A Multiplication Layer for Sequence Data

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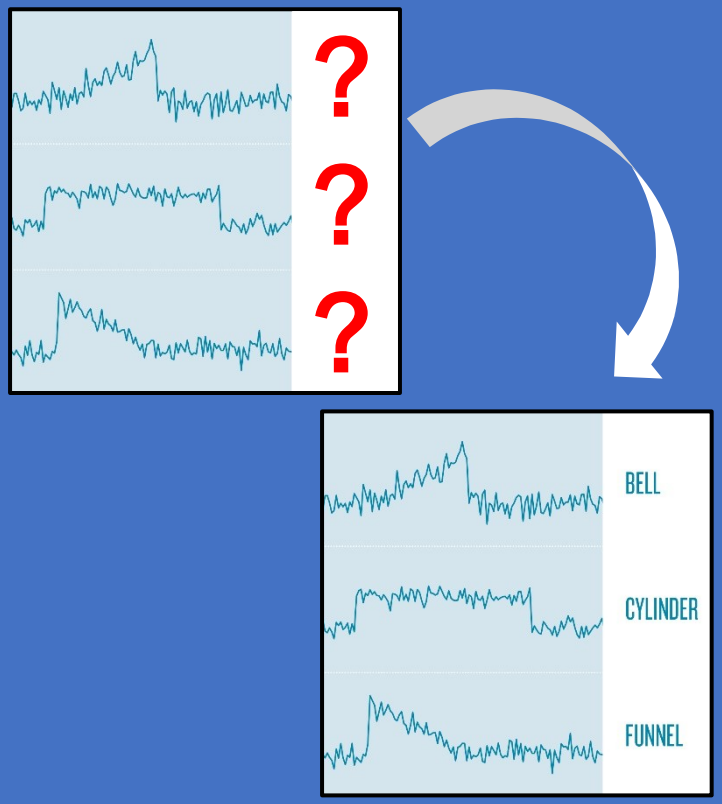
START

P2

What is time series classification ?

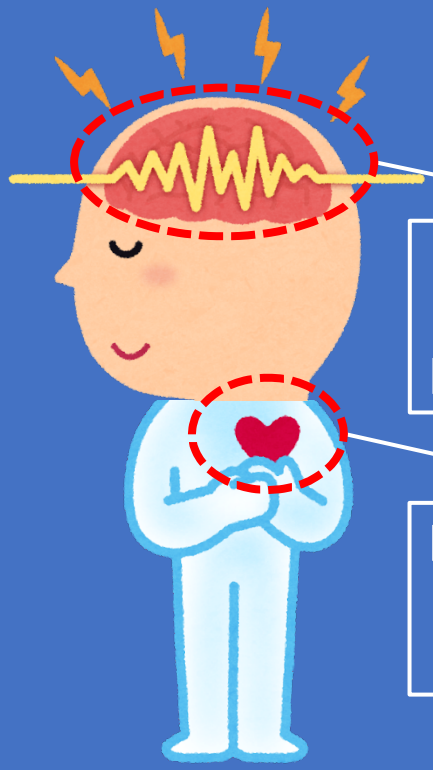
Assigning labels to each observed time series

