IMPROVED BULLETIN GENERATION USING AN ITERATIVE PROCESSING FRAMEWORK

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Auto Analyst

The Auto Analyst is the software controller of the Iterative Processing Framework (IPF) -- its goal is to emulate analyst intuition. The high-level process is as follows: After a first pass through a standard event building pipeline (signal detection and signal association), the resulting events are compared to historical information with the goal of identifying expected signals which are missing from the set of signals currently available, or which are present but erroneous in some respect. Waveform data are reprocessed to improve the set of available signal detections, and signal association is repeated when changes are made. The process is repeated until stability is achieved. IPF also introduces seismic events detected using waveform correlation into automatic processing prior to signal association. The signal associator first associates automatically generated signal detections to the events detected with waveform correlation prior to generating new events.

Signal Detector – WavePro

WavePro is our implementation of a configurable waveform detector, similar to the Detection and Feature Extraction (DFX) application. WavePro is a modular tool that is able to read waveforms, perform quality control on the data, run signal detection algorithms, and extract various features from these detections.

In the context of IPF, the role of WavePro is two-fold:
1) Act as a standard first-pass signal detector, passing results to the Auto Analyst
2) Provide iterative signal detection and feature extraction capabilities to the Auto Analyst

Example #1:
Below is an example of a signal detection at IMS Primary Seismic Station PS33 (ZALV) that was originally missed on the first pass of our signal detector. For a built event, the Auto Analyst queried the Expected Signal Database and determined that there is a high probability that a ZALV P detection should exist. Using this knowledge, the Auto Analyst generated an origin beam to the known event location and re-processed the waveforms through the signal detector with a lower detection threshold (from 4 to 2.5). By doing this, the detection was found and successfully associated to the event.1
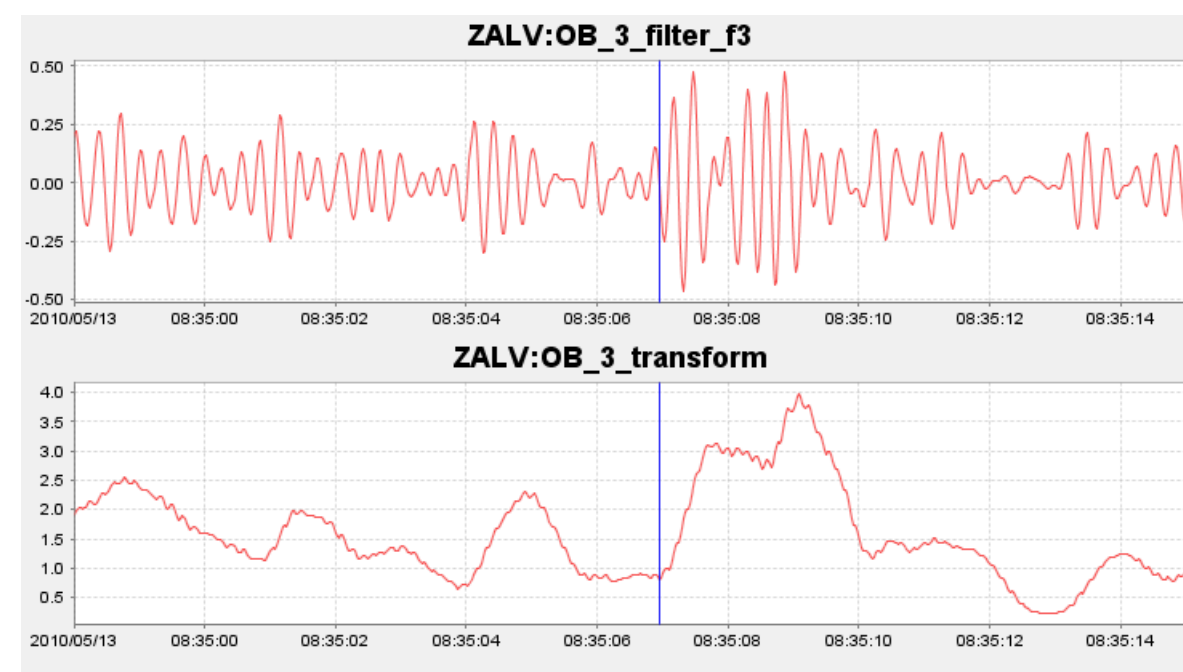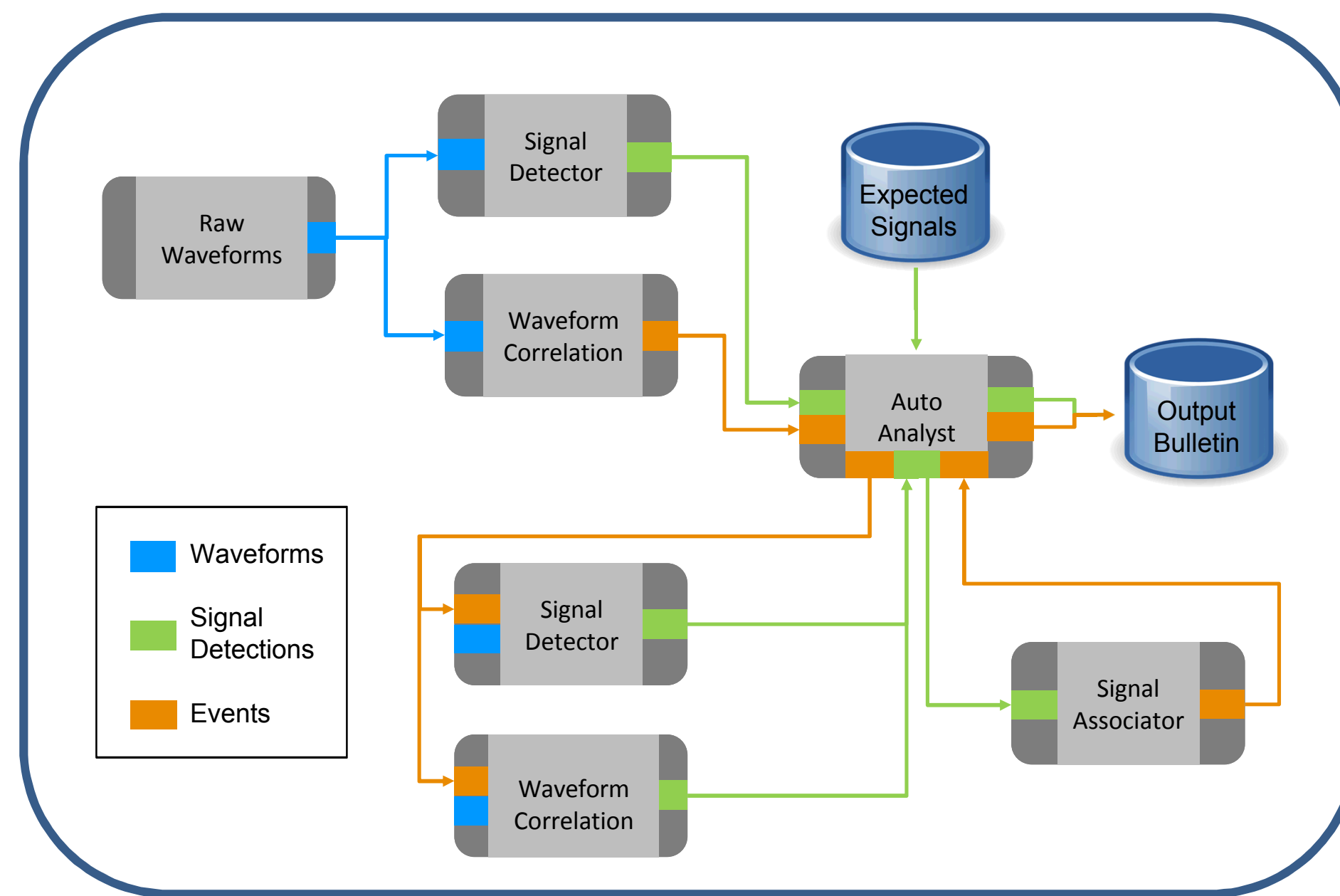

