

# Time Series Analysis

02/2017



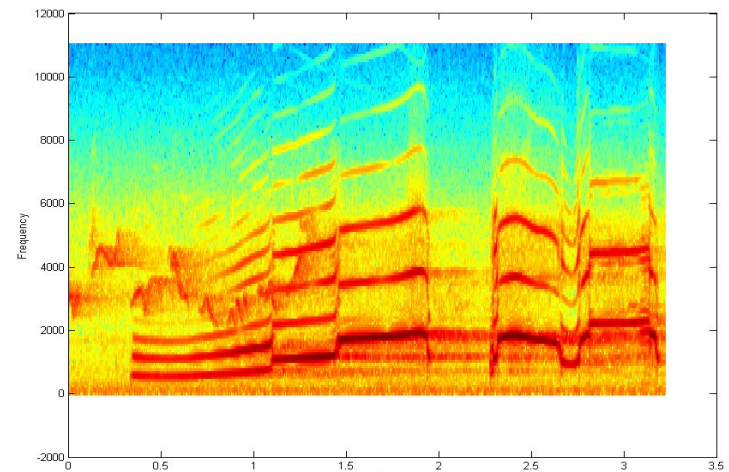
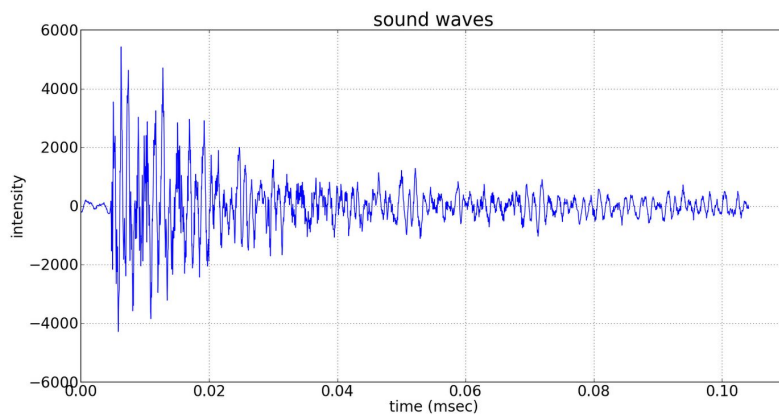
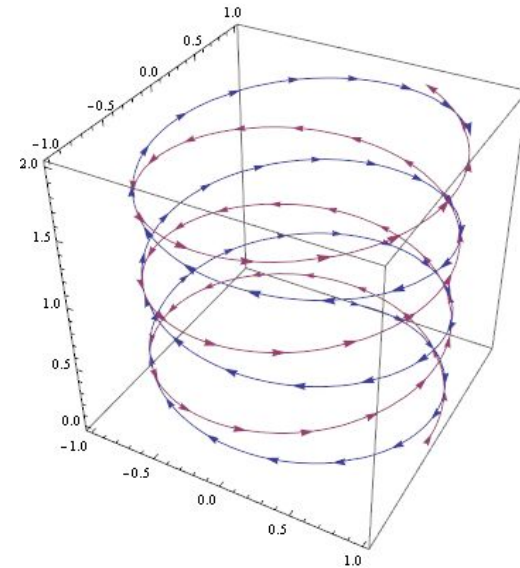
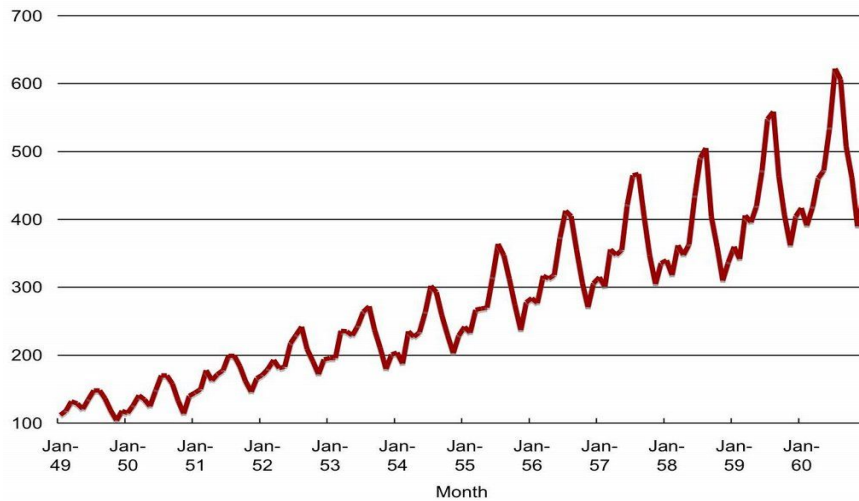
# About me

- Ph.D. In computer science at VŠB-TU Ostrava
  - Neural networks & unsupervised self-organization
- Experienced in simulations
  - flood prediction system for MSK
  - traffic monitoring & prediction systems
- Experienced in computer graphics & scientific visualization
  - GIS related realtime 3D visualizations
- 5 years in applied ML and artificial intelligence
  - Lead researcher in GoodAI - general artificial intelligence
  - CTO in NeuronSoftware - sound processing with ML
  - Lead ML in CEAI - natural language processing

# Outline

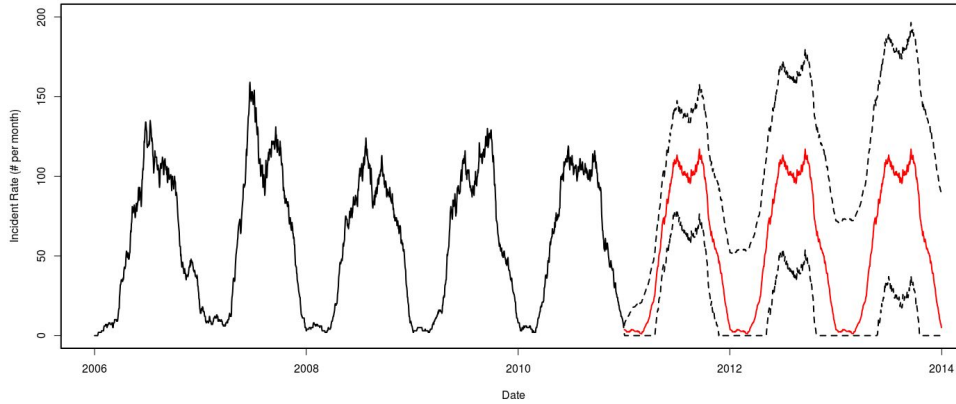
- Time series intro
  - Examples, tasks
- Classical analysis
  - Stationarity, decomposition, ARIMA
- Stochastic model example
  - Hidden Markov Model
- Neural networks
  - Feed-forward networks & backpropagation
  - Recurrent networks, unfolding, BPTT, LSTMs
- Task-related data preparation
  - Normalization, supervised or unsupervised task
- Practical Examples
  - Recurrent networks test
  - Simulated rainfall-runoff model prediction
  - Trampoline jump classifier
  - Weather forecast

