Local event detection with neural networks (application to Webnet data)

J. Doubravová, J. Horálek[1] and J. Wiszniowski[2]

[1]Department of Seismology
Institute of Geophysics, Czech Academy of Sciences

[2]Department of Seismology
Institute of Geophysics, Polish Academy of Sciences

Workshop CzechGeo/EPOS, 16.11.2016

INSTITUTE OF GEOPHYSICS
OF THE ACADEMY OF SCIENCES, CZECH REPUBLIC

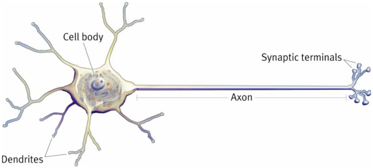
CZECH GEO

Motivation

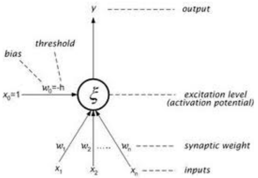
- seismic networks produce huge volumes of continuous data
- good seismic event detection
  - for manual processing to reduce false alarms to be inspected (specific)
  - for automatic processing detect all the weak events (sensitive)
- in artificial neural networks the useful information is extracted (even if we are not able to describe the algorithm)
- in artificial neural networks the forward problem is solved **fast**

Biology facts

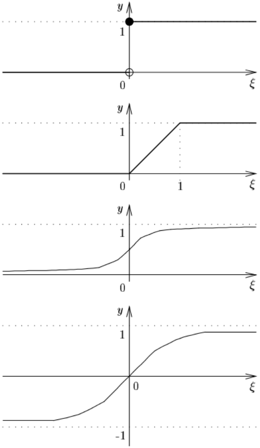
- neural network - interface between organism and environment
- information from receptors spread through neurons to effectors
- in cerebral cortex 15-33 billion neurons
- dendrites (inputs), synaptic terminals (output, connected to up to 5000 other neurons dendrites)
- synaptic permeability between dendrite and axon is adjusted
- if the activity of dendrites is above threshold - neuron generates an electric impulse



Formal neuron

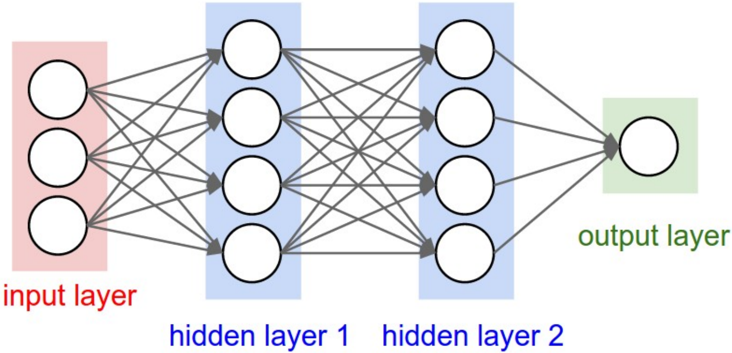


- n real inputs x = dendrites, bias $x_0 = 1$
- weights w = synaptic permeability, $w_0 = -h$ threshold
- activation potential $\xi = \sum_{i=0}^{n} w_i x_i$
- activation function $y = \sigma(\xi)$

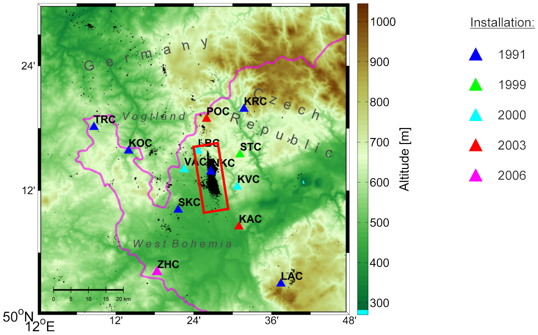


Artificial neural network

- to solve more complex problems - neural networks
- typical applications: classification, pattern recognition, regression