Example #2:
To the right is an example of a computed FK for a P-Wave signal detection at IMS Primary Seismic Station PS23 (MKAR). The **X** marks the overall max FK value and hence the assigned azimuth/slowness value for this detection. However, this computed azimuth/slowness value is incorrect. The **O** marks the correct secondary peak, as computed by the Auto Analyst by initiating the search starting from the origin beam from a generated expected arrival.
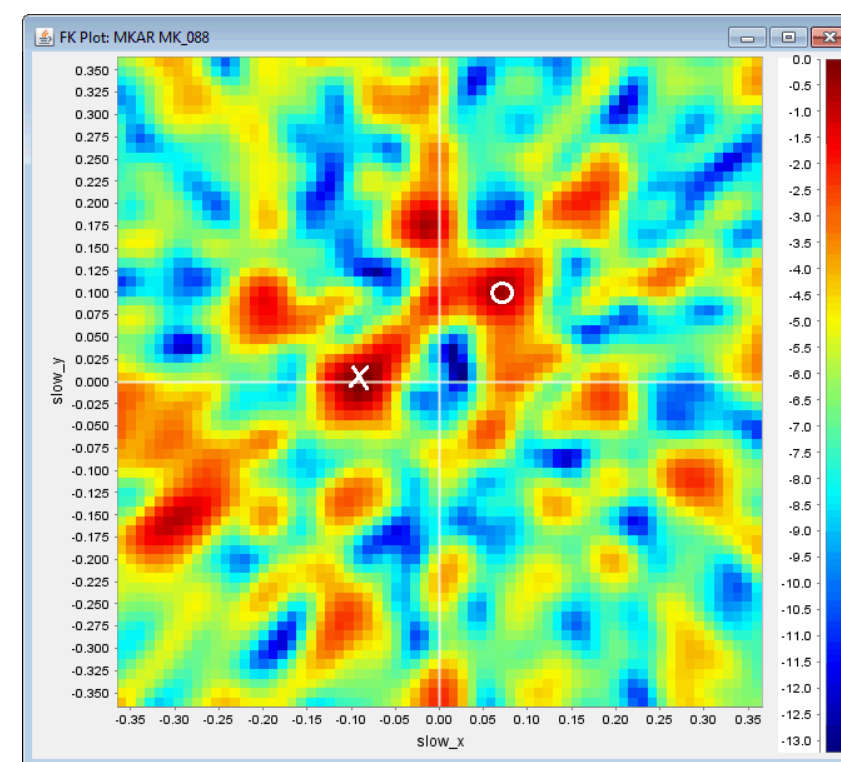
Overview

The International Data Center (IDC) automatic seismic event bulletin is generated by performing two sequential processing steps: first, station processing to find detections, and second, network processing to form events. This processing paradigm differs significantly from that applied by human analysts. Analysts bring to bear considerable human intuition acquired during the processing of past events and use that to iteratively reprocess data resulting in a significantly improved bulletin. Our Iterative Processing Framework (IPF) attempts to mimic analyst behavior during automatic bulletin generation.

