Collaborative Environmental Education Using Distributed Virtual Environment Accessible from Real and Virtual Worlds

Masaya Okada
Graduate School of Informatics, Kyoto University, Kyoto 606-8501 Japan
okada@bre.soc.i.kyoto-u.ac.jp

Hiroyuki Tarumi
Faculty of Engineering, Kagawa University, 2217-20 Hayashi-cho, Takamatsu-city, Kagawa 761-0396 Japan
tarumi@acm.org

Tetsuhiko Yoshimura
Graduate School of Informatics, Kyoto University, Kyoto 606-8501 Japan
yoshimu@i.kyoto-u.ac.jp

ABSTRACT

We have designed and implemented a support system for collaborative environmental education, DigitalEE, which realizes distributed virtual environment accessible from real and virtual worlds. This system introduces the following diverse features into environmental education: global arguments supported by the Internet, giving learners pseudo experiences by virtual reality, supplementing real natural experiences by augmented reality, and giving learners experts' valuable knowledge by distance education. Shared virtual space in the distributed virtual environment is "3D virtual nature", which is a VRML world representing the real nature. Learners learning through direct experiences can enter the 3D virtual nature from the real world with mobile computers, whereas experts and other participants can enter the 3D virtual nature from distant locations with their personal computers. People throughout the world can communicate with each other while sharing the same place virtually between real and virtual worlds. Learners' observation, experts' knowledge, and other participants' information are continuously accumulated in the shared 3D virtual nature as VRML objects and web pages, and the world is being updated dynamically in the learning process. With these ideas, DigitalEE realizes a new style of environmental education such as collaborative outdoor learning supported by knowledgeable experts throughout the world and interactive virtual tours to inaccessible natural environment.

Categories and Subject Descriptors

K.3.1 [**Computers and Education**]: Computer Uses in Education—*collaborative learning, distance learning*

General Terms

Design

Keywords

Distance learning, distributed virtual environment, environmental education, mobile computing, virtual tours

1. INTRODUCTION

Environmental education (EE) is one of the categories of education emerging against the background of diverse global environmental problems and continued destruction of vital ecosystems. Environmental education has had little relationship to information technologies so far, but recent studies on environmental education are noticing the potential of information technologies in environmental education. For example, global communication supported by the Internet such as exchanging, gathering, and releasing information is being considered to be useful for environmental education [13]. However, there are few specific principles to make effective use of such useful communication functions, and many educators have insufficiently practiced and examined environmental education using these functions. GLOBE [5], which is noticed as environmental education program using the Internet and scientific data, has aspects similar to conventional scientific education, and it is under development as environmental education. On the other hand, present environmental education has potential needs for not only a system supporting virtual tours to inaccessible natural environment such as rain forests but also a system helping understanding by supplementing real experiences in visited natural environment [12], but there has been no system satisfying such potential needs. Moreover, distance education is also being noticed because it is cost-effective, and its' principles are well suited for environmental education [8].

Considering potential of information technologies such as the Internet, virtual reality, augmented reality, and distance education in environmental education, we propose a support system for collaborative environmental education. The system digitally realizes environmental education, and is called "DigitalEE (Digital Environmental Education)". DigitalEE has functions realizing global arguments via the Internet, giving pseudo experiences by virtual reality, supplementing real natural experiences by augmented reality, and giving learners experts' knowledge by distance education. It creates a new style of environmental education such as collaborative outdoor learning and interactive virtual tours.