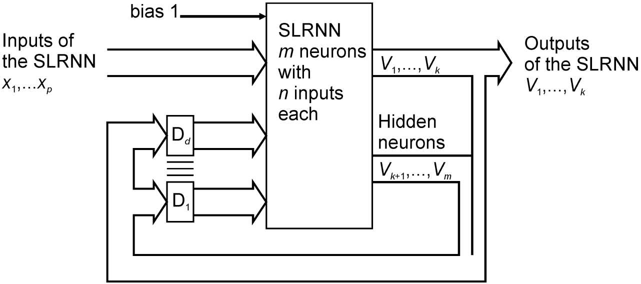
WEBNET data



- 22 stations in total
- 13 stations online
- 250Hz, three component ground-velocity records

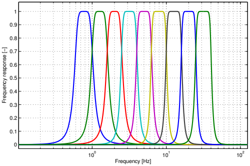
SLRNN - network architecture

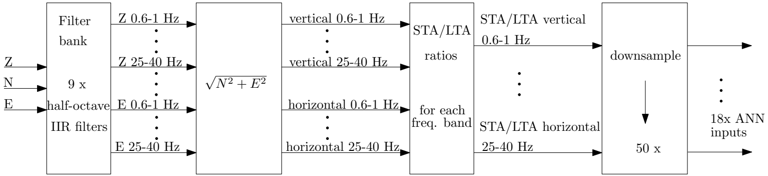
- outputs of neurons are fed back as inputs = recurrence, memory
- delays of more samples $D_1..D_d$ (1, 2, 4, and 8 samples)
- 8 neurons, 18 inputs, 3 outputs (**event**, P, S)



SLRNN - input data processing

- STA window 2x shortest period, LTA window 10x longest period
- decimation to 0.2 s time steps - compromise between the acceptable computational load and good separation of individual waves



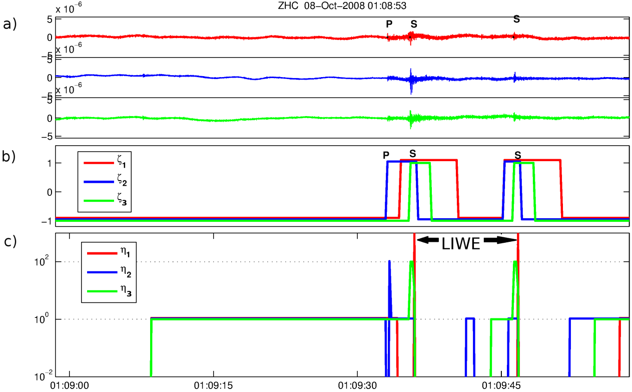


Training

- supervised learning: find w_{ij} to get the best fit of the actual and required outputs
- 100 events for each station (different magnitudes, locations or focal mechanisms)
- 100 examples of disturbances and non-local events (quarry blasts, regional or teleseismic events, disturbances by wind or storms...)

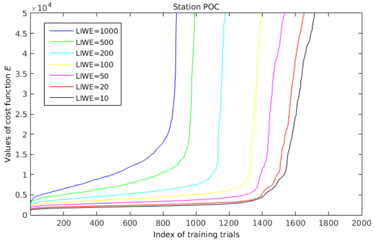
Training - example

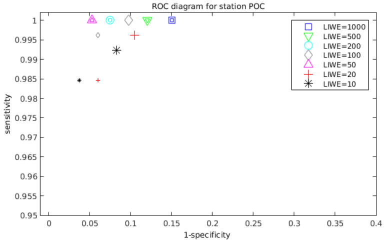
Learning Importance Weight of Events(LIWE) - sensitivity of **event** output to S wave onset = very important parameter



Cost function and ROC for various LIWE

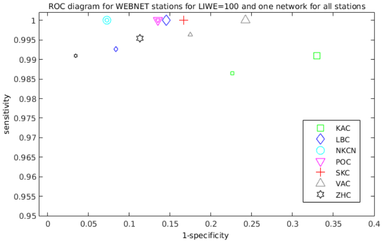
- sensitivity = detected events / all events
- specificity = rejected disturbances / all disturbances