# Time series - examples

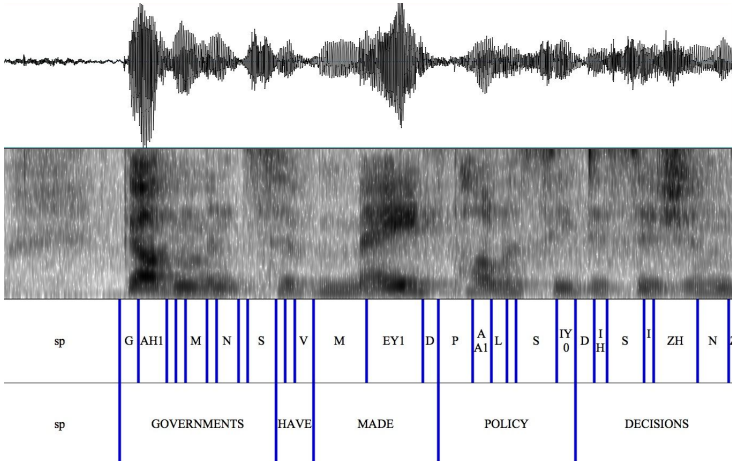
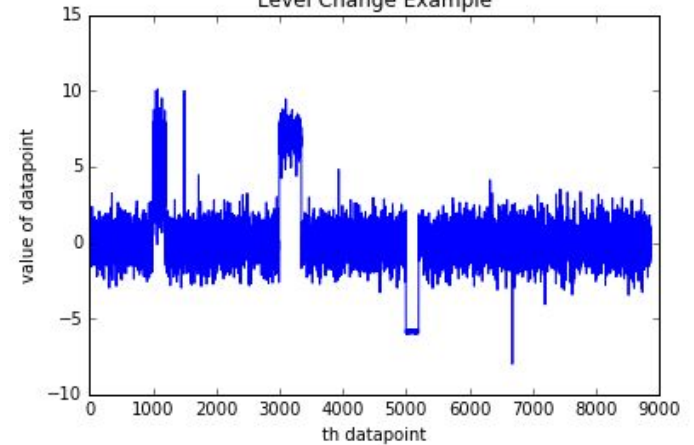


# Time series - tasks

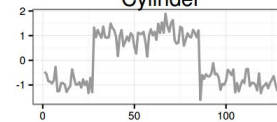
Projected bicycle collision rates in Montreal



