundation called Apache Jakarta Lucene.

e) WEKA's Sparse ARFF format
Once the text has been extracted and pruned from the training objects it can be readily converted into WEKA's standard ARFF format. The output is a relation that contains two attributes. The first attribute is a string that identifies the text. The second attribute is the ID of the topic that the text was classified under (each topic in the system is identified by a unique ID that is generated by the system). Each instance in the relation represents the text and topic (class) from one training object. Once the training objects are converted into the standard ARFF format they are converted into the sparse ARFF format. WEKA contains a filter, called StringToWordVector that performs this task. The words in the text become the attributes and the data consists of word counts. The objective of the sparse ARFF format is to reduce storage requirements by not storing values that contain a 0. If a particular word does not appear in a particular instance it has a count of 0 and therefore is not represented in the sparse relation. For example, the "foodtypes" relation above would be transformed into a sparse relation as follows:

```
@attribute class {junkfood, goodfood}
@attribute are numeric
@attribute bad numeric
@attribute chips numeric
@attribute fattening numeric
@attribute fatty numeric
@attribute foods numeric
@attribute greasy numeric
@attribute hamburger numeric
@attribute is numeric
@attribute potato numeric
@attribute really numeric
@attribute these numeric
@attribute this numeric
@attribute blimpie numeric
@attribute low-fat numeric
@attribute sells numeric
@attribute subs numeric
@data
{1 1,3 2,4 1,10 1,12 1}  {7 1,8 1,9 1,13 1}  {1 1,2 1,5 1,6 1,11 2}  {0 goodfood,14 1,15 1,16 1,17 1}
```

The first instance \{1 1,3 2,4 1,10 1,12 1\} represents the text "these potato chips are fattening chips." The pairs of values in the instance are of the form attribute-index [space] attribute-value. The attribute-index is zero-based. The attribute-value in this case is a count of the number of the times the attribute (which is the word) appears in the text. The order of the words in the text is lost in this transformation process as only the count of each word has meaning. The words in the text "these potato chips are fattening chips" have the following properties:

- are -> index 1 appears 1 time
- chips -> index 3 appears 2 times
- fattening -> index 4 appears 1 time
- potato -> index 10 appears 1 time
- these -> index 12 appears 1 time

So we have the sparse instance \{1 1,3 2,4 1,10 1,12 1\}. The values that the class attribute can assume are indexed ("junkfood" has an index of 0 and "goodfood" has an index of 1). Since the potato chips sentence is classified as "junkfood" the value of the class attribute for this instance is 0. Since the value of the attribute is 0 it does not appear in the instance. This example is not entirely representative of the way a sparse relation is created in the system because it contains stop words (such as "the") and the words have not been stemmed. The set of attributes in the "foodtypes" sparse relation consists of a unique list of words that appear in all the texts taken together. The number of
attributes can only increase with each new instance.

f) Training the System
Once the training objects have been transformed into a sparse relation (sparse ARFF format) the relation is fed into a WEKA classification algorithm. This process is referred to as building the classifier and simply means that the classifier is being trained. The WEKA algorithms provide the means to do this. Once the classifier has been trained, the system serializes (saves) the results of the classifier to a file on the user's hard drive. Saving the results of the training process enables the system to remember what has been learned so it does not have to be re-trained every time the program is opened.

g) Classifying a new Object
Classifying a new object involves determining a topic to assign it to. The WEKA classifiers (algorithms) used in this system are referred to as distribution classifiers. This means that once the classifier has been trained it can be used to determine what is called a class distribution for a new instance. The class distribution is simply a list of all classes (in our case topic IDs) along with a probability value of each that indicates the likelihood that the given instance belongs to the particular class (in our case topic ID).

Before a new object can be classified it must be transformed into a sparse instance. The text from the new object is extracted and pruned in same way that the text is extracted and pruned from the training data. The words in the text contained within the object become the attributes and the value for each attribute is a count of the number of times the word appears. The attribute list used is the attribute list from the sparse relation that was used to train the classifier. So the resultant sparse instance that is created is ultimately dependent on the sparse relation for the training data. The consequence of this is that if there is a word in the new object that is not modelled (does not appear in the training data) it cannot be counted because there would be no attribute to represent it with then. WEKA's StringToWordVector filter is not used to transform the new instance to a sparse instance is to apply the filter to the entire training set plus the new instance. As this would use more system resources it was decided that it would be more efficient to manually transform the new instance into a sparse instance.

After the new object has been transformed into a sparse instance (that relates to the sparse relation for the training data) the WEKA classifier is used to determine the class distribution for the new instance. Once this process is finished, the top 5 classes (topic IDs) in the class distribution are chosen according to the highest probabilities and these are then shown the user.

h) The Algorithms
There are three types of algorithms implemented in WEKA that are made available in this system. The implementation of these algorithms in WEKA is much more detailed than what is discussed in this document.

1) Naive Bayes
Naive Bayes is a popular algorithm that is based on probabilities. It is naive in the sense that it assumes that each attribute is independent of each other and of equal importance. Take the following dataset of a survey from a movie theatre:

<table>
<thead>
<tr>
<th>Preference</th>
<th>Actor</th>
<th>Liked Cast Away</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adventure</td>
<td>Tom Hanks</td>
<td>No</td>
</tr>
<tr>
<td>Comedy</td>
<td>Tom Hanks</td>
<td>No</td>
</tr>
<tr>
<td>Drama</td>
<td>Tom Hanks</td>
<td>Yes</td>
</tr>
<tr>
<td>Adventure</td>
<td>Tom Hanks</td>
<td>Yes</td>
</tr>
<tr>
<td>Adventure</td>
<td>Tom Hanks</td>
<td>Yes</td>
</tr>
<tr>
<td>Drama</td>
<td>Tom Hanks</td>
<td>Yes</td>
</tr>
<tr>
<td>Comedy</td>
<td>Helen Hunt</td>
<td>No</td>
</tr>
<tr>
<td>Comedy</td>
<td>Helen Hunt</td>
<td>Yes</td>
</tr>
<tr>
<td>Drama</td>
<td>Helen Hunt</td>
<td>Yes</td>
</tr>
<tr>
<td>Adventure</td>
<td>Helen Hunt</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Each person was asked to choose a preference for movie type, their favourite actor, and whether or not they liked Cast Away. In this example, we want to use the above information to predict whether or not a person will like Cast Away based on their movie and actor preference. From the above data we can determine the likelihood for each of the attribute values as follows:
Preference  Liked Cast Away
Adventure   3/4 yes, 1/4 no
Comedy      1/3 yes, 2/3 no
Drama       3/3 yes, 0/3 no

Actor       Liked Cast Away
Tom Hanks   4/6 yes, 2/6 no
Helen Hunt  3/4 yes, 1/4 no

If a person likes Adventure movies there is a 3/4 chance that they will like Cast Away based on the training data. Naive Bayes takes these numbers and multiplies them together to predict the class. For example, if a person likes Tom Hanks and has a preference for Adventure movies then the likelihood that the person will:

like Cast Away: 4/6 * 3/4 = 0.50
not like Cast Away: 2/6 * 1/4 = 0.083

The numbers are then normalized as follows:
like Cast Away: 0.50 / (0.50 + 0.083) = .86
not like Cast Away: 0.083 / (0.50 + 0.083) = .14

There is a lot more to the Naive Bayes algorithm that is discussed here but hopefully this discussion provides a simple overview of the algorithm. In the training data for this system, the attributes are the words and the attribute values are the word counts. The attribute values (word counts) in this system are not discretized. That is they are not bucketed or put into ranges of values.

