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DIGITIZATION OF STRONG MOTION FILM RECORDS USING A HIGH RESOLUTION DESKTOP SCANNER

A.G. BRADY, J. G. DIEHL and R.L. NIGBOR

(1) 735 DeSoto Drive, Palo Alto, California, 94303
(2)(3) Agbabian Associates , Inc., 1111 So. Arroyo Parkway, Suite 470, Pasadena, California 91105

ABSTRACT:

Despite the availability of modern, low cost digitial instruments, there are still thousands of film recording strong motion accelerographs being used in instrument arrays and networks around the world. The application of desktop scanners to earthquake data processing has been helpful because of the ease of utilization and low cost. Strong motion accelerograph network operators who before simply archived significant records because of lack of access to an adequate digitizing system, now find desktop scanners an effective way to utilize data. However, their usefulness has been limited by low resolution compared to laser-dependent methods of digitization. Currently available film accelerogram digitizing software claims to be able to accommodate higher resolution scanners, but until now few scanners were available to evaluate such performance.

In this study a complete, high resolution scanning digitizing system is assembled, tested and evaluated using a modified version of the Kinemetrics ScanView image conversion software, and the standard USGS accelerogram processing software. The investigation includes performance evaluation of the scanner, amplitude and spectral evaluation of the digitization noise, and comparison with methods previously used by the USGS for strong motion data processing.

KEYWORDS:

Digitizing; earthquake accelerograms; scanners; accelerograph records; desktop

OBJECTIVES

The purpose of the new system is to scan film accelerograms at a minimum resolution of 600 dpi in each direction, convert the picture files into Volume I files (USGS format), and produce results in the form of plots.

Following were the minimum performance requirements identified for the system:

1. Resolution of 600 dpi.
2. Mass Storage: At 600 dpi, a typical scanned CR-1 record file could take from 20 to 40 MBytes of disk space. While later, these can be compressed down to less than 500K, temporarily the hard disk must have sufficient capacity to store multiple raw files until archival.
3. Compatible output: The system should be capable of printing data at 600 dpi as well as digitizing. This is to allow direct comparison of digitized data and raw film records for quality control.
4. Display: The monitor used with this system was to be sufficiently large so that operators need not receive undue stress after many hours in front of the screen.
5. Speed: Speed of digitization, especially from a 600 dpi scanner, was to be maximized.
6. Archival: The system should be capable of reading and writing archival quality records of accelerograms. The archiving system should have sufficient capacity for storing the large quantities of data required by the USGS film accelerograph network following a large earthquake.

SYSTEM DESIGN

Table 1 summarizes the hardware selected for the digitizing system. The brand of computer was chosen primarily by reputation for value and performance The processor is the highest speed currently (Spring, 1994) available for IBM AT compatible software. Speed was also enhanced by providing 64MBytes of RAM for use in handling the picture files.

The Tamarack 12000C high resolution scanner was selected primarily because it offered 600 by 1200 dpi optical (hardware) resolution, with the possibility of extension to 1200 by 1200 or even 2400 dpi using interpolation. Another attractive feature was the optional "x-ray scan kit" for digitizing transparancies using a backlighting device. The scanner is shipped with Aldus PhotoStyler SE for controlling the scanner and rough editing of the raw image.

The SONY magneto-optical (MO) system was chosen for features of fast, low-cost, fully rewritable, removable, high density, and reliable data storage.

Table 1

USGS SCANNING SYSTEM
HARDWARE SPECIFICATION

COMPUTER
Gateway 2000 4DX2-66V IBM AT compatible PC
Processor: Intel 80486DX, 66 MHz
Bus: 16bit ISA
Memory: 64MB, 256K cache
Video: ATI Ultrapro SVGA with 1MB V-RAM VESA
Monitor: 17 inch NEC 5FGe Multisync
Hard disk: 2 x 1GB SCSI, 11msec
SCSI Controller: 32bit VESA