Objective



http://www.zib.de/features/similarity-search-and-insect-classification

Application



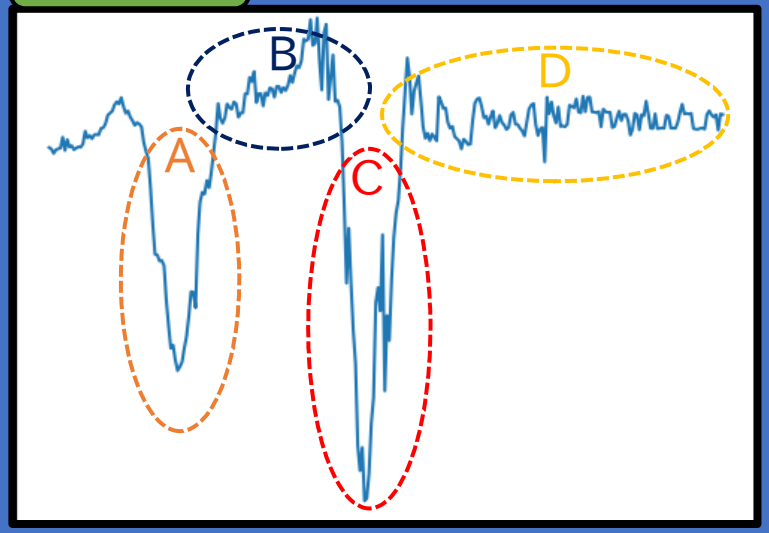
EEG analysis
↓
Emotional analysis

Heart rate analysis
↓
Disease detection

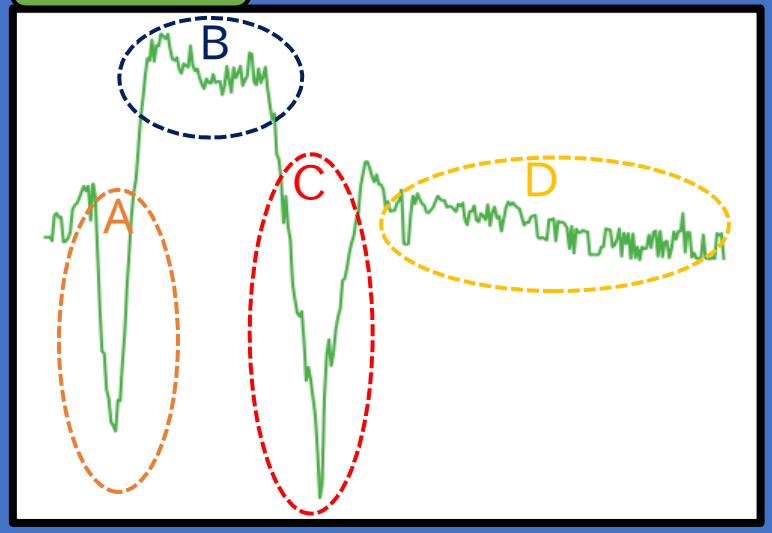
P3

Where is the best feature to classify ?

Class A



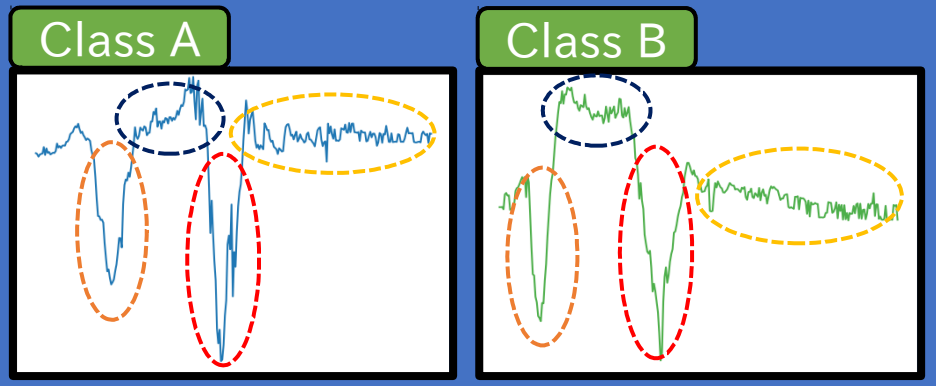
Class B

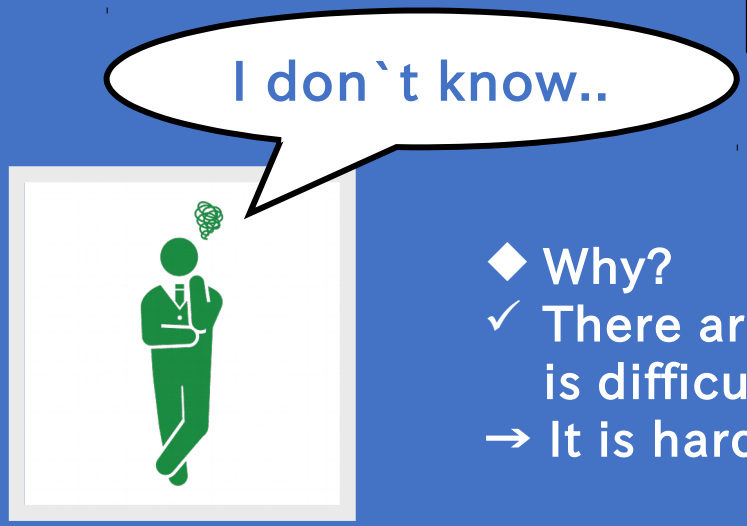


Did you notice these places, right ?

Problem

P4 The answer is ..!





- Why?
  - ✓ There are **multiple** patterns and pattern that is difficult to notice easily.
  - → It is hard to judge where to place weights.

Many studies have been conducted to classify the labels

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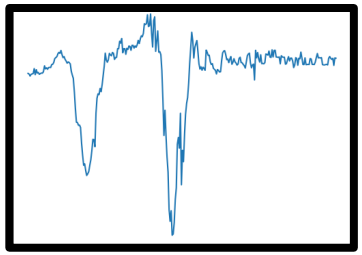
How to classify ?

