Remote Electron Microscope

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We have introduced functions and application examples of remote electron microscopes that combine network technology and scanning electron microscopes based on actual experiences such as remote analysis or event presentation. Most of the elements in this system configuration are commercially available and the remote-observation and data-transfer functions are configured with commercial products including the telephone lines.

1. Introduction

Network technology has made remarkable progress in recent years and exchange of large volumes of data is no longer an exceptional case. For example, a number of contracts for ISDN(Integrated Services Digital Network) circuits, which are especially suitable for transmitting image information, exceeded one million channels in November 1995, and new systems like remote education[1] and image transmission for medical purposes[2] are now being actively studied. In short, the multimedia society is fast becoming a reality as a result of these developments. As a part of this trend, several tens of reports have been issued on remote-electron-microscope technology that combines electron microscope and network technologies, and the reader is referred to the references quoted in this paper for details[3-4].

The present situation is such that anyone with a telephone line can make use of a remote electron microscope at any time in a relatively easy manner. This report therefore does not focus on the technical aspects of a remote electron microscope but rather on its basic functions and usage formats that currently exist or are being studied at NTT.

2. System Functions and Configuration

A remote-electron-microscope system employs a telephone line or similar to connect a site where an actual electron microscope has been set up with a distant site where a user is located. System functions can be broadly divided into 1) "remote observation" that allows the user to inspect the image observed by the electron microscope, 2) "remote operation" that allows the user to perform simple operations like moving the electron microscope's stage, and 3) "data transfer" that transmits electron-microscope photographs desired by the user. The basic system configuration for achieving these functions is shown in Fig. 1. Note that most of the elements in this configuration are commercially available and that the remote-observation and data-transfer functions are entirely configured with commercial products including the telephone lines.

Focusing on the above functions, the remote-observation function enables transmission of video-camera images of the electron microscope and the operator in addition to the image observed by the microscope with the aim of providing a comprehensive human interface.

In the data-transfer function, transfer

time increases as the desired quality of the transferred photograph becomes higher. Although picture quality is often a subjective matter, a relationship can be established between acceptable picture quality of a transferred photograph and transfer time, as shown in Table 1. According to this relationship, a good-quality photograph can be transferred in about two minutes. In addition to this time, however, about one minute is required for the electron microscope to capture the image and about two minutes are required to print it out on the user side. The development of computer technologies and high-speed network services in the future will promote reduced cost for the equipments and operations.

Only the remote-operation function includes non-commercial products such as automatic stage-driving equipment that works in unison with the electron microscope. This automatic stage-driving equipment is shown in Fig. 2 and an example of a screen display generated by driving software is shown in Fig. 3. Main function of this driving software are 1) movement toward a desired sample; 2) fine adjustment of observation position; and 3) magnification and reduction of the observed image.

3. System Application

Although a wide variety of applications can be considered for this remote electron microscope, the following three usage formats are either being employed at present or under study: 1) remote analysis service tool for technicians, 2) remote microscope tool for students, and 3) event tool. These applications are each described below.

3.1 Remote analysis service tool

NTT's research laboratories are located in various areas such as Musashino and Atsugi that are not necessarily close to each other. In the past, this meant that a technician in the Atsugi area who wished to make use of an electron microscope in the Musashino area for in-person analysis would have to travel more than two hours one-way for this purpose. This remote analysis service tool was originally constructed to eliminate such trips for in-person analysis. In particular, a system was established in January 1996 that connected the electron microscopes set up in Musashino and Ibaraki with videophones set up in each of the laboratories at Musashino, Atsugi, and Ibaraki.

This application requires remote observation and data transfer as minimal functions. With these functions, the user (technician) can give suitable instructions to the location where samples are actually being observed and promptly receive photographic data from the microscope. In addition, the recent availability of inexpensive videophone systems for use with personal computers is making it possible to connect from one's own desk in a research laboratory.

The main benefits of this application are saving on travel time and quick reception of quality data from microscope observations. This system also incorporates effective security measures considering the importance of maintaining confidentiality in materials-analysis services.

3.2 Remote microscope tool

Inspecting plants and insects is often part of the curriculum in middle- and high-school science classes, and this is normally done through the use of magnifying glasses or optical microscopes. It has been proposed, however, that remote microscopes take on the role served by optical microscopes in such activities. The main reason for this is that compared to the several 100x magnification achieved in practice by optical microscopes, an electron microscope can easily achieve magnification of several 10,000x.

The functions required for this application are remote observation and remote operation. The latter function enables students themselves to move the sample at the electron microscope and to magnify and reduce the observed image. It also enables observations of up to several 10,000x magnification using simple operations the same as those of optical microscopes. Such uncomplicated microscope operations are indispensable to this kind of application and important from the viewpoint of education . Whether or not remote microscopes that combine network technology and electron microscopes can become an effective tool in science education is now being examined by a

joint study called the "CoNET Plan" sponsored by NTT in cooperation with the Ministry of Education[5].