SCANNER
Tamarak 12000 PC with 1200 x 600 hardware resolution
and 1200 x 1200 resolution with firmware
8-1/2 x 11 inch scan area
Slide X-ray scan kit for difficult images (provides back-light)
Picture Publisher scanning and image editing software

DATA ARCHIVING
Sony RMO-S550 5 1/4 inch Magneto-Optical Disk Drive
provides:
Rewritable, High Density storage capability 650 MBytes per disk
SCSI interface

PRINTING
Hewlett-Packard Laserjet 4M with 600dpi resolution

The Hewlett-Packard Laserjet 4 is the industry standard for 600 dpi printing. The "M" option provides the additional utility of automatic switching between the H-P PCL and Postscript printer control languages for superior performance in data handling.

Table 2 summarizes the software utilized in this system.

The Kinemetrics Scanview software was selected because of its commercial success (indicating accepted performance at 300 dpi) coupled with Agbabian Associates' close association with the original development of the software (Dr. R. Nigbor was co-author). Scanview was originally written and tested for a 300 dpi scanner resolution. Minor modifications of the FILMCNV program source code were required for use with 600 and 1200 dpi resolutions. (The modifications are now incorporated into the new Kinemetrics Scanview software.)

Table 2

USGS SCANNING SYSTEM
SOFTWARE SPECIFICATION

SYSTEM SOFTWARE:
DOS 6.2
Microsoft Windows 3.1
Standard Microsoft Windows Utilities

Digitizing Applications Software
Aldus "Photostyler" scanning/image editing program (bundled with scanner)
Kinemetrics "Scanview" film accelerogram digitizing software
Agbabian Associates RTV1 program for 1:1 comparison of printed accelerograms with film records; used for QA
USGS BAP software (Converse et al 1992)

"RTV1" was written by Agbabian Associates for use in checking and quality assurance of the digitization process. It provides a 1:1 plot of film records at 600 dpi (using the Hewlett-Packard Laserjet 4M). Laid underneath the film record over a light table, such a plot is indispensable for quality assurance evaluation of the final product.

SYSTEM TESTING:

The purpose of these tests was to evaluate the performance of the Tamarack 12000C desk-top scanner for the purpose of strong motion accelerogram processing. The performance was evaluated to verify resolution, and measure the noise characteristics of the scanner. It is important to note that these tests did not evaluate either the noise characteristics of the SMA-1, or the performance of any specific data processing software, as these evaluations have been performed exhaustively elsewhere.

Flatbed Scanners

Almost all flatbed scanners use an array of charge-coupled devices (CCD), or row of photosensitive cells, on the scan head. In general, a basic CCD provides twice the resolution in one direction than the other. Very often, scanners which claim 600 dpi actually are using a CCD array of 600 dpi by 300 dpi, and using firmware interpolation to acheive 600 by 600 dpi. For this reason, it is useful to describe two types of resolution: hardware, or "optical" resolution, and interpolated resolution. It has been found that for 1-bit, true black-and-white scanning (such as is normally used for accelerogram digitizing), interpolated resolutions do not apply (1). Finally, it is important to recognize that doubling the dot-per-inch (dpi) resolution results in quadrupling the amount of memory required to store the information.

The USGS system uses a Tamarack 12000C which captures images measuring up to 8.5 by 11.75 inches using an optical resolution of 600 by 1200 dpi. It uses a proprietary engine and a Toshiba CCD array, and interfaces to a computer through a SCSI interface. The USGS system includes an optional attachment for scanning transparancies which provides a moving light source *behind* (above) the film for enhanced imaging. Following is a comparison of digitizing systems:
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Two areas of performance were evaluated. The first was to accurately measure the actual resolution of the scanner. The second was to measure the noise characteristics of the scanner within the passband of interest.