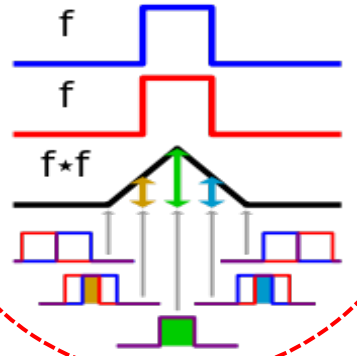
Hand crafted



Input data

Feature extraction

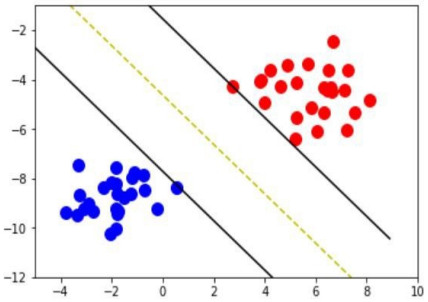
Autocorrelation



www.ibric.org/scicafe/read.php?Board=scicafe000692&id=15891

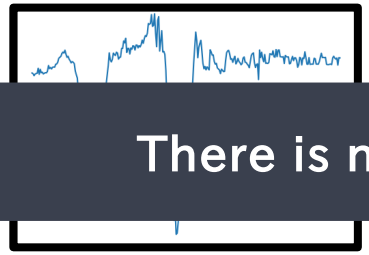
Classifier

SVM



https://medium.com/deep-math-machine-learning-ai/chapter-3

Deep learning

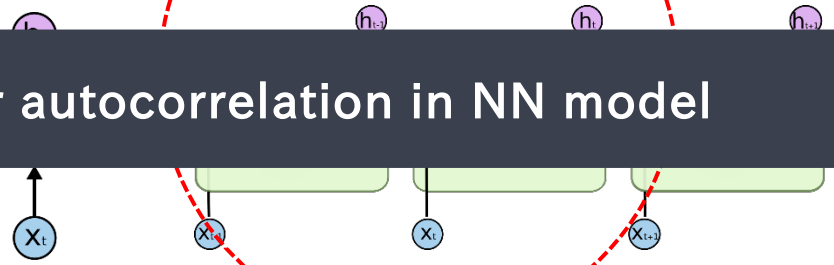


Input data

Neural Networks model

RNN

LSTM

