A Real-time Interactive Educational Seismology Exhibit

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Robert J. Mellors, Eric Riggs, Jennifer Eakins and Frank Vernon

Introduction. Modern seismology has rapidly passed the level of many educational displays. While seismologists almost exclusively use digital data, the traditional pen and ink drum recorder remains the mainstay of many educational seismology exhibits in museums. Although a drum recorder retains several major advantages such as familiarity and visual appeal, it also has several clear disadvantages, both technical and educational. Chief among the technical disadvantages are the poor data quality of many museum displays due to high noise levels and the difficulties and cost of replacing paper, pens, and ink on a routine basis. The use of a drum recorder also leaves a misleading and antiquated impression of how modern seismologists work.

Another feature of museum displays is that the sensor is usually kept well away from the actual display to reduce seismic noise levels. However, having a sensor near the display is very useful for adding interaction to the display. Visitors can create their own seismic signals by jumping, a feature which is especially popular with children. In general, interactivity in museum displays has been shown to increase the attractiveness of the display. Interactivity is believed to promote learning, at least for some learning styles, although it is not always clear exactly what is being learned [*Feher*, 1990; *Falk and Dierking*, 1992].

In this paper we describe an innovative exhibit that provides interactivity, displays high-quality seismic data, and transmits the data in real-time to a local seismic network. A strong motion sensor is located under the display, allowing people to jump, stamp feet, and otherwise create seismic waves that appear almost immediately on a computer monitor. During periods of little museum activity, which is at least 14 hours per day, the sensor records useful low noise data that can be merged with regional seismic network data for scientific analysis. In addition to the data from the local sensor, traces from several nearby quiet regional broadband stations are displayed using the off-the-shelf Antelope software package (BRTT, 200). A map, updated in real-time, is also displayed with a choice of local, regional, and worldwide views of recent earthquake locations. In this paper we describe the exhibit as well as preliminary responses to the display from the public and science teachers.

The exhibit is located at the Mission Trails Interpretative Center, a museum at the Mission Trails Regional Park (MTRP) within the City of San Diego. Attendance at the museum is roughly 60,000 per year and the Center is a popular field trip destination for K-12 school groups. Exhibits at the museum are focused on the general theme of the park environment. The park has a staff of 11 with one person working full-time at the museum, as well as a number of volunteer docents.

The primary purpose of the display is to add an educational component on earthquakes and seismology to the content presented in the Center. This material is highly relevant in Southern California and San Diego. The communities served by the Center are less than 100 km west of the Elsinore and the San Jacinto faults, both of which are seismically active strands of the right-lateral strike-slip San Andreas fault system that defines the Pacific/North American plate boundary in this area (Figure 1). Several other less active faults fall within the city of San Diego or lie just offshore. Earthquakes large enough to be felt occur several times per year with damaging events occurring on the order of every ten to twenty years, usually from large events at regional distances. Consequently, the need for awareness of earthquake causes and potential hazards is fairly high in the area.

The main educational goals of this installation are to provide an interactive, stand-alone display that presents accessible and scientifically complete instruction on earthquake causes and effects. Supporting goals and learning objectives include having visitors learn how seismic sensors measure ground motion, be able to observe and understand seismograms from nearby local earthquakes and larger teleseismic events, and view real-time event maps of the region. In addition to this material, which is presented in a computerized, interactive format, we have developed an accompanying static display that explains earthquakes and faults with an emphasis on Southern California and the San Diego region. This poster hangs on the wall next to the computerized display. Also under development are materials, which visitors can take with them, outlining basic earthquake preparedness and common myths and misconceptions about earthquakes and faults.

As a secondary, scientific purpose, the station also serves to increase station density in the San Diego area. The region includes stations from several seismic networks, notably the USGS/Caltech networks and the Anza network [*Vernon*, 1989] but in general, station density around San Diego is relatively low, at least compared to Los Angeles. The data from MTRP is primarily useful for improving the locations of events in the immediate area but it is also useful as a strong motion instrument when a large event occurs.