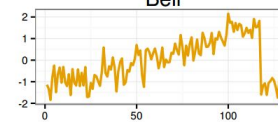
Level Change Example



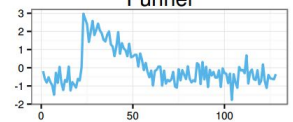
Cylinder



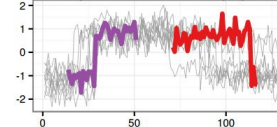
Bell



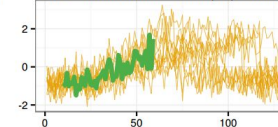
Funnel



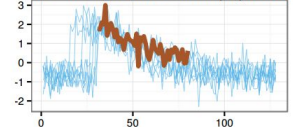
Class Cylinder and best rep. patterns



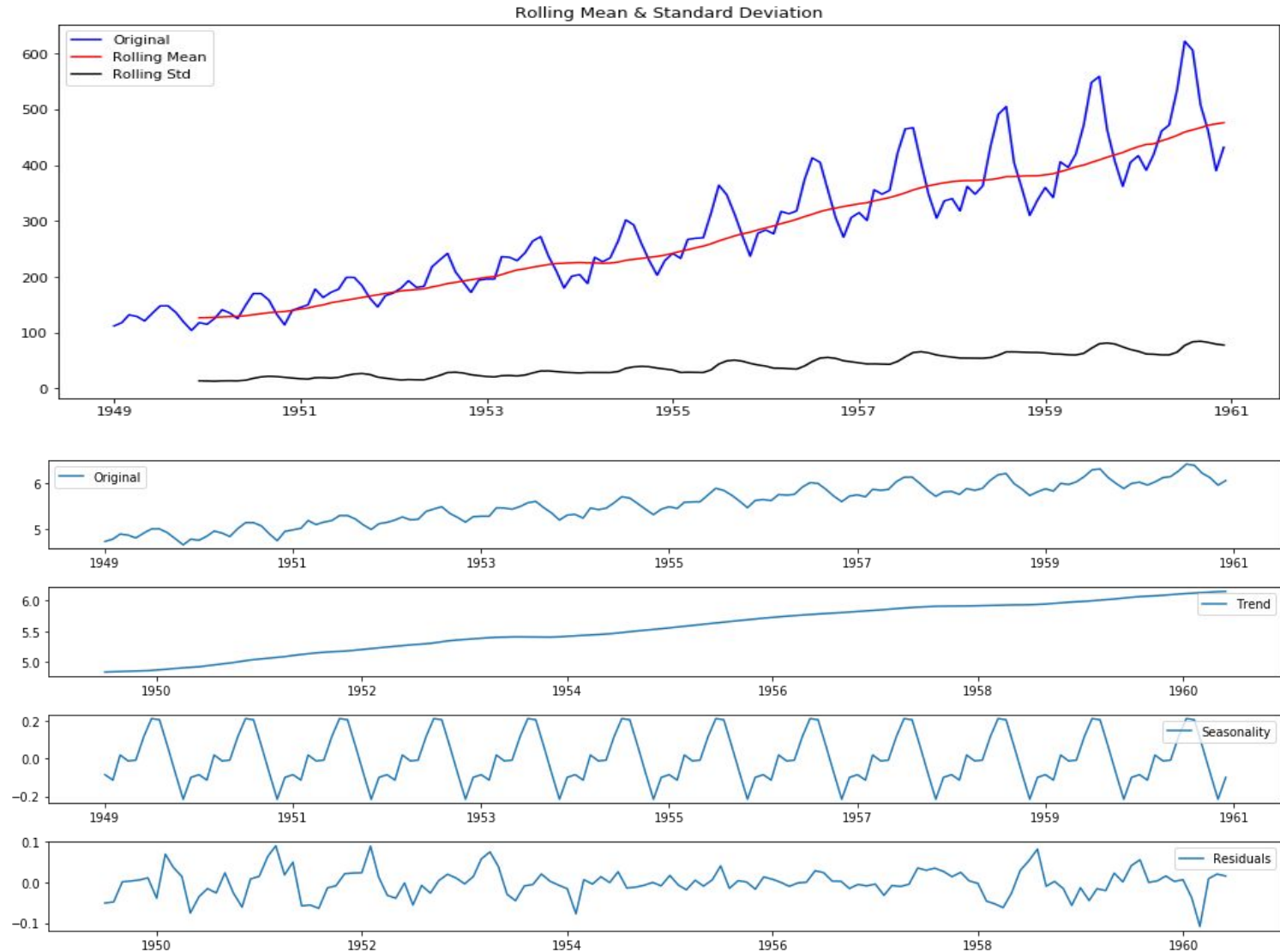
Class Bell and best rep. pattern



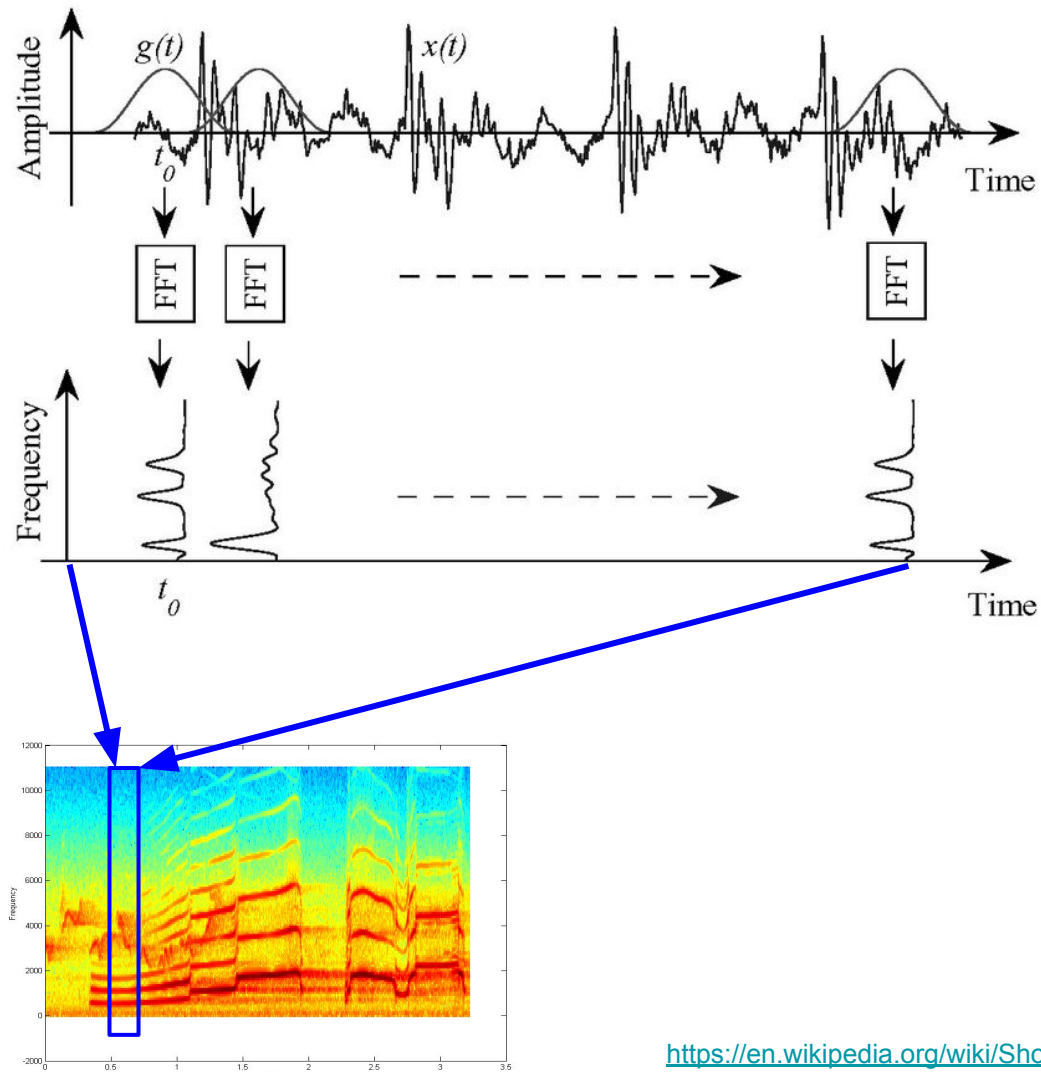
Class Funnel and best rep. pattern



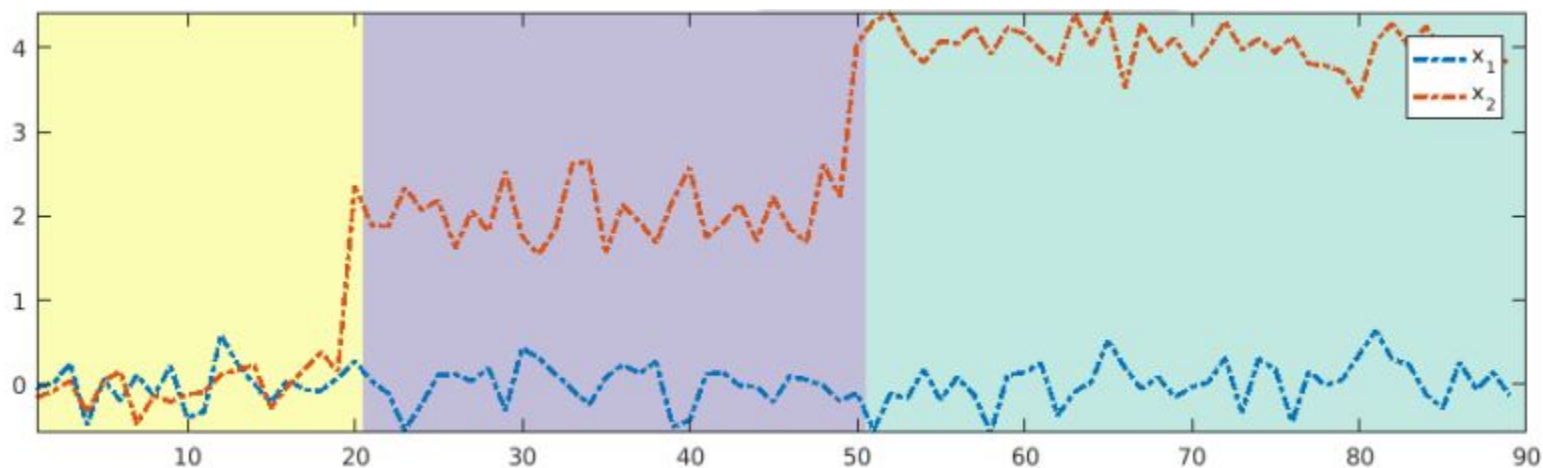
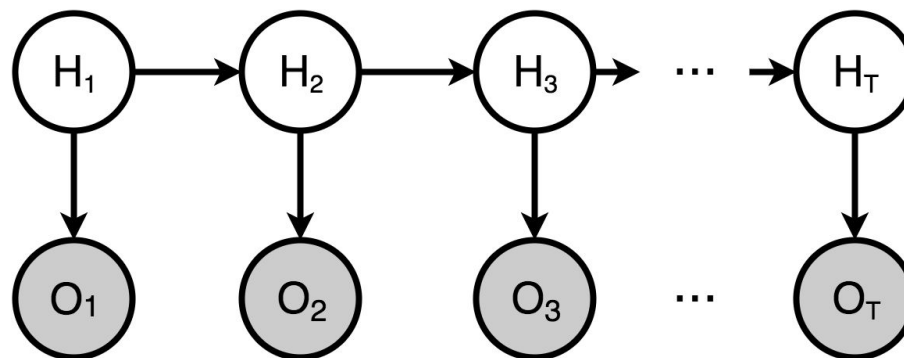
# Time series - decomposition



