Detection of Background Seismic Waves Anomalies With a Hierarchical Temporal Memory (HTM) Cortical Algorithm

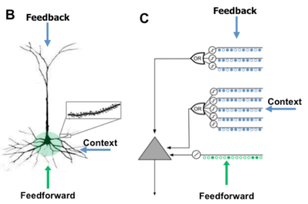
#Ruggero Micheletto[1] (ruggero@yokohama-cu.ac.jp), Kahoko Takahashi [1]
1. Yokohama City University

Summary

We used an unsupervised cortical algorithm to detect in real time anomalies in simulated and real seismic signals. The algorithm works on-line receiving continuous seismic acceleration signals from a streaming station. This could be a software source that is simulating the data stream from a suitable algorithm, or could be data timeseries from a database of real seismic events.
Our system is based on the Numenta HTM engine that implements a cortical algorithm based on an innovative neural model in which dendrites act as coincidence detectors and synapses are formed continuously. The HTM networks learns and adapts to the seismic background noises and it is able to notice anomalies in real time and without the necessity of supervision.

HTM algorithm

* Uses an innovative model of the neuron, based on realistic biological paradigms



The HTM neuron has realistic dendrides with multiple synapses

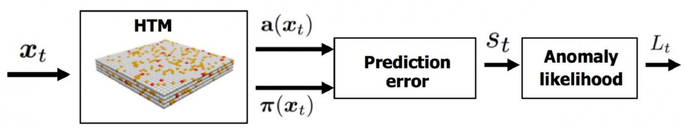
Each dendride send signal to spike when there is a "coicidence"

The coicidence is a quasi- symultaneous arrival of multiple spikes on the synapsis of that dendride.

Distal or lateral input make the neuron to spike earlier and easier. It like a prediction signal. These properties are in line with many experimental tests on biological neurons.

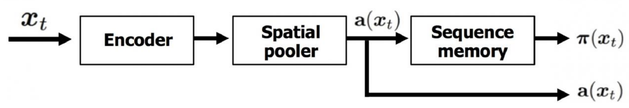
a

Anomaly detection using HTM

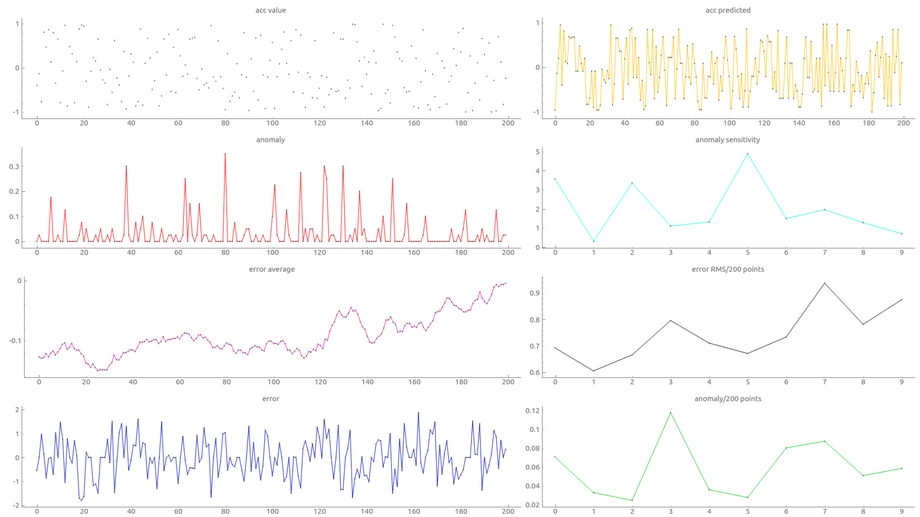


b

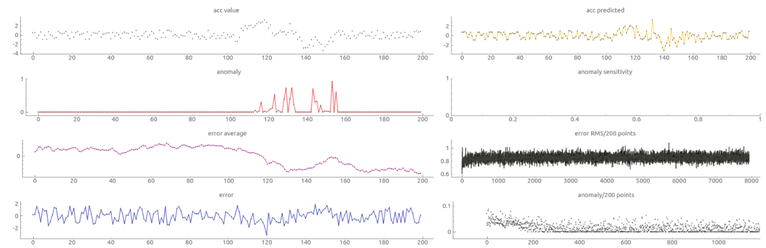
HTM core algorithm components



Beginning of exposure to data



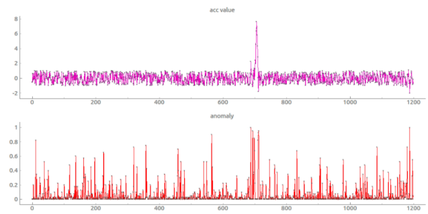
After long exposure to data



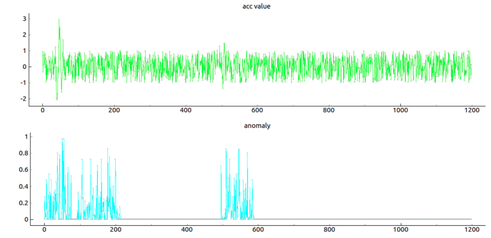
This approach to seismic detection could be useful not only to recognize earthquakes and contribute to early warning networks, but also could be of importance for detecting variations of the background noises characteristics that are not detectable with conventional methods or by conventional machine learning methods.

Synthesis of jitter waveforms are done with this equation

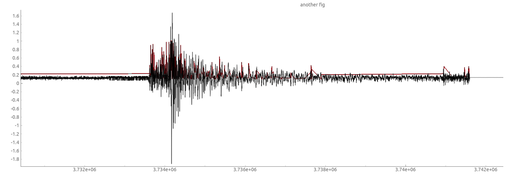
$$A_c(t) = \Sigma_n a sin(2\pi f_n t) + \epsilon$$



Anomaly response to very small signals



An example on a generic earthquake waveform



References
Ruggero Micheletto, Ahyi Kim,
"An HTM based cortical algorithm for detection of seismic waves", arXiv:1707.01642 (2017)
Yuwei Cui, Subutai Ahmad, Jeff Hawkins, "Continuous Online Sequence Learning with an Unsupervised Neural Network Model" (2016), Neural Computation.

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We thank Matt Taylor of Numenta Inc, for his personal help via e-mail and for making detailed video on how to use numic HTM python implementation of the HTM algorithm

Conclusion

1. The conventional method (STA/LTA) tends to unstable under noisy environments.
2. A cortical neuronal algorithm seems to be sensitive to very small jitters
3. The HTM algorithm tested reacts to jitter signals of nearly the same amplitude of the noise.
4. The method is completely unsupervised and does not depend on tunable parameters