Installation. The display consists of a SunBlade workstation with dual monitors (Figure 2). The workstation is connected to an "Etna" accelerometer and digital recorder [*Kinemetrics*, 1995], which is physically about the size of a shoebox and is secured to the concrete floor immediately under the display case. A window and light illuminate the seismometer/recorder so it is visible to the public. The Etna unit has an internal 3-component Episensor force balance accelerometer with a response from DC to 200 Hz. The digitizer provides 155 Db dynamic range. Antelope real-time data acquisition software [BRTT, 2002] records the data at 100 samples per second. The unit is also attached to a Global Positioning Service (GPS) antenna on the museum roof to provide timing data (Figure 2).

Installation was straightforward due to good coordination between the museum staff, contractors, and scientists. The sensor was oriented and attached to the concrete floor with a bolt. A GPS antenna was attached to the roof and cables were run from the antenna to the display. A local contractor built the display case with advice from museum staff. The main problem was with a firewall at the museum Internet connection, which is via cable modem, but was solved after some effort. Footprints are painted on the floor immediately in front of the display along with a sign saying, "jump" to encourage the creation of seismic waves, which become visible on the display after a one to two second delay.

Completion of the installation was a noteworthy event for the museum. Members of the local government and friends of the museum along with the general public and media were invited to attend the 'grand opening' of the display. At the dedication ceremony, the mayor of San Diego, a council member and one of the seismologists demonstrated the signal generated by jumping (to the amusement of all).

The data flow is two-way between the station and the main data server located at University of California San Diego (UCSD). MTRP data flows to UCSD and data from other nearby digital stations are available for display at the museum. The data available are fully configurable and could include any of the data streams recorded by the UCSD Antelope data server. Data from the sensor has GPS time control so that the waveforms can be used to supplement arrival times from other stations. MTRP data is consequently also available for display at nearby schools and other museums, if needed. Data quality is fair although somewhat noisy as expected due to the setting, (even when 30 elementary school children are not jumping up and down in front of the display). As the data is sent in real-time across the network, no additional work or data processing is required of the museum staff for the arrivals to be available. Although the data stream is noisier than most stations, the standard autopicking and event identification algorithms handle it satisfactorily.

The two-monitor setup allows one monitor to display the real-time seismic data while the other shows a set of seismicity maps. The real-time seismic data from the local sensor (underneath the display) is displayed as an unfiltered single trace that scrolls across the window similar to an oscilloscope. The time scale on this display is short (5 or 10 minutes window) so that the signals produced by jumping are immediately visible. Below this window is another window with a set of traces from the vertical components of nearby (less than 100 km) seismic stations. The time scale on this display is larger and is usually set at about 15 minutes. This provides an easy way to distinguish earthquake from local noise, as earthquakes will show up on almost all of the stations and slowly scroll across the screen. The number of windows, time-scale, and data shown are all completely configurable. The second monitor shows a map of the Southern California region that is updated every 30 seconds. Events are displayed at different sizes and colors, depending on the age and magnitude of the event. The map display is also completely configurable and it is possible to show worldwide seismicity as well if desired.

A disadvantage of the current real-time display is that earthquakes scroll off the active display in just a few minutes. Increasing the time scale keeps the seismograms visible longer, but makes separate events, particularly local events, difficult to see. For example, setting the time scale to 6 hours makes it difficult to distinguish between P and S for nearby events. In the case of notable earthquakes (i.e. widely felt events or well-recorded teleseisms), a separate static window centered on the event is also opened manually and left visible for several weeks.

Evaluation. A preliminary informal evaluation of the exhibit was embedded in a larger study of teacher knowledge as part of a professional development workshop for local elementary teachers from the San Diego Unified School district. The workshop was a segment of a multi-day Urban Systemic Program Earth Sciences Institute conducted in collaboration between San Diego State University (SDSU) and the school district. The seismology portion of the workshop used the display as a major instructional station, which was coupled with other hands-on, inquiry based activities in seismology. Overall, 65 teachers participated in the study, completing questionnaires about the exhibit and other group and also completing individual tasks designed to measure and characterize the prior knowledge of elementary teachers about earthquakes. The analysis of these data is still ongoing.

