Deep Leaning For Time Series Classification and Regression

A Hands-on Introduction to Time Series Classification and Regression

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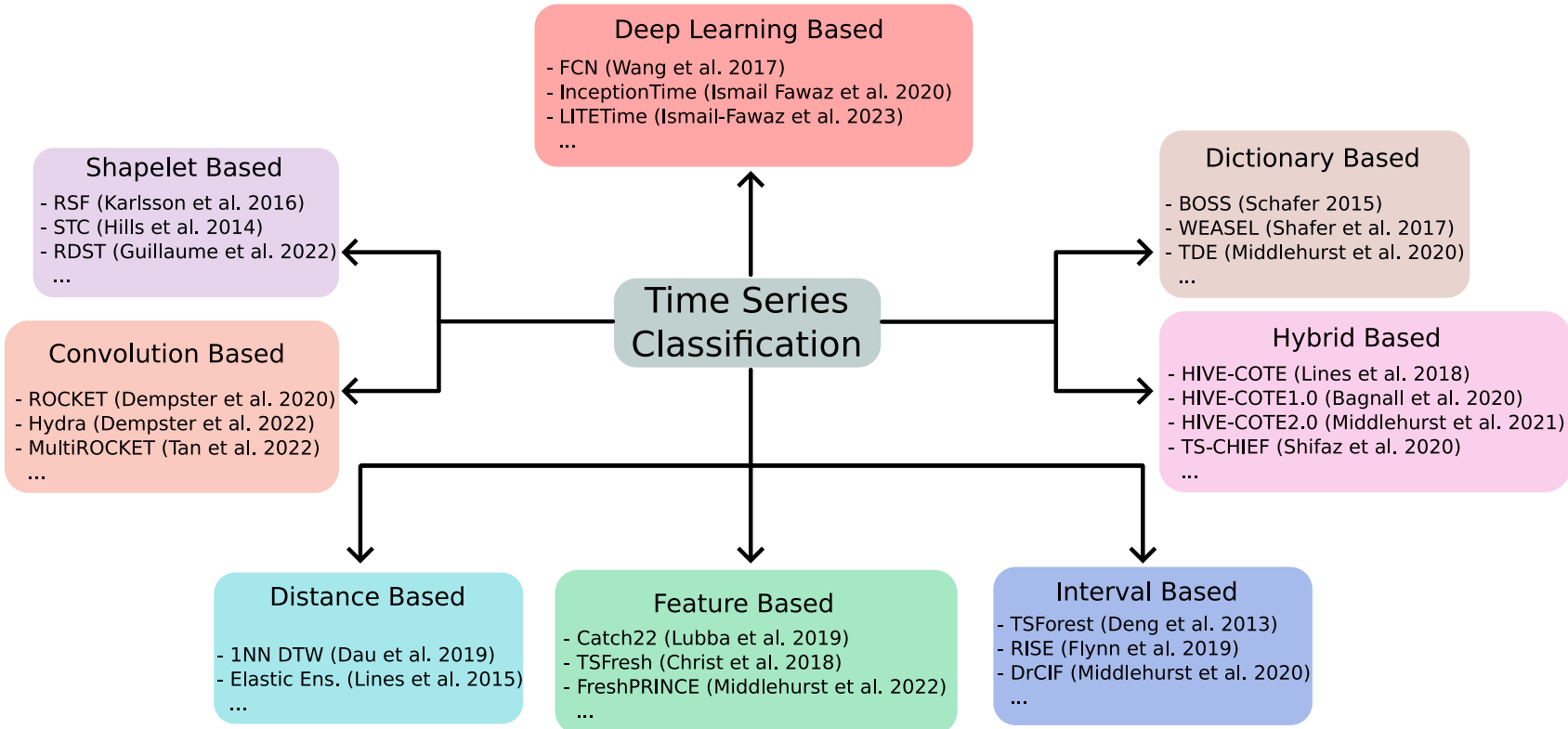
ACM SIGKDD International Conference on Knowledge Discovery and Data Mining 2024

