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The Northern California Earthquake Management Center: A Unified System from Realtime Earthquake Monitoring to Data Distribution

http://www.ncedc.org

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Anatomy of the NCEMC Earthquake Monitoring System

Introduction to the NCEMC

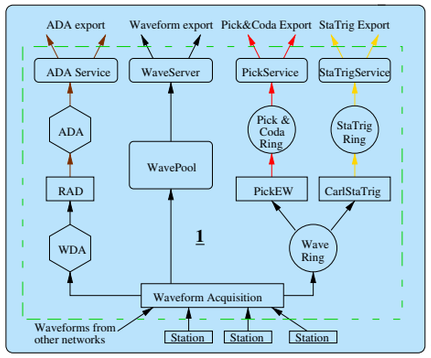
The Northern California Earthquake Management Center (NCEMC) is one of three management centers of the California Integrated Seismic Network (CISN), which is responsible for earthquake monitoring in California. The NCEMC is a distributed center with components located at the UC Berkeley Seismological Laboratory and the US Geological Survey in Menlo Park. Data from the Berkeley networks, USGS Northern California network, and other contributing networks are used to provide robust realtime earthquake information to emergency response organizations and the public, and to collect, archive and distribute these data to scientists through the Northern California Earthquake Data Center (NCEDC).

Real time and near-real time data are also exchanged among the CISN management centers (NCEMC, SCEMC at Caltech, and Engineering Management Center at California Geological Survey) to provide redundant earthquake monitoring for California,and to provide both the scientific and engineering research groups with the appropriate earthquake data. The CISN is a region of the Advanced National Seismic System (ANSS).

The CISN software for the NCEMC described here is work-in-progress and represents an ongoing collaboration involving all of the CISN partners. It draws heavily on components from multiple sources: TriNet software developed by SCSN, Earthworm software developed by USGS, database schemas, moment tensor, and finite fault codes developed by UC Berkeley, and the Jiggle event analysis tool developed by SCSN.

The CISN is working to establish a common CISN sofware environment. The NCEMC development will support the distributed structure of the NCEMC, and enhance the CISN's capacity for redundant state-wide earthquake monitoring. Newer CISN components,such as the CISN Messaging System and Proxy Wave Server, have already been designed to operate at the multiple and distributed CISN management centers.

NCEMC Network Services



1. Network Services

The NCEMC software components that provide access to continuous waveform and derived parameters are called Network Services. While station support and data collection are performed separately by UC Berkeley and the USGS NCSN, picks, codas, and amplitude data, will be produced and shared between the operation centers continuously. Waveforms will be available from each operation center through waveserver requests. The processes for each data service use shared memory, and therefore must run on the same computer. The services incorporate both Earthworm and CISN-developed modules.

A. Pick and Coda service - provides remote processes with a stream of phase picks and coda durations from the available data channels.

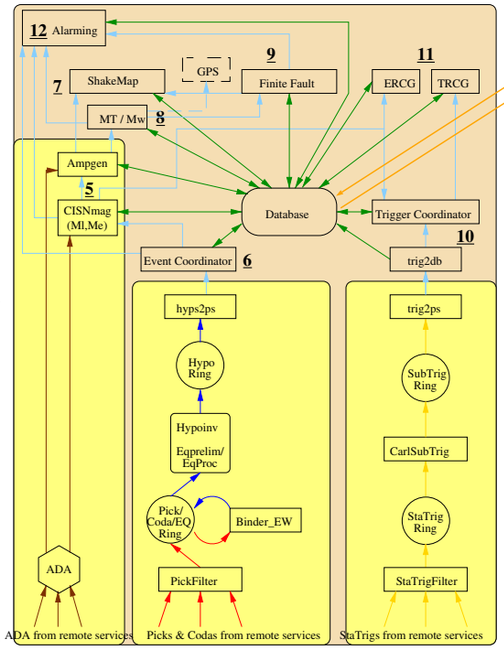
B. Station Trigger service - provides remote processes with a stream of station triggers (useful for subnet triggering) from the available data channels.

C. WaverServer - provides interfaces for remote processes to request and retrieve waveforms from the wavepool of available data channels.

