DEVELOPMENTS IN THE CSMIP STRONG-MOTION AUTOMATED RECOVERY AND ANALYSIS (SARA) SYSTEM

A. Shakal¹, H. Haddadi² and T. Reitz³

ABSTRACT

The recovery and processing of strong motion records have historically been a time-intensive process, often leading to critical delays in the availability of important data after an earthquake. A Strong-motion Automated Recovery and Analyses (SARA) system was developed by the California Strong Motion Instrumentation Program in the California Geological Survey to automate and accelerate the availability of strong motion data after an earthquake. The overall approach is that when an accelerograph is triggered by ground motion, it establishes communication with the central SARA system, where one of a set of PCs automatically interrogates the accelerograph and proceeds to transfer the file to the SARA facility in Sacramento where it is automatically processed. Recent developments include expansion to accommodate new field accelerographs, increased quality control and increased rate of handling incoming records. Data communication methods have been extended to use digital data cellular devices and accommodate file transfer by Internet protocols such as FTP. Automated recovery and processing makes it possible for many strong motion records to be available soon after an earthquake, through the Internet Quick Report (IQR) of the Center for Engineering Strong Motion Data (CESMD) at www.strongmotioncenter.org.

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The recovery and processing of strong motion records have historically been a time-intensive process, often leading to critical delays in the availability of important data after an earthquake. A Strong-motion Automated Recovery and Analyses (SARA) system was developed by the California Strong Motion Instrumentation Program in the California Geological Survey to automate and accelerate the availability of strong motion data after an earthquake. The overall approach is that when an accelerograph is triggered by ground motion, it establishes communication with the central SARA system, where one of a set of PCs automatically interrogates the accelerograph and proceeds to transfer the file to the SARA facility in Sacramento where it is automatically processed. Recent developments include expansion to accommodate new field accelerographs, increased quality control and increased rate of handling incoming records. Data communication methods have been extended to use digital data cellular devices and accommodate file transfer by Internet protocols such as FTP. Automated recovery and processing makes it possible for many strong motion records to be available soon after an earthquake, through the Internet Quick Report (IQR) of the Center for Engineering Strong Motion Data (CESMD) at www.strongmotioncenter.org.

Introduction

Automated near-real-time strong-motion record recovery and processing was first implemented as a pilot project by the California Strong Motion Instrumentation Program (CSMIP) in 1995 [1]. Since that start, the Strong-motion Automated Recovery and Analysis (SARA) system has been expanded to accommodate data recovery from many stations, employing several accelerograph types and communication types. The processed data results are currently passed to the web-based Internet Quick Report and ShakeMap at the Center for Engineering Strong Motion Data

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Instrumentation in the CSMIP Network

The CSMIP network currently has 1,300 stations, 1,100 of which provide their data automatically through the SARA system. The remaining stations have power limitations, no ready access to communication, or are not designed for communication. The communication types at CSMIP stations, once nearly all standard phone lines, are shifting to data cellular and IP links.

Accelerograph types in the CSMIP network include Kinematics Altus series and Rock series, and the Reftek 130 SM and 130 MC series. An active test instrument of each type is set up in the data recovery laboratory, and before a new algorithm or procedure is used in field instruments, it is tested using the laboratory instruments.

SARA System

From its beginning, the SARA system has expanded significantly, both in capacity and in functional capability. In operation, field accelerographs connect with a front-end recovery PC within a set, according to the station location and the type of instrument. Establishing communication when needed provides significant economy over continuous communication lines when many stations are involved. The source area for each front-end PC is randomized geographically, so data from a southern California earthquake, for example, will access all the front-end PCs, not just a southern California subset, maximizing the capacity of the system.

A schematic representation of the SARA system is shown in Figure 1. Record processing is automatically initiated when a binary event file has been loaded to a receiving PC from a field accelerograph. After recovery of the file, the record is automatically converted from the instrument’s binary format to raw counts or voltages (Volume 0). Raw files from partner networks are also processed and loaded to the CESMD through the SARA system. Volume 0 files are processed to raw acceleration (Volume 1), then preliminarily filtered and integrated to obtain processed acceleration, velocity and displacement (Volume 2), and finally the response and Fourier spectra (Volume 3) are computed. The preliminary processing uses a long period corner at 3.3 seconds to provide the data values needed immediately for ShakeMap generation. For moderate and large magnitude earthquakes, the filter corner is later shifted to longer periods. QC is applied during the automated processing. A number of error types have been defined, and the system looks for these during execution. Records with a QC error are identified with a flag, to allow later review by an operator. If the error is serious, the record is not posted for release until review and action by a duty seismologist.

After processing of a record is complete, the results are passed to the machines of the CESMD which produce the Internet Quick Report (IQR) of strong motion data and generate the ShakeMap products. [2].
Strong-motion Accelerogram Recovery and Analysis (SARA) System

Figure 1. Schematic of the SARA strong-motion automated recovery and analysis system. The field stations communicate with the front-end PCs by a communication program. For security, the public-facing front-end PCs are standalone, and not on the central network of the Buffer, Importer and Collector machines. In the event of AC loss, all PCs are on battery backup, and shift to standby diesel generator after 10 seconds.

Accelerogram-Earthquake Association

The SARA system associates a given record with an earthquake, using the time the instrument was triggered and the time and location of the earthquake. Using the earthquake parameters provided by the authoritative network for the event and received from the USGS metadata distribution system, the Collector associates incoming accelerograms with the appropriate earthquake. The instrument triggering may be caused by the P-wave, S-wave or, especially for a distant event, surface wave. A record is associated with a given earthquake if the instrument’s triggering time occurs between the expected arrival times of the P and surface waves at the station. P and Rayleigh wave velocities are chosen to provide a somewhat larger time window than likely, for conservative association. If a record has unreliable timing (e.g., bad time code), or no time, the system sets the record aside for operator action. A set of active unassociated records, and a set of earthquakes available for association are kept. After a specifiable interval, unassociated records are moved from the active pool to an unused-records set. Also, after a time interval, specified in the system’s configuration, active earthquakes are moved from a current-earthquakes set to a past-earthquakes set, and are no longer used in checking for association.
SARA Performance

The current record recovery rate is as high as one record every 4 seconds (i.e., 15 records downloaded and processed record every minute). As an example, Figure 2 is a recovery-time diagram for the M4.6 Banning earthquake of January 6, 2016 at 06:42:34 PST (14:42:34 UTC). It shows the time of recovery of records at the Collector relative to the time of the first record. The first record reached the Collector at 06:44:53, or 2 minutes and 19 seconds after the earthquake origin time. That is, the record had been downloaded from the field station and processed by a front-end machine before being sent to the Collector. The time includes the data transmission time of the record from the field station to the front-end PC, the processing of the record through V3 (spectra), and the routing of the results through the Buffer to the Collector. After the first record, records arrived at the Collector every 4 seconds for the next 2 minutes. A total of 50 records were received in the first 4 minutes.

Figure 2. Recovery of records by the SARA system. Time of record recovery (relative to the first) versus the record number, for the M4.5 Banning earthquake of 1/6/2016.

References