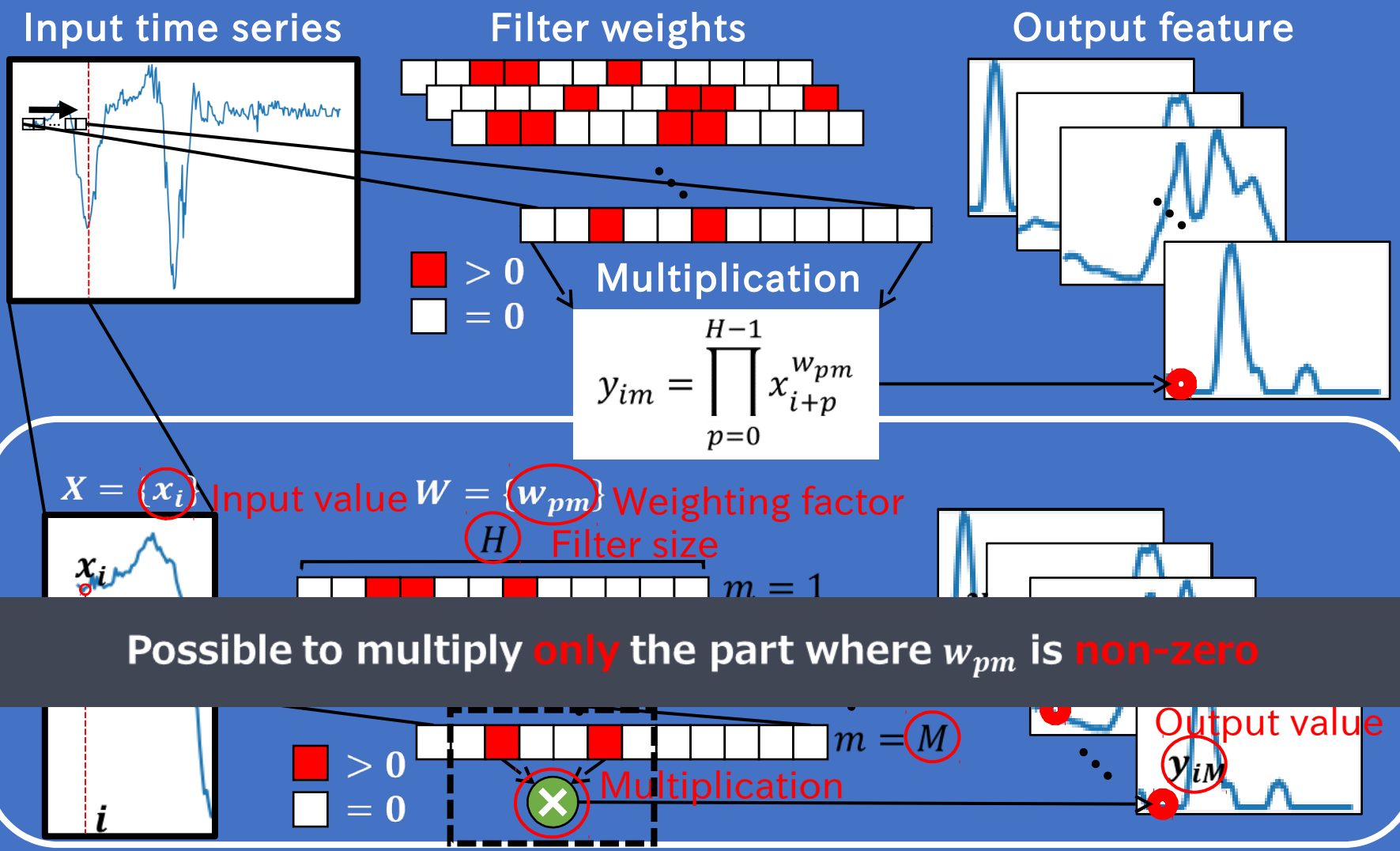


https://qiita.com/KojiOhki/items/89cd7b69a8a6239d67ca

There is no layer for autocorrelation in NN model

P6

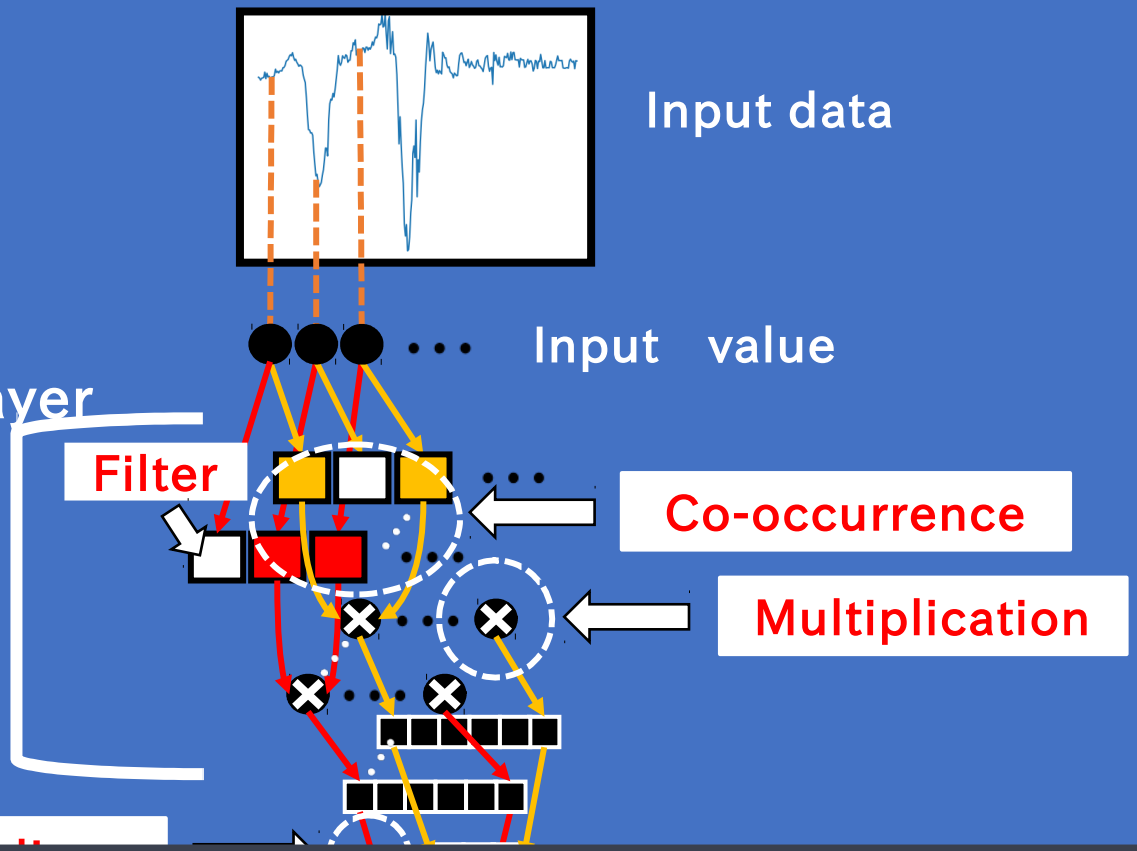
Let me propose multiplication layer !



Our research

P7

How to use ?



Possible to discriminatively extract high-order autocorrelation features

NN model

Our research

high-order autocorrelation | discriminatively

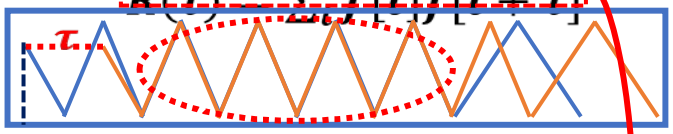
P8

What it means ?