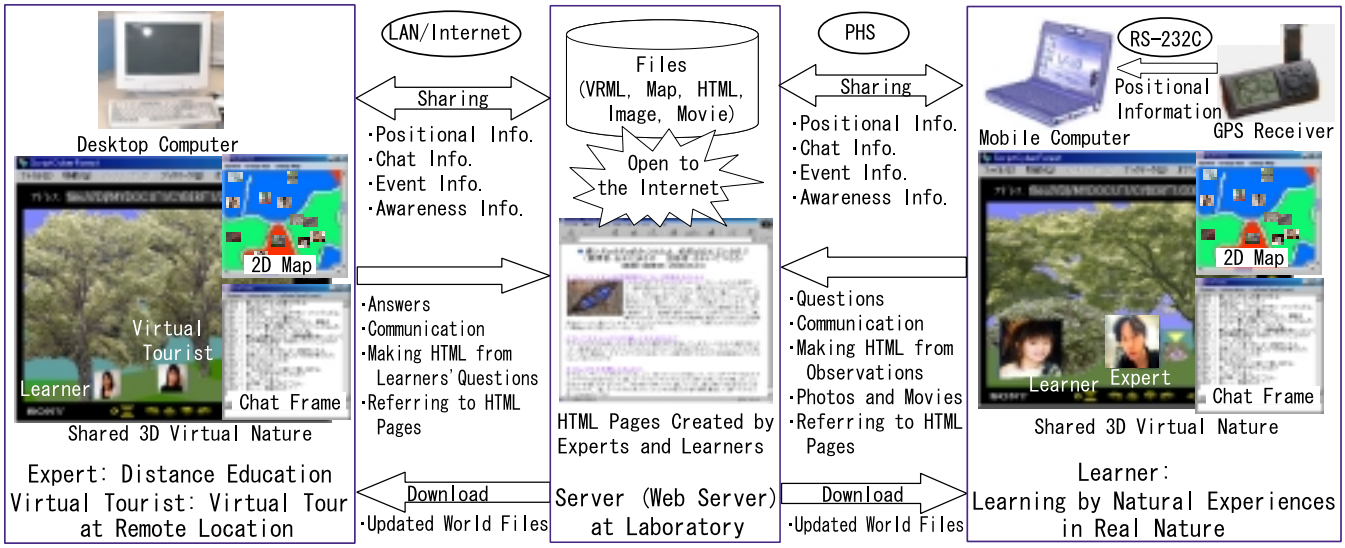

Figure 1: System structure of DigitalEE.

2. IMPLEMENTATION OF DIGITALEE

There are two types of environmental education. One is based on direct experiences like an environmental education program through natural experiences, and the other is based on indirect experiences like learning with books or videotapes. It is obvious that learning by natural experiences is important in environmental education. However, learning by natural experiences without indirect experiences is not environmental education but just a fun. Considering many past failed studies reporting no change of environmental attitude after learning by natural experiences [3, 4], it is quite important to improve quality of indirect experiences supporting direct experiences. On the other hand, environmental education based on indirect experiences is practiced by giving learners indirect experiences such as environmental knowledge and information with educational materials. However, in many cases, general learners can hardly feel abstract concepts as reality. Consequently, environmental education based on indirect experiences often functions as education just forcing knowledge on learners, not as education making learners obtain desirable senses of values. For a solution to this problem, it is necessary to improve quality of indirect experiences themselves and to introduce contexts of direct experiences into environmental education based on indirect experiences. In short, we can never practice effective environmental education without mutual supplements of direct and indirect experiences, and accordingly we emphasize importance of developing a system realizing effective mutual supplements of the two kinds of experiences.

2.1 Implementation Circumstances

We introduce design and implementation of DigitalEE, our developed system supporting collaborative environmental education. The system realizes DVE (Distributed Virtual Environment) [10] accessible from real and virtual worlds by introducing technologies of mobile computing and augmented reality into conventional DVE. DigitalEE is designed with a client-server model (Figure 1), and is implemented with a server computer (OS: Solaris 7, CPU: 333MHz, RAM: 256MB) and five client computers (OS: Window98, CPU: Pentium II 400MHz, RAM: 128MB). Behavior of the system is described with Java (JDK1.1.8 and JDK1.2.2). The model of shared virtual world is described with VRML97, and a free browser, Community Place Browser Version 2.0 (Sony Corporation) is used to display it.

Figure 2: A learner using DigitalEE in real nature.