2) Nearest Neighbor
This algorithm calculates a distance metric between the new instance and each training instance. The distance metric is based on a Euclidean formula that takes into account the difference between the values of each attribute. In this system the attributes are the words and the attribute values are the word counts. The general formula is the square root of the sum of the differences squared. For example, say we have the following data:

Instance 1:
attribute: "Canada" occurs 8 times
attribute: "Prime Minister" occurs 2 times

Instance 2:
attribute: "Canada" occurs 6 times
attribute: "Prime Minister" occurs 1 time

A simple distance metric between these two instances may be calculated as:

\[ \text{sqrt}((8 - 6)^2 + (2 - 1)^2) = \text{sqrt}(2^2 + 1) = 2.236 \]

There are other factors involved in the distance calculation not discussed here such as normalizing the attribute values (so that they fall in the range 0 to 1) and so forth. The idea behind Nearest Neighbor is that once we calculate the distance metrics we predict that the class for the new instance is the majority class of the nearest K number of neighbours. If the value of K were set to 5, for example, the algorithm would choose the majority class of the 5 training instances with the smallest distance metrics. Nearest Neighbour is known as a lazy classifier. It is lazy because it does not learn anything from the training data but rather defers all processing until it is called upon to classify a new instance. One disadvantage is that the algorithm must read the entire training set to classify a new instance. However, this "disadvantage" allows for the possibility of the training data to be partitioned to multiple processors/machines for massive datasets. Nearest Neighbour is referred to as an instance-based learner.

3) Support Vector Machines
A discussion of the Support Vector Machines (SVM) algorithm [9] is beyond the scope of this paper. This algorithm was included in the system because it is one of the Distribution Classifiers implemented in WEKA.

5. Discussions

In this paper we presented an idea of mining learning objects from the Web to build learning object repository automatically, as well as the design and implementation of such a mining system. However, there are several limitations to the web mining approach taken by this system. The machine learning algorithms used in this system are limited to acquiring very basic and mostly mathematically derived knowledge from text. That is, the algorithms do not have any knowledge of the structure of language nor do they attempt to acquire such knowledge. For example, as mentioned earlier, the order of the words in a text is lost in the process of transforming the text into WEKA’s ARFF format. However, for text to be grammatically understood the order of the words must be intact. Some sentences, for instance, may assume a different meaning if the order of the words is changed. Information is also lost during the pruning process where words are stripped to their
roots. Expressions in language are also not processed. For example, exclamation and question marks are omitted. Understanding grammar is typically the function of a grammar checker but such understanding would probability be one of the many requirements to classifying text in a manner that involves some kind of understanding. This is based on the assumption that in order to classify text one must be able to acquire an understanding of the structure of the language first.

Perhaps the most notable limitation is that this system does not yet possess any domain knowledge about the concepts, relationships or associations, and applicability (usage) of language. Such knowledge would be required on various levels from words to sentences to paragraphs to complete texts and beyond. For example, the meaning of a sentence is sometimes only understood if taken in a larger context (as in a paragraph or even the entire text). Several questions may be raised at this point. How can this knowledge be represented/organized with constructs that a machine can understand? How can a machine apply this knowledge? This type of knowledge is sometimes referred to as "common sense". This includes not just knowledge about the meaning of language but logical inferences as well. For example, consider the sentence; "Bob is 30 years old and has a son John who is 35 years old". This sentence is grammatically correct but it is logically impossible for a son to be older than his father. Even if we could teach a machine to acquire such knowledge (either by deduction, induction, or pre-programming), there is also the challenge of aggregating it so that it can be used to classify text. In spite of their limitations, the classification algorithms have been generally successful in certain applications. The Reuters-21578 collection of documents has been used to benchmark the performance of classification algorithms.

Beyond the limitations of text categorization, this system cannot be used to classify non-text objects such as images. In order for this system to use the algorithms to classify non-text certain features would have to be extracted from the objects and used in the algorithms. For example, in the case of an image, such features that could be used may be the height and width of the image along with the size of the image file. This information could then be used to train the algorithms. However, one very serious limitation of this approach is that the content of the image is completely overlooked yet the content is what defines the essence of the image. At the very minimum, one would have to come up with a technique to compliment the classification algorithms with an image recognition algorithm.

References

A Distributed Multimedia Streaming Network System

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Abstract—This paper introduces a distributed multimedia streaming network system, which allows many client connections for multiple live and interactive webcastings with presentation synchronization and sharing. The system has an interactive and connection-balancing server and multiple servers-nodes. Each servers-node consists of two servers: a streaming server handles the interactive video/audio streaming with a small delay, and a document server handles the synchronization and sharing of documents. The system is designed for real-time interactive webcasting of international conferences and only requires that presenters and audiences have access to the Internet using standard browsers for participation in the webcasting environment.

1 INTRODUCTION

The use of webcasting services has become increasingly popular in many venues, such as education, commercial training, etc. In order to broadcast a large event, the server system has to have high bandwidth connections and powerful hardware specifications; nevertheless, the number of audience connections will still be limited.

Although multicast webcasting services can allow a large number of audience connections they are still, in practical terms, not very popular because many routers used around the world do not support multicast webcasting services. Consequently, even if a webcasting system uses multicast services, many audiences would still not be able to participate in the webcasting environment.

Therefore, in order to allow much greater audience participation through many more connections, we have developed a distributed multimedia streaming system that contains multiple servers-nodes, each of which is controlled by an interactive connecting balancing server. The system is designed for easy expansion through the addition of more servers-nodes to the system’s environment in order to handle more connections to the system.

2 SYSTEM OVERVIEW

The system uses a Web-based client/server architecture that includes an interactive and connection-balancing server (ICBS) and multiple servers-nodes. Each servers-node in the system has two servers: a video/audio interactive streaming server (VASS) and a document synchronization/sharing server (DSSS) (Figure 1). Each servers-node acts independently within the system; the system environment itself is an independent operating system. Each servers-node is activated when it receives a connection request from the ICBS. The administrator can use any major operating system for each servers-node, i.e., Windows, UNIX, etc.

The ICBS is the main controller unit in the system and has a control server script application installed. This server works as a Web server and contains the system’s database, including system capacity, events information, etc.

The ICBS accepts audience connections and forwards them to available servers-nodes. The server accepts questions or comments from the audience and forwards them to the presenters’ site. The server also has a Web-based user interface that allows the system administrator to book his/her events. If the system administrator utilizes user names and passwords for protection, the server will check audience authentications before forwarding their connections to available servers-nodes.

The VASS can publish and replay the real-time video/audio and document control text streams. In order to handle low-delay media streams, the server has a Macromedia Flash Communication MX 1.5 installed, which can handle up to 500 concurrent connections with a
maximum bandwidth of 100 Mbps. The server performs a replay role in the system when it receives media streams and delivers them to audiences, and it performs a publishing role when it sends the streams to another server.

