OBSERVATION SOFTWARE

By

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ABSTRACT

High-precision and high-accuracy observation of Satellite Laser Ranging (SLR) requires laser ranging equipment with the latest optical and electronic technologies as well as special software to control this kind of system. Currently SLR observation requires one or more skillful operators at each observation site. Four local observation sites in the Keystone Project/SLR are uninhabited systems remotely controlled from the control center. Moreover a control center operator does not need specialized knowledge of SLR since the operation sequence is automated and the SLR can be remotely operated by a computer network.

Keywords: satellite laser ranging, software system, remote control

1. Introduction

Observation of SLR is performed on the basis of various kinds of information --

satellite orbit (Inter-Range Vector: IRV format), earth rotation parameters, the correction of orbital information (Time-Bias) etc. -- provided from world-wide data centers. Raw data sets obtained by laser ranging are changed into the international form (Merit-II format and Quick-Look format). After that, these data sets are used to analyze the position of the observation site, and are sent to world-wide data analysis centers so that they can be used for orbital generation or global analysis etc.

The Keystone Project/SLR with few millimeters precision and accuracy is introduced the latest optical and electronic technology[(1)-(4)]. Observation software needs to control this ranging equipment in order to perform high-precision measurements. The purpose of the Keystone Project is to monitor the crustal movement of the metropolitan area. The ranging is required at 24-hour every day except the bad weather day. For this reason, it is not realistic to use an observation method that requires two or more skillful operators. Therefore the Keystone system is requires maintenance-free hardware, and software that intensively manages and controls the four local sites.

This system has a control center in Koganei as well as the four local sites. By using a network to connect the four local sites and the control center, an operator at the control center can simultaneously handle all of the local systems. Moreover, a skillful operator is not necessary for ranging. Non-skillful operator can make observations due to a user-friendly interface and a lot of automation.

2. Operation Modes

There needs to be an operator at the control center in order to control the four unmanned local sites. However, when a certain problem occurs in the system or when an individual setup is needed for an experiment, it is necessary to have an operation mode which can allow to control each local site independently. To deal with these problems, this system has three kinds of observation operation modes. Each mode can be easily changed. Fig. 1 shows the data flow in each mode.

Central-Control Mode: This mode is the most common operation mode in Keystone. Only one operator at the control center can control all of the sites. All information relating to the ranging preparation is automatically received and updated. An observation schedule is created on the basis of the collected information. At each local site, the actual observation follows the observation schedule. After finishing observation, observed data sets are processed in order to reject the noise points and are then transmitted automatically to a control center. An operator has only two jobs to do. One is sending the tracking start command to a computer, and the other is sending the stop tracking command to a computer.

A tracking stop command is sent when the weather becomes bad at a certain local site, or when the operator judges that for some reason ranging is impossible.

Remote-Control Mode: Each local site is remotely controlled, but a setup unique to its site is also possible. This mode is used when an operator needs to use an individual setup or an individual schedule or when an operator wants to investigate the situation at a specific site. This mode can be operated completely like the central-control mode. An operator is not required to memorize different user interfaces. However, the operator has to be skillful since the purpose of this mode is to use an individual setup and the individual schedule of a local site.

Site-Control Mode: This mode is used when the control center cannot control a local system and an operator has to observe directly at the local site, such as when system maintenance needs to be performed or there is a network failure. Information for the observation prediction can be directly acquired from the world-wide data centers. And, the ranging data can be directly transmitted to data analysis centers throughout the world. This mode requires one or more skillful operators at a local site.

3. Network

We already mentioned that the computer network is important for the Keystone system, in order to control the uninhabited local system from the control center. Fig. 2 shows the network structure.