During the part of the program at the exhibit, organizers gave a brief explanation of the display and then the teachers were free to investigate on their own. The goal of the workshop was to engage the teachers and assess their level of Earth science knowledge. At the end of the workshop, a short, seven item Likert-style survey was administered. It was designed to assess their impressions of the display's completeness, understandability, the degree of interactivity, and overall educational usefulness. Teachers were also encouraged to submit written comments, and we received 13 responses. The survey was not intended to determine content but was meant to be a guide to further improve the display and workshop. A typical question was "The exhibits were interactive and encouraged further investigation" which was answered on a 5 point scale ranging from "strongly agree," to strongly disagree". There was also a space for individual comments at the end. In addition to the workshop, museum docents have subsequently kept track of various questions asked about the display and have provided a notepad for additional written comments.

The survey responses indicated that the teachers generally understood the concepts presented and that the interactivity of the display encouraged further investigation and helped generate understanding. They also reported that the display encouraged collaboration among visitors as well as individual thinking. The comments were especially useful and included suggestions such as "students wouldn't spend time reading poster on the wall", which has since prompted a major re-design of the poster. Additional clarification of key scientific concepts such as the measurement of magnitude was also encouraged. The teachers also suggested that a written guide for both teachers and students with perhaps vocabulary would be useful, and one is now under development. It should be noted that K-6 teachers often have less formal training in science than higher level (grades 7-12) have, so these comments and responses are particularly encouraging, and have been instructive on the appropriate level and depth of material presented in written form. The public comments sheet in general reinforced the results of the teachers but spanned a wider range.

Conclusions. Overall, the feedback on the new display is encouraging. The interactivity is a major draw and appears to increase the attractiveness of the display (in the opinion of the museum docents). Use of an on-site accelerometer allows both interacting and the recording of local events. Filtering is kept to a minimum and unfortunately most teleseisms are not easily visible on the data from the local sensor due to the noise level. However, teleseisms are easily visible on the seismic traces from the nearby stations, which are generally high-quality broadband stations in quiet locations.

The simultaneous display of data from several stations also makes it easy for visitors to distinguish earthquakes from local noise. A common mistake when data from only one station is shown is misidentifying noise spikes as earthquakes. Even experienced seismologists can have difficulty with small events. However, local noise spikes at one station are now easily distinguished from earthquakes, which appear on all the stations. The slight delay visible between stations for local events allows visitors to roughly locate the event by identifying the station that first shows the event. More advanced concepts such as the increasing P and S difference with distance are also clear.

The display has recorded a variety of local and teleseismic events, notably the Feb. 22 M_L 5.7 Calexico event, which was felt widely in San Diego, as well as several closer smaller events (Figure 3). Explosive blasts from a nearby quarry are also well recorded. An unexpected benefit of the new display at the Center is that it has provided a convenient local setting and backdrop for news crews from local television stations to use for news reports and to interview local scientists after newsworthy earthquakes.

From a maintenance standpoint, very little effort is required to keep the display operating. Both seismometer and display computers have worked well since the first day. The Internet connection allows any software changes or database revisions to be done remotely. Most of the effort has been just altering the display to optimize the viewing.

Improvements need to be made. Initially, we allowed access to the display with a mouse to allow changing of maps but found that the desktop was not robust enough to prevent users from accidentally modifying or shutting down the display. The initial reaction of many children to immediately grab the mouse and start clicking, which eventually has adverse effects on the display and operating system. Also, the display software is intended primarily as a tool for seismologists, so some display details such as the use of day-of-year and Greenwich Mean Time to display the date and time decrease comprehension. While much of the display is customizable, some details are more difficult to modify than others. One area of needed improvement is the captions next to the display, which should explain the display in a concise but understandable manner. Another difficulty is the scale of the real-time display, which shows a scrolling "oscilloscope" type wiggle. Short time windows are used for the user-created seismic waves, but this causes real events to scroll off the display quickly. The most common events are local and regional with a waveform length of less than 60 seconds and consequently require a short time-scale. Our current solution is to open a window showing all events that exceed certain amplitude or are felt in the area. Currently this is done manually but we would like to create an automatic version.

