



Eleventh U.S. National Conference on Earthquake Engineering
Integrating Science, Engineering & Policy
June 25-29, 2018
Los Angeles, California

PRISM, PROCESSING AND REVIEW INTERFACE FOR STRONG MOTION DATA SOFTWARE

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ABSTRACT

We present the Processing and Review Interface for Strong Motion data (PRISM) software, developed by the National Strong Motion Project (NSMP) of the U.S. Geological Survey (USGS). PRISM automates the processing of strong-motion records by providing batch-processing capabilities. The PRISM is platform-independent (coded in Java), open-source, and does not depend on any closed-source or proprietary software. The software consists of two major components: a record processing engine composed of modules for each processing step, and a graphical user interface (GUI) for manual review, edit and processing. To facilitate the use by non-NSMP earthquake engineers and scientists, PRISM (both its processing engine and GUI components) is easy to install and run as a stand-alone system on common operating systems such as Linux, OS X and Windows (version 7 or higher). PRISM was designed to be flexible and extensible in order to accommodate implementation of new processing techniques. Input to PRISM currently is limited to data files in the Consortium of Organizations for Strong-Motion Observation Systems (COSMOS) V0 format, so that all retrieved acceleration time series need to be converted to this format. Output products include COSMOS V1, V2 and V3 files as: (i) raw acceleration time series in physical units with mean removed (V1), (ii) baseline-corrected and filtered acceleration, velocity, and displacement time series (V2), and (iii) response spectra, Fourier amplitude spectra and common earthquake-engineering intensity measures (V3). A thorough description of the record processing features supported by PRISM is presented with examples and validation results. All computing features have been thoroughly tested.

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We present the Processing and Review Interface for Strong Motion data (PRISM) software, developed by the National Strong Motion Project (NSMP) of the U.S. Geological Survey (USGS). PRISM automates the processing of strong-motion records by providing batch-processing capabilities. The PRISM is platform-independent (coded in Java), open-source, and does not depend on any closed-source or proprietary software. The software consists of two major components: a record processing engine composed of modules for each processing step, and a graphical user interface (GUI) for manual review, edit and processing. To facilitate the use by non-NSMP earthquake engineers and scientists, PRISM (both its processing engine and GUI components) is easy to install and run as a stand-alone system on common operating systems such as Linux, OS X and Windows (version 7 or later). PRISM was designed to be flexible and extensible in order to accommodate implementation of new processing techniques. Input to PRISM currently is limited to data files in the Consortium of Organizations for Strong-Motion Observation Systems (COSMOS) V0 format, so that all retrieved acceleration time series need to be converted to this format. Output products include COSMOS V1, V2 and V3 files as: (i) raw acceleration time series in physical units with mean removed (V1), (ii) baseline-corrected and filtered acceleration, velocity, and displacement time series (V2), and (iii) response spectra, Fourier amplitude spectra and common earthquake-engineering intensity measures (V3). A thorough description of the record processing features supported by PRISM is presented with examples and validation results. All computing features have been thoroughly tested.

Introduction

Robust automated earthquake ground-motion data processing is essential for generating corrected acceleration time series and derived products for rapid use in earthquake-engineering applications and for seismological studies. The U.S. Geological Survey's National Strong Motion Project (NSMP) developed the PRISM (Processing and Review Interface for Strong-Motion data) software to meet this need. PRISM incorporates many of the processing techniques implemented in its predecessor, the software program BAP (Basic Strong-Motion Accelerogram Processing [1]).

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PRISM automatically processes raw acceleration records to generate data products that include corrected acceleration, velocity and displacement time series, acceleration, velocity and displacement response spectra, Fourier amplitude spectra, and standard earthquake-engineering intensity measures. PRISM employs widely accepted methods for processing the strong-motion records and quality control assessments.