2.2 Assumption on Practicing DigitalEE

An environmental education program using DigitalEE is carried out by announcing the date and time when the program will be practiced via the Internet and by calling for the following participants throughout the world: learners learning by natural experiences in real nature, experts tele-educating learners at remote locations, and virtual tourists making virtual tours at remote locations. The term "a virtual tour" is defined as visiting natural environment virtually and learning the environment by pseudo experiences. The term "a virtual tourist" is defined as a learner making virtual tours, who has no accessibility to real nature and is unable to learn the environment by direct experiences. For participation in

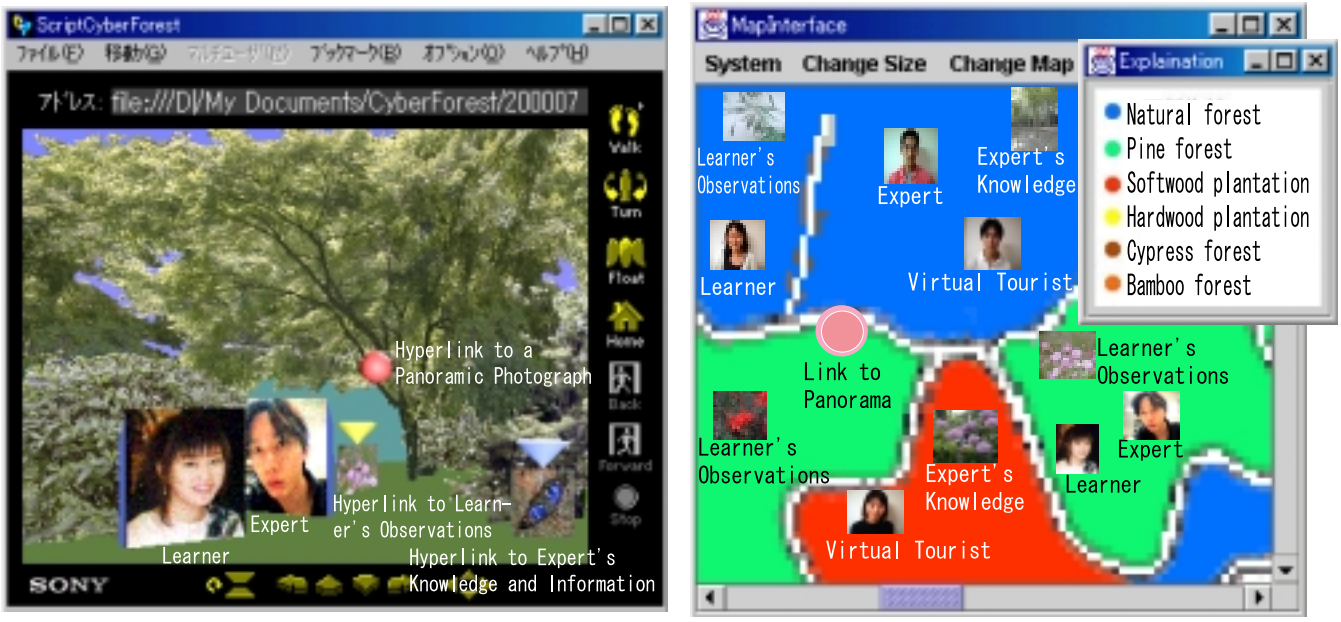

Figure 3: 3D virtual nature (left) and a vegetation map (right).

DigitalEE, learners use a mobile computer equipped with a GPS (Global Positioning System) receiver, PHS (Personal Handyphone System), and a digital camera (Figure 2). On the other hand, experts and virtual tourists participate in DigitalEE by using a desktop computer or a notebook computer that is connected to the Internet.

2.3 An Overview of DigitalEE

Shared virtual communication space in our implemented DVE is "3D virtual nature", which is a VRML (Virtual Reality Modeling Language) world representing Kamigamo Experimental Forest, one of the Kyoto University forests. Not merely learners in the forest but experts and virtual tourists from all over the world can participate in the 3D virtual nature via the Internet. The server controls all clients' information (login/logout, positions, chat, events and awareness), and transmits updated information to all clients as occasion arises. Based on the transmitted information, all participants are drawn as avatars created with their face photographs in both the 3D virtual nature and a 2D vegetation map (Figure 3). It is difficult to express natural environment realistically with VRML, but poor expression ability of VRML is compensated for by panoramic photographs that can be freely seen in all directions (Figure 4). By clicking some particular sphere objects in 2D/3D interfaces, participants can refer to the panoramic photographs, and can get detailed and realistic information about the environment.