There are Local Area Network (LAN) using 10 Mbps Ethernet for connecting the computers in the local sites and in the control center, and a star-type Wide Area Network (WAN) using 128 Kbps digital line to connect between the control center and each local site. There are two kinds of packets on the network at the local site. The first is the control-command packet for the ranging. The second is the video-image packet from surveillance cameras[(5)]. The control command from the control center should be sent to the local site as soon as possible. On the other hand, the video-image packet which has huge capacity and needs a lot of bandwidth is not required for real-time transmission. The heavy traffic of low-priority images does not interfere with the transmission of high-priority control command since an IP router is used to separate the control LAN from the image LAN. WAN is separated similarly and each line occupies only a maximum of 64 Kbps of bandwidth. There is analysis LAN at the control center. The analysis computer shares files between the file server and network is occupied by the packet of file sharing. Therefore analysis LAN is separated from other LANs.

File transfer between Keystone and world-wide data centers uses FTP or E-Mail via the Internet. The network of Communications Research Laboratory (CRL) has been connected to the Internet. The Keystone network can easily connect to the outside only by connecting to the CRL network.

4. Computers

There are computers with various functions at the control center and at each local site. All computers are IBM PC/AT compatible computers, and Windows NT workstation is run on these computers as an operating systems. All computers have network interface cards, and can communicate with each other via a network.

There are three computers at each local site. The first computer is the site control computer (SCC) that is used to control ranging. When the site-control mode is in the operation mode, the SCC can be directly used by an operator at a local site. Other operation modes can control the SCC from control center. The SCC is also used to receive the observation schedule which is transmitted from the control center, and is used to transmit MERIT-II and Quick Look formatted data. The other two computers are the Dome Control Computer (DCC) and the Ranging Computer (RC) that are used to control actual devices such as dome, telescope, laser devices etc. These two computers are controlled by SCC commands.

The Central Control Computer (CCC) and four Remote Control Computers (RCCs) are located in the control center. CCC is only used in the central-control mode. RCC is used to control the SCC from the control center, and if operation mode is the remote-control mode, an operator directly uses RCC for controlling the SCC.

To archive ranging data sets, the file server is connected to analysis LAN. The file server has a MO jukebox which can insert 15 rewritable optical disks in addition to internal hard disk. An optical disk has 4.6 Gbytes capacity on both sides. The file server records the ranging data sets on both the optical and internal disks to increase the data security. The optical disk can be ejected from the jukebox in order to save it semi-permanently. Fig. 3 shows pictures of the computers.

5. Software

The Keystone system has three operation modes as described in Section 2. Therefore, similar sets of operation software are installed into CCC, RCC, and SCC. However, the central control function and the device accessing tool are installed only into the corresponding computer. Software is divided into Windows ".exe" file by function[(6)]. Here, characteristic functions are described.

5.1 Site Operation Executive

The site operation executive controls the ranging sequence and the user interface. In Fig. 4, the observation status of each site is indicated by a Face Icon. An operator without special knowledge can understand whether the status of local site is good or bad. If an operator clicks the Face Icon, detailed information appears such as the return signal from satellite or the laser's status. This window is also used to setup the parameters or to fine tune the telescope etc. Since this program can operate from every CCC, RCC or SCC computer, the right of control is called a token and is limited to only one computer so that two or more computers can not simultaneously send a control command. A computer that wants to send a control command but does not have a token can get a token from another computer that has one. The computer without a token cannot send a command for ranging control but can monitor the ranging sequence. In addition, an operator needs to grant permission for the movement of a token.

5. 2 Mission Planning System

The mission planning system is used to create the observation schedule and is separated into two functions: One is to generate the satellite orbit data using prediction information from the data centers. The other is to assign the schedule of satellite tracking and terrestrial target ranging. Now, more than 20 satellites outfitted with corner-cube retro-reflectors (CCRs) -- geodetic satellites, earth observation satellites, and communication satellites -- have been launched, and more will be launched in the future. Therefore, we need tracking priority in order to efficiently achieve co-observed passes.

Creating the optimum schedule in terms determining the local station coordinates is difficult and will be investigated in the future. In addition there are the particular cases like when a specific satellite needs to be intensively observed due to an international requirement, or when a schedule should be changed due to bad weather (the ranging toward a low-orbital satellite is possible but toward a high-orbital satellite is impossible in light cloudy weather). To address these situations, the system first determines the priority of each satellite, and then creates a schedule automatically. After that the operator can freely schedule. Fig. 5 shows a screen image of the mission planning system.