The PRISM software consists of two major components: a module-based record processing engine, and a review tool which is an interactive graphical user interface (GUI) for visually inspecting, editing and processing. The processing engine is integrated into both the automated processing system and the GUI to ensure computational consistency. The processing engine tracks parameters used in each of the processing steps and embeds them in the metadata of the computed data products to ensure the ability to replicate the processed record from the original input.

The PRISM software is open source and written in Java, so that it is easy to install and run as stand-alone software on common operating systems such as Linux, Mac OS X and Windows (version 7 or later). Input to PRISM currently is limited to single-component data files in the V0 data format of the COSMOS (Consortium of Organizations for Strong-Motion Observation Systems) [2]. Output products are COSMOS V1, V2 and V3 files.

PRISM Processing Engine

The main features of the PRISM processing engine are:

- platform-independent, extendable, open-source software;
- customizable processing parameters specified in a configuration file;
- resampling in the frequency domain;
- phase arrival time and maximum amplitude picking for time series;
- time-domain mean-removal, integration and differentiation;
- acausal bandpass filtering;
- baseline correction computed in the velocity domain, and its derivative applied as a baseline correction to the acceleration time series;
- generation of products that include compatible acceleration, velocity and displacement time series, response spectra, Fourier amplitude spectra, and standard earthquake-engineering intensity measures;
- log files for quality control and reproducibility; and
- modularity to enable use by other strong-motion applications (e.g., PRISM Review Tool).

The processing steps in the automated workflow are described in [3, 4] and test results are documented in [5]. A set of conservative processing parameters for generating COSMOS V1, V2 and V3 data products are included in the software distribution. The processing includes quality assurance steps to flag particular records that require further review by analysts, and manual tuning of processing parameters can be implemented in the PRISM Review Tool. In the following, V1, V2 and V3 processing are summarized.

Volume 1 (V1) Processing

Data in digital counts are converted to physical units, and the mean of the entire raw acceleration time series is removed. A full instrument response correction is not applied because the sensor response is flat to zero frequency, and the cutoff frequency of the low-pass filter applied in V2 processing typically is lower than that of the natural frequency of an accelerometer (>50 Hz). Instead, a simple scaling factor is used [6]. Note that PRISM is not intended to process records with a lower natural frequency (<50 Hz).

Volume 2 (V2) Processing

Corrected acceleration, velocity, and displacement time series are obtained by applying prescribed baseline correction methods and filtering to ensure that the spectral content of the resulting products is within the range of the sensors' frequency response and has a signal-to-noise ratio (SNR) well above that of expected background noise level [3,4].

The first step in V2 processing is to check the sampling rate of the acceleration time series. If the V1 acceleration has low time resolution (less than about 200 samples/s) the time series is resampled to 200 samples/s in the frequency domain (as described in appendix A of [3]) prior to V2 processing to reduce numerical noise [4]. The V2 processing flow (Fig. 1) involves the following steps:

1. detect event onset;
2. remove pre-event mean from entire acceleration time series;
3. integrate to velocity;
4. compute best-fit trend in velocity record (discussed in more detail later);
5. compute derivative of best-fit trend to velocity, remove from acceleration, and integrate baseline-corrected acceleration to velocity;
6. perform quality check (QC) of velocity record;
7. taper and pad acceleration record to condition for filtering;
8. apply bi-directional acausal band-pass filter to acceleration in the time domain;
9. integrate filtered acceleration and check for ill-behaved velocity records; an adaptive baseline correction (ABC) [3] is applied if needed.