Overall, the display has been a clear success. It has enhanced the exhibits at the museum and added an interactive component. Comments by visitors as well as the survey of the teachers indicate that it provides valuable and engaging information. Scientifically, the data is good quality and is useful for improving nearby locations and is also well suited to serve as strong motion recorder when a larger event occurs. This type of display provides a useful alternative to other, more traditional types of seismic displays.

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Affiliations.

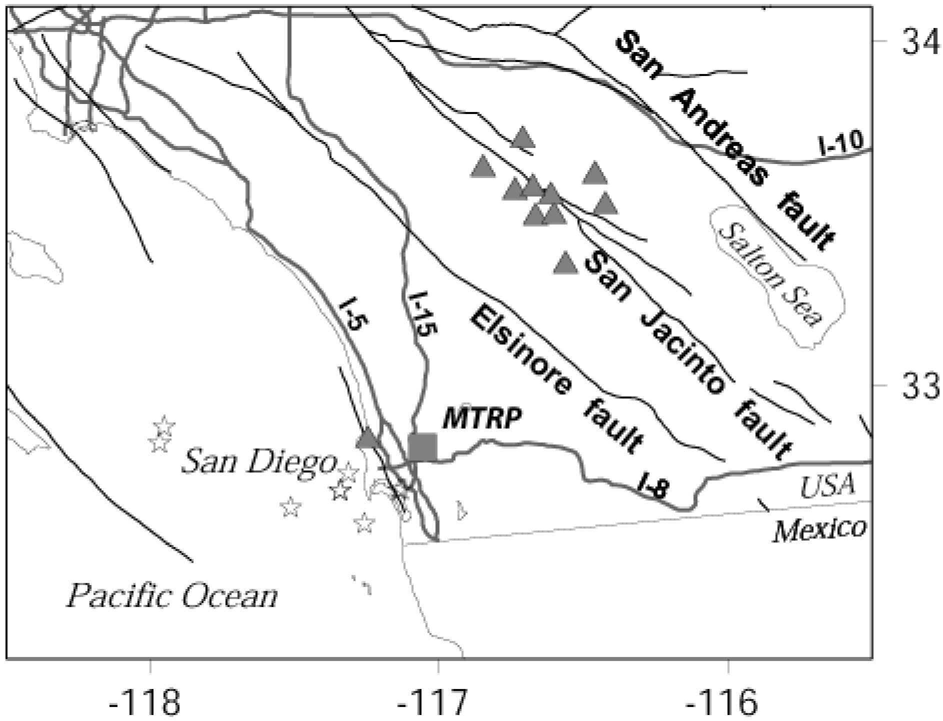
Department of Geological Sciences
San Diego State University
San Diego CA 92182
(R.J.M and E.R.)

Institute of Geophysics and Planetary Physics
Scripps Institute of Oceanography
University of California San Diego
San Diego CA 92122
(J. E. and F. L. V.)

Figure 1. Map of Mission Trails and San Diego region. Major highways and faults are shown. The MTRP station is shown as a square and other seismic stations on the display as triangles. Stars show detectable events from 1 year (2001) of seismicity.

Figure 2. Photo of display showing a local earthquake as recorded by the museum sensor.

Figure 3. Example seismograms of earthquake (top, a Ml 2.0 at 16:11:42 UTC on 17 May, 2002 located about 30 km west of the station) and a typical set of “jumping” seismograms (bottom) recorded a few minutes later.



34
33
-118
-117
-116
San Andreas fault
I-10
Salton Sea
San Jacinto fault
Elsinore fault
I-5
I-15
MTRP
San Diego
I-8
USA
Mexico
Pacific Ocean

Figure 1.