# Time series - Short-time Fourier Transform

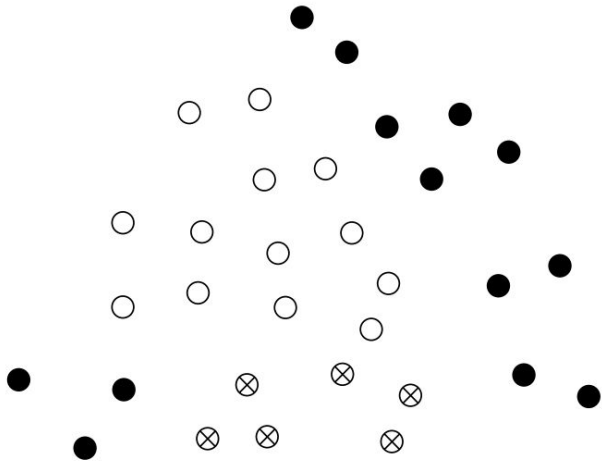


# Hidden Markov Model

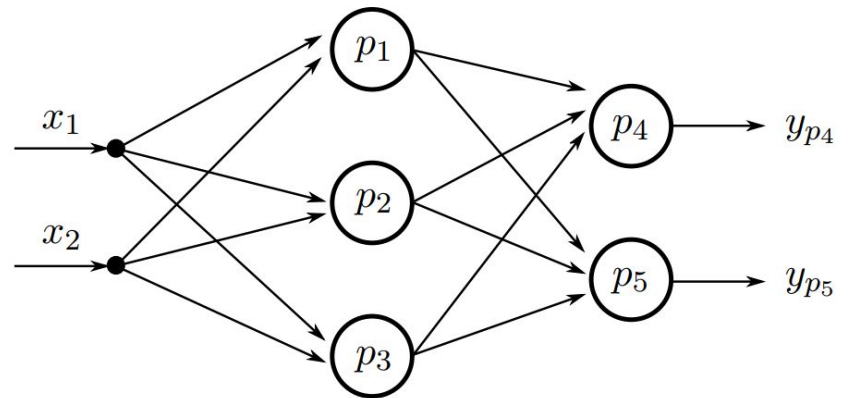




# Neural networks

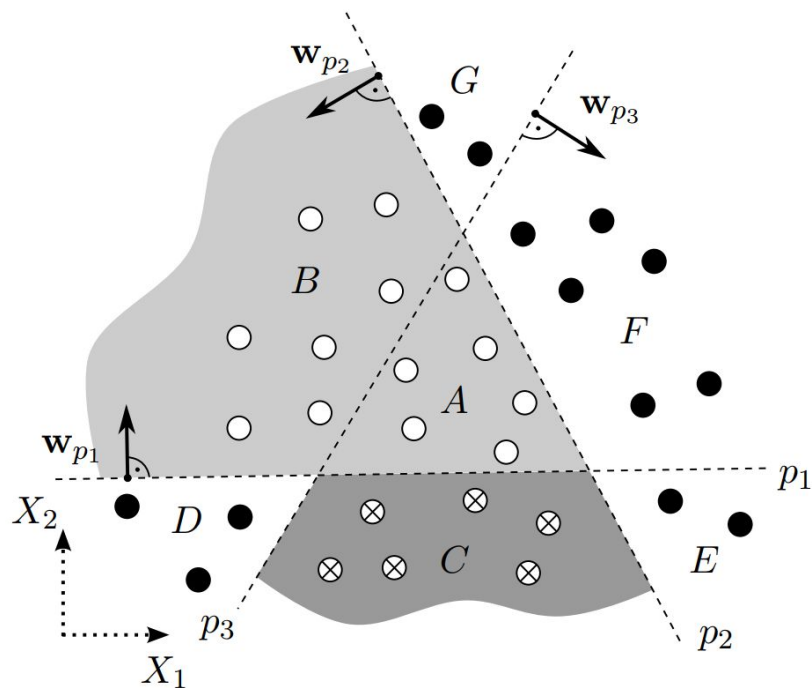


(a) Input set

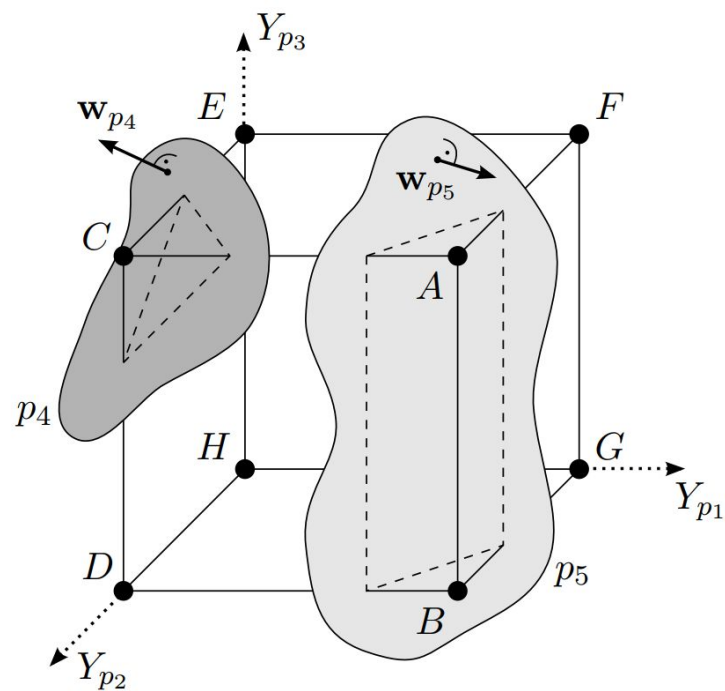


(b) Example network

# NN - Classification example



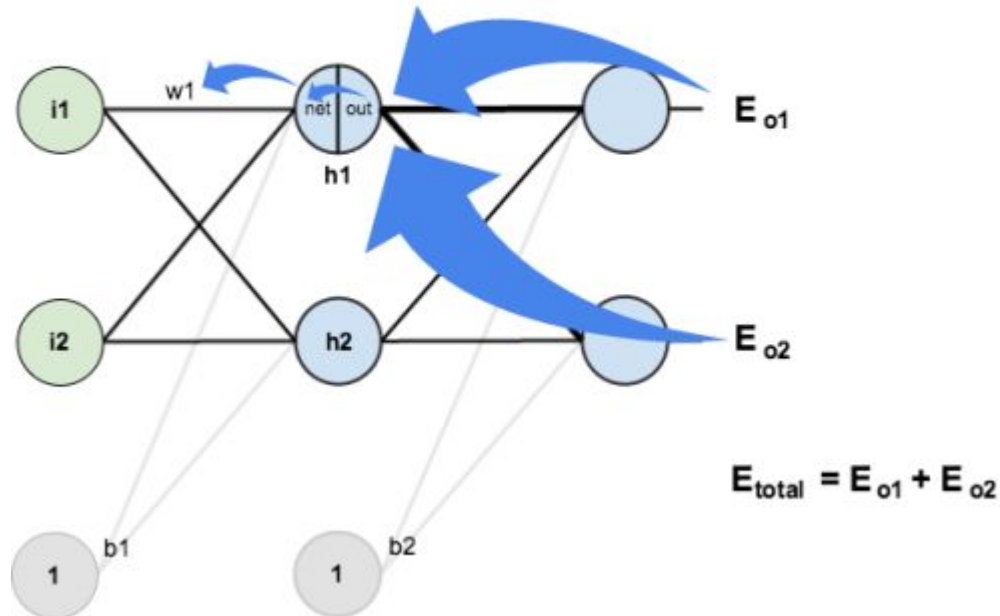
(a) Input space of first layer



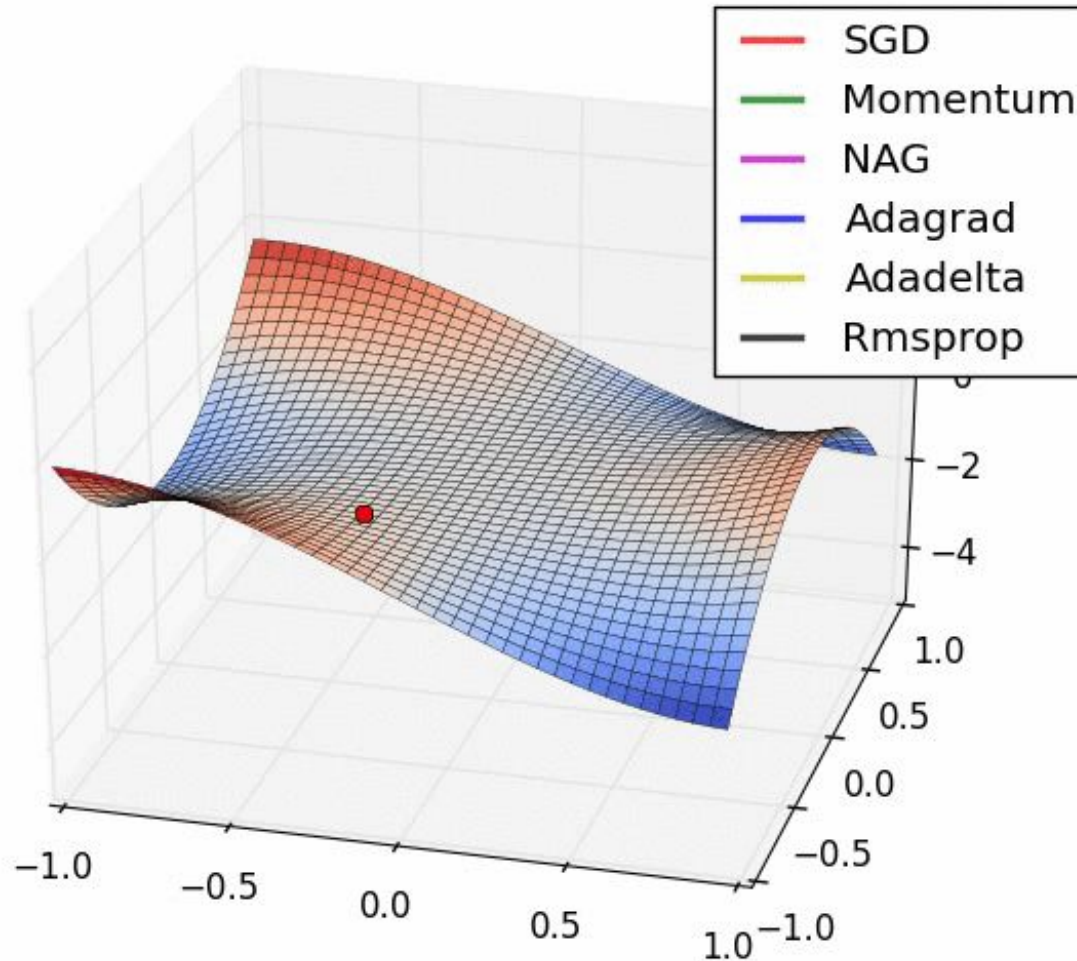