3.3 Event tool

A remote electron microscope can be used as a tool to attract an audience at exhibitions, festivals, and other events by having people experience images from the "micro world" that they cannot encounter in their daily life. The application requires at least the remote-observation function, and it is also important that a large-screen monitor be provided as the number of viewers might be large. Moreover, depending on the situation, the data-transfer function could be added to provide photographs of observed images for use as presents or souvenirs. This event tool has so far been presented at about ten events inside and outside of NTT. One example is Ecolife Fair '96 sponsored by the Environment Agency (June 7-9, 1996), as shown in Fig. 4.

4. Summary

In this paper, we have introduced functions and application examples of remote electron microscopes that combine network technology and electron microscopes based on actual experiences over these last two years. From this point on, the convergence of network technology and various types of analysis technologies will continue with the goal of eliminating the walls formed by distance between equipment, operators, and users, the three main elements of remote-electron-microscope systems, and further developing analysis technology.

5. References

[1] Takeyama et al., NTT Technical Journal, Vol. 9, No. 3., pp. 64-68, 1997

[2] Ichikawa et al., NTT Technical Journal, Vol. 9, No. 3., pp. 69-74, 1997

[3] A. Shapiro, Fifth International Conference on Technology and Education, Vol. 2, 190 (1998)

[4]G. Y. Fan and P. J. Mercurio, Ultramicroscopy, Vol. 52, Nos. 3-4, 499 (1993)

[5] Asahi Shinbun, Morning Edition, November 24, 1996, "NTT Leads Private Contribution to Internet Setup at 1000 Schools"

Table 1 Transfer conditions of picture data

Picture Element	Image Compression (%)	Transfer Time (s)	Image Quality
500 x 500	17	9	X
	25	12	X
1000 x 1000	15	29	△
	25	58	○
2000 x 2000	15	110	○
	25	223	○

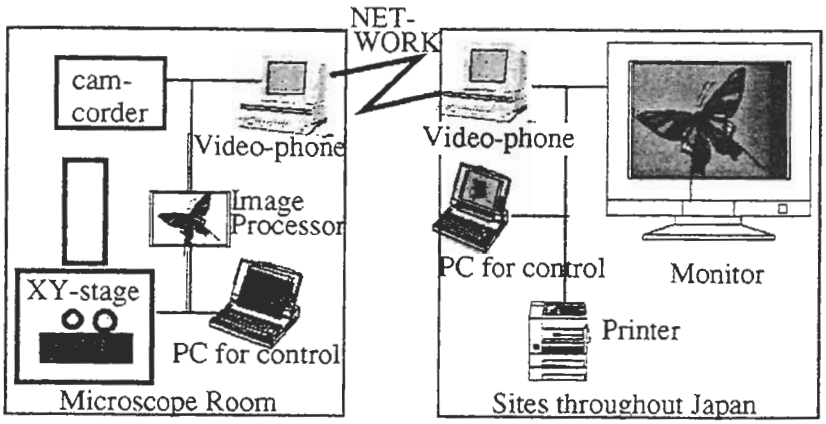

Fig. 1 Remote-electron-microscope system

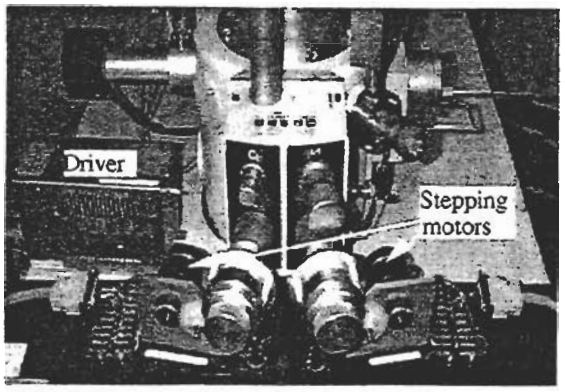

Fig. 2 Stage driving components

Current Position:2 -50 890

No.	Name	X	Y
1	Mouth of butterfly	-123	1234
2	Wing of butterfly	-50	890
3	Mouth of mosquito	310	-300
4	Eye of mosquito	400	-567
5	Pollen of Japan cedar	1234	678

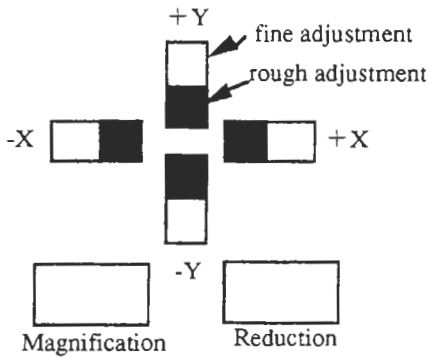

Fig. 3 A screen display from driving software

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Fig. 4 View of Ecolife Fair'96