Experts and virtual tourists enjoy walk-through navigation in the shared 3D virtual nature, and they are drawn as avatars in the 2D/3D interfaces based on positional information obtained by mouse movement. However, differently from other conventional DVE systems, learners' avatars are drawn at the corresponding position in the 3D virtual nature according to not positional information obtained by a mouse but the positional information sent from the GPS receiver

Figure 4: A panoramic photograph.

via a serial port. In addition to positions of learners' avatars, learners' views from VRML browsers are also automatically moved while synchronizing with learners' movement calculated by the GPS information. Participants in DigitalEE can virtually share the real nature in real and virtual worlds, and can interactively communicate with each other by using a chat frame while identifying each face and position.

Learners observing the environment can send the server photographs and movies taken in the real nature, and can record achievements as HTML pages including both the contents and observations on the web server. Similarly, experts and virtual tourists can record their knowledge and information

about the environment as HTML pages. Since link objects to the HTML pages are being created in semi-real time in shared 3D virtual nature, all participants can freely refer to the HTML pages from shared 3D virtual nature. Participants can find what others are viewing since awareness information is shared. By programs through four seasons, 3D virtual nature becomes to reflect information on four clearly distinguishable seasons such as various plants blooming in only a particular season since learners in the real nature actively record environmental information in the 3D virtual nature in their learning processes. Participants can also observe changes of the environment through four seasons while referring to 3D virtual nature representing other seasons.

2.4 Interaction Among Participants

2.4.1 Learners Really Existing in the Real Nature

Learners observe natural environment while referring to a vegetation map, the other learners' observations being updated in semi-real time, and 3D virtual nature representing other seasons. They ask experts about unknown things by chat, and they record their achievements including realistic direct experiences in semi-real time on the web server.

2.4.2 Experts Virtually Existing in the Real Nature

Experts make answers to participants' questions, and give participants environmental information while referring to observation recorded by learners and information recorded by virtual tourists. They record their knowledge and information, which are thought to be valuable for learners and virtual tourists, as HTML pages in semi-real time on the web server.

2.4.3 Virtual Tourists Virtually Existing in the Real Nature

Virtual tourists interactively communicate with learners and experts while enjoying walk-through navigation, and elicit information on the real nature from them. Virtual tourists indirectly learn the environment by communicating with them and referring to the HTML pages created by them on the web server. They can get both realistic information obtained through learners' direct experiences and valuable information based on experts' profound knowledge.

2.5 Advantage of 3D Virtual Nature as a UI

The topographies of 3D virtual nature were created with DEM (Digital Elevation Model) data, which are gridded elevation data representing terrain, and VRML plant objects were arranged on the topographies under a method suggested by Honjo [6]. Honjo's method is the way to create a VRML plant object from a photograph taken in the real nature by clipping unnecessary background from the photograph, changing it into transparent GIF format, and mapping it onto two crossing thin board objects as an image texture. Conventional methods in computer graphics, which are the ways of modeling plants as polygon models, demand much modeling time of world creators, and require much rendering time of viewers. The Honjo's method can express realistic 3D virtual nature with VRML plant objects based on the real photographs, and it can overcome the unavoidable problems of conventional methods.

The main reason why we chose not 2D panoramic views with some software like Apple's QuickTime VR but the 3D virtual world implemented with VRML as a main user interface is to realize effective learning situations for virtual tourists and smooth communication between learners and virtual tourists. Generally, many objects such as plants, ponds, and bogs exist in the natural forests. Although 2D panoramic views enable users to look around and zoom in/out from one predefined viewpoint, the views makes many invisible objects hidden by other objects. The 2D panoramic views having only two-dimensional information do not enable users to move to the objects' rear and to observe the hidden objects. Even if many 2D panoramic views are prepared, many hidden objects still remain. The 2D panoramic views make it possible for learners to view only places that educators thought important, and they can realize educator-oriented education reflecting educators' intention. However, such education can never support discovery learning, which is substantial in environmental education. For learners, processes finding valuable information by themselves and investigating the environment with interests are essentially required. Thus, 3D virtual nature having three-dimensional information, which enables users to walk around in the world freely and to look around from arbitrary points, has more advantages.