5.3 Post-Range Processing

The raw data of SLR includes many noise points from sunlight, ground light, and system itself. Analysis software requires data sets which include only signal points. Therefore, we are necessary noise elimination process called the post-range process. The post-range processing eliminates the noise from the raw data and creates a MERIT-II full-rate file and a Quick-Look normal-point file. If we can transmit the raw data sets to the control center, we can easily separate the noise and signal by eye. But the raw data sets have large capacity which makes it impossible to transmit the raw data to the control center via a small network. This program is therefore required to perform a noise elimination process automatically at the local site. Several kinds of algorithms exist for automatic noise elimination and these have also become a our new research subject(7)(8).

5.4 Archiving

The archiving program stores the raw range data or the MERIT-II / Quick-Look format data on the disk. The raw data is stored on the optical disk which is connected to the SCC. An optical disk has capacity of about 2.3 Gbyte per one side, and it should be changed fixed maintenance performed every four months. MERIT-II and Quick-Look format data are transmitted to the control center and are stored on two kinds of disks -- the optical disk and internal hard disk that are connected the file server. The file server has a MO jukebox and can change the optical disk automatically.

5.5 Virtual Control Panel

All observation is controlled by the SCC, but laser ranging equipment is actually controlled by other programs like the Virtual Control Panel (VCP). VCP corresponds individually to each type of hardware. It can drive a telescope or the output power of laser. Furthermore, when a telescope approaches the sun, VCP stops the telescope in order to prevent it from directly receiving solar light. VCP is also able to be directly controlled by an operator who needs to carefully setup the equipment for an experiment or maintenance.

6. Conclusion

Today, continuous observation of laser ranging requires about five to ten specialized operators per station. The Keystone system which has four stations with highest performance in the world can be controlled by only one operator without specialized knowledge. This paper described the software for using an automated system to control observations. The purpose of this system is not only to investigate automation, but also to develop a system which can correspond to various types of operations.

It is considered that the design concept of this system is not restricted to the Keystone Project, but is referred from laser ranging station to develop or reconstruct in the future.

References

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Figure Captions

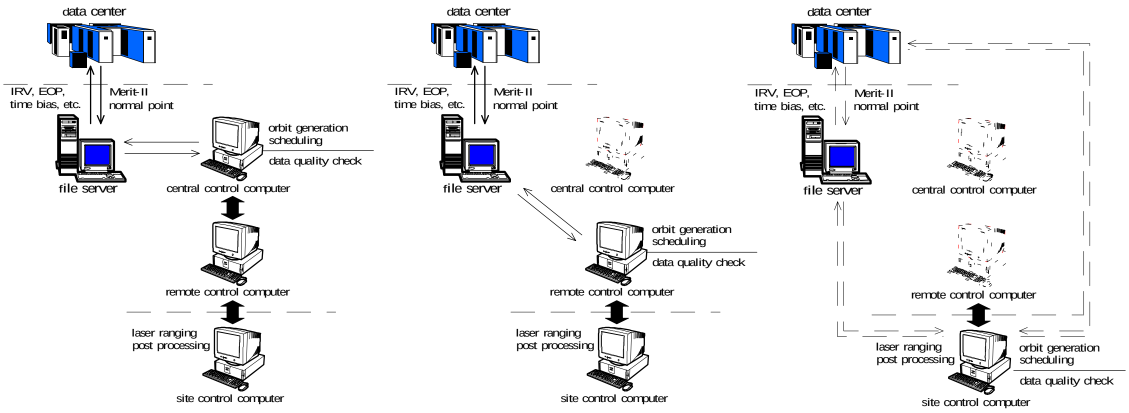
Fig. 1 Data flows in each operation mode.

Fig. 2 Network structure of Keystone Project.