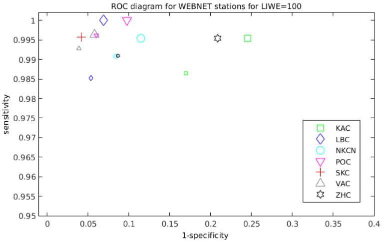




ROC for joint and individual training

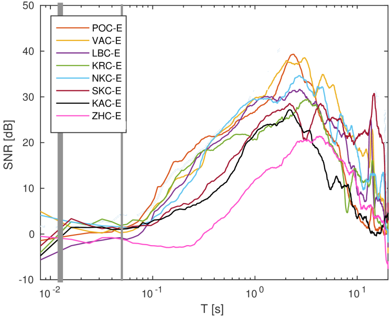
- in case that the training P- and S-onset picks are not evenly present on all stations, it is helpful to use joint training
- if the picks are complete for the station and all events, individual training performs better





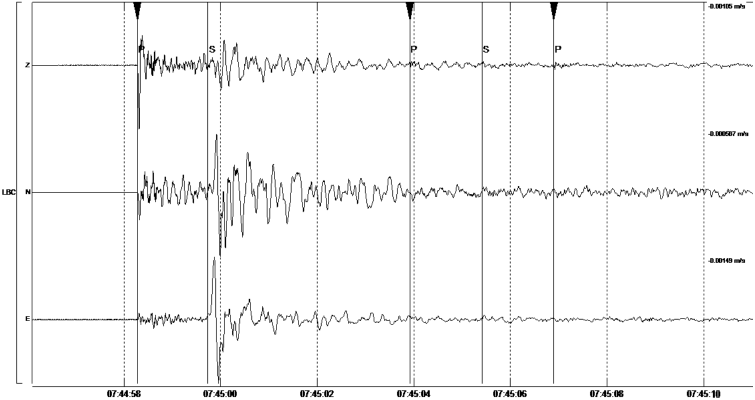
Signal-to-noise ratio

- the worst trained stations (KAC and ZHC) also those with higher noise
- the best trained stations (LBC, POC, VAC) with lower noise (higher SNR)



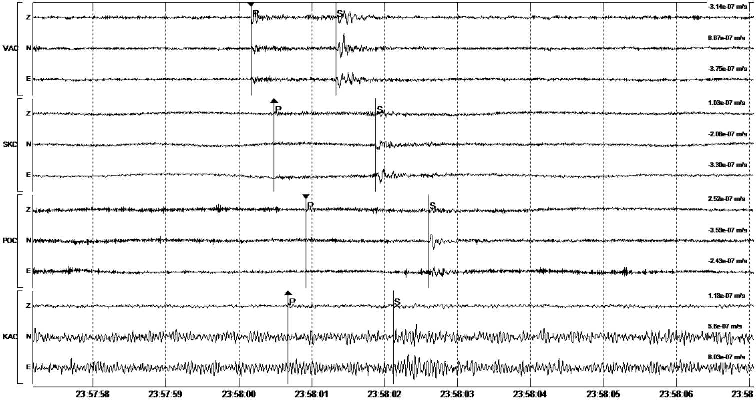
Undetected events - examples

Events $M_L = 2.3$ and $M_L = 2.2$ masked by a coda of $M_L = 3.8$ earthquake



Undetected events - examples

detection of $M_L = -0.3$ event failed on station KAC due to higher noise level



Summary

- SLRNN proved to be an appropriate tool for local event detection
- LIWE - very important, affects the number of successful trials
- in case the training P- and S-onset picks are not evenly present on all stations => joint training helps
- if the picks are complete for the station and all events => individual training performs better

- Outlook
  - use the network = coincidence - rejection of false alarms + confirmation of events
  - try to teach similar network for Reykjanet data