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Development and Application of a Distance Learning System by Using Virtual Reality Technology

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SUMMARY

There is a great demand for distance learning in various fields, such as provision of learning opportunities and learning information to infirm children and pupils, introduction of diversified subjects by collaboration among schools, support of credit acquisition, and applications to continuing education. Various distance learning systems have been proposed and put into practice. But, in addition, various problems in the present distance learning systems have been pointed out, involving both installations and operations. This paper proposes the virtual school as a possible new form of distance learning, in which virtual reality technology is used. Based on a prototype virtual school that was developed, the feasibility of the virtual school is investigated. An experimental class using the prototype system is also reported. © 2002 Wiley Periodicals, Inc. Syst Comp Jpn, 33(4): 61–68, 2002; Published online in Wiley Interscience (www.interscience.wiley.com). DOI 10.1002/scj.1120

Key words: Distance learning environment; distance learning; virtual school; virtual reality.

1. Introduction

There is a great demand for distance learning in various fields, such as provision of learning opportunities and learning information to absentee and infirm children and pupils, introduction of diversified subjects by collaboration among schools, support of credit acquisition, and applications to continuing education [1]. Various distance learning systems have been investigated and developed. Recently, there has been intensive investigation and testing of distance learning systems utilizing communication satellites, multimedia technology, and computer networks such as the Internet. There are many reports on these activities [2–4].

However, several problems of distance learning systems using communication satellites have been pointed out [4, 5]: special installations and technicians are needed, funding and installation are difficult due to the high costs, and it is difficult for the teacher to assess the level of understanding of students in a distant classroom. Distance learning utilizing the Internet has also been proposed, but this approach confronts the problem that sufficient communication is difficult due to the discrepancy between video and voice owing to the effect of communication speed, although distance learning systems with low installation cost can be created [5]. There are also problems common to all of the distance learning systems proposed to date, such as the lack of a sense of realism and psychological distance of the students [4], which must be solved in order to realize effective distance learning.

Consequently, the authors took a viewpoint different from that of past distance learning environments and developed the "virtual school" [6], which is a distance learning environment based on virtual reality technology. This virtual school is a distance learning environment in which the teacher and students share the same space, and the students participate in a virtual learning space constructed on the Internet by using a personal character called an "avatar."

This paper presents the concept of the virtual school, our proposed new distance learning environment. First, the virtual school is outlined and the system configuration is described. Then the feasibility of distance learning in the virtual school is investigated, and an experimental class using the prototype system is reported.

2. Basic Functions and Implementation of the Virtual School

2.1. Overview and basic functions

The distance learning environment has been developed chiefly for the purpose of conducting education between a distant teacher and students. This presumes that the participants in distance learning are in separate locations. The participants in such a system are not present in the space or at the same time. But the virtual school proposed in this paper is an entirely new distance learning environment, which differs from past distance learning environments in that the same learning as in a real school is realized by students and a teacher sharing the same space and time.

The virtual school is constructed on a computer network by using virtual reality technology. The student comes to school in the form of a personal character called an avatar [7] and participates in classes with other students in a classroom provided as part of the virtual school. In the classroom, the other students are also represented by avatars. The students communicate with each other in a situation that is close to the communication with friends that occurs in a real classroom, by operating their own avatars with gestures or hand motions. During class, the student may answer questions asked by the teacher, or study from an assigned text. It is possible, as in a real classroom, to observe the learning of other students.

Thus, by utilizing network technology and virtual reality technology, the students have the feeling of being in a real school. The purpose of this study is to solve various problems, such as realism, which have been encountered in past distance learning systems. The virtual school realizes this goal by means of the following three basic functions.

(1) The function of sending the virtual learning space and the text information to be used in it to the student's terminal.

(2) The function of managing and transmitting information concerning the position and movement of the student in the virtual learning space.

(3) The function of communication between students or between student and teacher.