Taxonomy of methods



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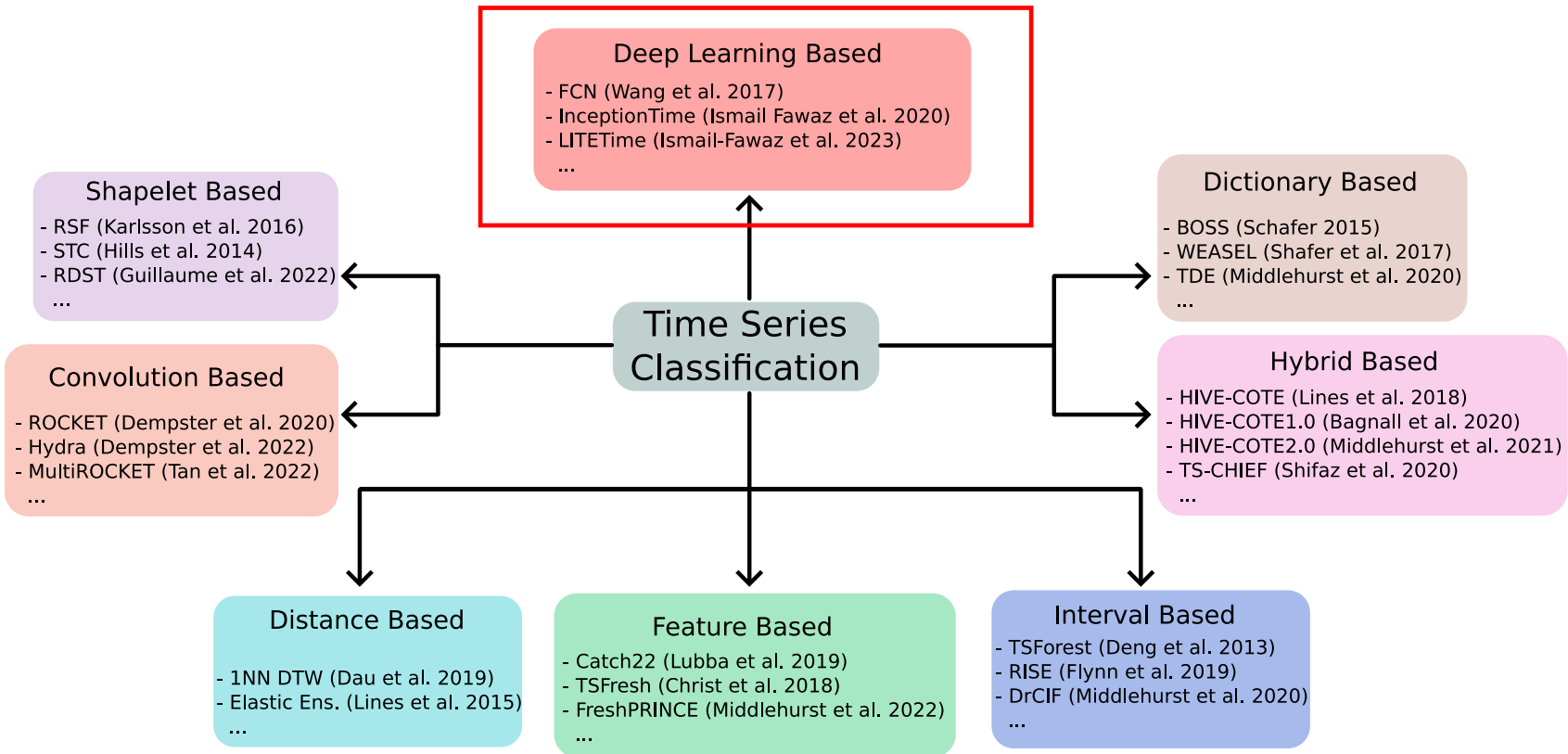

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Why Deep Learning ?

- Around 2017, reviewers began to question the potential performance of deep learning for TSC while assessing papers on non-deep learning TSC methods.
- Deep learning has achieved great success in other data types, such as computer vision and natural language processing (NLP), so why not with time series?