On the other hand, it is important for realization of smooth communication among participants in real and virtual worlds to share communication contexts in both worlds sufficiently. For sharing sufficient communication contexts, realizing a situation of that participants exist at near places virtually and look at the same things virtually is essential. The 2D panoramic views can hardly realize such situation in principle for the reason mentioned above, and they are unsuitable for a user interface.

Adopting 3D virtual world implemented with VRML as an interface for bridging real and virtual worlds makes effective learning situations for virtual tourists and supports smooth communication between learners and virtual tourists. 3D virtual nature can give a sense of being immersed in the virtual nature and a sense of visiting the real nature to users, especially people not having accessibility to the real nature.

2.6 Recording Knowledge in the Shared Space

Learners can simultaneously send the server all the following information: photographs, movies, text descriptions including observations of observed objects in addition to positional information given by the GPS receiver. Like learners, experts and virtual tourists can also send the server photographs, movies and text descriptions including their knowledge and information on the environment. The server is also a web server containing HTML pages with the contents created by all participants such as photographs, movies and text descriptions. In order to enable all participants to refer to the HTML pages from 2D/3D interfaces, the server pastes a photograph given by the participants as an object at senders' existing position in 2D/3D interfaces, and makes a link between the object and the HTML page. To paste photographs in "shared" 3D virtual nature, it is necessary that all participants share only one file of 3D virtual nature and update it in real time to avoid inconsistency. We have realized it in the following way. All partic-

ipants virtually share one file of 3D virtual nature on the server, and when the server gets files from participants, the server exclusively locks the file of 3D virtual nature and inserts necessary VRML codes into suitable positions of it. The inserted codes are the descriptions declaring objects' models and positions, designating necessary files, making a link to a HTML page, and dispatching events to the related Java program. By downloading both photographs and code sections that are not stored locally and reloading them with the browser, participants can get the latest 3D virtual nature with pasted photographs. Therefore, learners can record their own achievements and experts can record knowledge and information, and all participants can share them in semi-real time. As a result, participants can communicate with each other by using the recorded knowledge and information as communication contexts. Incidentally, for discrimination of VRML objects pasted by participants, one of the three kinds of cone objects (learners' observation: a blue cone, experts' knowledge: a yellow cone, virtual tourists' information: a purple cone) is displayed in the 3D virtual nature to point the objects.

2.7 Supporting Awareness

DigitalEE adopted an awareness model using avatars in virtual worlds in order to give awareness information to people in two different worlds, real and virtual worlds. In addition to this awareness model, DigitalEE supports an awareness model mentioned below. When a participant clicks an object, his or her browser shows a HTML page linked by the object, and simultaneously send the participant's ID and clicked HTML page's URL to the server. Since the server controls all the information on the memory, participants can find what other participants are viewing by inquiry to the server. This function supports mutual communication while viewing the same information virtually.

2.8 Seasonal Changes of 3D Virtual Nature

Natural environment is a space constantly changing in time transition. With the passage of time, 3D virtual nature is also dynamically changing while synchronizing with seasonal changes of the real environment. As the server manages 3D virtual nature along a time-axis, participants can view 3D virtual nature representing environmental condition at arbitrary time from a file retrieval window. Knowing past environmental condition and observing seasonal changes of the environment are important for learners to obtain deep and favorable impression [11].

2.9 A Simple Function of Modeling VRML

This system makes it possible to paste photographs taken in the real world at the corresponding position in a 3D virtual world. With this function, we can paste real plants in the 3D virtual world as photograph objects. If we modify them later with an image editor, we can create 3D virtual nature with plants derived from real photographs. In addition, using DEM data can add more detailed information to 3D virtual nature. When DigitalEE is practiced in the future, staff members in schools can construct 3D virtual nature by using this function. In fact, some parts of the 3D virtual nature representing Kamigamo Experimental Forest were actually created with the modeling function.

2.10 Further Development of DigitalEE

2.10.1 Instructing Learners with Tele-Pointer

For effective learning, it is important that experts are able to tell learners what to notice and observe in the real nature. Thus, we are now developing a function that experts at remote locations can instruct learners by tele-pointing at 3D virtual nature and panoramic photographs.