Volume 3 (V3) Processing

V3 processing, performed in either the time or frequency domain as appropriate, involves computation of elastic response spectra, FAS, and earthquake-engineering IMs. Elastic response spectra (relative displacement, SD, relative velocity, SV, and absolute acceleration, SA) are computed using the method of Nigam and Jennings [7] for 0%, 2%, 5%, 10% and 20% of critical damping over a wide range of periods (0.04–15 s). The lower and upper bounds on spectral periods are independent of the band-pass filter corners. Pseudoacceleration and pseudovelocity spectra can be computed as $\omega^2 \times SD$ and $\omega \times SD$ (ω = cyclic frequency), respectively. The Fourier Amplitude Spectrum of acceleration (FAS) is computed by applying a fast Fourier transform (FFT) to the baseline-corrected and filtered acceleration time series from step 8 (or

step 9, if implemented), where the time series is extended to a power of 2, as required by the FFT algorithm, by adding zero pads. A weighting function (Hamming window [8]) is applied to minimize spectral leakage. The frequencies at which the FAS is computed are non-uniformly distributed over range the 0.066–25 Hz range (periods of 0.04–15 s) to achieve a more uniform curve when plotted on a log axis. In addition, three-point smoothing is applied.

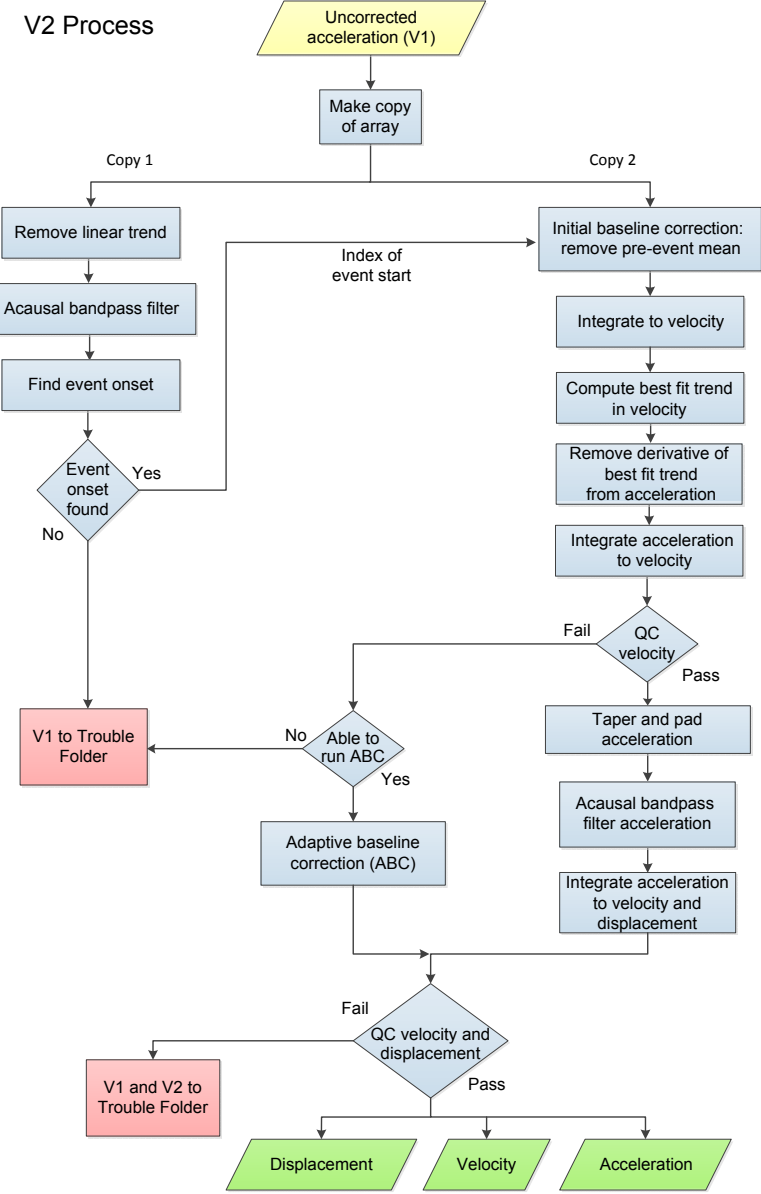


Figure 1. Flowchart showing volume 2 (V2) data processing adopted for uncorrected acceleration time series to produce corrected acceleration, velocity, and displacement.