COMPARISON OF SCANNING SYSTEMS

Characteristic	Trifunac & Brady, CIT, 1969	Trifunac & Lee, USC, 1979 (also CDMG)	Brady, USGS, 1979	Nigbor, Kinemetrics, 1990	Brady, Diehl, Nigbor USGS/AA, 1994
dots per inch	digitizer: 800	500	2500	300 (will accept any TIF)	600
dynamic range (visual is 100:1 or 40dB)	55dB	51dB	65dB	46dB	53dB
raw samples per second	manual: 30-50 (unequal spacing)	197	985	118	236
output sample rate (interpolated)	50	50	200	200	200

<u>Scanner resolution Test</u>

Resolution was measured using set of PM-189 standard certified resolution targets from A&P of St. Paul, Minnisota. These targets included accurate resolution wedges in two axes with lines spaced as close as 600 dpi, as well as a circular target with radial lines that require at least 800 dpi to reproduce. This target was scanned at 600 pi resolution, the image enlarged, the the results printed. These are presented in Figure 1. The resolution wedges are visible all the way to 600 dpi, indicating that the scanner resolution is indeed 600 dpi.

<u>Digitizing System Noise Test</u>

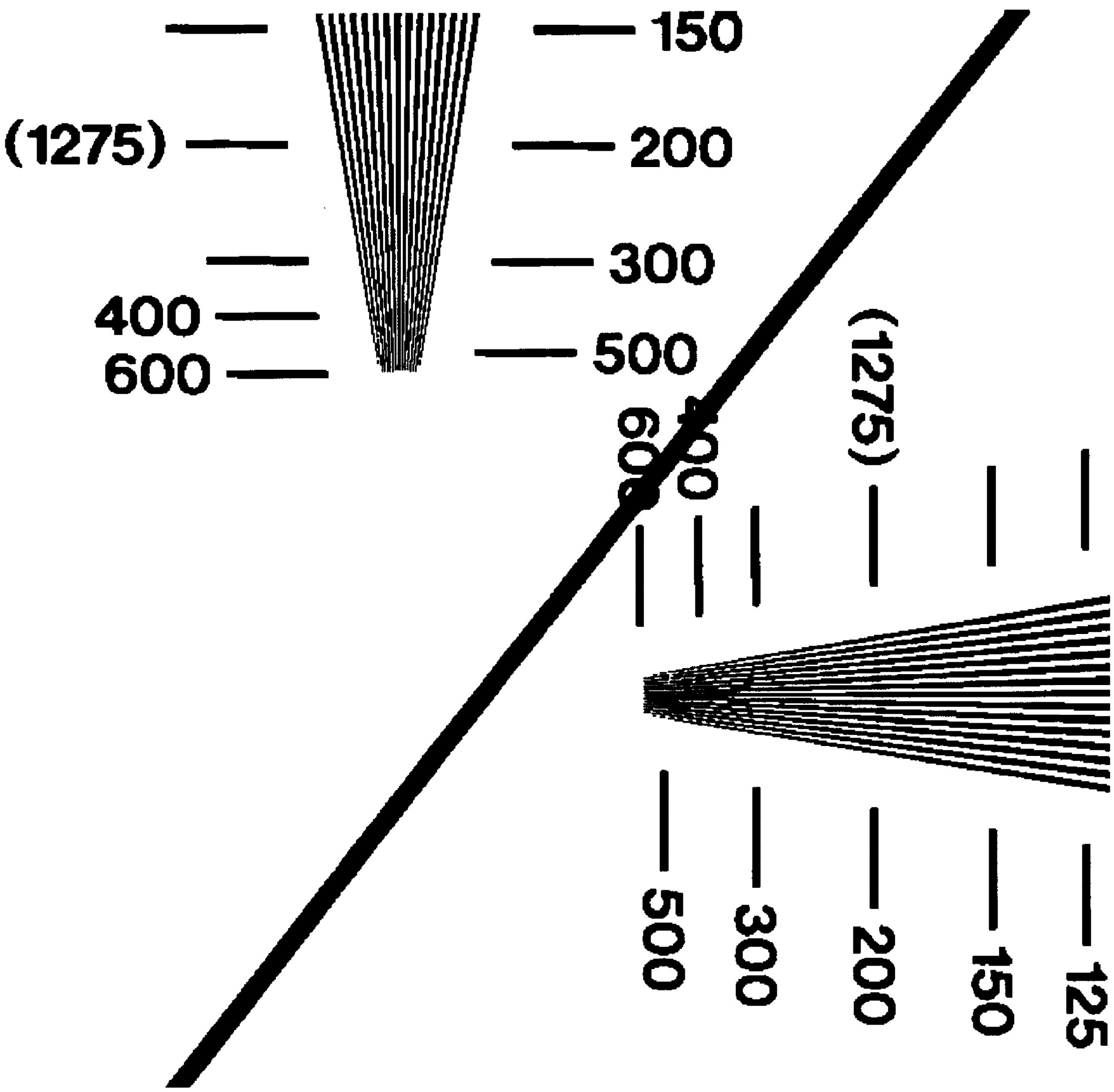
Noise was evaluated using a variation on the standard procedure. The usual approach to investigating intrinsic noise in an accelerogram digitizing system (2,3,4,5) is to digitize a straight line on an accelerogram as though it were an acceleration trace. Digitizing and processing two fixed traces, treating one as a fixed trace and the other as an acceleration data trace, yields a good estimate of the noise floor of the processing system.