2.10.2 Technologies for Comfortable Learning

It is desirable for comfortable outdoor learning that computers used by learners are small and light enough not to give learners mental and physical stress. It is now considered to reduce learners' stress by using wearable computers and smaller computers. At the present time, I/O devices of wearable computers are immature and unsuitable for this system, and performance of smaller computers such as palm computers and Windows CE computers is quite poor. Therefore, these are now unavailable for DigitalEE, but if future technological innovation sufficiently improves these technologies, we will introduce these devices into DigitalEE.

3. ADVANTAGES OF DIGITALEE

3.1 Distance Education by Competent Experts

It is suggested that now environmental education lacks an ecological viewpoint [9], and it is thought that a lack of educators who have sufficient knowledge to realize environmental education with the ecological viewpoint causes this problem. DigitalEE can contribute to a solution of this problem by participation of experts with ecological knowledge via the Internet from all over the world. Education supported by knowledgeable experts and intellectuals from all over the world has great significance considering that giving learners sufficient knowledge and information desirably changes learners' environmental attitude [2].

3.2 Global Arguments on the Environment

With DigitalEE, practitioners of environmental education even in other countries can show their activity, experiences and concrete examples to other participants. People abroad who have interests in the local environment and people even in hospital can communicate with each other while sharing the practical experiences of the practitioners. DigitalEE realizes interactive worldwide discussion on the environment, which enables learners to consider environmental issues with people throughout the world while grasping the local environment from a global viewpoint. Global arguments with various people are strongly expected to have beneficial effects on raising learners' environmental consciousness and helping comprehension of global environmental problems.

3.3 Accumulating Environmental Knowledge

3D virtual nature and web pages created by various participants include quite valuable information such as learners' realistic observations derived from direct experiences and experts' profound knowledge. Since these contents are automatically opened to the Internet, learners can actively inform their achievements with an easy way. Anybody in the world can access the information via the Internet, and his or her own knowledge can be also added to in 3D virtual nature. Accordingly, common knowledge sources on the web server increase in proportion to the number of participants

and practices of the program, and databases on the diverse environment in all over the world are created as 3D virtual nature. Knowledge accumulated on a global scale will raise people's consciousness of environmental preservation.

3.4 Mutual Supplements of Two Experiences

3.4.1 Supplements by Learners' Realistic Information

By learning with knowledge sources including learners' real natural experiences, learners' and virtual tourists' learning can be supplemented by environmental knowledge that are more realistic and vivid than conventional educational materials strongly reflecting creators' own senses of values. Furthermore, with DigitalEE, virtual tourists learning with pseudo and indirect experiences can interactively communicate with learners really visiting in the real nature, and both learners and virtual tourists can share real natural experiences in real time. Learning the environment with others' direct experiences as own indirect experiences means that contexts of direct experiences are introduced into environmental education. Thus, with DigitalEE, environmental education based on direct and indirect experiences can be effectively supplemented with learners' vivid and realistic information.

3.4.2 Supplements by Experts' Profound Knowledge

With DigitalEE, experts specializing in natural environment, who hardly exist around learners in general, can support environmental education by giving their expertise to learners and virtual tourists as their indirect experiences in real time. Moreover, learners learning by direct experiences and virtual tourists learning by indirect experiences can learn the environment while using experts' profound knowledge accumulated in databases as indirect experiences. Consequently, environmental education based on direct and indirect experiences can be effectively supplemented with the expertise.

4. EXPERIMENTS

Differently from LAN having wide bandwidth (100Mbps), data communication with PHS having narrow bandwidth (64kbps) was thought to be the bottleneck of this system. Therefore, several experiments were conducted to investigate whether or not data communication could be smoothly done with PHS.

4.1 Methods

Problems in exchanging information for controlling DVE with PHS (64kbps) were investigated under the situation of connecting three desktop computers (data connection: LAN) and two mobile computers (data connection: PHS) to the server (OS: Solaris7, CPU: 333MHz, RAM: 256MB). The five computers have almost the same performance (OS: Windows98, CPU: Pentium II 400MHz, RAM: 128MB). The experiments were also conducted to investigate whether or not time for transferring files with PHS was short enough not to exceed tolerance level.