The DSSS, which is a Web server, has a small program application installed that enables it to share presentation documents in response to participants’ requests. The server stores such documents, e.g., PowerPoint files or image files, in a remote controllable format.

When a publishing servers-node receives a connection request from a replay servers-node, the publishing DSSS sends the documents that will be shared to the replay DSSS. In turn the replay DSSS sends the documents to participants when it receives requests from their sites.

When a session using this system is enabled for the first time, participants need to download Flash Player to their computers (if they don’t already have it), which is detected automatically by their Web browsers. PCs of participants that have high bandwidth connections to the Internet will have better quality audio/video streaming of content.

The presenter’s Web page has a control document menu that allows him/her to turn the document slides, overwrite notes, or highlight important sections or figures. These control commands are converted into a text streams format, which are sent to the system’s environment.

The presenter(s) require a Web cam, microphone, and speakers for his/her PC in order to send video/audio streams to the webcasting environment, while the PCs of audience participants require speakers so they can listen to the presenter’s audio.

The system also includes some suitable tools that allow audience participants to control their reception of the presenter’s video/audio from the system’s replay servers-node.

3 NETWORK CONNECTIONS

Because the system is a Web-based client/server architecture, all participants are connected via the Internet and need only standard Web browsers. There are two types of system connections: server-to-server and client-to-server (Figure 4).

3.1 Server-to-Server Connection

Within the system the server-to-server connection is always established from the publishing servers-node to a replay servers-node. When a replay servers-node receives a request from another servers-node it becomes a publishing servers-node that is connected to the request servers-node.

The server-to-server connection is always a high-priority connection in the distributed system. For example, if there are two simultaneous connections—one from a participant to a servers-node and one from another servers-node to the first servers-node—the servers-node will make the connection with the requested servers-node first and then with the participant. In addition, each servers-node always reserves some available server-to-server connections. At any time, if a servers-node requests a connection with another servers-node, the connection must be established. When a server-to-server connection is established, the connection’s information will be provided to the replay servers-node for backup purposes.

If the publishing servers-node should go down, the replay servers-node will request connection with the next level of servers-node by using the connection’s information. For example, at the 4th Level servers-node the replay server is connected to one of the 3rd Level servers-nodes, which is the publishing servers-node. If the 3rd Level servers-node goes down, the replay servers-node at the 4th Level will request a new connection with the 2nd Level servers-node.

The flow of the server-to-server connection is established from the 1st Level Node to the 2nd Level Node. If the system has more client-to-server connections than the 2nd Level servers-nodes can handle, the system will activate the next level servers-node (3rd Level Node, 4th Level Node, etc.) (Figure 2). In the system, each servers-node is independent of the system and, therefore, the system can handle multiple simultaneous events under the control of the ICBS.
For security purposes, the system has a backup servers-node in case the 1st Level servers-node should shut down. If the backup servers-node is activated, the connections to all audience participants will remain active but the connections to 2nd Level servers-nodes will be transferred to the backup servers-node.

### 3.2 Client-to-Server Connection

The most important connection is the client-to-server connection because of the connections balancing role played by the ICBS. The ICBS always keeps track of the connections to the servers-node for balancing purposes. If there are too many connections for one servers-nodes level the ICBS will activate the next servers-node level. When a participant leaves the webcasting environment, the action will be reported to the ICBS, which will then make space for the next participant’s connection.

There are two types of client-to-server connections, audience-to-server and presenter-to-servers.

#### 3.2.1 Presenter-to-Servers Connection

The presenter-to-servers connection is established when the presenter makes a connection with the servers-node, which is the 1st Level servers-node. There are two scenarios in order to specify the 1st Level servers-node.

In the first scenario there is only one 1st Level servers-node, which means that all connections from presenters are made to the servers-node.

In the second scenario, the system administrator selects the 1st Level servers-node and has to block all other clients’ connections to the servers-node. This scenario is more complicated because it requires that the administrator have more system knowledge in order to book webcasting events.

Our current system uses the first scenario. However, by using two scenarios, the system guarantees that the presenter-to-server connection is always securely established.

If the connection with the server is disconnected because of a network fault, power failure, computer performance, etc., the presenter has to click the “Reconnect” button on their Web page user interface. The system will then reconnect to the 1st Level servers-node; if this connection cannot be established, the system will make another connection with the 1st Back-up Level servers-node.

#### 3.2.2 Audience-to-Server Connection

The connection is always established at the 2nd Level or 3rd Level servers-nodes, etc. When an audience participant connects to the system the connection goes to the ICBS.

Before establishing the connection the server checks the client authentication and, if confirmed, it then forwards the connection to an available servers-node (Figure 3). If the connection is lost, the participant has to click the “Reconnect” button on their Web page user interface. The connection is then redirected to the ICBS and the server will forward it to another available servers-node.
4 TOOLS AND INTERFACES

4.1 Synchronization Audio/Video Streams and Document Sharing

When the presenters open their Web pages they will be connected to the 1st Level servers-node, enabling their media content, such as video/audio streaming and command text streaming, to be sent to the servers-node. The 1st Level servers-node then becomes the first publishing servers-node.

When the first audience participant(s) connects to the webcasting environment system the ICBS forwards that connection to the 2nd Level servers-node, which becomes a replay servers-node. The replay servers-node will then request a connection with the first publishing servers-node. When the request is accepted, the connection is established and the data will be sent over. The data, whether it is a video/audio stream or a document-sharing stream, will be sent from the replay servers-node to the audience’s Web page in near real time (Figure 5).

In fact, there is perfect synchronization of the video/audio stream and the document-sharing stream because the two streams are encoded into one stream under the control of the VASS. After this stream is sent over to audience’s site, it is decoded inside the audiences’ Web page. Then the video/audio stream and document-sharing stream will appear on the audience’s Web page.

![Fig. 4: The System Architecture](image-url)
4.2 Administrator’s System Web-Based Interface

The system is designed for easy scalability. In order to handle more audience connections, more servers-nodes should be added to the system environment.

The distributed system is controlled by system administrators. Therefore, the Web-based administrator system user interface is designed for system registration and event controlling. Of course, the administrator’s authentication is used to secure the system. There are two main user interfaces on the Web page.

4.2.1 System Registration

Two servers, which are installed as Web servers, are required for each joining servers-node. One server has to have Macromedia Communication Server installed for real-time media stream sharing, and the other has to have a small server script application installed. Both servers also require a broadband connection so there can be more connections from audiences than the servers-node allows.

After the administrator sets up the hardware requirements, s/he then has to go to the system Web page to activate the servers-node. The administrator must then fill out some Web forms with the servers-node information that specifies the
servers-node’s capacity, after which the administrator clicks the “Register” button to complete the activation process. The system will automatically generate a user name and password and e-mail them to the administrator to enable him/her to enter the system.

4.2.2 Events Controlling Interface

When the administrator logs in to the system, s/he will see the system events schedule, system availability status, and an events booking interface on the Web page.