Autocorrelation

$R(\tau) = \sum_t f[t] f[t+\tau]$

Ex)



co-occurrence takes place when pattern is same

High-order autocorrelation

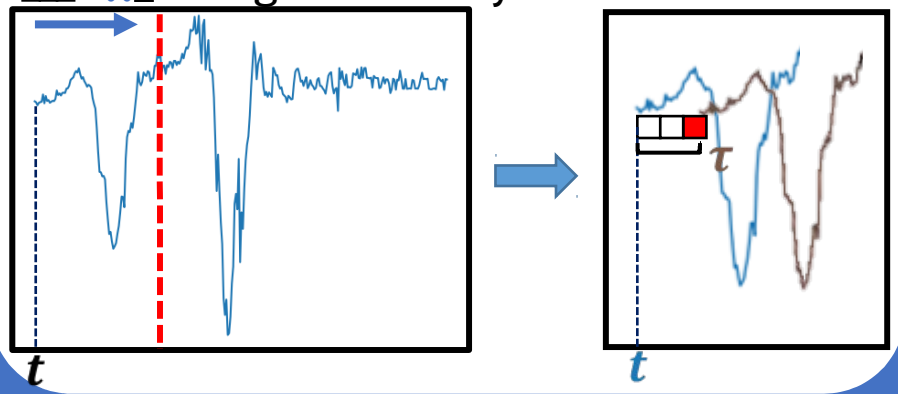
Lth-order autocorrelation

$$R(\tau_1, \tau_2, \ldots, \tau_L) = \sum_D f[t] f[t+\tau_1] f[t+\tau_2] \cdots f[t+\tau_L]$$

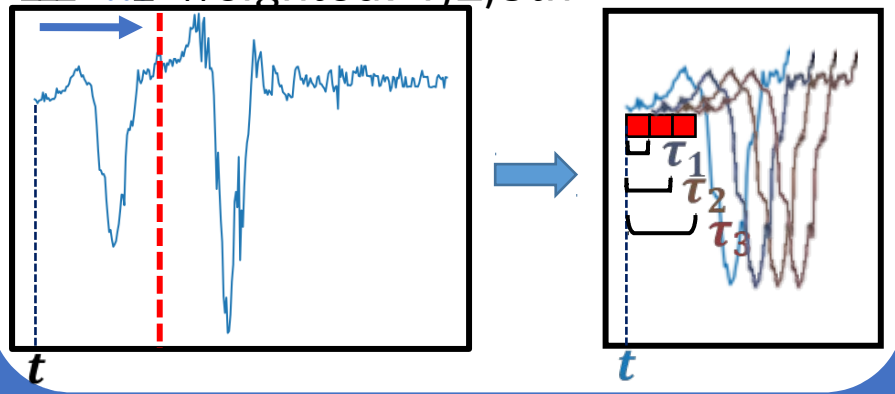
$$\mathbf{D} = \{t | t + \tau_l \in D, \forall l \in \{1, 2, \ldots, L\}\}$$

Key point : we can extract autocorrelation features in any situation.

weighted: Only 3th



weighted: 1,2,3th



Our research

high-order autocorrelation | discriminatively

P9

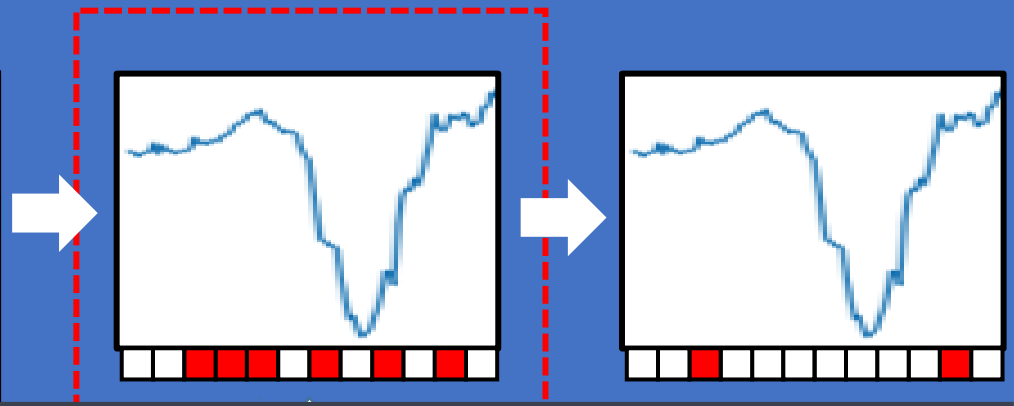
What it means ?

Constraint 1

✓ Let w be zero if possible

Constraint 2

✓ If all w are added, it becomes



Key point : The features can be extracted discriminatively.