The flat-bed scanner offers the opportunity to digitize a straight line without the intermediate step of creating a film record. In this case a 38ga copper wire (.004") was stretched across the surface of the glass until just past yield, and taped in position during the scan. No attempt was made to position the wire along the exact axis of the scan. In fact, this test was repeated twenty times with the wire retaped for each scan.

The ability of the Scanview system to reconnect two segments was evaluated by placing two feducial marks at each end of the stretched wire. The wire was stretched, taped, and scanned, removed, restretched (new section of wire), retaped, and scanned again to simulated a second segment. The combined straight line was evaluated for straightness (using a least squares goodness of fit).

Two at a time, the twenty stretched wires were scanned and digitized using the Scanview software, and combined to produce ten approximately 50-second acceleration traces in the .V1 format. These were then processed through Kinemetrics' VOL2D and VOL3 programs to produce20% damped response spectra.

Figure 1: Scanner Resolution Test results



Only high-pass filtering at 0.1 Hz (ormsby filter) was performed; no low pass filtering or instrument correction was done.

Figure 2 shows the mean and mean +/- sigma digitizing noise spectra from this test. The published California State Strong Motion Instrumentation Program (CSMIP) noise spectrum (20% damped, average of 60-second fixed trace records) is also plotted.

Fixed Trace Digitization

In addition to this test, the traditional test using two fixed traces was also performed for comparison with the previous systems. In this test one fixed trace was used as an acceleration trace, and the other as a fixed trace subtracted to compensate for any film distortion or common vibration. The digitized 28-second long fixed traces show the noise of the digitizing system. The 20% damped response spectrum is also plotted in figure 2. This noise spectrum is below the CSMIP curve.

Sample Accelerogram Digitization

The last test was intended simply as a qualitative comparison of the new USGS digitizing system with the older procedure. The USGS provided a film copy of an original SMA-1 record of the 1979 El centro Earthquake from station 826 on Dogwood Road (the El Centro differential Array), featured in many software tests at the USGS. Figure 3 contains the uncorrected plot of the three components. The USGS version, digitized by the previous commercial contractors, is indistinguishable from the plot in Figure 3, although the detail of the three peak values indicates differences of 1%, 0.1%, and 00.6%, respectively.

CONCLUSIONS:

The USGS Data Management Project is pleased with its new digitizing system. Although its least count, even at 1200 dpi, does not match the least count (1 x 10^{-6} m), which used to be available from the previous digitizing contractors, the system is accurate, convenient, and avaliable. The new USGS film accelerograph digitizing system has now been used to digitize all of the USGS Landers, Big Bear, and Northridge SMA records.