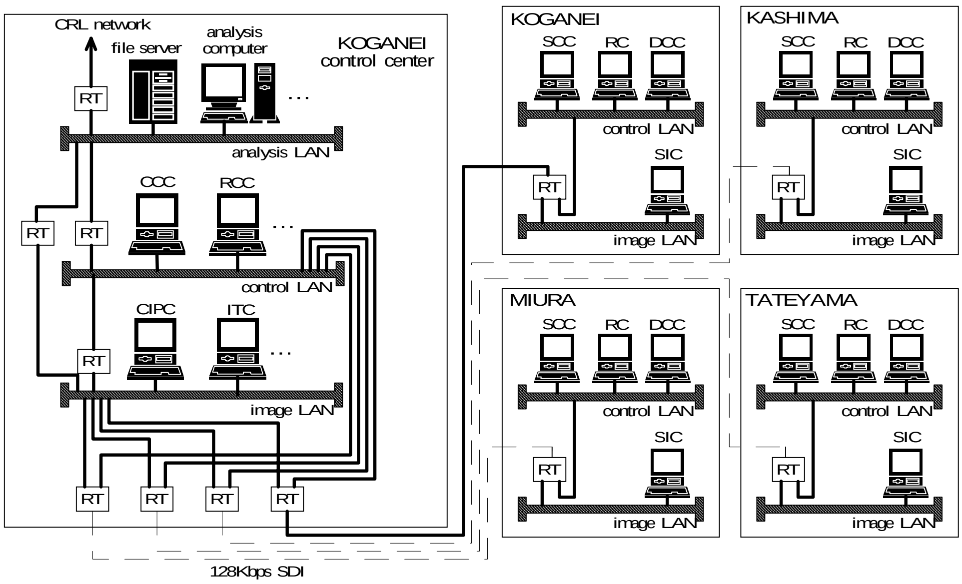
Fig. 3 Pictures of the computers.

Fig. 4 View of the Site Operation Executive.

Fig. 5 View of the Mission Planning System.



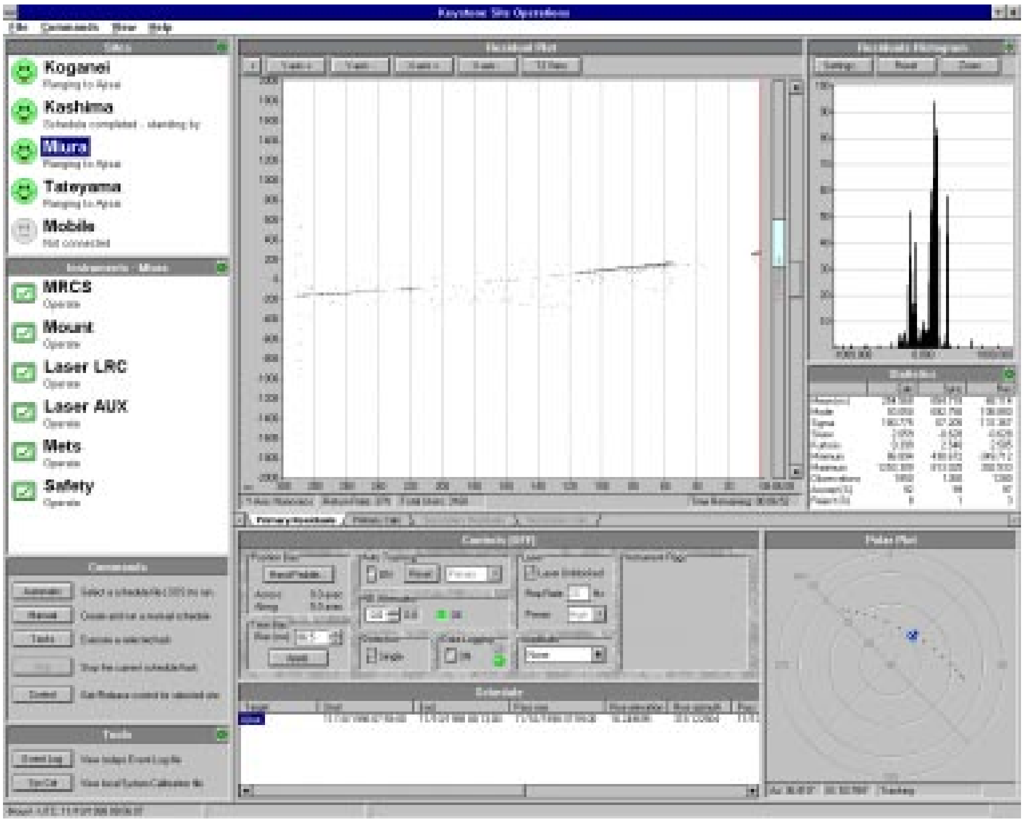
(a) Central-control operation mode (b) Remote-control operation mode (c) Site-control operation mode