Signal Correlator - SeisCorr
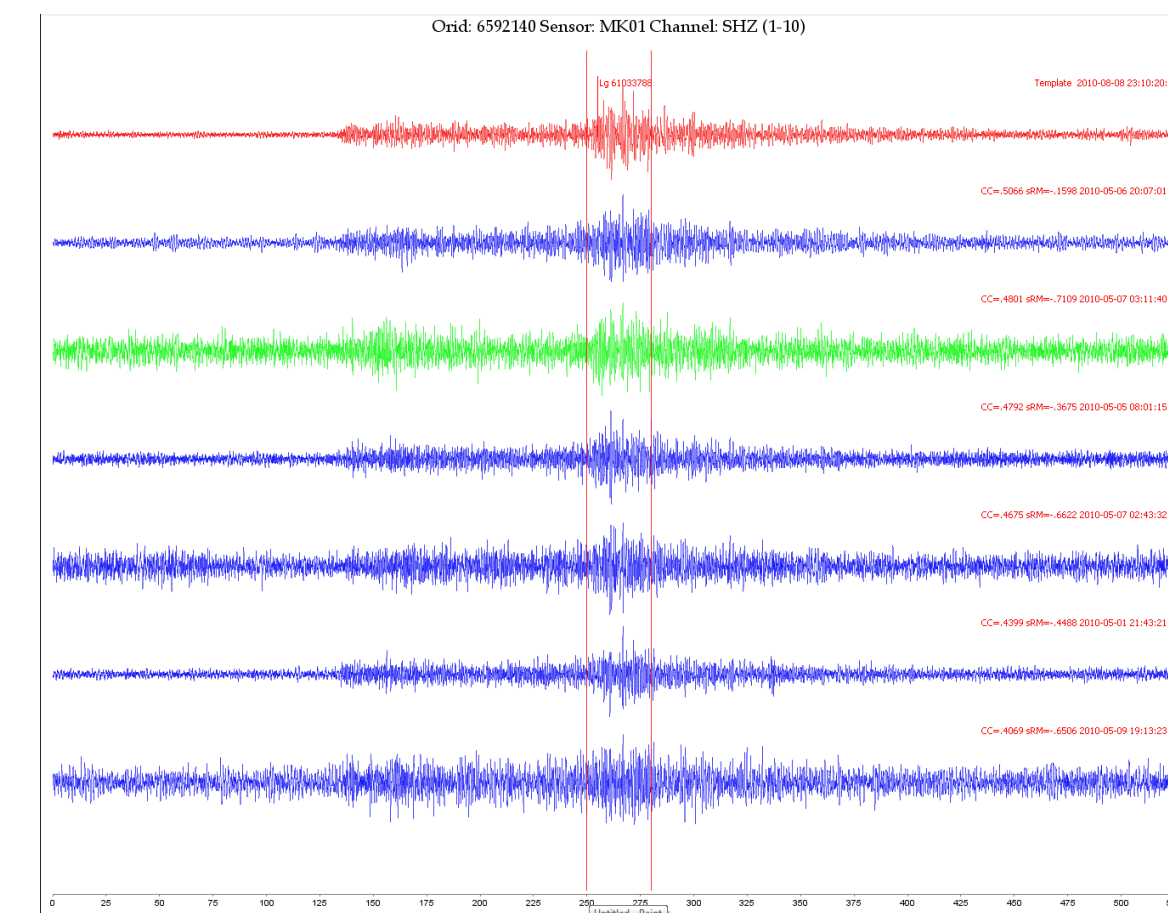
Example:
Waveform Correlation allows the detection of similar events and has been shown to perform better detecting noisy and low amplitude event waveforms than traditional energy detection. A template waveform (red) from a known event can be correlated against the raw data stream to find similar events (blue waveforms). The green waveform is an event which the traditional signal detector did not detect, but which was detected using waveform correlation. This event is sent to Auto Analyst with associated metadata (estimated origin time, estimated latitude/longitude, estimated magnitude).

Signal Associator – Pedal

The Probabilistic Event Detection, Association, and Location algorithm (PEDAL) associates a set of isolated seismic observations from a network of stations into a list of hypothesized seismic events consistent with those observations. The Earth is discretized into a 3D grid of nodes that spans the globe, including depth. Adding time extends the grid to 4D. Given a set of observations within a specified time window, a 'fitness' value is calculated at each grid node by summing station-specific conditional fitness values. Assuming each observation was generated by a refracted P wave, these values are proportional to the conditional probabilities that each observation was generated by a seismic event at the grid node. The node with highest fitness value is accepted as a hypothetical event location, subject to some minimal fitness value, and all arrivals within a longer time window consistent with that event are associated with it. During the association step, the assumption that the arrival was a direct P arrival is relaxed and a variety of different phases are considered. Once an arrival is associated with an event, it is removed from further consideration. While unassociated arrivals remain, the search is repeated to find other events until none are identified that satisfy a minimum fitness criteria.

In the context of IPF, PEDAL accepts a set of "known" events generated by SeisCorr and associates input signal detections to those origins before generating new events and associating signals to them.