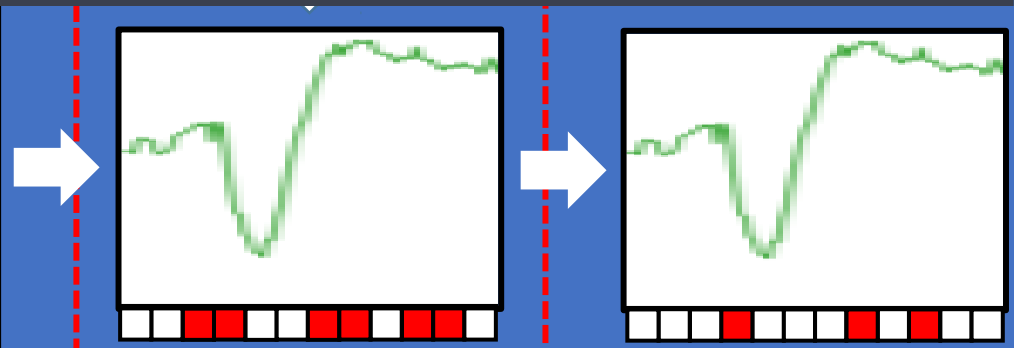
Constraint 3

✓ Let w have values between zero and one

+

Comparison

✓ Compare with each other class extracted features

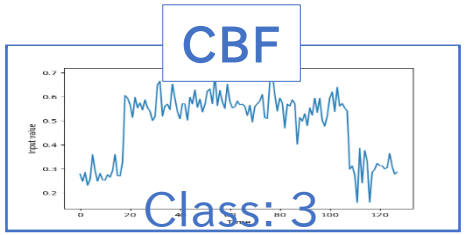


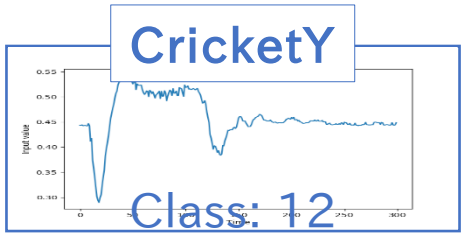
Learning by constraints

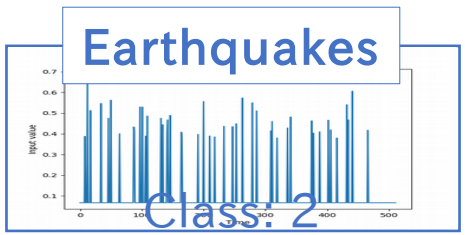
P10 Let's check how effective the proposed layer is !

- ✓ Combining the Multi. with the **head** of NN model
- ✓ Comparing when Multi. is **absent** and **Conv.** is combined instead of Multi.

Dataset







Input

Model

Multi. + NN model

Conv. + NN model

NN model

Multi. Conv.

Filter size: 96
Number of filter: 30
Activation: relu

+

NN model

RNNs
LSTMs
GRUs
Deep CNN
LENET

P11

Comparison of classification accuracies

Model	CBF	CricketY	Earthquakes
RNNs	0.331	0.07	0.748
LSTMs	0.939	0.144	0.784
GRUs	0.522	0.151	0.763
RNNs + Conv.	0.997	0.164	0.712
LSTMs + Conv.	0.982	0.09	0.683
GRUs + Conv.	0.983	**0.09**	0.698
LENET + Multi.	0.976	0.[illegible]6	0.748
Deep CNN + Multi.		0.[illegible]1	0.748
RNNs + Multi.		0.[illegible]1	0.748
LSTMs + Multi.	0.970	0.[illegible]0	0.748
GRUs + Multi. (1)	0.971	**0.636**	0.741
GRUs + Multi. (2)	0.932	0.07	0.799

Big difference

Differences in parameters

Discussion (CricketY)

Comparing extracted features of Multi. with those of Conv.

