

Applications of Leapfrog Teleconferencing Technologies to Distance Learning

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1.0 Introduction

One of the most promising applications of videoconferencing is distance learning, where videoconferencing is used to communicate between an instructor and remote students. This can be useful in many situations where it is impossible or expensive to gather an instructor and students in the same room. Distance learning systems could be used to allow home bound students to keep up with their studies, or for students to attend specialized classes not held within their school. Videoconferencing could also be used for students within a classroom to communicate with outside experts, or to work together with students in other classrooms. In addition to these scenarios, teleconferencing could be used to offer classes to remote students as part of continuing education programs. In the work environment, distance learning systems could deliver training courses to employees within their offices, or in their homes.

Current videoconferencing technology is insufficient for supporting truly engaging Educational interchange, for two reasons. First, it is difficult for students to become fully immersed in a remote learning environment. Second, an instructor cannot interact smoothly and successfully with more than a few remote students.

New and truly compelling leapfrog technologies are emerging from telecommunications research laboratories in the United States and in other parts of the world that are changing the landscape of distance educational capabilities. These new teleconferencing technologies provide the means for addressing both of the aforementioned problems, by allowing remote students to control their view of the classroom, and allowing the instructor to merge multiple video streams from different locations to construct a virtual classroom.

2.0 An Instructor's View of a Remote Classroom

In this scenario, there is a "local" classroom with an instructor at the front of the room, and some number of "local" students facing the instructor. In addition, there is a remote classroom accommodating up to several hundred students. There is a camera trained on the front of the local classroom, whose image is displayed on a large screen teleconferencing display at the front

of the remote classroom. The local students can see and hear the instructor first hand, and the students in the remote classroom can watch the instructor on the large screen display.

To allow the instructor to see the students in the remote lecture hall, there is a wide-angle-lens video camera at the front of the lecture hall facing the assembled students. This image is presented on a display screen that can be seen by the instructor. This display may be a small display screen built into the instructor's podium or perhaps a large-screen display on the side or rear of the classroom.