4.2.2.1 Events Schedules and System Availability

For each servers-node, the system shows its entire capacity. The administrator can see maximum audiences-connection numbers to each servers-node on the Web page, which also shows the servers-node’s status, i.e., whether or not it is already booked for some events.

When a webcasting event is booked, the event will be listed on the Web page. The administrator will see the event date, event duration, and number of audiences. The administrator can change the information at any time.

4.2.2.2 Event Booking Menu

The system uses a “First Come-First Serve” rule, which means that after the system administrator books an event the system will block other events if they are to take place at the same time and the system capacity can not handle new events.

In order to use the webcasting system, the administrator has to make a reservation for his/her events. There are suitable tools to achieve their needs.

First, the events can be viewed with or without authorization. If the events use an authorization to participate, the administrator has to create a user list. S/he needs to enter the e-mail addresses of all invited audiences into the system database. The system will automatically generate user names and passwords and send them, along with event information and the event URL, to all audiences by using the registered e-mail addresses. The process is done automatically by the ICBS. On the event date, the audience participants can just click on the URL in order to participate in the event’s environment.

Second, the system also needs more information about the events like document sharing, event duration, and the event date. There are some Web forms on the Web page that need to be filled out in order to complete the booking process. When all information is filled out, the administrator clicks on the “Submit” button to complete the booking process. The system will then notify the administrator about the booking event status.

4.3 Participant’s Web-Based Interface

There are two main participants’ Web-based user interfaces: presenter and audience user interface.

4.3.1 Presenter’s Menu Control User Interface

The presenter’s user interface is designed for full control of his/her presentation.

4.3.1.1 Document Sharing Control Menu

While the presenter is giving their presentation, s/he can move from slide to slide, backwards and forwards, or even jump to any slide in the presentation document. At any time the presenter can add or delete a slide from the shared documents. When s/he wants to add a new instance slide into the shared document, s/he can select a background color, and the system will insert a new document slide at the end of the sharing document (Figure 6).

Fig. 6: Presenter Document Sharing Control Menu

4.3.1.2 Document Sharing Interactive Tools Menu

A set of interactive tools allows the presenter to conduct the event more efficiently (Figure 7). First, the reset tool can be used to clean up the instance slide to start a new presentation by clicking the button on the presenter menu. Second, the pen tool simulates a real pen on the virtual board. After activating the pen tool, the presenter can draw a line by pushing a button on the pen, which corresponds to a single click on a mouse, and then dragging it. Third, the highlighting tool simulates the half-transparent marking pen, which the presenter can use to emphasize specific portions on the virtual board. Fourth, the color tool allows the presenter to change the color of the pen and the highlighting tool.
Although webcasting services have become more popular, the number of possible audience connections is still limited, despite the availability of broadband Internet connections and more powerful servers. Multicast webcasting services have been introduced to the webcasting environment in order to handle a large number of audience connections. However, in order to deliver and view the multicast media contents, Internet providers have to update their routers, but the update process is very slow. Therefore, if we use multicast services for the webcasting events at this time, there would be many audiences that could not view the webcasting events.

The proposed system provides a distributed multimedia system, which allows a large number of connections from the Internet. It also provides all the necessary tools for conducting an efficient shared presentation.

The system is going to be implemented with several servers in San Jose, Tokyo and Vélizy (France) for realtime streaming of the annual IEEE International Workshop on Robot and Human Interactive Communication.

Clicking the color icon in the floating menu brings up the color palette, which disappears after the presenter clicks on a suitable color. The thickness picker tool is used in the same way as the color picker to change the pen and highlight size.

**REFERENCES**


Session 4: Cognitive Perception Mechanisms
Chaired by: Dr. Hongxue Wang
Cross-Modal Matching between Tactile Sense and Vision for Different Difficulty Level in the Human Brain: A Study using functional MRI

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Abstract

In cognitive science and the brain functional imaging, it is mostly reported about study of the integrated cognitive function between vision and tactile sense. However, study of the brain function for cross-modal matching between the vision and the tactile senses about the task from which different difficulty level is not yet reported. In this study, we identified the cognitive cerebral nerve mechanism based on two kinds of tasks, the high difficulty level, and the low difficulty level, by the normal subject using functional MRI. The experimental result suggested that cross-modal matching between vision and tactile sense according to the same nerve system regardless of task difficulty, although more information support is required for vision-tactile sense matching with high difficulty.

1. Introduction

Generally, man performs sensation and recognition to an object using various feeling information. The integration of neural signal from different sensory modalities is a prerequisite for many cognitive and behavioral functions. As the cognitive function, it compensates the ambiguity of each sensory information and informational lack and carries out integrated cognition. As for cross-modal matching it is judging whether one kind of feeling information is as same as the feeling information on another kind. The brain study of Monkey, the brain area where two or more sensory information is integrated included intra-parietal sulcus, superior temporal sulcus, pre-motor cortex, prefrontal cortex and superior colliculus [1]. In the study of visual-tactile integration that used spherical ellipsoid by PET [2], brain activities were in postcentral gyrus including intraparietal sulcus, superior parietal lobule, right cerebellum, prefrontal cortex, and thalamus. Banati et al [3], using PET, to make a crossmodal match between a metal arc placed a card (tactile presentation) and one of four circles presented simultaneously on a computer screen in front of the subject (visual presentation), the crossmodal recognition task of visual-tactile integration revealed in anterior cingulate, inferior parietal lobule, dorsolateral prefrontal cortex, insula and superior temporal gyrus. By these experimental results, the cerebral nerve mechanism about the integrated cognition of vision-tactile sense is deeply related to a cognitive task and cognitive difficulty level.

Up to now, for the same cognitive subject and different cognitive difficult levels, study of brain function of visual-tactile integration is not reported. Therefore, in this study, by making length into a subject, we examined tactile-visual matching for different difficulty level about cerebral function and mechanism

2. Materials and Methods

2.1 Subjects

Ten normal male volunteers, aged between 20 and 32 years. All subjects were right-handed. None had previous or present history of significant medical illness. All subjects understand the contents and the purpose of an experiment well.

2.2 Task design

This experiment includes two different difficulty level tasks, that is, high difficulty level task (VT_H) and low difficulty level task (VT_L) for visual-tactile matching task. VT_H is that presented length from vision and tactile sense is almost the same. In this case, it is difficult to judge whether sensory length from vision is as same as sensory length from tactile sense.

VT_L is that presented length from vision and tactile sense has a large difference. In this case, it can judge very easily that presented length is different from vision and tactile sense.
Fig. 1 gives a flow chart for the experiment, and Fig. 2 illustrates the experimental condition.

**Fig. 1** Flow chart of the VT_H and VT_L during the fMRI scanning. In the VT_H, stimulus length from vision and tactile sense is the same; In the VT_L, the tactile stimulus length and visual stimulus length has a remarkable difference (C: control condition, no stimulus)

**Fig. 2** The experimental procedure of visual-tactile matching. The subjects can see the circular stick when presented them on the screen over their head through a mirror. They cannot see their right hand for the tactile stimulus presentation by experimenter.