PRISM computes various earthquake-engineering IMs that are written to the headers of the COSMOS V3 files. These IMs are Arias intensity, bracketed duration, duration interval, response spectrum intensity, root mean square acceleration, and cumulative absolute velocity. Details on how these parameters are computed are given in [3].

Examples of V2 And V3 Products

The end products of PRISM are illustrated in Fig. 2 for an example record of a low-amplitude ground-motion record from the 2014 moment magnitude (Mw) 6.0 South Napa earthquake in California. For this record, the pseudospectral acceleration, pseudospectral velocity, and displacement response spectra (V3 products) are presented in Fig. 3.

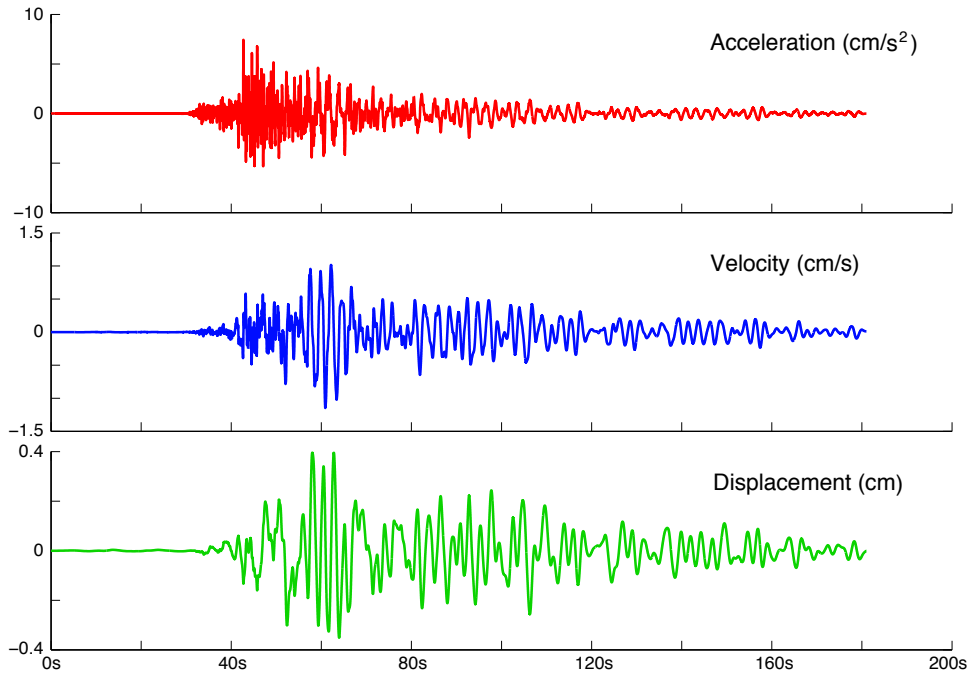


Figure 2. Graphs showing a final suite of acceleration, velocity and displacement time series (COSMOS V2 products) for channel HNE at station C002 recorded with 200 samples-per-second from the 2014 Mw 6.0 South Napa earthquake in California.