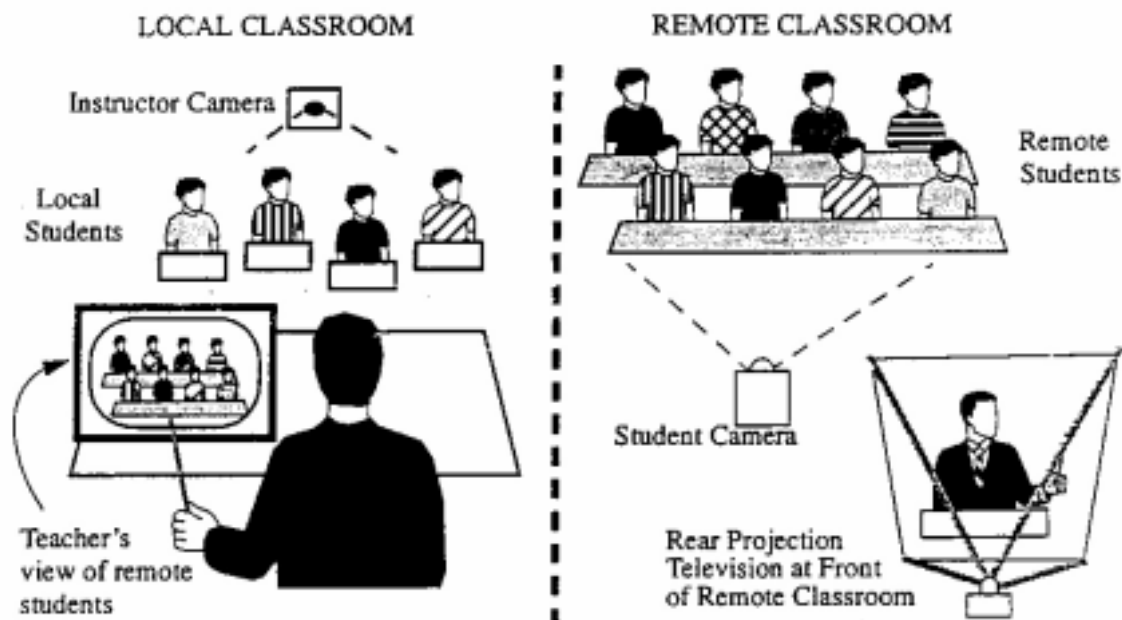
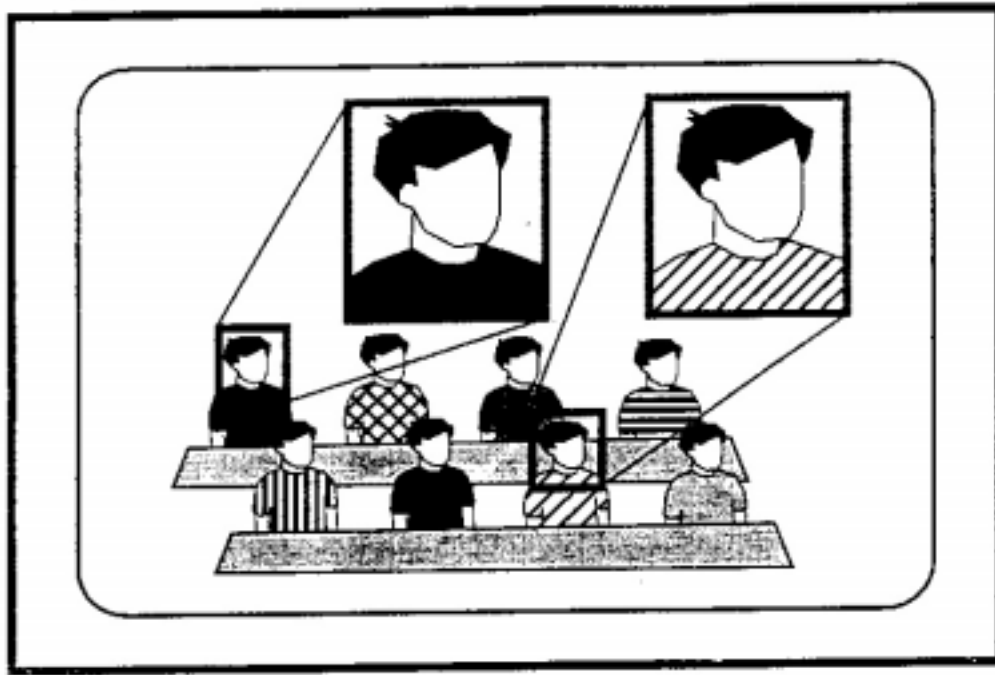


Fig. 1 Local classroom and remote classroom setup, showing cameras and displays within the local classroom and the remote classroom

However, there is a problem with this approach. If the entire lecture hall is displayed on a small display screen, each of the students in the remote classroom will only occupy a small area on the screen. This display will allow the instructor to determine "mega-trends", such as the arrival or departure of the class, but it will be difficult to talk with individual remote students, or to take questions. There are several techniques that can be used to mitigate this problem:

Panning Camera: With the camera in the remote classroom is a Panning Camera, the instructor can electronically pan to different spots in the lecture hall, changing the display to focus on a student asking a question. Multiple views from the Panning Camera can be combined with a video composing bridge so the display may contain one or more close-up views of students in the remote lecture hall, perhaps combined with a view of the entire lecture hall. The overall view could be annotated with graphics to indicate where the close-up views originated.



Teacher's classroom display showing the entire remote class with two student close-ups, and graphics.

Figure 2

Person-Spotting: In order for the instructor to focus on a particular remote student asking a question, the instructor has to detect that a question is being asked. Students using directional microphone arrays asking questions can be detected automatically through audio person spotting (detecting their voices) or video person spotting (detecting a waved hand). The person-spotting system may automatically construct a close-up view of the student, as above. Alternatively, the students speaking or raising their hands may be outlined or spotlighted using overlaid -graphics over the video image so the instructor can detect the questions, and control which close-ups are brought up.