(b) Input space of second layer

# NN - Backpropagation

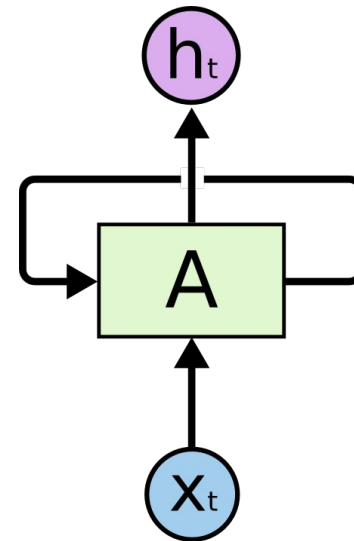
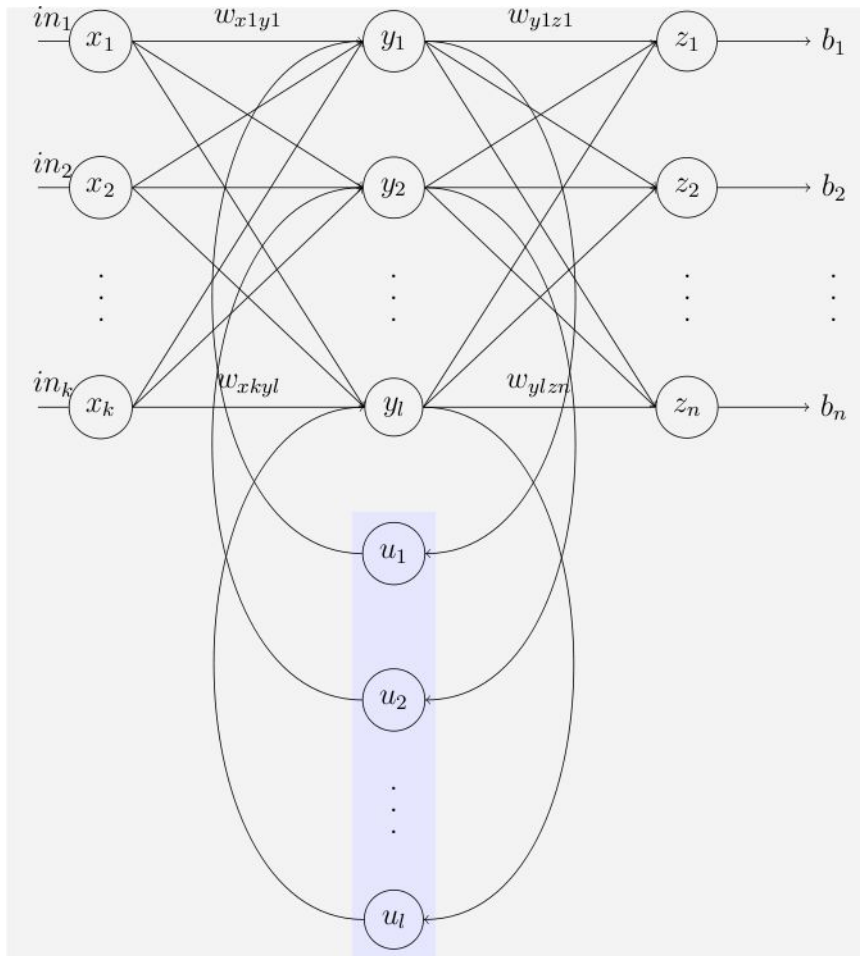
$$\frac{\partial E_{total}}{\partial w_1} = \frac{\partial E_{total}}{\partial out_{h1}} * \frac{\partial out_{h1}}{\partial net_{h1}} * \frac{\partial net_{h1}}{\partial w_1}$$
$$\downarrow$$
$$\frac{\partial E_{total}}{\partial out_{h1}} = \frac{\partial E_{o1}}{\partial out_{h1}} + \frac{\partial E_{o2}}{\partial out_{h1}}$$