The cerebral blood oxygen level dependent (BOLD) was measured during three different conditions, that is, a control condition, VT_H and VT_L. The time chart of experiment is shown in Fig. 1. As for a Control state, visual stimulus and tactile stimulus is not presented. In the VT_H and VT_L, visual stimulus and tactile stimulus are presented simultaneously. In the case of VT_H, both presented length is the same. In the case of VT_L, both presented length has a remarkable difference. Each condition (control, VT_H and VT_L) scanned 10 times, and at each time is 3.5 seconds. If control, VT_H and VT_L were made into 1 cycle, then 4 cycles will be repeated.

### 2.3 Tactile stimulus presentation

In order to decrease the effect of a motion of an extra finger as much as possible, we made a tactile stimulus presentation equipment. It consisted of the two same injectors (original length of 7cm), and both are connected with the hose filled with water. Therefore, when moving the quantity of one injector piston at the experimenter side, another injector piston at the subject side is moved by the equal quantity. We used this way present tactile stimulus to the subjects.

If the habituation to the stimulus arises, change of the amount of blood flows will become blunt and detection of areas activated will become difficult. That is, in many cases, the same activity paradigm is repeated continuously, observation shows the tendency, which domains activated to become small [4]. Therefore, in this experiment, while presenting length so that habituation may not arise to subjects, tactile length presented in VT_H and VT_L is changed 4 times at random.

### 2.4 Visual stimulus presentation

The visual stimuli were presented on a rear projection screen in front of the equipment by notebook PC control via projector. Subjects visualized images on the screen by looking through a mirror attached to the top of the fMRI head coil. The visual information of object length used the image of the circular stick of different length whose diameter is 1.2cm.

### 2.5 Experimental process

In VT_H and VT_L, visual information is controlled by the personal computer and projected on screen by projector, and subjects can see vision information when presented them on the screen over their head through a mirror. The experimenter stands beside the subject, and presents tactile information using tactile presentation equipment to the subject while the visual information is presented.

The subject was holding the injector used the thumb and the middle finger of their right-hand during experimenting, and they cannot see their right hand for the tactile stimulus presentation by experimenter. When the tactile information and the visual information are simultaneously presented, the subject was requested to consider in their head, which it is whether sensory length from vision is as same as sensory length from tactile sense. In the control condition (Rest), since stimulation is not presented, subject is required to consider nothing.

### 2.6 function MRI scanning

fMRI was conducted using a 1.5 Tesla MRI scanner system (Siemens, Magnetom Vision) with a standard head coil was used. T2 * weighted time-series images depicting blood oxygen lever-dependent (BOLD) contrast were
acquired using a single shot Echo-Planar Imaging (EPI) was carried out with following conditions: repetition time \( TR = 3.5 \text{s} \), time to echo \( TE = 55.24 \text{ms} \), flip angle = 90°, field of view \( FoV = 256 \text{mm} \), matrix size = 64×64 mm, slice gap = 0 mm. Each slice was 4 mm thick without separation and parallel to the inter-commissural plane. A total 3660 volumes images effective repetition time (\( TR \)) of 3.5 s/volume, the first two images were discarded to allow for stabilization of the magnetization.

### 2.7 fMRI analysis by SPM99

Image processing and statistical analysis were analyzed by statistical parametric mapping (SPM) (Friston et al, 1995a, 1995b) using SPM99 software (Welcome Department of Cognitive Neurology, London, UK, SPM for functional MRI).

In the SPM99, statistics calculation of the BOLD signal change is carried out with general linear mode approach [5]. We hypothesized that the BOLD signal change was accorded to the box-car style, and the box-car style is corrected with hemo-dynamical response function (HRF). Prior to the statistics calculation of SPM99, in order to correct the subject's motion in each session, all volumes were corrected and spatially realigned with respect to the first volume (in all cases, actual head movement was<2 mm) using a least-squares approach. The realigned results were normalized into the standard space of Montreal Neurological Institute (MNI) to allow for group analysis [6]. Furthermore, normalized results were smoothed with 10 mm full width at half maximum (FWHM) Gaussian kernel to the decrease the spatial noise. The results are activated areas, which have the significant BOLD signal change.

Group activation across the subjects was performed using a random effect model. Four contrasts were compared as follows: (i) \( VT_H - VT_L \) \{\( VT_H - \text{Control}\) - \(VT_L - \text{Control}\}\); (ii) \( VT_L - VT_H \) \{\( VT_L - \text{Control}\) - \(VT_H - \text{Control}\}\}; ( iii ) \( VT_H - \text{Control}\); ( iv ) \( VT_L - \text{Control}\). Resulting \( t \)-statistics were normalized to Z-scores for each contrast. The chosen threshold of significant for main effects of conditions was \( P < 0.001 \) and \( P < 0.05 \).

### 3. Results

The results from the group analysis are shown in Fig 3 (\( VT_H - \text{Control}\)) and Fig.4 (\( VT_L - \text{Control}\)), and in Fig.5 (\( VT_H - VT_L\)) and Fig.6 (\( VT_L - VT_H\)). The spatial locations of the significant activation clusters are listed in Table 1 (\( VT_H - \text{Control}\) and \( VT_L - \text{Control}\)) and Table 2 (\( VT_H - VT_L\) and \( VT_L - VT_H\)) with the corresponding Z-scores.

Fig.3 is activated brain area in case \( VT_H \) task compared with control condition (\( VT_H - \text{Control}\), \( p < 0.05 \), Threshold>5.01). The activation was in intraparietal sulcus, angular gyrus, and dorsolateral prefrontal cortex of brain outside side, and in thalamus of brain inside side, and right cerebellum.

Fig.4 is activated brain area in case \( VT_L \) task compared with control condition (\( VT_L - \text{Control}\), \( p < 0.05 \), Threshold>5.01). The activation was in postcentral gyrus, inferior parietal lobule, and lateral occipital cortex.

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**Fig.3** Brain activation map during the \( VT_H \) compared with control condition from group analysis (\( p < 0.05 \), corrected)

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**Fig.4** Brain activation map during the \( VT_L \) compared with control condition from group analysis (\( p < 0.05 \), corrected)
Fig. 5 is activated brain area in case VT_H task compared with VT_L task (VT_H - VT_L, \(p < 0.001\), Threshold > 3.01). The brain outside side, the difference of activation brain region of VT_H and VT_L was not found, and in the brain inside side, activity was accepted in right anterior cingulate gyrus and left calcarine sulcus.

In the brain outside side, the difference of activation brain region of VT_L and VT_H was also not found, and in the brain inside side, activity was accepted in Occipital forceps of corpus callosum.

