Development of Remote Pseudo-Dynamic Test Method via Internet

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ABSTRACT

This research studied the remote control of distant share-use facilities by integrating information communication technology and high-performance computing technology, and through the recognition of data and conditions of an experiment in real time. A system for distance monitoring and controlling a seismic experiment was developed. This system was used to develop the method of a remote pseudo-dynamic test.

Transfer protocol is needed to remotely transmit data through Internet. In this study, the data-socket transfer protocol was used. Because the time-integration method is needed for the pseudo-dynamic test, the Newmark explicit method was chosen to avoid unnecessary iteration. An analog signal to communicate with the FlexTest CTC controller was used to control the actuator. Codes for the remote pseudo-dynamic test were developed by integrating remote-data transmission, time integration, and input/output of the analog signal. The pseudo-dynamic test was remotely executed using this program.

The results of the remote pseudo-dynamic test and an analysis using a common program showed little difference. Based on this comparison, it was concluded that the result of the remote pseudo-dynamic test was meaningful. Thus, the application of the remote test was verified.
1. INTRODUCTION

Domestic and overseas research facilities are not concentrated but spread out. Personal computers, as well as large, expensive experiment facilities and super-computing equipment, are also spread out. Consequently, researchers spend much time and effort looking for research facilities and trying to acquire separate platforms to use these facilities. To improve this situation, projects such as NEES (Network for Earthquake Engineering Simulation) by NSF (National Science Foundation) and KOCED (Korea Construction Engineering Development) collaboratory program are being undertaken to provide researchers with more ideal research conditions, thereby enhancing research ability, by organically linking various facilities. Research conditions can be improved by sharing experimental data and numerical data. If this sharing can be achieved, a sub-structure compatible with research and distribution of data will be formed and this network can provide important data on earthquake safety for main infrastructure.

Efforts at controlling distant share-use facilities have been exerted by combining information communication technology and control-measurement technology. Sharing of experimental data in real time has also been attempted. This technology can link experiment facilities not only in America but also elsewhere in the world. Korea can take the lead in the field of networking spread-out facilities by developing this technology. As a preliminary study, a remote pseudo-dynamic test was performed via Internet.

2. ELEMENTS OF REMOTE PSEUDO-DYNAMIC TESTING

There are a number of requirements for remote pseudo-dynamic testing. First, a programming language for remote pseudo-dynamic testing algorithm must be chosen. Second, a communication protocol is required to transmit data through the Internet. Third, the time-integration method must be used to execute the pseudo-dynamic test. Finally, the in-house program must be able to communicate with FlexTest CTC controller to operate the actuator. The following sections will explain the described requirements.

2.1 Programming Language

To develop an in-house remote pseudo-dynamic test program, LabVIEW, developed by National Instruments, was chosen as the programming language. LabVIEW is the best language for control and measurement, and it has a graphical user interface, which saves time and effort in programming. Moreover, as the version of LabVIEW has been upgraded, the Internet application of LabVIEW will be enhanced. Using this language, the program integrating the data transmission via the Internet, the time-integration algorithm, and the signal generation that would operate the actuator was completed.

2.2 Remote Data Transfer through the Internet

A protocol was needed to transmit data through the Internet. TCP/IP (Transmission Control Protocol/Internet Protocol) is the fundamental protocol for the Internet, but the exclusive use of TCP/IP made it difficult to transmit specific data. As such, dstp (DataSocket Transfer Protocol) was
chosen as a sub-protocol for data communication through the Internet. With LabVIEW as the programming language, various dstp functions could be easily used.

In this experiment, a local client operated the actuator and a remote client performed time integration and determined the displacement to be imposed on the test structure. These displacement data were sent to the local client through a datasocket server using dstp, and experimental data from the imposed displacement were sent to the remote client in the same way. This data transfer using dstp was done by programming using LabVIEW [J. Travis, 2000].

2.3 Time-Integration Algorithm

In a pseudo-dynamic test, a time-integration method is needed to determine the displacement to be imposed on the test structure. In this study, the single-degree-freedom pseudo-dynamic test was performed. Since the effect of cumulative errors is negligible at lower modes, error-correction processes such as frequency-dependent damping were not considered [P. B. Shing et al., 1984]. The Newmark explicit method was selected because it is less sensitive to errors and can avoid unnecessary iterations. This algorithm is described in Fig.1.