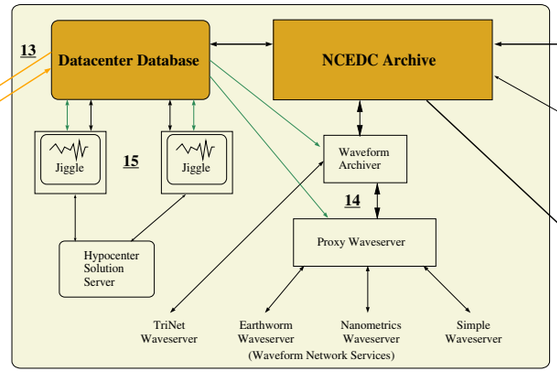
D. ADA (Amplitude Data Area) service - provides a time-aligned set of amplitudes data (PGA, PGV, PGD, MI100, integrated velocity squared, Spectral Amplitudes) at a reduced sample rate of 5 second intervals from each velocity and acceleration channel. The time-alignment ensures that redundant systems processing the same waveform data will generate the same ADA timeseries

Within the NCEMC, two computers at UC Berkeley will duplicate network services for all Berkeley stations, and two computers at Menlo Park will duplicate network services for all northern California USGS stations.

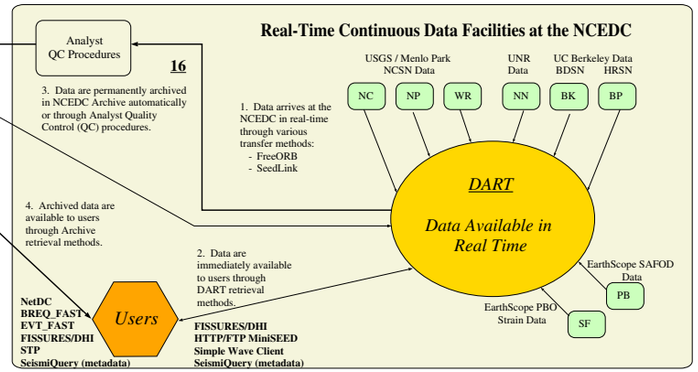
NCEMC Earthquake Processing



NCEMC / NCEDC Event Analysis and Archiving



NCEDC Continuous Waveform Archiving



Shared Memory Usage in Earthquake Processing System

Each of the yellow boxes above represent a group of process that communicate or exchange data via shared memory, and must therefore run on the same computer. However, each group may run on a separate computer if desired.

2. Event Detection

The Earthworm-based event detection uses data imported from both local and remote network services. Picks and codas can be imported from redundant network services computers for increased robustness, since they are filtered to allow only a single copy of each data to pass to the upstsream software.

3. Subnet Triggering

The Earthworm-based subnet triggering software uses data imported from both local and remote network services. Station triggers can be imported from redundant network services computers for increased robustness, since they are filtered to allow only a single copy of each data to pass to the upstsream software.

4. ADA Aggregation

Reduced amplitude data from multiple (and optionally redundant) Network Service systems are imported and aggregated to provide a single collection of amplitude from all channels available to the NCEMC.

5. CISNmag and Ampgen

The CISNmag process rapidly computes the local (ML) magnitude and optionally the energy magnitude (Me) from the pre-processed reduced amplitude data imported from the network services systems. Once the magnitude is know, Ampgen is notified, and uses the reduced amplitude data to determine peak ground motion parameters require for Shakemap. All parameters are entered into the database and associated with the event, origin, and/or magnitude.

CMS Messaging System and Database: Reliable Communication

Once an event is detected and entered into the database, subsequent processing modules read event parameters and write their results to the database. The dark green arrow represent these database query and update transactions. The light blue arrow represent message notification that are handled by the CISN Messaging System (CMS), an open-source network-based publish/subscribe system that routes messages from a publisher to subscribers of that message type. CMS was designed to provide reliable inter-process communication both within a computer and across the network. Most CMS messages contain just the message type and the eventid, since the message recipient read the current event information from the database. The exceptions are messages from hyps2ps and trig2ps, which contain the complete initial event and subnet trigger descriptions.

6. Event Coordinator

The Event Coordinator receives earthquake notifications and updates from the earthquake location system, inserts the earthquake and associated parameters into the database, informs the alarming system about the state of the earthquake, and notifies the the CISNMag process at the appropriate time to compute MI (and optionally Me) magnitudes from the ADA.

7. Shakemap

The Shakemap system is notified after the strong ground motion parameters have been entered into the database. Ground motion and event parameters are read from the database each time shakemap is run or rerun to ensure that the most up-to-date and complete data are used.

8. Moment Tensor and Moment Magnitude

The moment tensor module is notified after CISNMag has computed a rapid local and/or energy magnitude from the reduced amplitude data. If the event is sufficiently large, the module will compute the moment tensor, possible fault planes, and moment magnitude. The waveserver interfaces provide by the Network Services is used to retrieve the raw timeseries data required for the analysis.