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Figure 2: Digitizer Noise Test Response Spectra

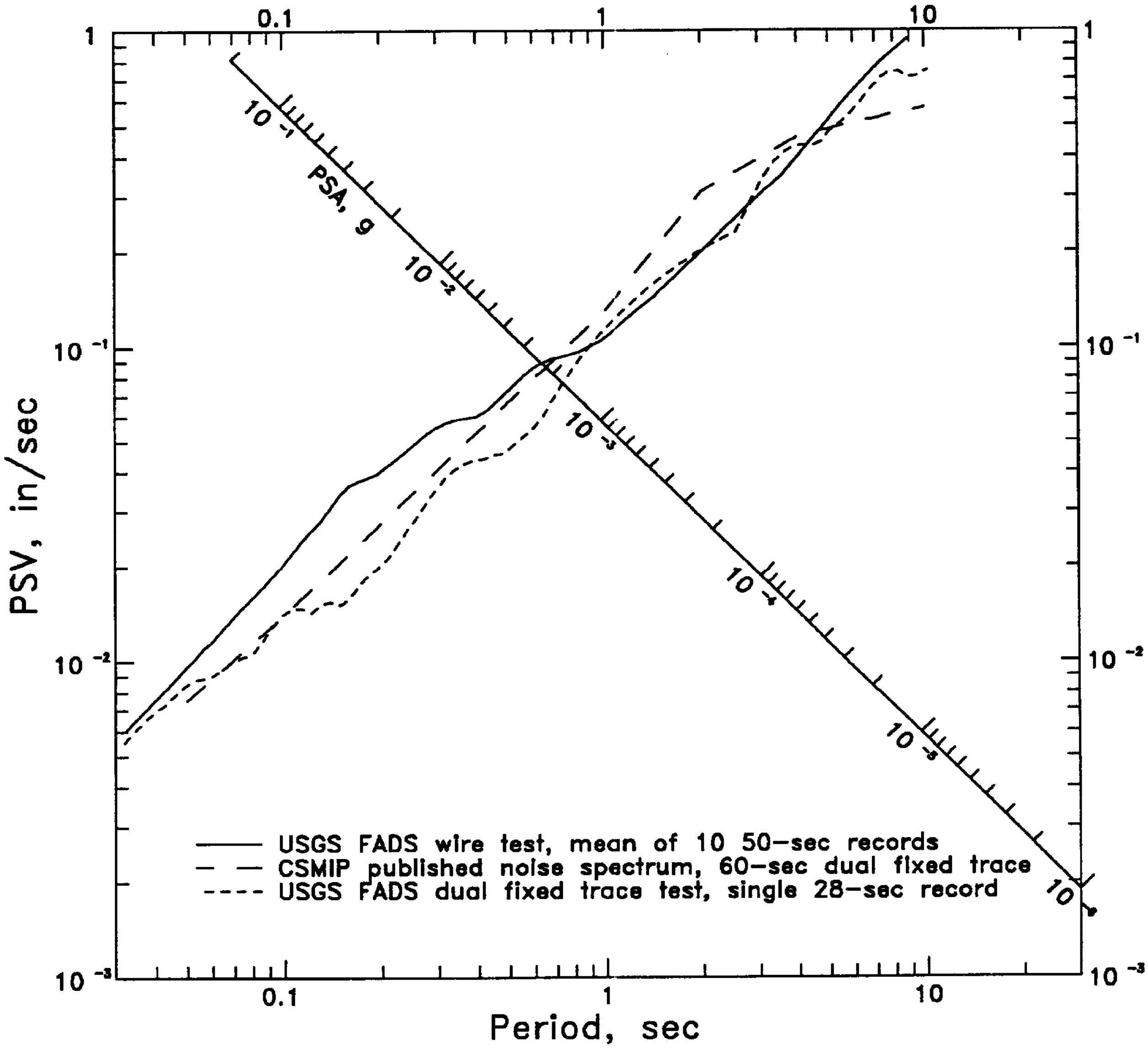

Figure 3: Uncorrected Accelerogram from 1979 El Centro EQ, Stn. 826, Dogwood Rd., Diff. Array (digitized using USGS FADS)