2.4 Interface Between the Controller and the Developed Program

A controller is needed to operate the experimental device. The developed program communicates with the exiting MTS FlexTest CTC controller, with which KEERC is equipped. As the interface is with the controller, the input/output of analog (voltage) signal was used. The MTS controller can use an external analog signal as an actuating command. In LabVIEW, the input/output-of-analog signal is very easy to generate [B. E. Paton, 1998]. Because of these features, the analog signal was used as a medium between the controller and the program.

![Algorithm of Newmark explicit method](image)
Figure 2. Block diagram of the remote program.

Figure 3. Block diagram of the local program.
2.5 Remote Pseudo-Dynamic Test Program

As stated, the developed program was programmed in LabVIEW. In programming using LabVIEW, there are two kinds of windows: one is called “block diagram” and the other “control panel.” The former is a window for programming. Instead of the text-type user interface, a graphical environment relatively easy to use is provided [G. W. Johnson, 1998]. The latter is a window for controlling experimental parameters and monitoring data of the test [L. K. Wells et al., 1997].

In Fig.2 and Fig.3, the block diagrams of the remote program and the local program are shown, respectively. The descriptions of these block diagrams are as follows.

As the test is started, the remote program determines the initial displacement according to the initial conditions. The displacement data are sent to the local program via the Internet using dstp. After imposing the displacement, the remote program receives the experimental data from the local program. Based on these data, time integration is performed and the next displacement is determined and sent to the local program. The local program generates the analog signal for actuating the experimental device according to the received displacement data. Then, experimental response data are taken through DAQ (Data Acquisition) board, and the local program sends the data to the remote program.

3. VERIFICATION TEST

A pair of in-house programs that can perform the remote pseudo-dynamic test was developed. However, the reliability of these programs when used in a remote experiment had to be verified. As such, an actual remote pseudo-dynamic test was executed using this program. Then, a test structure was prepared. A steel column was used as a specimen. The specification and installation are shown in Fig.4 and Fig.5, respectively.

![Figure 4. Specification of test structure.](image-url)
Figure 5(a). Side view of test structure.

Figure 5(b). Front view of test structure.
The El Centro ground acceleration records were chosen for the input excitation acceleration. Four hundred input data that have a time interval of 20 ms were used. Seismic responses for 8s were thus obtained. The time histories of the seismic responses are illustrated in Fig.6.

Figure 6(a). Time history of displacement.

Figure 6(b). Time history of velocity.
Figure 6(c). Time history of acceleration.

Figure 6(d). Hysteretic curve.
The reliability of the output data compared to the data from the remote test was questioned. The test structure was thus analyzed using a common program-- SAP2000. The structure of the actual experiment was simulated in the analysis except for the damping, which accounted for the energy dissipation [A. K. Chopra, 2000]. Fig. 7 shows the comparison of the results of the actual experiment and the analysis. Minimal difference can be seen between the two sets of results. Therefore, it was concluded that the result of the remote pseudo-dynamic test was meaningful. The feasibility of the remote test was thus verified.

4. CONCLUSIONS

A system that can monitor and control an experiment remotely through the Internet was developed. Using this system, a method of remote pseudo-dynamic testing was devised. Moreover, an in-house program integrating remote data transmission, time integration, and input/output of analog signal for remote pseudo-dynamic testing was developed. Using this program, a pseudo-dynamic test was remotely executed. The results of the remote pseudo-dynamic test and of the analysis, using a common program, showed little difference. Based on this comparison, it can be concluded that the result of the remote pseudo-dynamic test was meaningful. The feasibility of the remote test was thus verified.
5. ACKNOWLEDGEMENTS

This study was supported mainly by the Korea Science and Engineering Foundation (KOSEF) through the Korea Earthquake Research Center (KEERC), partly by the fund of the Korea Bridge Design & Engineering Research Center (KBRC) and partly by the fund of BK21 Program of Korea Ministry of Education. The authors wish to express their gratitude for the supports received.

6. REFERENCES