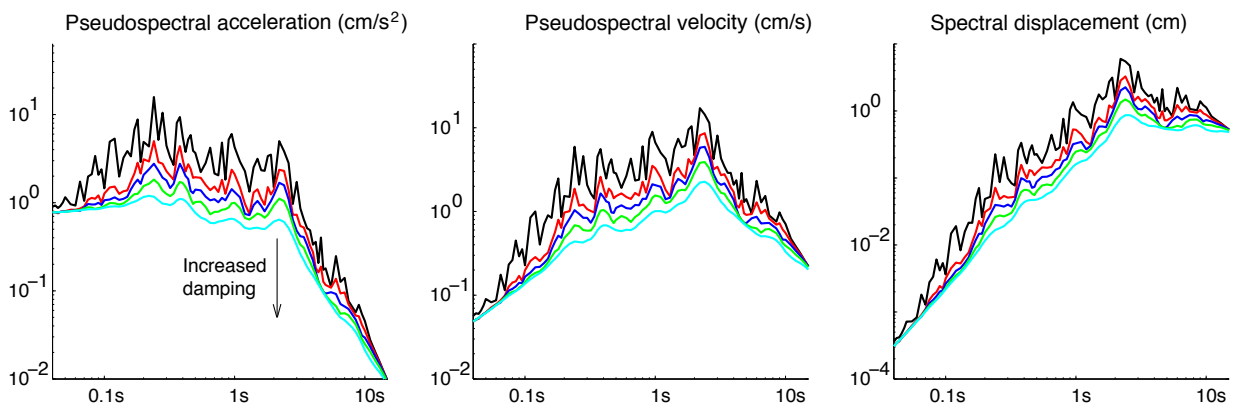


Figure 3. Graphs showing pseudospectral acceleration, pseudospectral velocity and spectral displacement ordinates (COSMOS V3 products) at five damping levels (0, 2, 5, 10, and 20%).

PRISM Review Tool

The PRISM review tool is a desktop application that provides an interactive GUI for visually inspecting, editing, and processing COSMOS V1 data to create corresponding new or replacement V1, V2 and V3 data products. Note that replacement of V1 in GUI can result from synchronizing among a set of channels or by trimming the original time series. The tool interacts with the PRISM processing engine via an application programming interface (API) for manual editing and processing tasks as well for generating COSMOS data products.

The main interface of the tool (Fig. 4) provides a standard menu and toolbar options for performing common tasks, including setting application preferences, loading COSMOS files, generating plots, navigating generated plot sets, and editing. The interface comprises several panels, including the *Node Explorer*, *Content Area*, *Properties*, and *Status*.