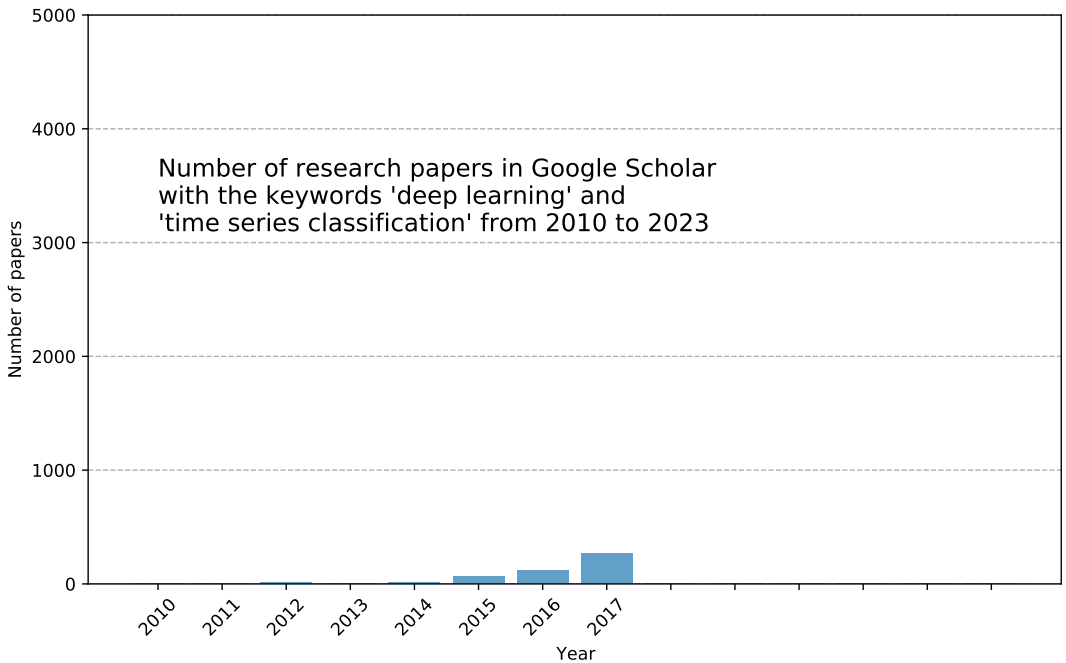

Figure: The number of research papers mentioning "deep learning" and "time series classification" increased rapidly in the last years:

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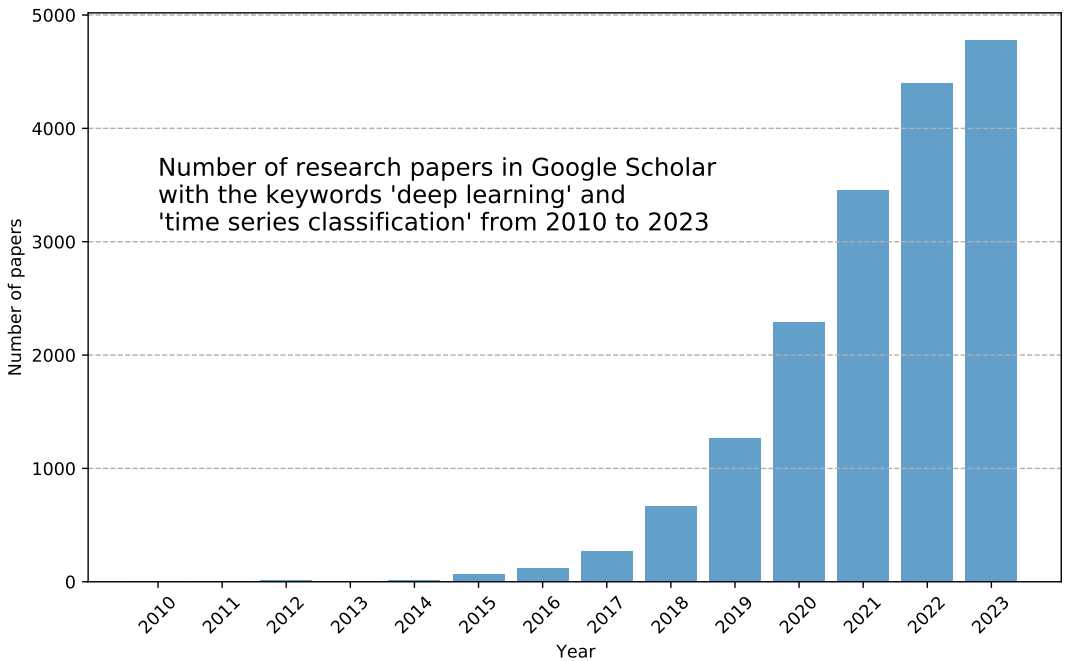
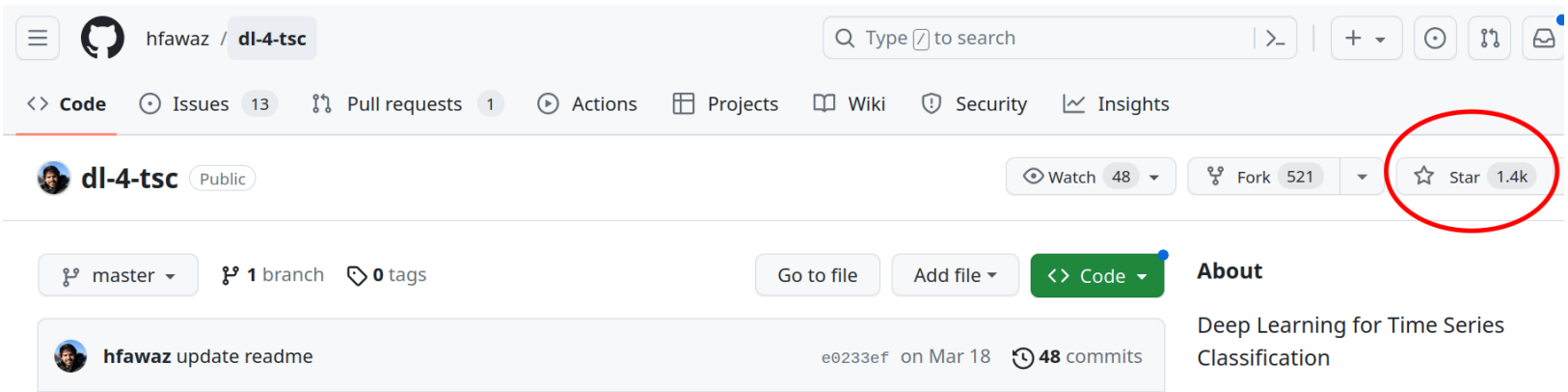