2.2. Implementation of the virtual school

Below we describe a method of implementing the virtual school described in Section 2.1 on a computer network. Two kinds of servers are provided in the virtual school: one is the server that sends the classroom data to each student, and the other is the server that detects the students' changes of position and the content of their utterances in the classroom and sends this information to all students in the classroom. The classroom data sent each time the student (avatar) moves in the classroom of the virtual school, and the position and other information on the student are sent each time the student moves or speaks. The client reconstructs the virtual space based on the classroom information and the position information on other students sent from the server, and presents the results to the student. Thus, complex operations such as 3D calculations are performed on the client side, and the load on the server is reduced. Figure 1 shows the concept of the system.

In implementing the system, it is very important to consider the computer environment of the remote student. Consequently, the classroom and the avatar are described in VRML (virtual reality modeling language), which is a structured language for describing 3D geometric figures in virtual reality [8]. The operations of the server and the avatar are described in the object-oriented programming language Java. Thus, all aspects of the virtual school are implemented in VRML and Java. In this way, the system can be used without providing special devices if there exists an environment that can be connected to a computer network such as the Internet, Java execution environment, and the VRML browser.

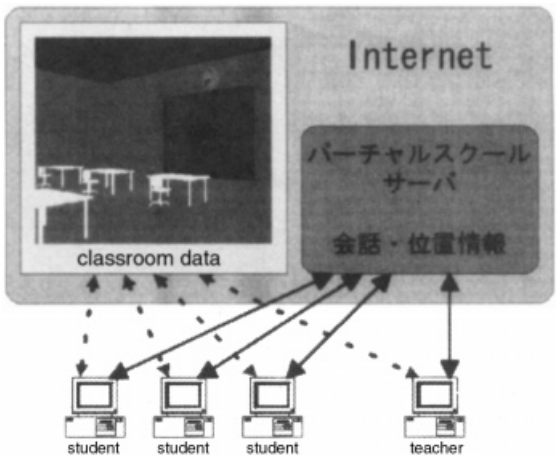

Fig. 1. The system configuration of the virtual school.

3. Prototype System

This section discusses the prototype system for the virtual school at its current stage of development. Figure 2 shows the use of the prototype system for the virtual school. The upper right window shows the situation in the classroom as viewed by the avatar representing the student. In this case, it is the image of the classroom viewed by the student using this image through his own avatar. A student raising his right hand is seen. Thus, other students and the teacher can be observed just as in a real classroom. The avatar, as well as the viewpoint, can be moved by using the mouse. The motion of the avatar, such as raising the hand, can be controlled by using the lower right panel of Fig. 2. In the left window of Fig. 2, the dialogue in the classroom is displayed in written form. The utterances are displayed in temporal order together with the name of the student.

The details of the above prototype virtual school are described below. Section 3.1 describes the operation of the avatar and the communication system in the virtual school. Section 3.2 presents the learning assist tool used by the teacher and the student in the learning in the virtual school. Section 3.3 reports on the classroom design system used by the teacher in designing the virtual classroom.

3.1. Avatar operation and communication

As discussed in Section 2.1, the individual student in the virtual school participates in learning through the avatar. Consequently, the operation of the avatar is the key to activity in the virtual school. All motions of the avatar, such as movement in four directions, change of direction, and shift of viewpoint, can be produced by means of the mouse.

In addition to the motion of the avatar, dialogue with gestures is also possible in the virtual school. Figure 3 shows an example of the use of the avatar. This is the case in which the "raise right hand" button on the avatar control is pressed. Linguistic information is sent by using the communication window shown in Fig. 4.

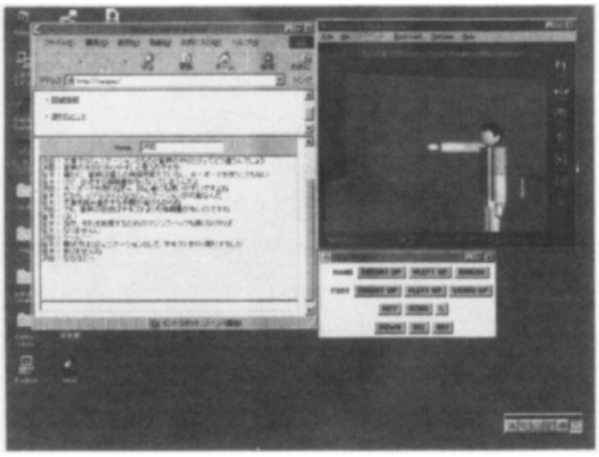

Fig. 2. An example of an actual display used in the virtual school system.