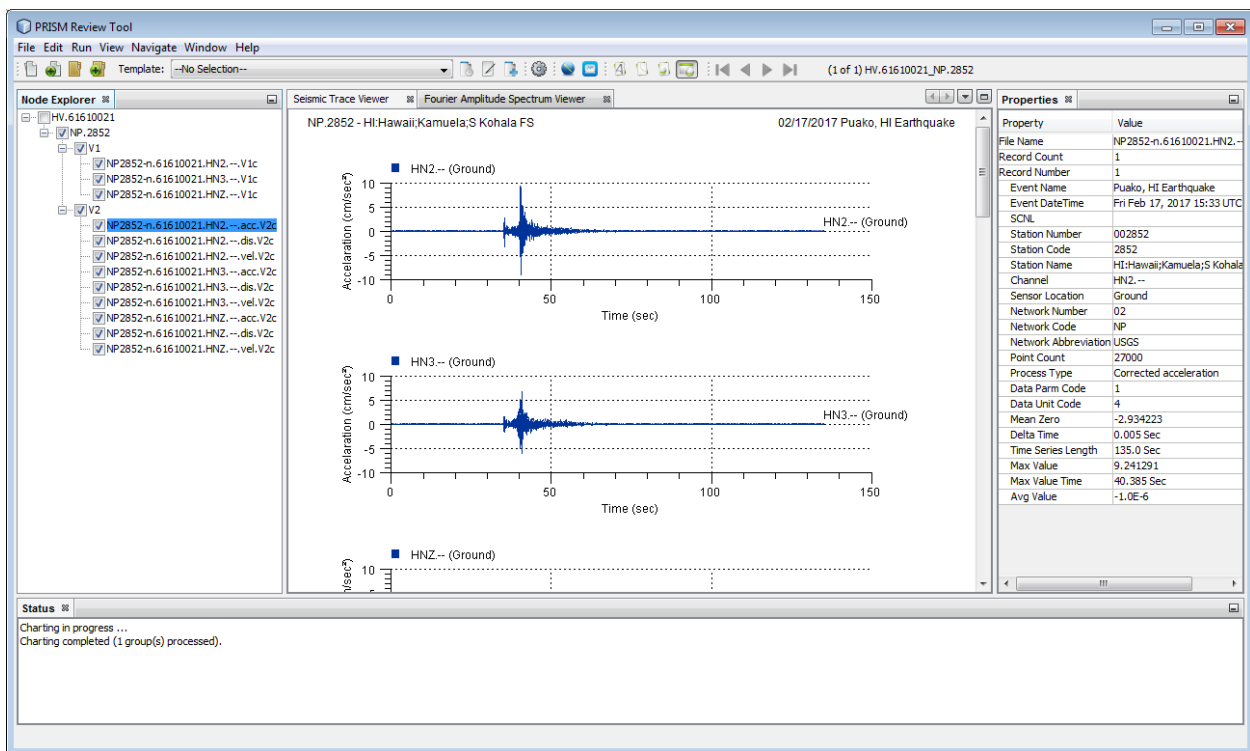


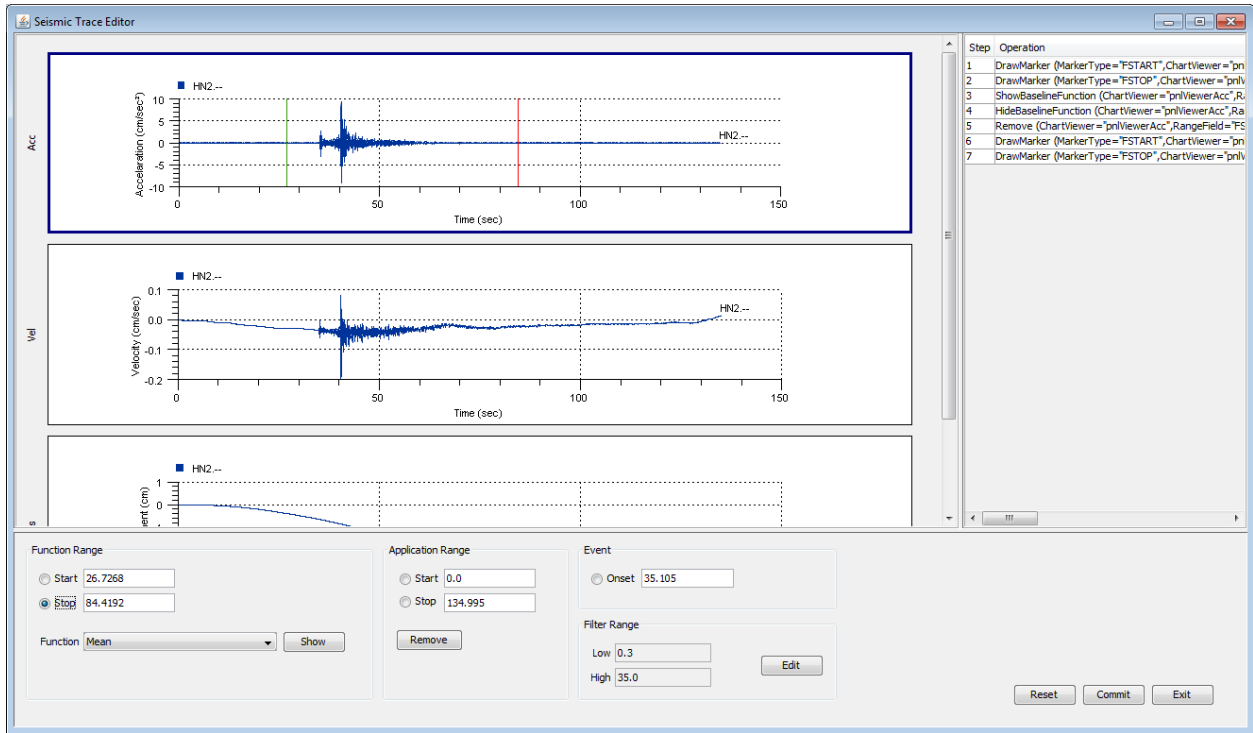
Figure 4. Main interface of the PRISM review tool, which provides standard menu and toolbar options for performing common tasks, including setting application preferences, loading input files, generating plots, navigating plot sets, and editing.