Figure: The number of research papers mentioning "deep learning" and "time series classification" increased rapidly in the last years.

DL4TSC - 2019

In **2019**, we presented a study of **Deep Learning for Time Series Classification** (cited more than 3.2K times (GoogleScholar)) [1].

- We selected models with enough details (or available code) to reproduce the model's architecture and benchmarked them on the UCR archive [2]
- We published the code on Github for reproducibility and got very positive feedback (>1.5K stars)

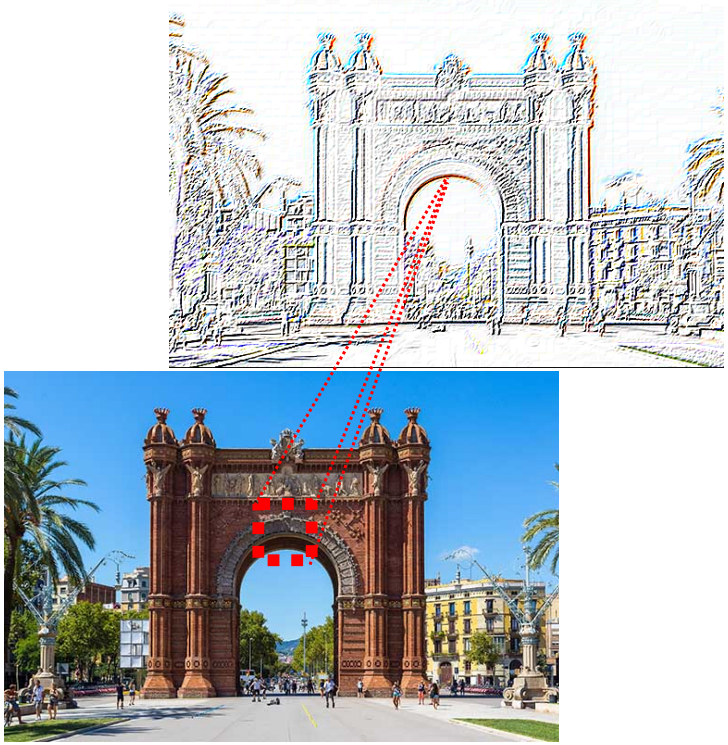


[1] Ismail Fawaz, H., Forestier, G., Weber, J., Idoumghar, L., & Muller, P. A. (2019). Deep learning for time series classification: a review. Data mining and knowledge discovery, 33(4), 917-963.

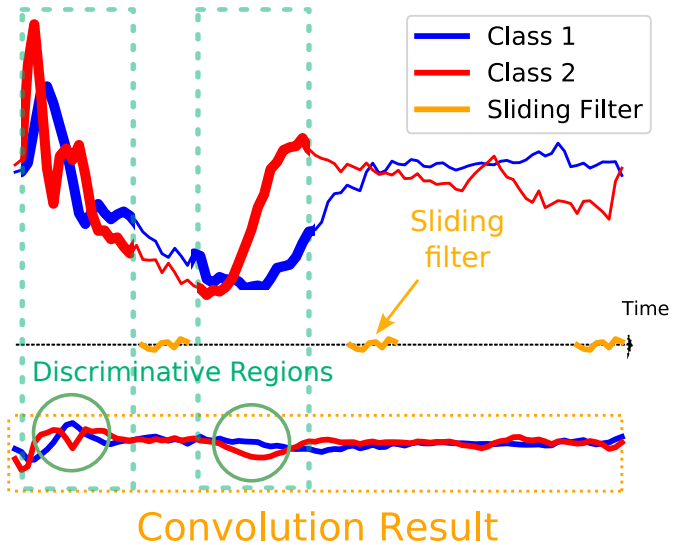
[2] Dau, H. A., Bagnall, A., Kamgar, K., Yeh, C. C. M., Zhu, Y., Gharghabi, S. & Keogh, E. (2019). The UCR time series archive. IEEE/CAA Journal of Automatica Sinica