3.2. Learning assist

3.2.1. Presentation panel

In order to make learning proceed efficiently in the virtual school, a presentation panel is provided in the classroom as a visual text presentation environment. Figure 5 is an example of the use of the presentation panel. A sensor is attached to the image information displayed on the presentation panel, and the next image is brought up by clicking on the image with the mouse.

3.2.2. Presentation window

In the presentation panel described in Section 3.2.1, it is sometimes the case that the image is difficult to see, depending on the position of the student or the viewing angle. There is also the problem that it is difficult for the student to review an arbitrary previous image. Thus, a presentation window was developed in which the text is displayed on all student terminals, accompanying the above presentation panel. Figure 6 shows the presentation window that is displayed when the presentation panel in Fig. 5 is used.

A controller is provided in the presentation window to allow switching between text presentation images. The next image is summoned by clicking on the "next" button in the controller, and the previous image by clicking on the "back" button. By selection from a pull-down menu, an arbitrary image can be displayed.

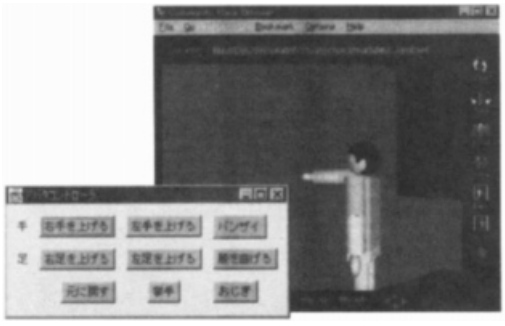

Fig. 3. The avatar controller and the avatar example.

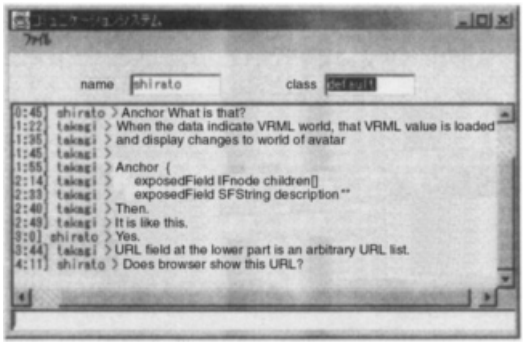

Fig. 4. An example of a communication window.

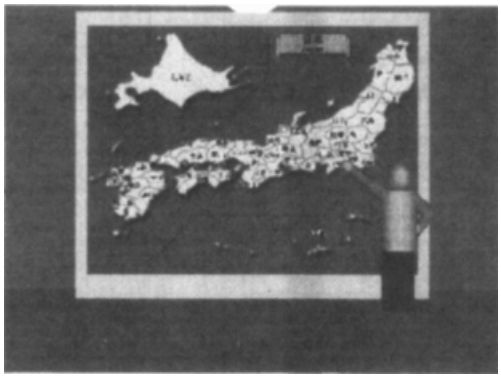

Fig. 5. An example of communication via avatar operation.

Fig. 6. An example of a presentation window.

A pointer function is also provided, to indicate a point, such as an explanation in the panel, to which the student should pay attention. As shown in Fig. 7, the teacher can indicate by dragging the mouse to, the point to be noted by the students in the text displayed in the presentation window. This point is indicated by an arrow on the image shown in the window on the student side. The student can also use the indicating pointer in the same way. In order to avoid confusion due to use by more than one student, the student must obtain permission from the teacher before using the pointer.

When the teacher clicks on a point in order to draw the attention of the student there, the indicating pointer appears at the corresponding point in the presentation window of the student side. When the student performs the same action, a pointer with a Q mark indicating a question is displayed in the presentation windows of the teacher and the student.