The instructor must be able to control the view of the remote classroom as easily as possible, without disrupting the class. Much of the time, fully automatic person spotting and panning will allow the instructor to maintain an awareness of the remote lecture hall without explicitly controlling the view. On occasion, when the instructor wants to address a question from a remote student, it may be desirable to take control of the view. This might be done by pointing a simple remote control device at the display screen, or using a touch-screen overlaid on the display screen.

3.0 The Remote Student's View of the Instructor

In the above scenario, the students in the remote classroom can watch images of the instructor on a large display screen at the front of the remote lecture hall. Depending on the type of class, there are many different types of images and educational materials that could be displayed on this screen. If the instructor is simply lecturing at a podium, then it is sufficient to have a single camera focused on the podium. If the instructor moves around the front of the classroom, draws on a blackboard or presents viewgraphs and other materials, additional cameras will be needed to transmit the images to the remote classroom. Possible video image sources include:

- A wide-perspective camera viewing the entire classroom from the rear. This image can be used to view an instructor moving around the front of the room. This can also be used to construct a "director view" for locating and controlling other views (discussed below).
- A camera viewing the instructor's podium.
- A camera on a blackboard. This would be a particularly good place for a Panning Camera, which can focus on different sections of the blackboard.
- A camera on a table used for scientific demonstrations.
- A camera capturing the image of a viewgraph being presented. This may be a regular camera focused on a viewgraph projector screen, or it may be integrated with the projector itself to capture the viewgraph image more directly.
- Cameras integrated with scientific equipment such as a camera connected to a microscope that transmits the magnified image.
- Stored video sources such as videotapes.
- Digital image sources from a PC. The instructor could transmit the image of a computer screen while demonstrating the operation of the computer. Alternatively, the instructor could show graphics or graphs or spreadsheets relevant to the lesson.
- Videoconferencing video sources. Any of the video images transmitted to the instructor could be sent to the remote lecture hall. For example, when the instructor answers a question from a remote student, the zoomed image seen by the instructor could be transmitted back to

the remote classroom, so it is clear who the instructor is talking to. The instructor could also establish a videoconference with outside experts, and share the image with the students in the remote classroom. The instructor could combine graphic annotations with other video sources, perhaps circling an interesting feature in a stored video image.

The display screen at the front of the remote lecture hall would display some combination of these video sources combined using a multimedia image composing bridge. As the instructor moves from podium to blackboard, or uses other instructional materials, the view would be changed to focus on the most important views. If the instructor is showing materials such as view graphs, the image of the instructor could be combined with the viewgraph view using a video composition bridge, so they are side-by-side. Alternatively, the instructor image could be made translucent and overlaid over the viewgraph image without obscuring the viewgraph.

Controlling the view displayed in the remote classroom is a demanding task. Possibly it could be done by a “director” who manually chooses the appropriate video images. This person could use a “director view” (described below) to select the individual images. Alternatively, some of the images can be selected automatically. If the instructor is moving, perhaps writing on a blackboard, then person-spotting techniques could be used to locate the instructor, and select a Panning Camera image to display to the remote lecture hall. Sensors on the viewgraph can detect when this machine is in operation, and select the viewgraph image. Probably the best solution would be a combination of automatic view selection, along with a director to manually adjust the views when necessary.