9. Finite Fault (and GPS) processing

The finite fault module is notified after the moment tensor module has completed. For a sufficiently large event, the module will attempt to determine the rupture dimension using a finite source inversion. The waveserver interface is used to retrieve the raw timeseries data required for the analysis. Finite fault information can be used as additional input to Shakemap. UCB is also working on software to rapidly determine fault motion directly from GPS data.

10. Trig2db and Trigger Coordinator

The trig2db module receives a message containing the subnet trigger infomation whenever the subnet triggering software is triggered. It enters the subnet trigger info into the database, and notifies the trigger coordinator. The trigger coordinator's job is to determine whether subnet triggers can be associated with events detected by the evnet detection system. If the subnet triggers cannot associate with a known event, the trigger coordinator creates an event with an unknown origin in the database.

11. Event and Trigger Request Card Generators

The event and trigger request card generators determines what waveform data should be archived and associated with either located events or subnet triggers respectively/ The channel and time windowselections are based on the hypocenter and magnitude or triggered subnet combined with selected channel lists and station locations. Both modules write the waveform request cards to the database.

12. Alarming

The Alarming system will be based on the existing CISN/TriNet alarming software.
The alarming module receives signals from many of the real-time modules. Based on rules stored in the database, it perform actions that include issuing notifications by email, pager, and EIDS to the appropriate recipcients. The alarming system may be enchanced to track the alarming actions that have been invoked for each earthquake.

13. Database Replication

Database replication methods are used to replicate all events parameters,subnet trigger parameters, and waveform request cards from the real-time system to the data center database, and to replicate station and channel metadata from the data center database to the real-time database.The data center database permanently maintains a complete copy of all events and and their parameters, but these data are periodically purged from the real-time database.

14. Waveform Archiver and Proxy Waveserver

The waveform archiver uses the request cards generated by the real-time system to retrieve and archive the selected timeseries from the waveserver provided by the network services. If the entire requested timeseries is not available from the waveservers, the waveform archiver will archive the portion of the waveform that is available, and will periodically re-request the timeseries and update the archive whenever it retrieves a more complete waveform. The waveform archiver can only communicate directly with a TriNet waveserver. The NCEMC developed the proxy waveserver that uses the TriNet waveserver protocol to communicate with the waveform archiver an implements multiple protocols to retrieve data from Earthworm, Nanometrics, and Simple waveservers.

15. Jiggle Event Analysis Tool

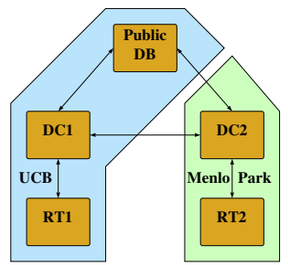
Jiggle is a Java-based interactive analysis tool developed by the SCSN for event analysis and review. Jiggle allows the analyst to review the event catalog, select an event for review, download and display the waveforms, phase arrivals, and coda, and amplitudes for the data channels, recompute phase arrivals and codas, recompute hypocenters and codas, and recompute Md and ML event magnitudes. Jiggle uses an configurable network-based solution server which performs the actual event relocation. The new event information is store in the database without deleting the previous information, so the history of the event analysis is preserved. Jiggle is normally configured to interact with the data center database and the archived waveforms, but can be configured to interact with the real-time database and to retrieve waveforms directly from the waveservers if desired.

16. Continuous Waveform Archiving

Analyst QC:
Selected stations from the NCEMC continuous data are subjected to an analyst Quality Control (QC) procedure. Waveform are scanned for data completness, and gaps in the timeseries are retrieve from the stations or primary waveserver and merge with existing data to create a complete timeseries whenever possible. The timeseries are checked for timing errors, and time corrections are applied when necessary.

Automated Archiving:
The remainder of the continuous timeseries in the DART are archived daily by an automated procedure that identifies channel days of data that need to be archived or updated, and will perform the appropriate archiving action.

NCEMC / NCEDC Robustness



The NCEMC will operate redundant real-time earthquake event processing system: RT1 at UCB, and RT2 at Menlo Park. One system will be designated the authoritative system, although both systems will perform event and subnet detection and replicate data to a data center database on-site. The two data center database and the NCEDC public database will replicate all data using multi-master replication to ensure that each data center and public database has an up-to-date and complete view of events. If any one data base or system fails, the NCEMC will still continue to fully operate.

Outstanding Development Issues

1. Rapid event alarming vs coda magnitudes

The original TriNet software computed only ML and Me magnitudes from the reduced amplitude timeseries data from the digiital stations in southern California. The sparser density of digital stations in northern California necessitates computing coda duration magnitude (Md) for small event. The CISN is developing plans to enhance the real-time system toensure that coda determination and the computation of coda magnitudes do not adversely impact CISN's ability to rapidly determine and distribute other earthquake parameters.