3.3. Classroom design system

In the virtual school, the teacher can design the classroom flexibly according to the curriculum, without being restricted by the existing classroom as in a real school. However, since the virtual school is created in VRML, VRML programming is required in designing the classroom. Consequently, a classroom designing system was developed for the virtual class, enabling the teacher to design the classroom easily with no special knowledge such as VRML programming or the operation of the software used to compose a space in VRML. In this system, the 3D classroom is designed using only 2D operations. Since no

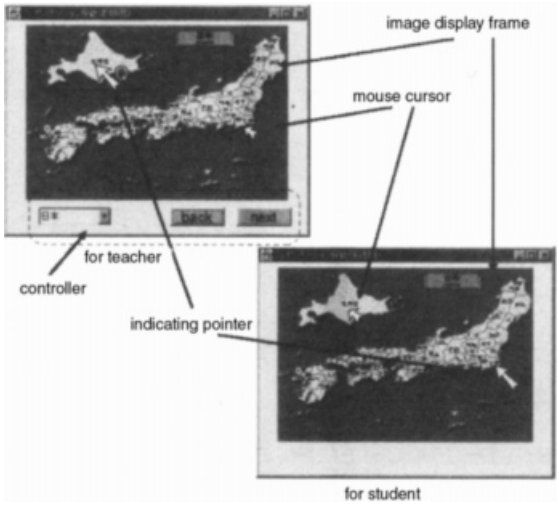

Fig. 7. Instruction via an instruction pointer.

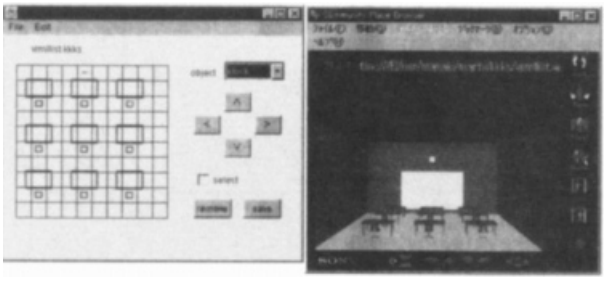

Fig. 8. Classroom design via the space construction system.

complex manipulation is required as in existing 3D design tools, the classroom can be designed by simple procedures. Figure 8 shows the window for classroom design and a classroom actually designed (right). Using this system, the teacher can provide the student with various learning environments.

4. Feasibility of Distance Learning in the Virtual School

This section discusses the feasibility of distance learning in the virtual school, based on the prototype virtual school described in Section 2. The discussion is based on preceding studies [9–11] in social psychology and computer communications and covers items such as (1) education of the disabled, (2) improvement of realism and reduction of psychological distance, (3) improvement of learning motivation, (4) performance of collaborative tasks, and (5) increasing opportunities for learning.

4.1. Realization of learning for the disabled

Students who are disabled or infirm and cannot usually go to school can participate in the virtual school as normal students. It is possible for them to experience the school, which otherwise would not be accessible to them, as an environment closer to a real school, since they can experience the atmosphere of a real classroom where they learn with other students, and also experience school life such as dialogue with their friends.

4.2. Improvement of realism and reduction of psychological distance

As discussed in Section 1, a serious problem in past distance learning environments has been improving and maintaining realism and reducing the psychological distance between students or between the teacher and the student. In past distance learning environments using TV conferencing systems, the students do not share the same space, although they can watch the reactions of others in real time. Thus, the feeling that the student is participating in learning together with other students is reduced, which increases the distance between the student and other students [11].

In the virtual school, on the other hand, the students share the same classroom, and the student can be visually aware of the presence and the motion of other students or of the teacher through the avatar. More precisely, as in the real classroom it is possible for the student to see another student question the teacher in the class, or for a student to discuss the content of learning with other students after the class (Fig. 9), or for somebody to use a physical object to explain matters not easily explained in dialogue, as in Fig. 7.

For these reasons, realism should be improved in comparison with past distance learning environments. By improving realism so as to give the sense that the students are in a real classroom, the psychological distance to other students and the teacher is reduced. By improving the functioning of the avatar and the dialogue function, the psychological distance will be further reduced.