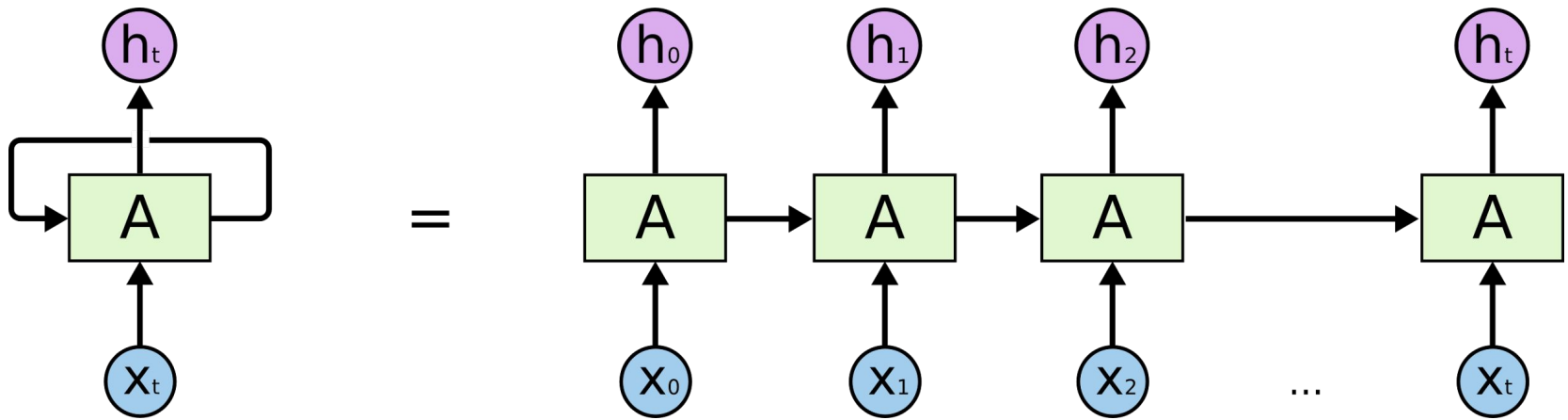
# NN - Backpropagation



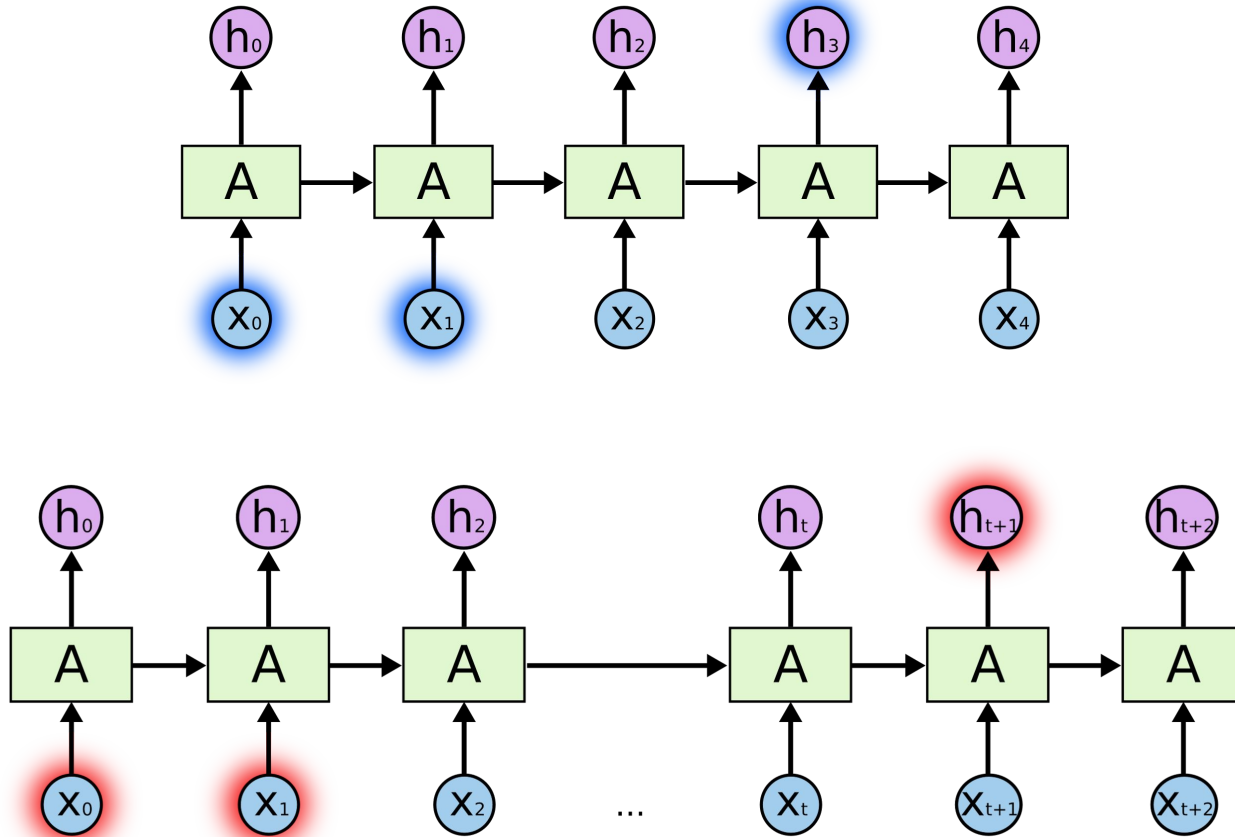
# Recurrent NN



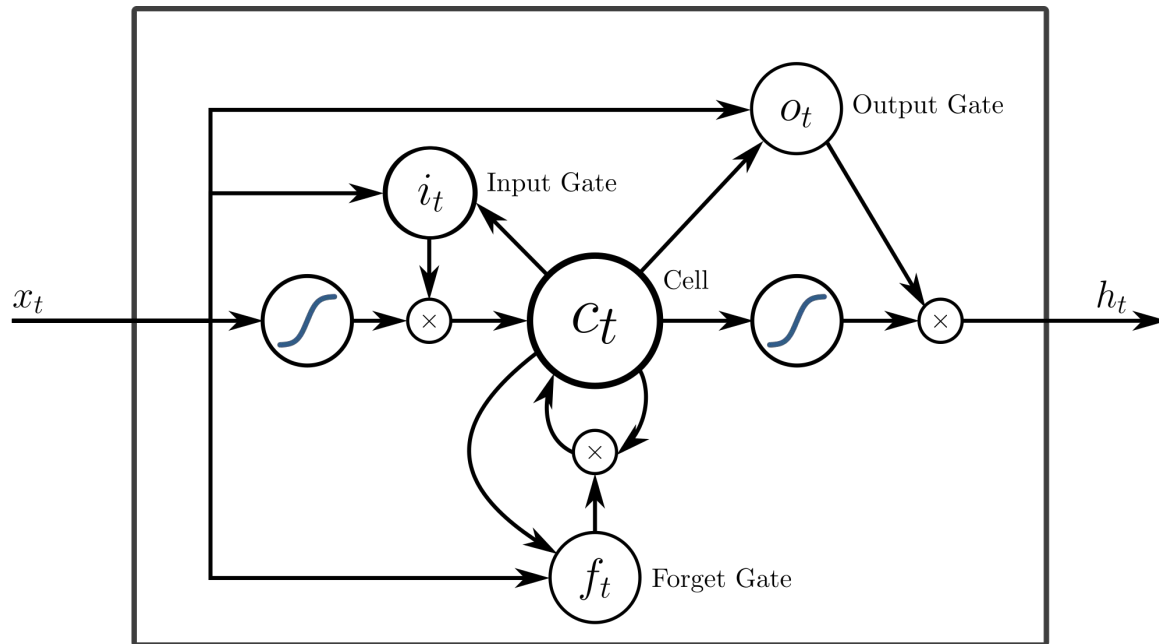
# Recurrent NN - unfolded



# Recurrent NN - time dependencies

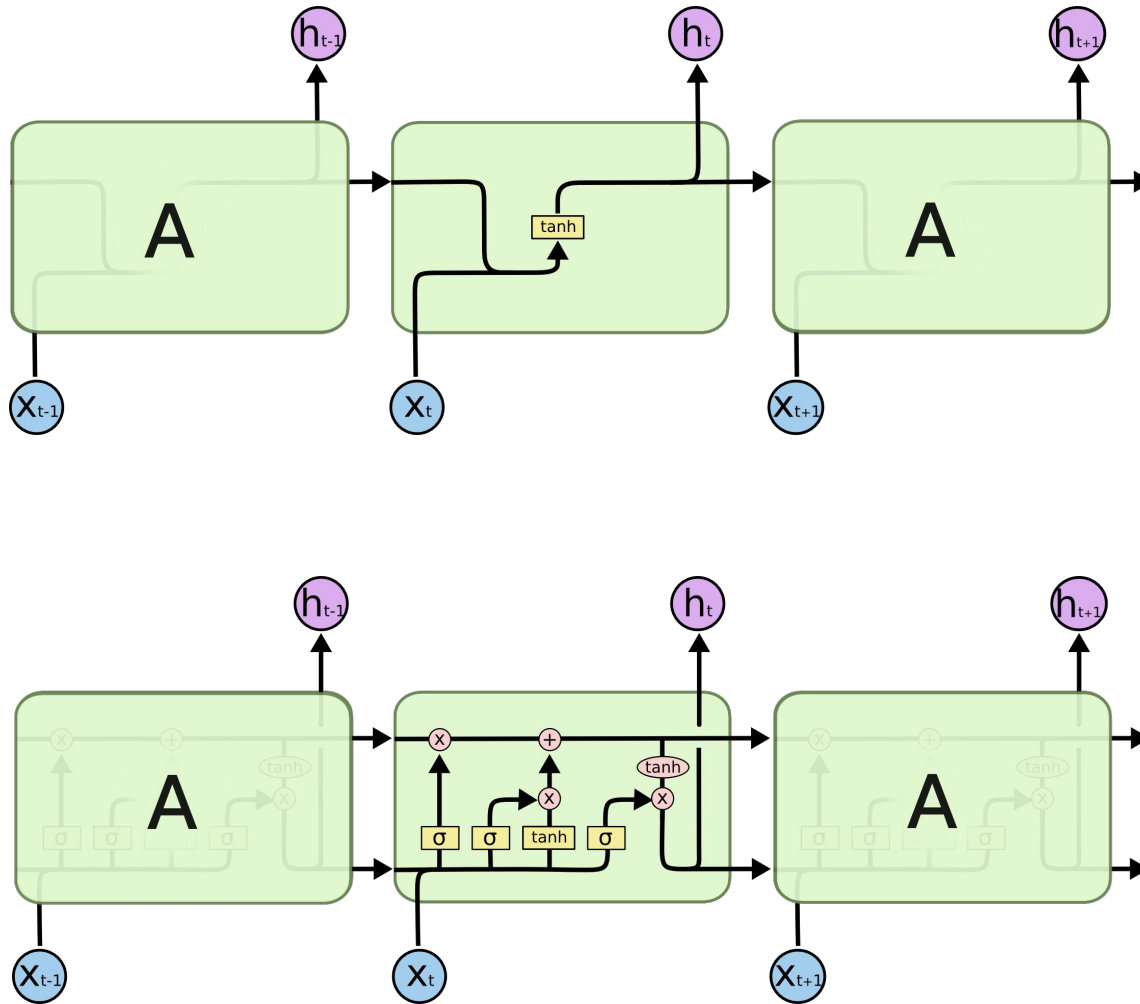


# LSTM network

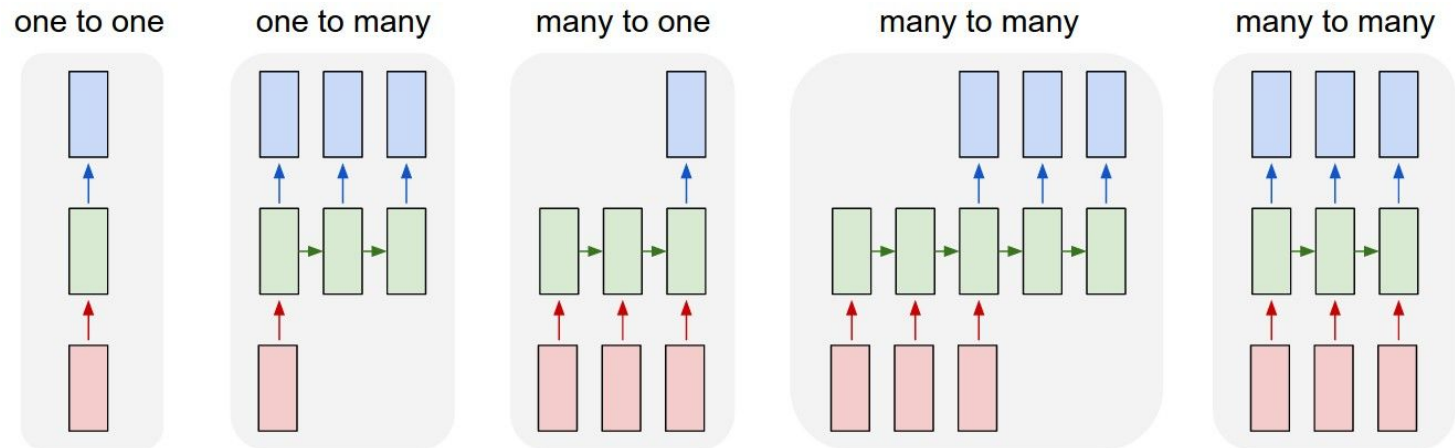




# LSTM network vs. simple RNN

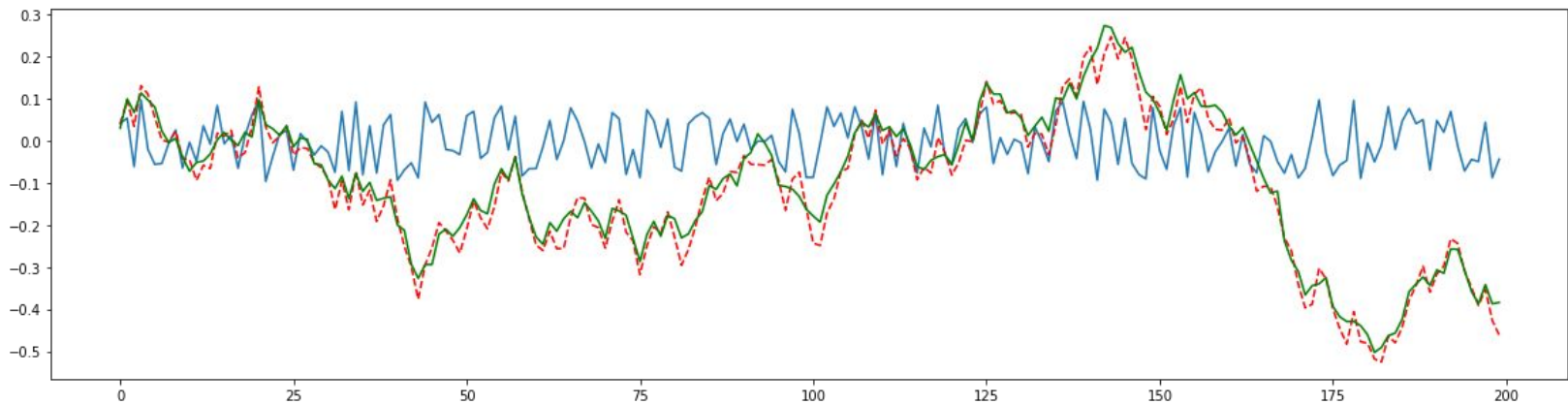


# RNNs & sequences



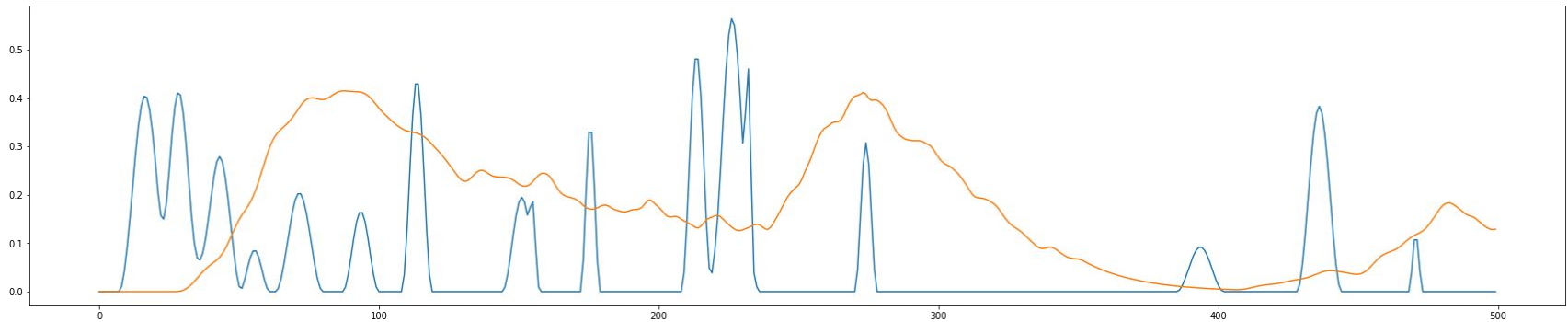
# Simple RNN test

- Regression task
  - Simple cumulative sum function as input