Table 1. Coordinates of significant activation \((p < 0.05\), corrected) from group analysis for VT_H and VT_L compared with control condition

| Anatomical area (BA) | VT_H-Control \(x\) \(y\) \(z\) \(Z\) | VT_L-Control \(x\) \(y\) \(z\) \(Z\) |
|---------------------|----------------------------------------|
| Thalamus            | \(20\) -60 0 6.59                     |
|                     | \(-20\) -10 0 5.22                     |
| Intraparietal sulcus| \(32\) -62 38 5.66                     |
| Angular gyrus (39)  | \(40\) -54 46 5.61                     |
| DLPFC (46)          | \(40\) 38 16 5.26                     |
| Dorsal thalamus     | \(36\) -70 -26 5.16                   |
| Postcentral gyrus   | \(-36\) -40 68 5.03                   |
| LOC (37)            | \(-40\) -62 0 5.49                    |
| IPL (40)            | \(-46\) -38 34 5.17                   |

("-" = left hemisphere, BA = Brodmann’ Area
DLPFC = dorsolateral prefrontal cortex, LOC = lateral occipital cortex, IPL = inferior parietal lobule)

Fig. 6 is activated brain area in case VT_L task compared with VT_H task (VT_L - VT_H, \(p < 0.001\), Threshold > 3.01). The brain outside side, the difference of activation brain region of VT_H and VT_L was not found, and in the brain inside side, activity was accepted in right anterior cingulate gyrus and left calcarine sulcus.

In the brain outside side, the difference of activation brain region of VT_H and VT_L was also not found, and in the brain inside side, activity was accepted in Occipital forceps of corpus callosum.

Table 2. Coordinates of significant activation \((p < 0.001)\) from group analysis for Comparison of VT_H and VT_L

| Anatomical area (BA) | VT_H-VT_L \(x\) \(y\) \(z\) \(Z\) | VT_L-VT_H \(x\) \(y\) \(z\) \(Z\) |
|---------------------|----------------------------------------|
| Anterior cingulate gyrus (32) | \(16\) 50 12 3.45 |
| Calcarine sulcus    | \(-12\) -90 -6 3.31                   |
| Occipital forceps   | 24 -44 18 4.16                     |
| Occipital forceps   | -22 -30 18 3.90                     |

("-" = left hemisphere; BA = Brodmann’ Area)
4. Discussion

From result of difference between VT_H - Control and VT_L - Control, the brain activity area of VT_H and VT_L are different (Fig.3 and Fig.4). However, from result of difference between VT_H - VT_L and VT_L - VT_H (Table 2), in the brain outside side, VT_H and VT_L activity difference was not seen. These results suggested that, in VT_H, intraparietal sulcus, angular gyrus, right dorsolateral prefrontal cortex, thalamus, and right cerebellum were activated strongly (threshold>5.01), postcentral gyrus, inferior parietal lobule, and lateral occipital cortex were activated weakly (threshold<5.01), and as opposed to VT_H, in VT_L, postcentral gyrus, inferior parietal lobule, and lateral occipital cortex were activated strongly (threshold>5.01), intraparietal sulcus, angular gyrus, right dorsolateral prefrontal cortex, thalamus, and right cerebellum were activated weakly (threshold<5.01).

In the brain inside side, activity of anterior cingulate gyrus and calcarine sulcus was seen during VT_H, and occipital forceps was seen during VT_L.

The calcarine sulcus is located in both sides of primary vision areas, and it is concerned with the initial vision information processing more. By previous study, activity of calcarine sulcus is related to binocular disparity [7].

Because anterior cingulate gyrus (BA32) is deeply related to taking out memory [7], therefore, when recognizing a difficult task, anterior cingulate gyrus was activated [8-10]. In this study, calcarine sulcus and anterior cingulate gyrus supply binocular disparity and memory information for visual-tactile matching in high difficulty level task. That is, more information support is required for visual-tactile matching with high difficulty than low difficulty.

By anatomy, occipital forceps of corpus callosum is the bunch of a fiber, which connects back occipital lobe. We thought that it might be related to regulate and restrain reaction of brain in judging quickly. In VT_L, judgment becomes easy because the difference between visual information and tactile information is very clear. Therefore, in order to control too much cerebral reaction, activity of occipital forceps was activated.

The brain outside side is the center of information processing. It consists of primary sensory area, such as visual area, tactile area, and auditory area, motor area, and association area that performs complicated information processing. In the association area, intraparietal sulcus is related to tactile cognition [11] and generating tactile mental representation [12], right dorsolateral prefrontal cortex plays a cognitive control role [13], inferior parietal lobule often activated by visual, tactile and auditory processing, and lateral occipital cortex is related to integrated processing of vision and tactile sense [14].

Therefore, upon the whole, visual-tactile matching with high difficulty and low difficulty about length have a different nerve mechanism. However, in the brain outside side, it shows the same nerve processing mechanism for visual-tactile matching with high difficulty level and low difficulty level about length from VT_H-VT_L and VT_L-VT_H, and in the inside side, in case VT_H, calcarine sulcus and anterior cingulate gyrus were activated that it is related to information support. For this reason, upon the high order information processing process, visual-tactile matching about length according to the same nerve mechanism regardless of task difficulty, although more information support is required for visual-tactile matching with high difficulty.

The results might be suggested that visual-tactile matching processed information according to the same nerve system regardless of task difficulty, although more information support is required for visual-tactile matching with high difficulty.

5. Conclusions

The study was conducting the identification experiment of brain activity on information processing process about visual-tactile matching of different difficulty level using fMRI and the tactile length stimulus presentation equipment manufactured by myself. From the experiment result, the difference in visual-tactile matching with high difficulty and low difficulty is not found in a brain inside side. However, in the brain inside side, the difference of brain activation region in both was found. The brain outside side is an important region which carries out integrated processing of the information. The calcarine sulcus and anterior cingulate gyrus located in the brain inside side was activated to supply binocular disparity and memory information for visual-tactile matching in low difficulty level task. Therefore, the results suggested that visual-tactile matching processed information according to the same nerve system regardless of task difficulty, although more information support is required for visual-tactile matching with high difficulty.

6. References


Brain Waves Data Mining for Human Multi-perception Activity Analysis

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Abstract

In order to investigate the structure of advanced human brain activities, various brain analysis methods are expected. It has been observed that brain wave data (EEG/MEG) extracted from human multi-perception mechanism are peculiar ones with respect to the specific state or the related part of a stimulus. Based on this point of view, we propose a way of peculiarity oriented mining for knowledge discovery in multiple human brain wave data, without using the conventional frequency analysis method to brain waves. The proposed approach provides a new way for automatic analysis and understanding of human brain waves to replace human-expert centric visualization.

1 Introduction

In order to develop artificial systems which match human ability in specific aspects, it is necessary to investigate human multi-perception mechanism systematically. Although many cognitive and brain scientists have already studied human information processing mechanism of auditory and visual, separately [2, 3, 4], the relevance between auditory and visual information processing needs to be investigated in depth [10].

It is also clear that these results reported, over the last decade, about human visual and auditory information processing, are greatly related to progress of measurement technology. It was only the measurement method which paste electrodes to the scalp to measure the electrical impulses within the brain, and inserting direct electrode in a brain. However, various noninvasive brain functional measurements are possible recently, such as fMRI, EEG/MEG, PET. If these measurement data are analyzed systematically, the relation between a state and an activity part will become clear. Furthermore, it is useful to discover more advanced human cognitive model based on such measurements and analyses. Hence, new instrumentation and new data analysis methods are causing a revolution in both AI and Brain Sciences. Furthermore, the synergy between AI and Brain Sciences will yield profound advances in our understanding of intelligence over the coming decade [9].