4.3. Improvement of learning motivation

As discussed in Section 4.2, in the virtual school it is possible for a student to question the teacher, or for students to instruct each other. Such a situation can also be observed by other students, which encourages them to ask more positive questions, or collaboration among multiple students may be used to solve the problem. In other words, effects on the behavior of the students are easily produced,

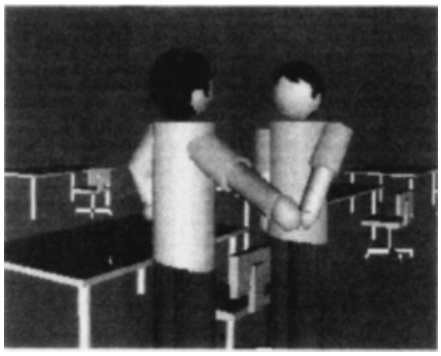

Fig. 9. An example of communication between avatars corresponding to students.

and the overall motivation for learning is likely to be improved.

It is known from studies such as Ref. 9 that communication systems in environments such as e-mail or electronic bulletin boards, where the users cannot see each other's faces, reflect mental aspects more than the background of the user such as location or age. This encourages a nervous user or one who finds it difficult to express his own view face to face to participate more actively than in ordinary face-to-face conversation. In the virtual school, dialogue is conducted through the avatar, and a similar effect is expected. In addition, the transmission of thought by body language is also possible through the avatar, and more positive expression from the students can be expected.

Thus, in the virtual school, learning activity is supported by the active exchange of ideas, which stimulates other students observing the situation. In other words, a cycle of effects is formed, which is expected to improve the motivation for learning.

4.4. Realization of collaborative tasks

In most distance learning to date, the texts have been prepared individually and used by each student. Thus, an environment in which multiple students share the same text has not been realized. From the viewpoint of group learning, it is important that the students in the group share the same text while learning. In the virtual school, the text is shared in a classroom. Thus, it is possible for the students to work on collaborative tasks. When a student manipulates the text, the result is observed by all students in the classroom through the virtual school server.

4.5. Enhancement of learning opportunities

The virtual school does not require special peripheral equipment. Anybody can join in the learning by simply obtaining a computer connected to Internet. In addition, less cost is required for the management of the virtual school and for maintenance of the installations. Thus, it is easy to start a school, and a unique education can be positively developed. In addition, students with restrictions of place and time can easily enjoy learning, utilizing their spare time through the virtual school. It will also be possible to participate in worldwide learning such as simulated visits, although problems of time difference and the like must be solved.

5. Trial Learning and Evaluation

In order to examine the effectiveness of the virtual school as a distance learning system, an experimental class was conducted for university students, using the prototype virtual school described in Section 2. The number of participants in this experiment was nine (one teacher and eight students). The participants other than the teacher had the experience of using chat systems on the Internet and VRML systems. The subject matter of the learning was "Methods for information retrieval on the Internet." A lecture and exercises on information retrieval on the Internet, mostly involving the use of search engines and so on, were presented. In the exercise, the students formed pairs and tried to solve the search task presented by the teacher by using the search engine described in the lecture. Table 1 shows the system configuration used in the trial class.

After the learning activity, a questionnaire with a five-point scale and free text was presented. The questionnaire included items concerning performance, items concerning manipulation, items concerning communication, and items concerning learning. The maximum score was 5. Figure 10 shows the average scores on the questionnaire. It is evident that the evaluation score exceeded 3 for all items. Among individual items, the scores concerning performance exceed 4, which indicates that the system in its present form is already sufficiently practical.

Furthermore, the system is based on manipulation by the mouse, which may be the reason for the high scores for the items concerning manipulation. High scores were also obtained for the gestures and hand motions of the avatar, and for psychological distance. Thus, the system that allows the teacher and the students to share the space, as well as the avatar, function very well.