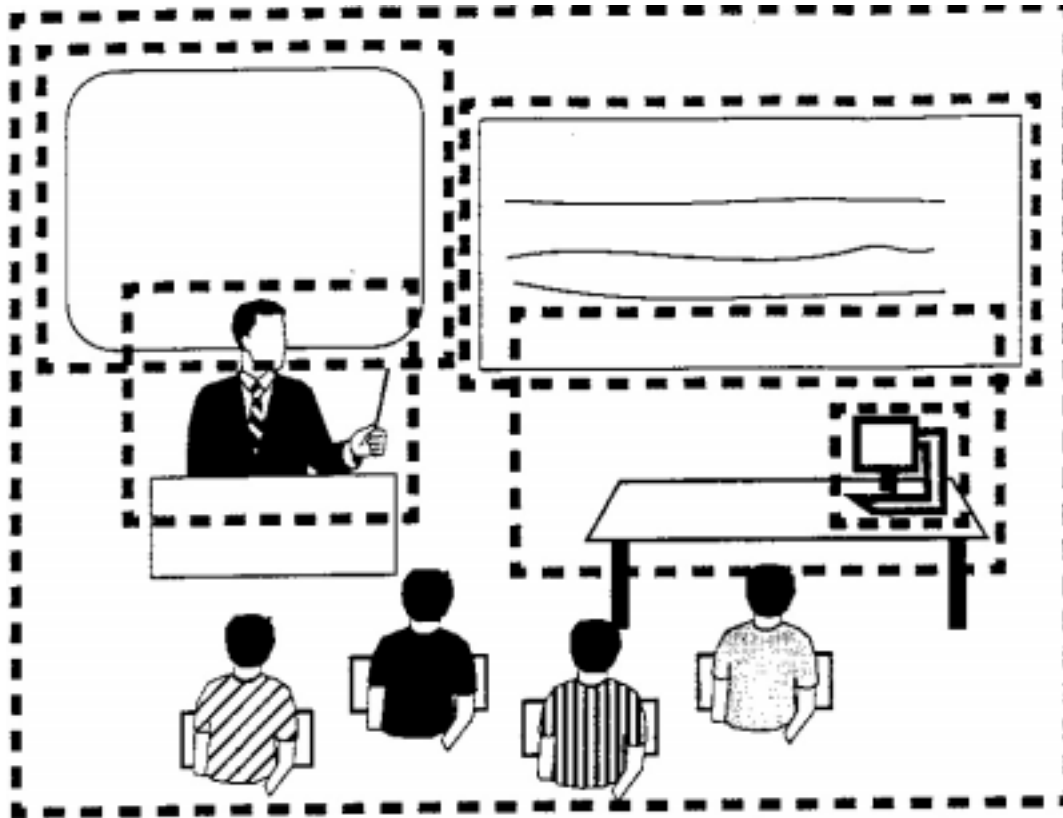
4.0 Individual View Control Using the Director View

In the remote lecture hall scenario, all of the students in the remote lecture hall view the same large-screen display at the front of the lecture hall. As discussed above, manual control by a director and automatic techniques can be used to pan the view to follow the instructor, and a video composing bridge can combine multiple images to construct the final view.

When single remote students have individual displays, each student can act as their own director, controlling the construction of the image they see. For example, when viewing the blackboard using a panning camera, the remote student can control the panning, perhaps focusing on a particular item on the blackboard.

With multiple video sources, it can be a challenge to control which video stream to view. This burden can be reduced by constructing a “director view.” This is an image composed of the wide-angle view of the entire classroom, with overlaid rectangles specifying the field of view of the different video sources. By selecting a particular rectangle, the remote student can automatically switch to a particular video stream, and select a view for a panning camera. The overlaid graphics can be highlighted to show the view that is selected.

The director view might be presented on a small auxiliary display below the main display, or it may be combined into the main display. If a director view was displayed on a touch-panel display, a video source could be selected by touching a field-of-view rectangle. Moving a finger within a rectangle could change the view from a panning camera.

