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A new approach to the telescope operation method for satellite tracking using a time synchronization technique

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Abstract

For the development of a telescope that is capable of precisely tracking satellites and high-speed operation such as satellite laser ranging, a special method of telescope operation is required. This study aims to propose a new telescope operation method and system configuration for the independent development of a mount and an operation system which includes the host computer. Considering that the tracking of a satellite is performed in real time, communication and synchronization between the two independent subsystems are important. Therefore, this study applied the concept of time synchronization, which is used in various fields of industry, to the communication between the command computer and the mount. In this case, communication delays do not need to be considered in general, and it is possible to cope with data loss. Above all, when the mount is replaced in the future, only the general communication interface needs to be modified, and thus, it is not limited by replacement in terms of the overall system management. The performance of the telescope operation method developed in this study was verified by applying the method to the first mobile SLR system in Korea. This study is significant in that it proposed a new operation method and system configuration, to which the concept of time synchronization was applied, for the observation system that requires an optical telescope.

Keywords: Time synchronization; Operation system; Satellite laser ranging; International Laser Ranging Service; Space geodesy

1. Introduction

To efficiently observe a satellite with fast motion, the aperture needs to be large and the focal ratio needs to be small so that a wide angle of view is available, and the tracking speed of the mount needs to be high so that precise real-time tracking is easily enabled (Lee et al., 2001). For satellite laser ranging (SLR), a fast mount driving speed is needed to enable the tracking of the lowest Earth orbit satellites with an average altitude of less than 300 km, and the altitude–azimuth mount method is typically used. In the field of domestic satellite tracking using optical systems, Kim and Min (2003) developed a high-speed tracking system, although it was not an SLR system.

Overseas, SLR systems have been produced by implementing the hardware and software provided by various manufacturing companies. For the SLR2000 system in

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the United States, a 2 kHz high-speed parallel communication interface between the host computer and the servo controller has been established using an improved tracking mount from Xybion Corporation (Patterson and McGarry, 2002). For the Graz system in Austria, on which the domestic research team has consulted with the Austrian research team, a mount manufactured by Contraves Goerz Corporation is in operation, and a communication speed of 50 Hz is maintained by installing the interface card for general purpose instrument interface communication in the computer. For a small optical telescope, a commercial controller is installed, and the interface required for commands is developed using a library provided from the controller.

There are some limitations to the existing methods used in the process of telescope development and operation. In this case, the speed of communication between the controller and the operation computer needs to be high, and is dependent on the specification of the product. In other words, if the mount is replaced with a mount from another manufacturing company, the relevant part of the host computer also requires an overall modification. Therefore, a new operation method for telescope driving is required to overcome these limitations, to easily enable independent development and operation.

The objective of this study is to propose a new operation method and system configuration for the independent development of a telescope driving system and a command computer. The proposed technique is applied to the real system, and its effectiveness was confirmed through the result of the test for verification.

For this purpose, the newly designed method is a time synchronization technique. Considering that the tracking of a satellite is performed in real time, communication and synchronization between the two separate subsystems are important. Therefore, the time synchronization technique based on universal time coordinate (UTC) was applied to the communication process between the two subsystems. Considering the potential need for system expansion and improvement in the future, a connectionless Ethernet communication method such as the user datagram protocol/internet protocol (UDP/IP), which is a general communication protocol, was used. In other words, the time synchronization technique for this study is one in which the tracking order and status information are delivered by communication packet tagged UTC information between the operation computer and mount for telescope driving developed independently. The methods used to verify the effectiveness of this technique application are as follows. The reliability of the communication is verified by the degree of packet loss. The time synchronization performance is checked by the periods of the transmission packets in each system. Finally, the traceability test in the normal tracking is performed through a method that uses trajectory comparison and image of the target satellite.

The results and improvements of the developed telescope operation method on SLR tracking are as follows. For a given time, several accurate tracking time and position data are transmitted before and after the given time, and accordingly, the communication period does not need to be short. Thus, delay does not need to be considered in general, and it is possible to cope with data loss. Above all, when the mount system that is in charge of driving is replaced in the future to improve the performance, only the general communication interface needs to be modified, and thus, it is not limited by replacement in terms of the overall system management.

The scope of this study is based on the accurate ranging system for geodetic observation – mobile (ARGO-M) (Jo et al., 2011; Lim et al., 2010, 2011), which is the first SLR system in Korea developed by the Korea Astronomy and Space Science Institute, has been completely developed. The ARGO-M is in test operation, as shown in Fig. 1 (Park et al., 2012a). The station code is DAEK (see web links below). Fig. 2 shows the subsystems constituting the ARGO-M. Among these, the Korea Astronomy and Space Science Institute took charge of the development of the ARGO-M operation system (AOS) (Seo et al., 2009, 2010). The scope of work included the data generation necessary for overall system operation, the operation scenario configuration, the required time and frequency system configuration, the communication interface design, and the checking of the operation result. The Korea Institute of Machinery and Materials took charge of the development of the tracking mount subsystem (TMS) (Park et al., 2010). The scope of work included the mechanical design and manufacture of the mount, the design and manufacture of the servo controller, and the tracking performance evaluation depending on the TMS self-production. For the ARGO-M, the AOS and the TMS were developed independently. This paper described the research results related with the work scope of the AOS explained earlier. The TMS design and self-tracking performance were presented in Park et al. (2012b).

In the present study, the position estimation method and the driving command generation and transmission system were first explained, which are essential for the AOS to transmit real-time satellite tracking commands. Also, the operation method using a time synchronization technique that is characteristic of this study, the system configuration including relevant equipment, and the communication interface were described. To verify the telescope operation method developed in this study, the results of the major performance analysis, obtained by applying the method to the ARGO-M that is currently in test operation, were presented.

2. Estimation of satellite trajectory and data processing

SLR can predict the position values of a satellite to be observed by downloading the consolidated prediction format (CPF) data (see web links below; Ricklefs, 2006a) in advance from the data center of the International Laser Ranging Service (ILRS) (Pearlman et al., 2002; Gurtner et al., 2005) via electronic mail or file transfer protocol.