The *Node Explorer* displays a hierarchical tree structure of nodes denoting COSMOS files currently loaded into the application. The structure stratifies the nodes by event name, station code, COSMOS file data type, and file names. The *Content Area* is the area in which generated plots are displayed. The viewer comprises two tab pages that display seismic time history plots and response spectral plots, respectively. The *Properties* panel displays a table of various attributes that pertain to a file that is currently selected in the *Node Explorer*. Finally, the *Status* panel displays output messages that are generated during runtime.

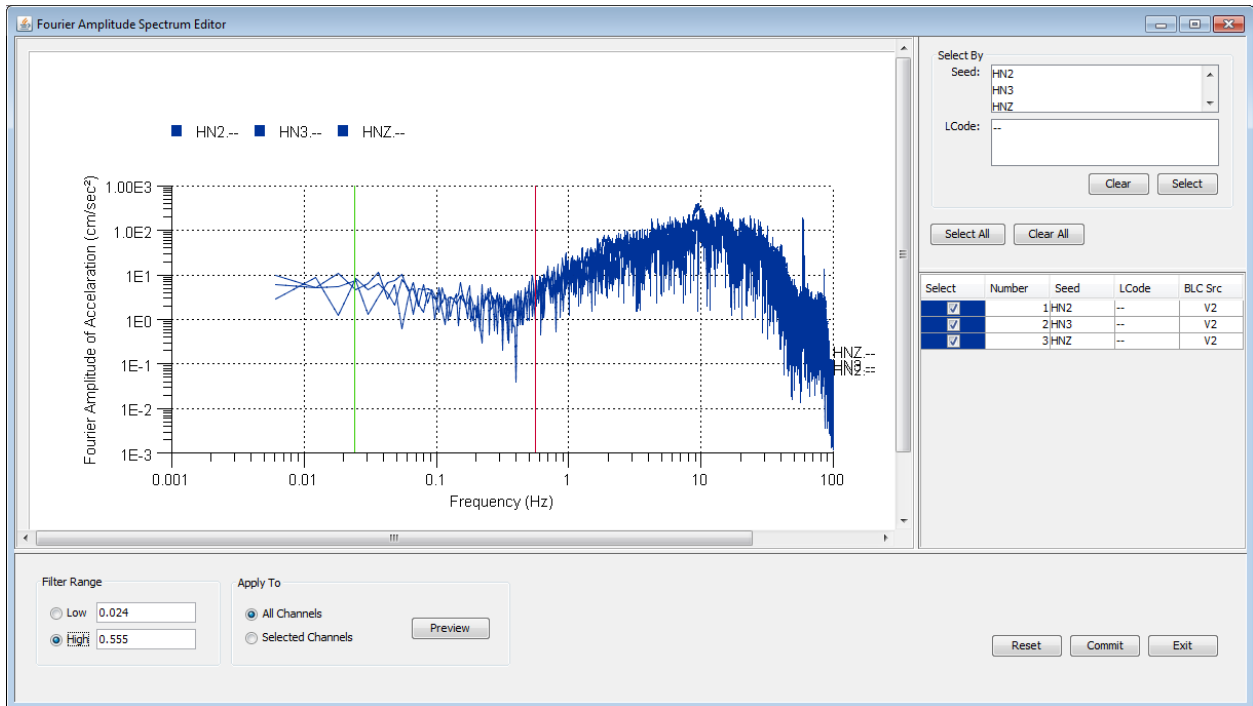
Editing can be performed in either the time domain (for applying baseline corrections) or the spectral domain (for selecting bandpass filter corners) of a selected data channel. Editing of seismic data is initiated by either right clicking a selected file in *Node Explorer*, then selecting *Edit* from the context menu that appears, or by selecting the seismic plot corresponding to the selected file, then right clicking and selecting *Edit* from the plot's own context menu. Similarly, editing of spectral data is initiated by selecting a spectral plot corresponding to a specific group of files of acceleration data, then right clicking and selecting *Edit* from its context menu.