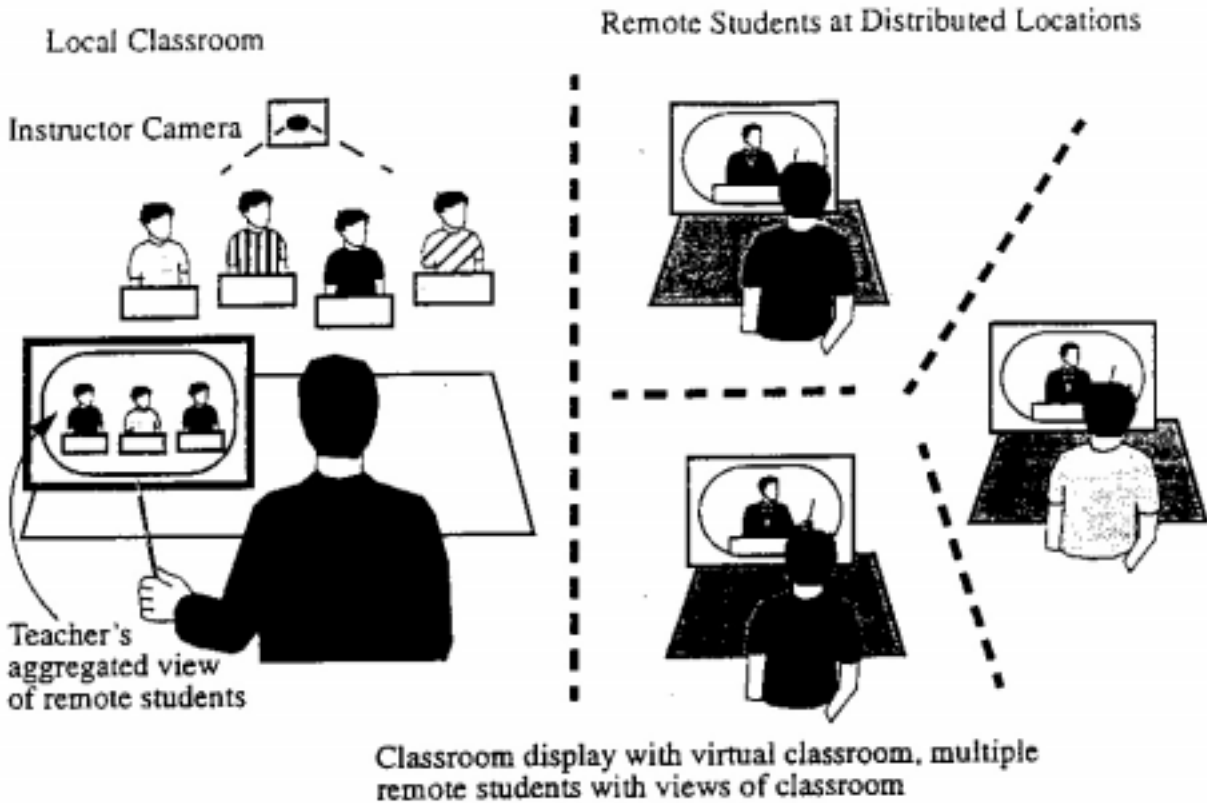


The director view, with overlaid view rectangles

5.0 An Instructor's View of Multiple Remote Students

The remote classroom scenario is most appropriate for higher education. A typical situation would be an instructor with a classroom of students, and a few remote students at one or more remote locations.

In this scenario, the instructor would have a display showing the individual images of the remote students, combined with a video composing bridge. The bridge can use chroma-keying to remove the backgrounds of the students, and arrange their images into a virtual classroom, perhaps with a simulated background. The image of the virtual classroom allows the instructor to interact with the remote students in the same way as the local students.



The panning and person-spotting techniques from the remote lecture hall scenario could also be applied to this display, to highlight a student asking a question. This may not be necessary if there are only a few remote students. Note that person-spotting techniques are simpler if there are individual video and audio streams from each of the remote students. For example, audio person spotting can be done by finding the maximum audio level from the remote student audio channels, rather than using directional audio techniques.

6.0 The Virtual Back Row

If the instructor interacts with multiple remote students using a small display at the front of the room, there is a clear distinction between the local students and the remote students. One way to reduce this distinction is by having the rear wall of the local classroom be single large projection display showing the multiple remote students. Each of the remote students will have a wide-

angle view of the local classroom, including the instructor and the backs of the local students, just as if they were sitting at desks at the rear of the room.