In recent papers [13, 15, 16], we have reported an interesting result on modeling, transforming, and mining multiple human brain data obtained from visual and auditory psychological experiments by using the fMRI. However, we observed each method has its own good points and weakness from the aspects of time and space resolution. For example, fMRI is excellent in space resolution, and it is inferior time resolution. On the other hand, brain waves (EEG/MEG) have their own characteristic. Although MEM is excellent in both the time and space resolutions, it is not practical because of the measuring method for giving a crack to a human body. Hence, in order to discover new knowledge and model of human multi-perception activities, individual data source obtained from only single measuring method is not analyzed, but multiple data sources from various practical measuring methods are required.

Furthermore, as the analysis methods of brain waves, frequency analyses, such as spectral analysis [1] and wavelet analysis [5], are the main stream. In recent years, topography has come to be widely used with progress of computer technology. Topography displays on the strength change of each frequency visually. Additionally, as an application of a statistical model [6], the clustering methods [7] are also used widely. Because it is based on the frequency band as the classification of brain waves, so-called the alpha wave and the beta wave.

However, brain surgeons are performing various analy-
ses and judgments from raw data, without filter processing in the case of brain waves diagnosis. It is considered that the analyses and judgments by an excellent doctor are based on the information processing within the doctor own brain. Hence, we can image that some kind of significant features may hide in raw brain waves data.

This paper is concerned to extract significant features from raw brain waves data in preparation for multi-aspect data mining. Our purpose is to understand human multi-perception activities by investigating the feature of brain waves for every state or part. We observe that brain wave data (EEG/MEG) extracted from human multi-perception mechanism are peculiar ones with respect to the specific state or the related part of a stimulus. Based on this point of view, we propose a way of peculiarity oriented mining for knowledge discovery in multiple human brain wave data, without using the conventional frequency analysis method to brain waves. The proposed approach provides a new way for automatic analysis and understanding of human brain waves to replace human-expert centric visualization.

The rest of the paper is organized as follows. Section 2 gives a global view of our methodology. Section 3 describes the design of EEG/MEG visual and auditory calculation experiments. Section 4 introduces our peculiarity oriented mining approach and its application in brain wave data analysis. Then in Section 5, we discuss the experimental results. Finally, Section 6 gives conclusions and further research directions.

2 Methodology

Figure 1 shows a global view of our methodology for multiple human brain data analysis. First, we need to design the experiments for obtaining various raw data from human multi-perception mechanism. The experiments include psychometrics and physiometry by using various powerful instruments such as fMRI to produce three-dimensional images and EEG/MEG (electroencephalogram/magnetoencephalogram) to measure brain’s electrical vibrations (i.e. brain waves), respectively, related to the human subject’s brain activities over time.

The data obtained from the experiments are transformed into the format in which data-mining techniques can be carried out efficiently and effectively, and stored in dedicated databases, respectively. Such databases are called multiple data sources that can be used to discover new models of human multi-perception. Furthermore, the discovered models can be tested and evaluated. Moreover, the process may repeat at different intervals when new/updated data comes and/or the results are not good enough. We argue that the multi-step process is an important methodology for knowledge discovery in the multi-media data obtained from the experiments with respect to human multi-perception mechanism. The proposed methodology attempts to change the perspective of cognitive scientists from a single type of experimental data analysis towards a holistic view.

In the following, we focus on investigating how to obtain multiple data sources by EEG/MEG visual and auditory calculation experiments and how to mine in such data sources.

3 Visual and Auditory Calculation Experiments

In order to study the relevance between auditory and visual information processing in a more advanced information processing activity, we deal with the brain waves data measured by the visual stimulus or auditory stimulus about human’s calculation activities (2-figures addition). Figure 2 shows the time chart of an experiment, in which figure (a) denotes progress of the whole experiment, figure (b) shows the flow in an on-task, and figure (c) shows the flow in an off-task. Each experiment took about 7 or 8 minutes, and we execute each of visual and auditory experiments 3 times, respectively.

Thus, in the experiments, five states (tasks) exist by the difference in the stimulus given to a subject as summarized below.

- **Auditory on-task**: The state which is calculating by hearing a number.
- **Auditory off-task**: The state which hearing the number which appears at random.
- **Visual on-task**: The state which is calculating by looking a number.
4 Peculiarity Oriented Mining

This section introduces our peculiarity oriented mining approach and its application in brain wave data analysis.

4.1 Identification of Peculiar Data

The main task of peculiarity oriented mining is the identification of peculiar data. An attribute-oriented method, which analyzes data from a new view and is different from traditional statistical methods, is recently proposed by Zhong et al. and applied in various real-world problems [12, 13, 14, 15, 16, 17].

Peculiar data are a subset of objects in the database and are characterized by two features:

1. very different from other objects in a dataset, and
2. consisting of a relatively low number of objects.

The first property is related to the notion of distance or dissimilarity of objects. Instinctively speaking, an object is different from other objects if it is far away from other objects based on certain distance functions. Its attribute values must be different from the values of other objects. One can define distance between objects based on the distance between their values. The second property is related to the notion of support. Peculiar data must have a low support.

At attribute level, the identification of peculiar data can be done by finding attribute values having properties (1) and (2). Table 1 shows a relation with attributes $A_1, A_2, \ldots, A_m$. Let $x_{ij}$ be the value of $A_j$ of the $i$-th tuple, and $n$ the number of tuples. Zhong et al. [12, 14] suggested that the peculiarity of $x_{ij}$ can be evaluated by a Peculiarity Factor, $PF(x_{ij})$,

$$PF(x_{ij}) = \sum_{k=1}^{n} N(x_{ij}, x_{kj})^\alpha$$

where $N$ denotes the conceptual distance, $\alpha$ is a parameter to denote the importance of the distance between $x_{ij}$ and $x_{kj}$, which can be adjusted by a user, and $\alpha = 0.5$ as default.

With the introduction of conceptual distance, Eq. (1) provides a more flexible method to calculate peculiarity of an attribute value. It can handle both continuous and symbolic attributes based on a unified semantic interpretation. Background knowledge represented by binary neighborhoods
A gap of a phase. We used the simple moving average of moving average that does not need to take into account attention to the form of brain waves, we applied the method band pass filter (BPF) in many cases. Since we paid our frequency analysis employs a low pass filter (LPF) and a waves data is shown in Figure 4.

The mining process of brain waves data

4.2 The Mining Process of Brain Waves Data

Brain waves data can be regarded as one of time series data with noises. Hence, the removal of noises and the modeling of data are required. The mining process of brain waves data is shown in Figure 4.

Generally speaking, the removal of noises at the time of frequency analysis employs a low pass filter (LPF) and a band pass filter (BPF) in many cases. Since we paid our attention to the form of brain waves, we applied the method of moving average that does not need to take into account a gap of a phase. We used the simple moving average of seven points in consideration of the frequency ingredient after a moving average.

Brain waves data are clustered for every task after noise removal. Furthermore, it is necessary to divide into the valid brain waves data and the invalid brain waves data. It is because eye movement like a blink has remarkable influence on brain waves. If unstable brain waves are used, it will be expected that the result of mining will become inaccurate.