On the other hand, the scores for conveyance of emotion and for realism are lower than those for other items. The reason is apparently that the proposed system has only the communication window as the means of transmitting linguistic information, and that emotion can be conveyed only in written form. The authors are now investigating a system in which communication can be carried on by voice, or in which the avatar has several facial expressions which can be selected by the student. The scores will be improved if these measures are incorporated. The scores for the collaborative task are lower than the others, apparently indicating that the information retrieval considered in the experimental classroom did not require much collaborative effort.

Table 1. System construction

	Computer	OS
Server	Sun Ultra10	Solaris 2.6
Client	PC (Pentium)	Windows98

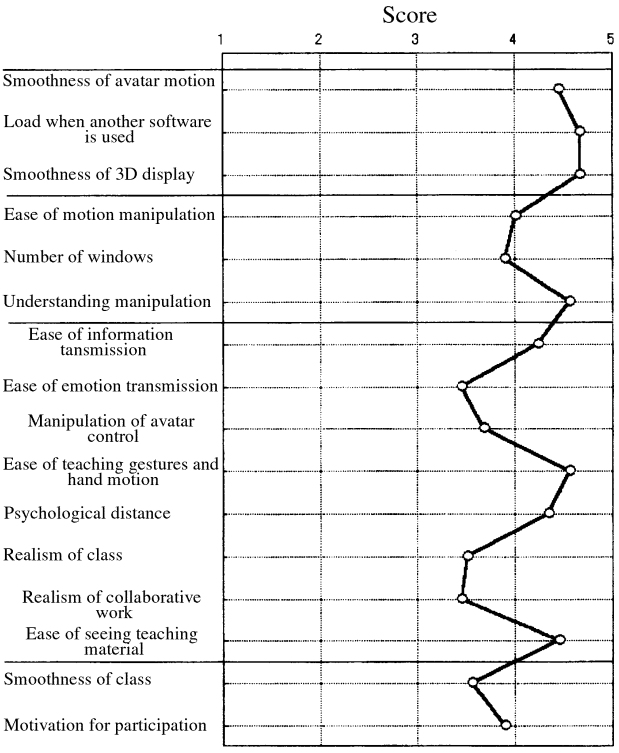

Fig. 10. The questionnaire results (mean scores).

The free text answers included opinions such as "too much concentration on the task, which prevents avatar manipulation or dialogue," and "simultaneous use of Internet browser and communication window is not simple." These comments revealed the following problems. First, the student must engage in avatar operation and chat operation simultaneously, leading to greater concentration on avatar operation and making the chat dialogue intermittent. Second, the presentation and manipulation of the windows is not easy, as in the cases of the presentation window and the communication window. It was also observed in this experiment that the activity of the virtual school stopped completely when students were concentrating on the task. It will be necessary in the future to analyze the problems of operation in the virtual school and to improve the user interface, as well as the method and content of learning, fully utilizing the characteristics of the virtual reality.

There was a comment from the teacher that it was difficult to inhibit personal talk among the students using chat, which resembles a problem in real schools. This seems to indicate that the virtual school in this experiment realizes to some extent an environment which is close to a real school.

6. Conclusions

This paper has proposed a new concept of distance learning environment called the virtual school, in which the teacher and the student share the same space and engage in learning by utilizing virtual reality technology and Internet technology. Then, based on the prototype virtual school developed up to this stage, several aspects of the feasibility of distance learning in the virtual school were examined, namely, learning by the disabled, enhanced realism and reduction of psychological distance, improvement of learning motivation, realization of collaborative tasks, and broadening of learning opportunity. An experimental class was conducted using the prototype system, and the results of a follow-up questionnaire are reported. This experiment has shown that the virtual school is effective in terms of execution, manipulation, communication, and class execution. It is necessary in the future to construct a system based completely on the prototype system reported in this paper, and to examine the effectiveness of the virtual school, including quantitative evaluation. The characteristics of the virtual school should be analyzed in order to develop appropriate teaching methods and texts utilizing the features of virtual reality. Learning by the disabled can be considered an application of the virtual school. It is planned in the future to construct a system dedicated to the learning for the disabled by improving the human interface, for example, and to investigate the effect of the virtual school on the psychological barriers of the disabled.

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