Since the remote students can view the entire classroom, including the other students, they can interact with the local students. Local students can turn around and address the remote students, as if they were located to the rear in the local classroom. The instructor can address all of the students in the same way. If the remote student images are combined with an artificial background similar to the local classroom, then there will be even more of a sense that the remote students are in an extension of the classroom.



classroom with rear display of virtual (remote) classroom

7.0 Students Working Together

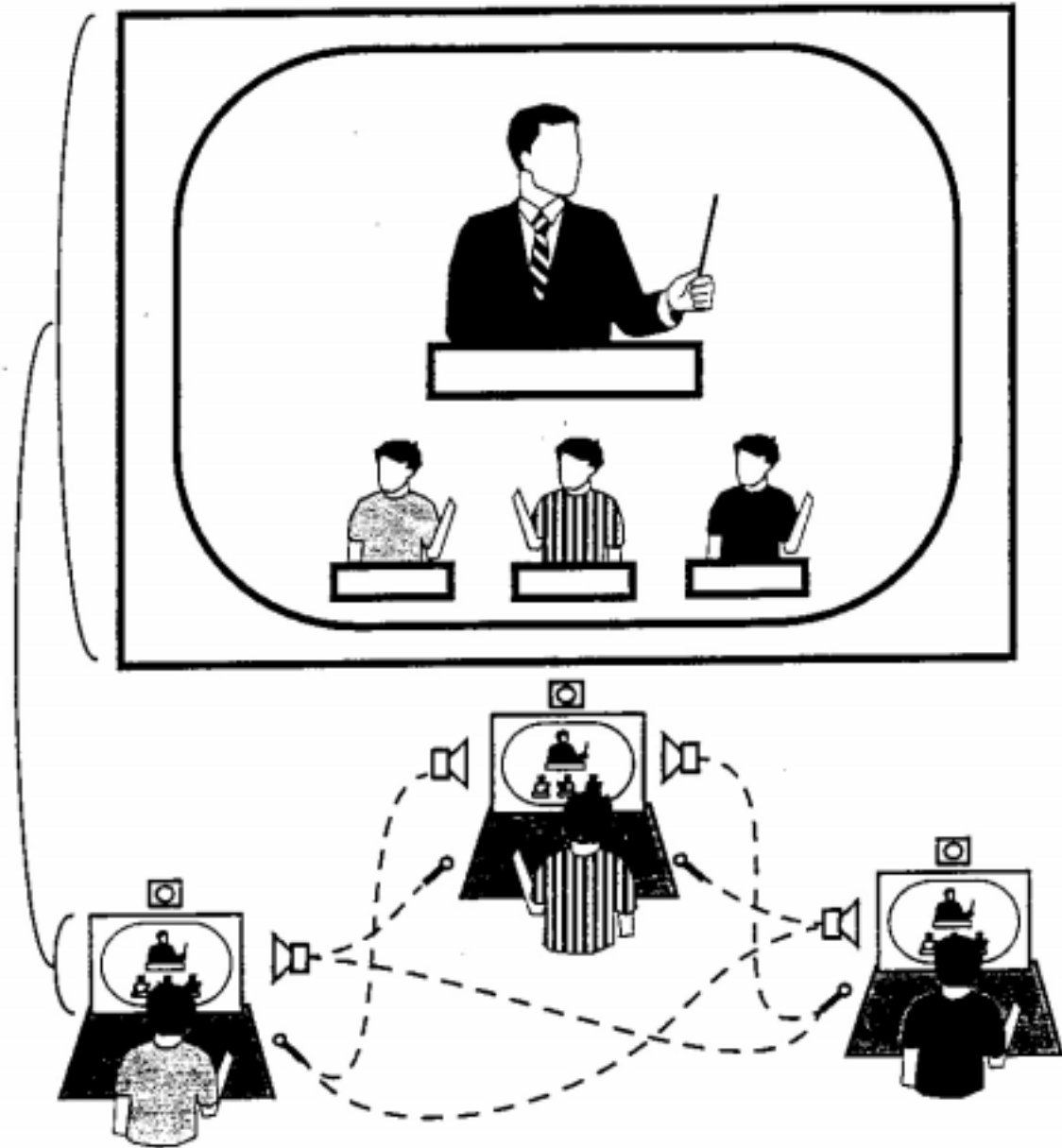
In the previous subsection, multiple remote students use their individual displays to view a common classroom. These displays can also be used for videoconferencing between the remote students, allowing them to ask questions of each other, or to work in groups with other remote students.