- Data preparation
  - Generate samples, visualize
  - Construct training set
- Build model
  - NN with fixed window, Simple RNN, LSTM
- Test RNN on longer sequences
  - For windowed model
  - For LSTMs



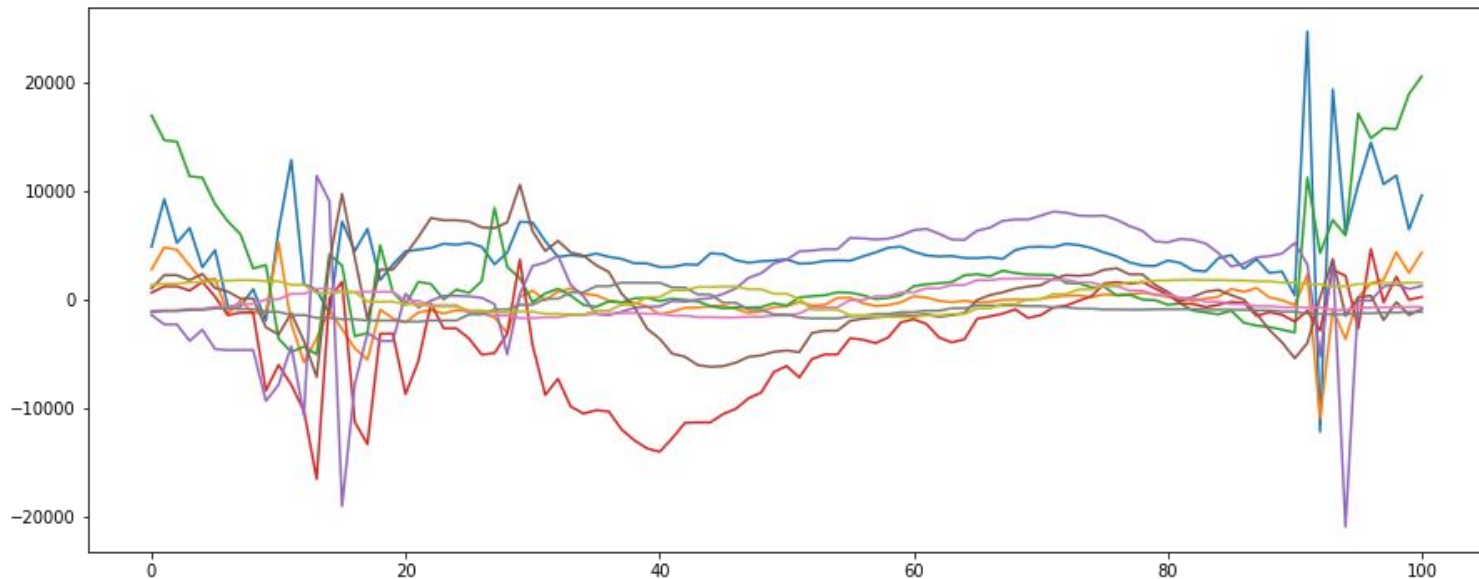
# Rainfall-runoff example

- Regression task
- Data preparation
  - Generate samples visualize
  - Construct training set
- Build model
  - NN with fixed window, Simple RNN, LSTM
- Build predictor for continuous prediction
  - For windowed model
  - For LSTMs



# Trampoline example

- Binary classification task
- Data preparation
  - Load into numpy arrays, visualize, select inputs
  - Normalize, pad, construct training set
- Build model
  - NN with fixed window, LSTM
- Build predictor for continuous prediction
  - Test on truncated sequences



# Weather forecast example

- Regression task
  - Explore feed forward model for inspiration
- Data preparation
  - Load into pandas dataset, visualize
- Build model
  - LSTM with fixed forecast window
  - Sequence-to-sequence LSTM (one step ahead forecast)
- Build predictor for continuous self-feed prediction