Separate editors, named the *Seismic Time History Editor* and *FAS Editor* (Fig. 5), are used to perform editing and processing of seismic and spectral data, respectively. The *Seismic Time History Editor*, takes either a V1 or V2 file as input, then uses the V1 file (retrieving it as necessary when the source input was a V2 file) then creates a temporary V2 process object that contains acceleration, velocity, and displacement data. These data are used to create the initial plots that are displayed at startup.

Editing of seismic data consists of baseline correction and bandpass filtering. Note that as each operation is performed, the operation is recorded into the table located to the right of the editor. Clicking on a step item in the table will take processing back to that particular step and subsequent operations that follow will then override steps previously taken after that step. After baseline correction, comes filtering (Fig. 5b), which involves setting the low and high filter range values. This step is performed by clicking *Edit*, which opens the *FAS Editor* dialog showing the spectral view of the acceleration data and the currently set low and high filter range values that can be edited. The last step in the editing process is to commit the changes by clicking *Commit*, which then generates and stores new or revised V2 and V3 data products. All of the accepted processing steps are stored as comments in the V2 and V3 products so that the results can be reproduced.



(a)



(b)

Figure 5. *Seismic Time History Editor* (a) and *Fourier Amplitude Spectrum (FAS) Editor* (b) of the PRISM review tool to perform editing, baseline correction and bandpass filtering of acceleration time series, respectively.

PRISM Availability and Installation

PRISM is a free software; its documentation, installation requirement, installers and GitHub links are available at <http://earthquake.usgs.gov/research/software/#prism>. This website also provides a simple four-step procedure with example data set to run PRISM processing engine.

Summary and Concluding Remarks

A robust automated data processing procedure is essential to ensure high-quality products for immediate use in engineering applications and for seismological studies. PRISM (Processing and Review Interface for Strong-Motion data) is a software package for automatically processing strong-motion acceleration records. The PRISM review tool is a desktop application that provides an interactive graphical user interface for visually inspecting, editing, and processing. The key points of this paper are:

- Using strong-motion records in digital counts as input, and with instrument response parameters stored in the input data files, PRISM automatically generates compatible acceleration, velocity and displacement time series, acceleration, velocity and displacement response spectra, Fourier amplitude spectra, and standard earthquake-engineering intensity measures.
- Although there are no unique procedures for processing, PRISM utilizes widely accepted methods (e.g., [19-13]) that are designed to remove low- and high-frequency noise in order to provide reliable estimates of velocity and displacement time series.
- All of the essential steps applied in PRISM, whether automatic or manual, are documented in the ASCII file headers of the processed time series so that users can evaluate the suitability of the data for their intended application.
- As currently implemented, digital records of relevant earthquake strong-motion records are acquired from instruments in the U.S. Geological Survey's Advanced National Seismic System [14] for input to PRISM using an instance of the Quake Monitoring System (AQMS) [15]. PRISM is used to automatically generate strong-motion products for rapid use in earthquake-engineering applications and for seismological studies.

Acknowledgments

PRISM development and maintenance are supported by the USGS through the National Strong Motion Project (NSMP). We thank our colleagues at the USGS, and in particular Lind Gee and Mara Tongue for their continuous support, David Boore for providing his Fortran source codes, and the NSMP staff who install and maintain the strong-motion network, collect and vet data, and providing easy access to the recordings. We also wish to thank, among others, the NSMP's Working Group members for initiation of the PRISM project. Special thanks are extended to Jamie Steidl, David Oppenheimer, Robert Darragh, Tadahiro Kishida, Vladimir Graizer, Abdullah Sandikkaya, Walter Mooney and Brad Aagaard for their reviews and constructive comments.

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