The simplest case would be a single remote student asking a question of another remote student. Using an image composing bridge, each of the two students could overlay a view of the other on top of the classroom view, so they could talk without losing track of the classroom lesson. When having such a side-conversation, their audio would not be broadcast to the local classroom, so they wouldn't disturb the ongoing lesson. These students would also have access to all of the

video displays from the classroom. For example, one student could answer a question by "pointing to" a particular section of the blackboard (controlling a panning camera to focus on that section, so both students would see an image of that section).

Multiple remote students could use videoconferencing to work together in groups. In an effort to break the homebound isolation, one would create a virtual environment. For example, each of three remote students would have a camera viewing them and would also have a display. In addition they would have stereo audio microphones placed to their left and right and stereo speakers similarly located. The camera views and audio inputs would be delivered to an image composing system. At the image composing system, the camera views are merged into an ordered arrangement (e.g. a single row, side-by-side if the number of students is not large). Chroma-keying or some other technique might remove the backgrounds of each of the homebound viewers. The combined view (with perhaps a classroom faux-background added for realism) is then image reversed "mirror-imaged" and broadcast to each remote student.

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Home set-up for an immersive education application

This mirror-image view of the ensemble of students is key to the operation of the joint social experience. Each of the students sees the group, including themselves, as though they were all in front of a mirror.

The experience of viewing one's self in a mirror is a very familiar one. One expects that when one raises the right hand, that one's reflected image raises its "right" hand in a mirrored gesture. (Actually upon some reflection, it is the mirror image's left hand that is raised.)

In the mirror image, objects to one's actual right appear to be to the right of one's reflected image. It will be easy then for classmates to come to believe that other classmates are really to their right, or to their left. To augment and reinforce this learned behavior, audio from students to the "right" of the local student can be made to come from the right (with stereo audio and the image composing system's ability to manipulate audio as well as video images) and analogously sounds from the left will come from the left. Microphones for the local students are set up to their left or right to provide this ambiance for the other students in the classroom. Thus, if a student wants to talk to the student to their right, they could simply lean slightly to the right, and talk. The student to their right will hear a voice coming from their left and note in their group image that it is the student to their left that has leaned over to talk.

In this manner, the students can all listen to the instructor, see each other's reactions to the instructor, and interact and kibitz with other students in the classroom.

8.0 Private Tutoring and Consultation

The previous subsections have described scenarios with a single instructor and many students. Distance learning systems can also be used for one-to-one tutoring. In this case, the technology is similar to normal teleconferencing. For the purposes of education, the instructor may want to provide multiple video and graphics images that the student can select and combine using an image composing bridge.

The instructor may also have access to multiple video views of the student and educational materials at the remote site, combined into a single display that the instructor can control. For example, in addition to the camera on the student, a panning camera could show an overhead view of the student's desk, so the instructor could examine what the student is working on. The instructor could take this image, annotate it with graphics over the video, and send it back to the student, to point at the particular problem that is incorrect, or a book that needs to be consulted.

A similar scenario could occur when consulting with a remote expert. Additional cameras could be employed to send images to the expert, who would annotate them and send them back.

9.0 Summary and Conclusions

New and truly compelling leapfrog technologies are emerging from telecommunications research laboratories in the United States and in other parts of the world that can empower both instructor and students in remote locations to have a more natural and interactive educational experience.

Biographical Information

Dr. Addeo has wide experience in multimedia telecommunications research projects at Bellcore where he served as the Associate Executive Director of the Multimedia Communications Department.

In 1994, Dr. Addeo was inducted into the New Jersey Inventors Hall of Fame for key patents that led to the widespread use of cellular telephone communications systems.

He was named to New Jersey Institute of Technology's achievement honor roll in recognition for a series of achievements that have exhibited "superior dedication, vision, courage and originality." Dr. Addeo is the author or co-author of more than 60 technical papers given at IEEE Communications Society conferences and meetings held all over the world. He is the recipient of ten US. Patents.

Dr. Addeo is the current chair of the Telecommunications Management Department at DeVry Institute.