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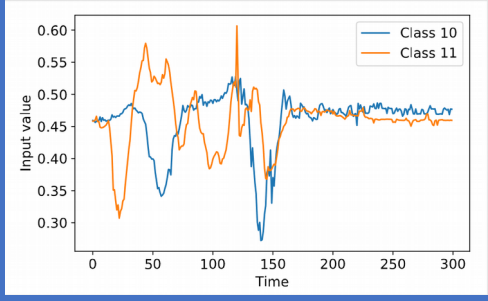
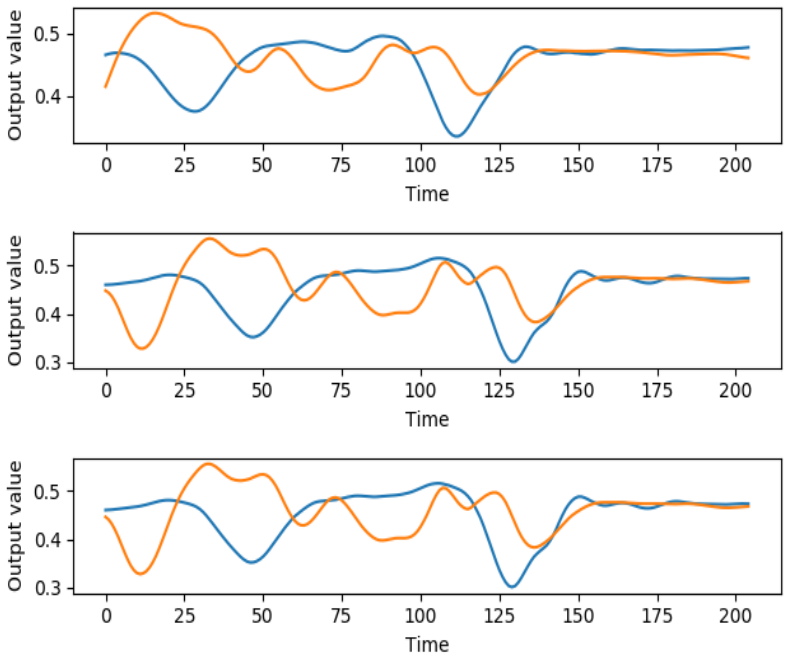
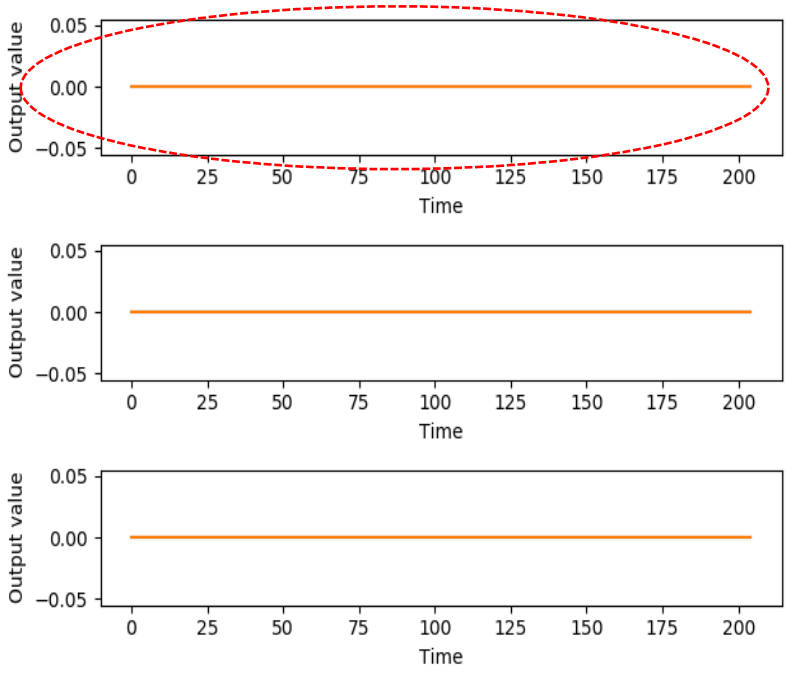
Visualization of extracted features



Multiplication layer



Convolutional layer



Big difference

Class 10 Class 11

Comparing filter weights of Multi. with those of Conv.

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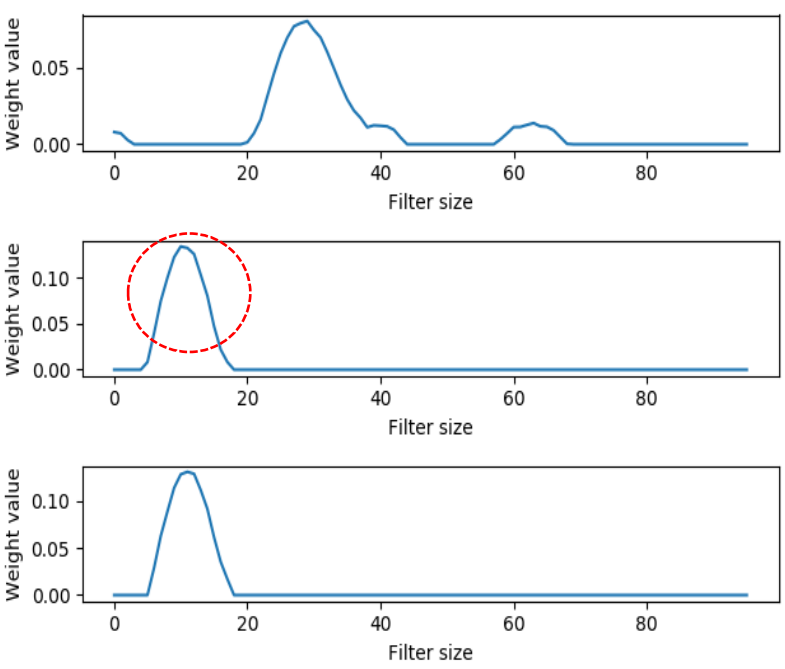
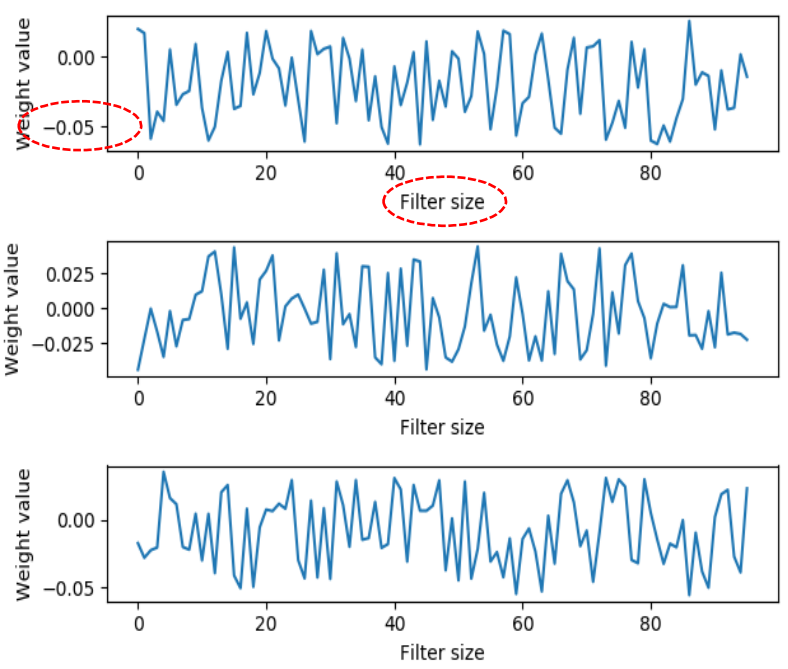
Visualization of filter weights