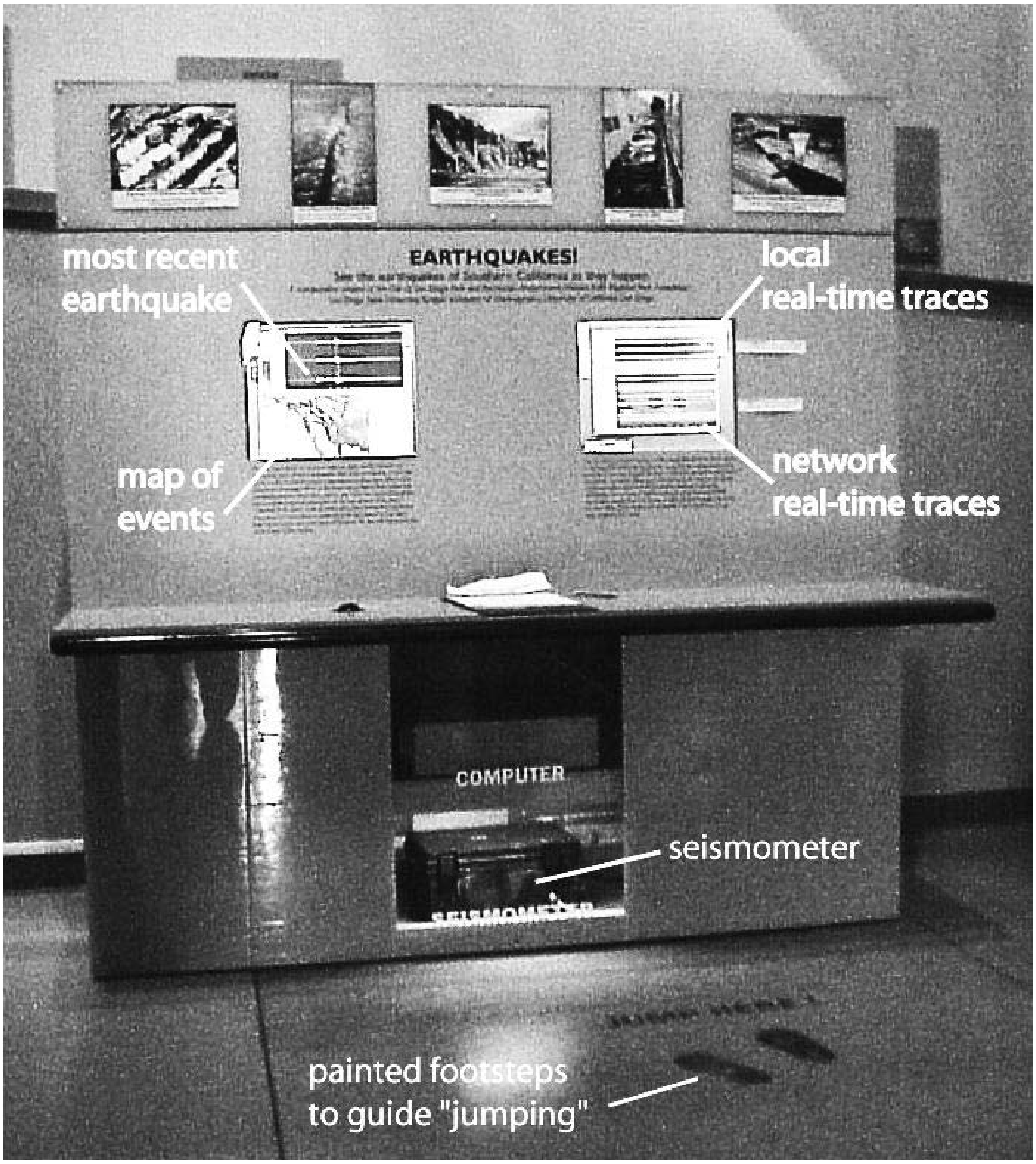
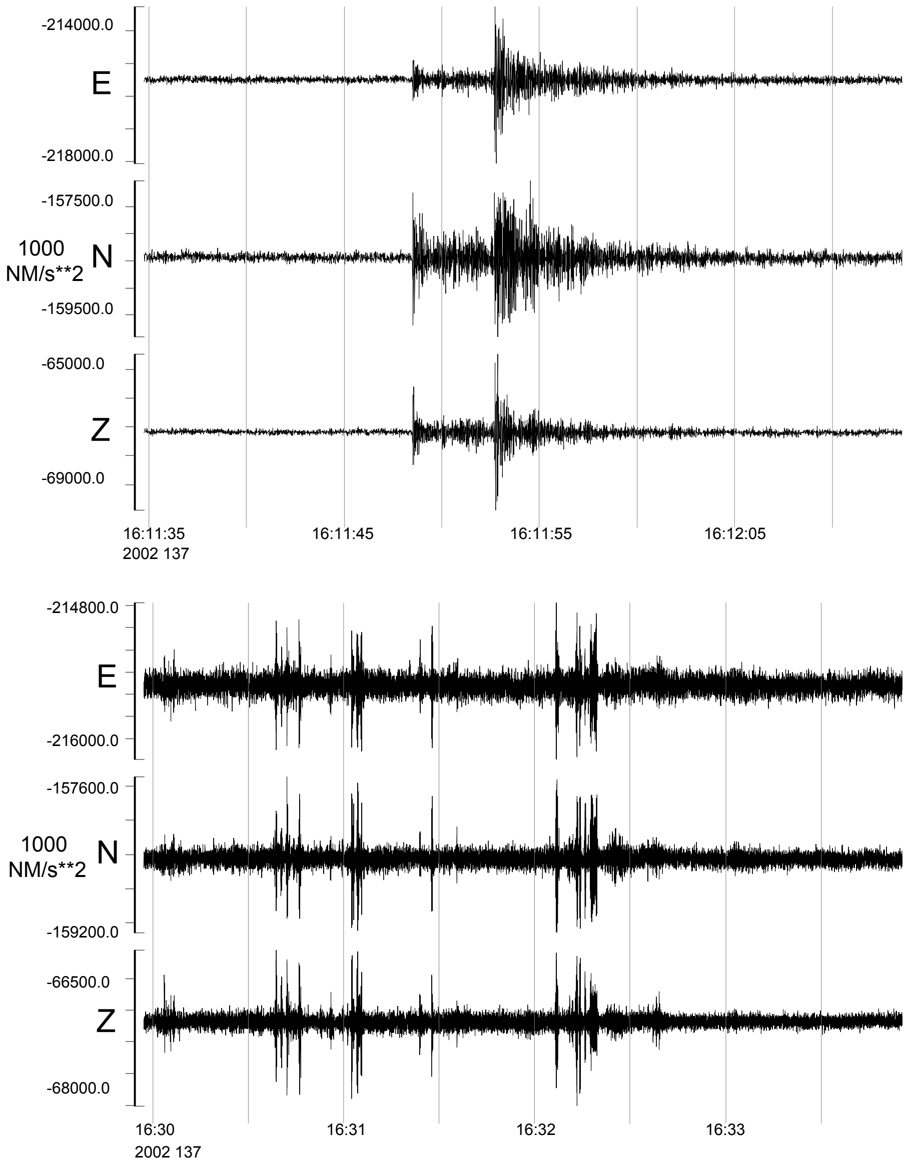

most recent earthquake
EARTHQUAKES!
local real-time traces
map of events
network real-time traces
COMPUTER
seismometer
painted footsteps to guide "jumping"

Figure 2.



-214000.0
E
-218000.0
-157500.0
1000
NM/s**2
N
-159500.0
-65000.0
Z
-69000.0
16:11:35
2002 137
16:11:45
16:11:55
16:12:05
-214800.0
E
-216000.0
-157600.0
1000
NM/s**2
N
-159200.0
-66500.0
Z
-68000.0
16:30
2002 137
16:31
16:32
16:33

Figure 3.