4.2 Results

1. There was no problem in exchanging information for controlling DVE such as information of positions, chat, awareness, and events since data size of the information is quite small and DigitalEE is designed to transmit only updated information at necessary time.
2. File transfer processes could be done in the time close to theoretical values — a web page (15.2KB): 2.3 seconds, a photograph file (12KB): 1.8 seconds, a movie file (60KB): 9.2 seconds, and a panoramic photograph (166KB): 23 seconds. It took rather long time to download the panoramic photograph since the file size was large, but there were no severe problem thanks to the design that allows users to move their viewpoints in the panoramic photograph freely even when the photograph was being shown as an interlace image.
3. The file transfer processes are implemented to be done in the background with a data stream different from the data stream for exchanging DVE information, and DigitalEE is going normally when file transfer processes are being done. Learners must download all photograph files that they do not have locally at one time to get the latest information on 3D virtual nature and to update the world, but there were no serious problems in both the time to update 3D virtual nature and behavior of DigitalEE according to the system design.
4. The server can update the codes of 3D virtual nature in negligible short time. When one photograph object is arranged in 3D virtual nature, the file size of 3D virtual nature increases by approximately 0.5KB and the time to download it from the server increases by approximately 0.06 seconds. However, it does not badly influence performance of this system since in the background learners can download only code sections they do not have locally.

4.3 Consideration

File uploading/downloading processes could be done within the time close to theoretical values, and DVE information could be quite smoothly exchanged in the bandwidth of PHS. There was no problem in data communication with PHS, which was thought to be the bottleneck of this system, and high performance of DigitalEE has been proved. Incidentally, we are supposed to conduct further experiments to verify human interaction realized by DigitalEE, suitability of user interfaces, and educational effects with DigitalEE in the near future.

5. COMPARISON

5.1 As a Study on DVE

DigitalEE is a DVE system to which mobile computing technologies are applied. Our study appreciates possibility of a 3D virtual world representing the real world as a user interface bridging real and virtual worlds. The study regards it as very important to communicate with each other sharing spatial contexts in two different worlds. Benford et al. [1] also appreciated people's position in DVE as spatial contexts, and they tried to support interaction between poets in the real world and audiences in a virtual world. However, in their study, shared virtual space did not represent the real world similarly to many other conventional studies on DVE, and poets' position did not correspond between real and virtual worlds. Except our study, no study has proposed a system realizing not only DVE representing the real world that is accessible from real and virtual worlds, but also communication while sharing positional information between these two worlds.

5.2 As a Study on Digital Cities

3D virtual nature is a sort of digital cities [7]. With DigitalEE, learners can paste their observations and experts can paste their knowledge in the 3D virtual nature in semi-real time. Thus, conventional static digital cities are realized as information space that is being updated dynamically. Participating digital cities from the real world with a mobile computer have never been studied, but development of DigitalEE is also important for examination of effects of participating societies realized by digital cities in the future.

5.3 As a Study on CSCL

Many past studies on CSCL (Computer Supported Collaborative Learning) tried to support learning in classrooms, but few studies have tried to support learning out of classrooms. Our study supports learning by natural experiences out of classrooms differently from many other studies, thus our study also has distinguished originality as a study on CSCL.

6. CONCLUSIONS

We have developed DigitalEE, a support system for collaborative environmental education by designing and implementing distributed virtual environment accessible from real and virtual worlds. The system bridges real and virtual worlds, and makes it possible for people in two different worlds to communicate mutually in one virtual space on the Internet while sharing spatial contexts without restriction of physical distance. DigitalEE realizes a new style of environmental education such as collaborative outdoor learning and interactive virtual tours. The proposed environmental education has the following advantages that have been difficult to be realized with methods of conventional environmental education: real-time and interactive environmental education supported by knowledgeable experts, worldwide arguments about the local environment from a global viewpoint with participants throughout the world, mutual supplements of direct and indirect experiences, and accumulation of environmental knowledge derived from real natural experiences. The ideas suggested by this study aims at changing conventional environmental education on a local scale into new environmental education on a global scale by improving educational styles of present environmental education. We made a suggestion of a future style of environmental education by introducing information technologies into environmental education having little relationship to information technologies.

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8. ADDITIONAL AUTHORS

An additional author: Kazuyuki Moriya (Department of Social Informatics, Graduate School of Informatics, Kyoto University, email: `moriya@i.kyoto-u.ac.jp`).

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