Multiplication layer



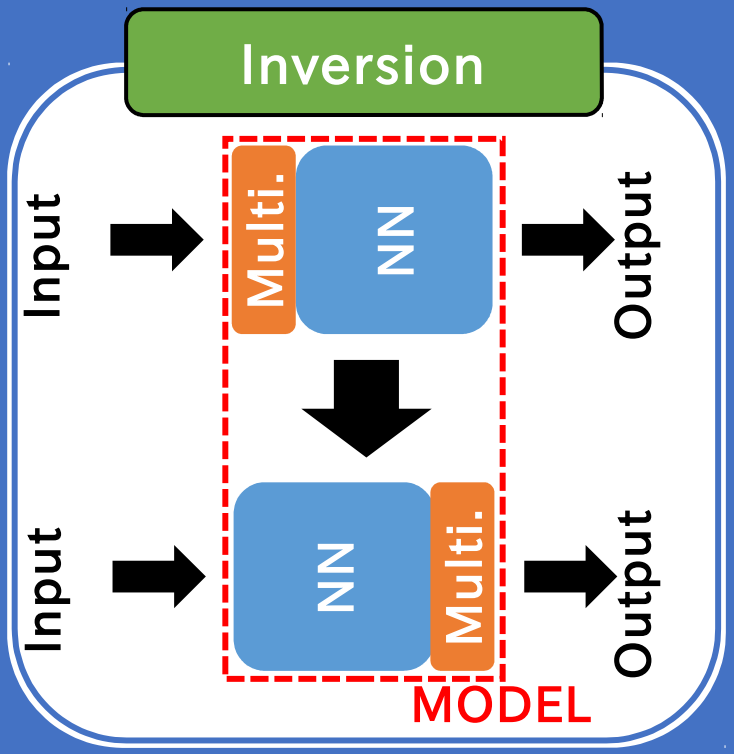
Convolutional layer

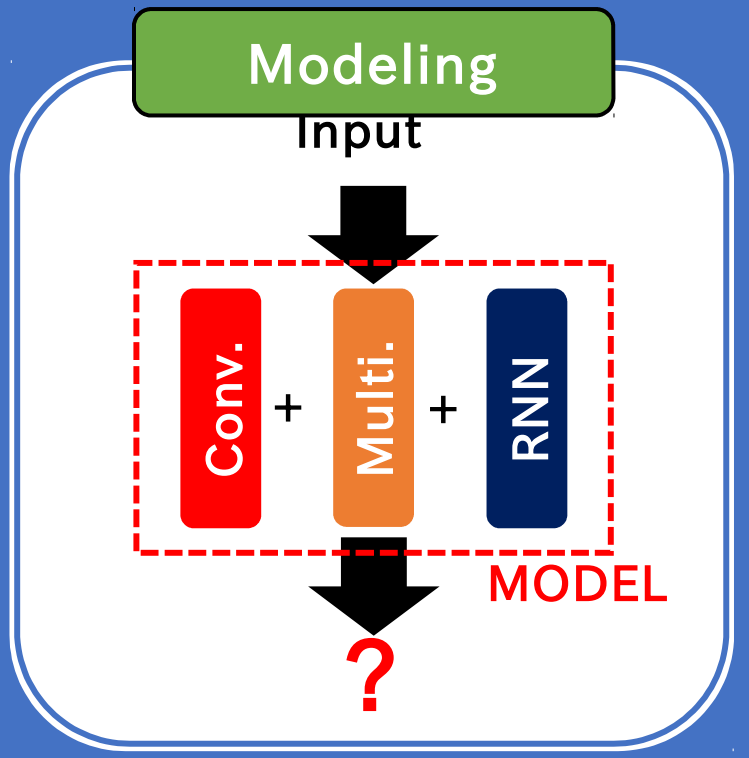


Big difference

P14

I'll do this !





Thank you for your attention !