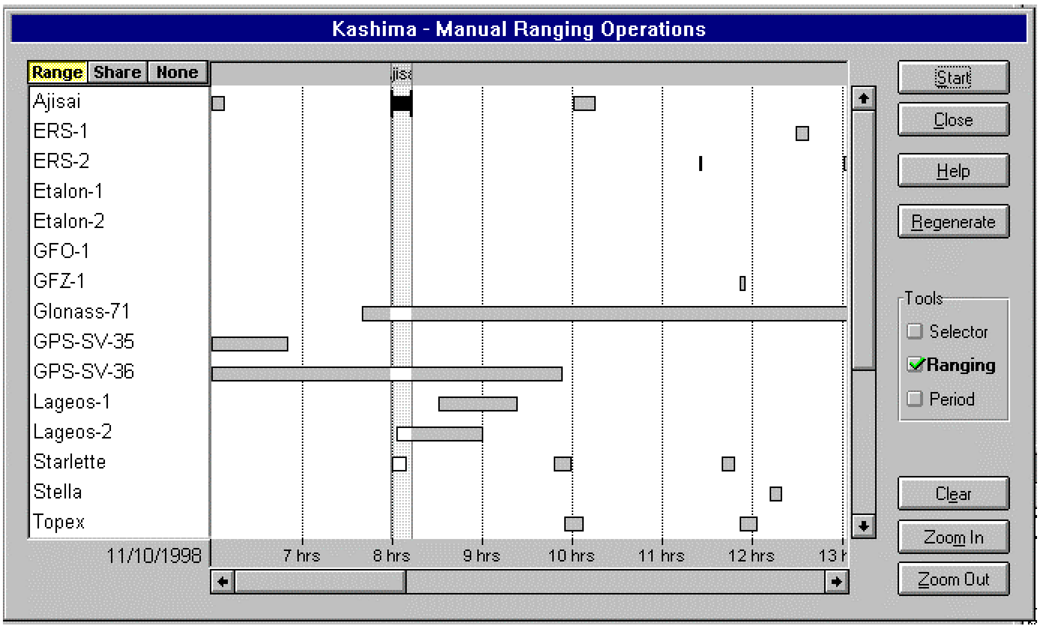
CCC: Central Control Computer
RCC: Remote Control Computer
SCC: Site Control Computer
SIC: Site Image Computer
ITC: Image Transfer Computer
CIPC: Central Image Processing Computer
RC: Range Computer
DCC: Dome Control Computer

(a) control center

(b) local site



Koganei
Kashima
Miura
Tateyama
Mobile
MRCS
Mount
Laser LRC
Laser AUX
Mets
Safety


Kashima - Manual Ranging Operations
Range
Share
None
Ajisai
ERS-1
ERS-2
Etalon-1
Etalon-2
GFO-1
GFZ-1
Glonass-71
GPS-SV-35
GPS-SV-36
Lageos-1
Lageos-2
Starlette
Stella
Topex
11/10/1998
7 hrs
8 hrs
9 hrs
10 hrs
11 hrs
12 hrs
Start
Close
Help
Regenerate
Tools
Selector
Ranging
Period
Clear
Zoom In
Zoom Out