The next important work is the modeling of brain waves data. A problem of using peculiarity oriented mining in time series data is that it will be influenced of a phase. That is, it will be necessary to shift the cut area of each data so that correlation may become strong. Hence, we change the data into 2-variate histogram that makes slope of a line and amplitude in order to leverage the feature of raw data. The visualization of 2-variate histogram is shown in Figure 5.

The histogram vertical axis denotes the class value of amplitude, and the horizontal axis denotes the class value of slope. Frequency of appearance is applied to the numerical value or the shade of color in a cell. The unit of amplitude is μV. A class is designed so that it might go up by -62 to 4 units. And, the unit of slope is μV / 2msec. Another class is designed so that it might go up by -11.7 to 0.6 units. The frequency is denoted with a rate that it can compare equally since each numbers of tasks differ.

There are 120 histograms each subject (i.e. 5 (task number) × 24 (channel number) = 120). In order to investigate how on-task brain waves are different from no-task brain waves, it is necessary to calculate the difference between histograms. For example, the new histogram can be generated by calculating the difference between the auditory on-task and no-task histograms, if we pay our attention to auditory on-task. Thus, the new histograms are utilized as the data for peculiarity oriented mining.

\[
N(x_{ij}, x_{kj}) = |x_{ij} - x_{kj}|. \quad (2)
\]

If \( X \) is a symbolic attribute and the background knowledge for representing the conceptual distances between \( x_{ij} \) and \( x_{kj} \) is provided by a user, the peculiarity factor is calculated by the conceptual distances [8, 11, 12, 14]. The conceptual distances are assigned to 1 if no background knowledge is available.

Based on peculiarity factor, the selection of peculiar data is simply carried out by using a threshold value. More specifically, an attribute value is peculiar if its peculiarity factor is above minimum peculiarity \( p \), namely, \( PF(x_{ij}) \geq p \). The threshold value \( p \) may be computed by the distribution of \( PF \) as follows:

\[
\text{threshold} = \text{mean of } PF(x_{ij}) + \beta \times \text{standard deviation of } PF(x_{ij}) \quad (3)
\]

where \( \beta \) can be adjusted by a user, and \( \beta = 1 \) is used as default. The threshold indicates that a data is a peculiar one if its \( PF \) value is much larger than the mean of the \( PF \) set. In other words, if \( PF(x_{ij}) \) is over the threshold value, \( x_{ij} \) is a peculiar data. By adjusting the parameter \( \beta \), a user can control and adjust threshold value.

### Table 1. A sample table (relation)

<table>
<thead>
<tr>
<th>( A_1 )</th>
<th>( A_2 )</th>
<th>...</th>
<th>( A_j )</th>
<th>...</th>
<th>( A_m )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( x_{11} )</td>
<td>( x_{12} )</td>
<td>...</td>
<td>( x_{1j} )</td>
<td>...</td>
<td>( x_{1m} )</td>
</tr>
<tr>
<td>( x_{21} )</td>
<td>( x_{22} )</td>
<td>...</td>
<td>( x_{2j} )</td>
<td>...</td>
<td>( x_{2m} )</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>( x_{n1} )</td>
<td>( x_{n2} )</td>
<td>...</td>
<td>( x_{nj} )</td>
<td>...</td>
<td>( x_{nm} )</td>
</tr>
</tbody>
</table>

\[
\text{Figure 4. The mining process of brain waves data}
\]
5 Experimental Results

Brain waves data are applied to the 2-variate histograms defined this time. The appearance rate is input into the cell by percentage. In this paper, the depth of a color is changed according to the rate. The relation of the depth of a color and the rate is shown in Figure 6. Since all experimental results are not able to be described in this paper, we showed CZ as an example. Figures 7 and 8 show auditory on-task and off-task, Figures 9 and 10 show visual on-task and off-task, and Figure 11 shows no-task, respectively.

On-task is that both amplitude and slope are narrow scope compared with off-task in a 2-variate histogram. It is clear also from the difference among four figures (Figures 7 and 8, as well as Figures 9 and 10). This phenomenon appeared similarly not only in CZ but also in almost all other channels. This is expected to be related to concentration of the soul at the time of calculation. It is already known that an alpha wave will appear mostly in the time of a closed eye, or the relaxed state. Furthermore, when it concentrates extremely at the time of calculation, it is said that the sheeter wave appears focusing on the frontal lobe. From the amplitude of each channel, and the feature of slope, we are able to check the opinion generally advanced.

The difference of an on-task or an off-task, and no-task
was also calculated about the histogram of each channel. And the peculiarity factors were calculated to each channel. Furthermore, it calculated also about the difference between an on-task and an off-task, and the difference between visual and auditory, and the peculiarity factors were drawn. Tables 3 and 4 show the results of the peculiarity analyses for each channel at the former and the latter of the position of electrode shown in Figure 3. The abbreviations used in the tables are shown below.

- AON: auditory on-task
- AOFF: auditory off-task
- VON: visual on-task
- VOFF: visual off-task
- NO: no-task
- POS: position of electrode
- L: left
- R: right
- F: front
- B: backside
- C: center
- P: peculiarity channel

From the tables, we can see that F7 and F8 channels are judged at almost all results to be peculiar channels. When the histogram was reconfirmed, it becomes clear that the difference of the frequency distribution is larger than other channels. Figures 12 and 13 give a 2-variate histogram to show the visualization of the difference of F8 channel auditory on-task and off-task. By comparing with the difference between Figures 7 and 8, we can see that the difference of F8 channel is larger. Since the two channels are close to an eyeball, it is considered that it is strongly influenced of muscles or an electric signal.

Another interesting result obtained from this subject's brain waves data analyses is that the part judged to be peculiar channel inclines towards right side of the brain in the
Figure 13. F8 channel auditory off-task

difference of auditory on-task and no-task. Conversely, it inclines towards left side of the brain in the difference of visual on-task and no-task. This reason is considered to originate in how to use individual left and right side of the brain. In order to show clearly whether to be a universal result, it is necessary to analyze more subjects' data. Moreover, it was not able to check about the hypothesis:

*auditory information may be transferred into visual information, in some cases of advanced information processing such as calculation*

which obtained from the result of our fMRI data mining [13, 15, 16]. It is necessary to be investigated in depth whether brain waves are the cause and whether individual difference is the cause about this reason.

### 6 Conclusion

In this paper, the amplitude and slope features of brain waves data have been utilized, and the data mining method which paid its attention to the peculiarity between channels has been developed. However, since it is immediately after beginning data analysis, the analysis of two or more subject data has not been completed. Hence, it is necessary to analyze two or more data continuously.

We have to discern carefully whether F7 and F8 channels are peculiar ones. It is necessary to investigate these channels about a different cause from others. The relation between visual and audio, left and right side of the brain is considered that the influence of individual difference is large. If individual difference is taken into consideration, a universal case and a special case also need to be distinguished.

Moreover, it is necessary to adjust the coefficient of the threshold value which judges a peculiarity data, or the class value of a histogram the optimal as an important subject. And the meaning of a difference becomes clearer by clarifying the pattern of a histogram, and the relation of a frequency ingredient. It is possible to obtain a still better result by this feedback work. Although it has not resulted by establishment of a method now, we think that expectation is possible as one of the wave data analysis method.
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