DL4TSC - Some Architectures

Convolutions on Images vs Time Series



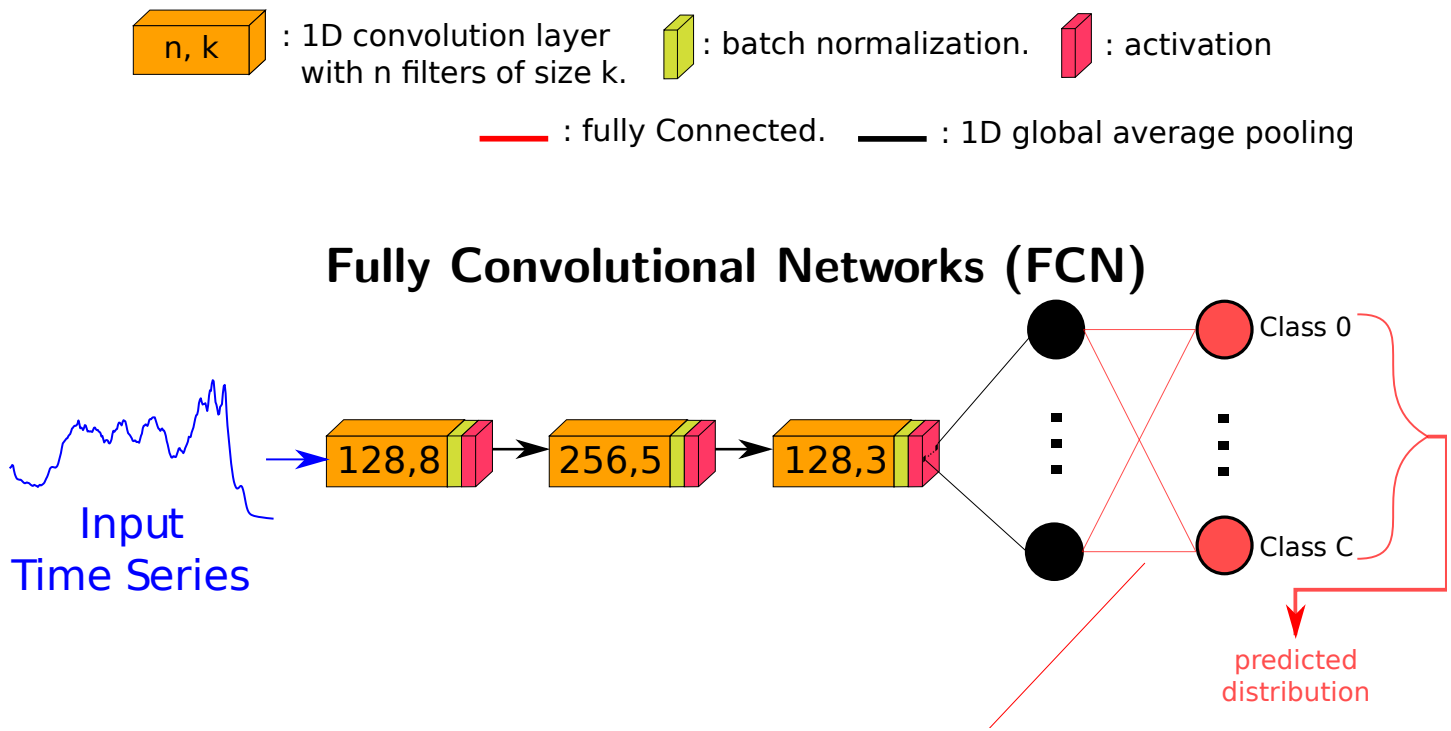
The result of a applying an edge detection convolution on an image



The result of applying a learned discriminative convolution on the ECG200 dataset

Image source: Arc de Triomf de Barcelona, Selbymay, Wikipedia

DL4TSC - Some Architectures



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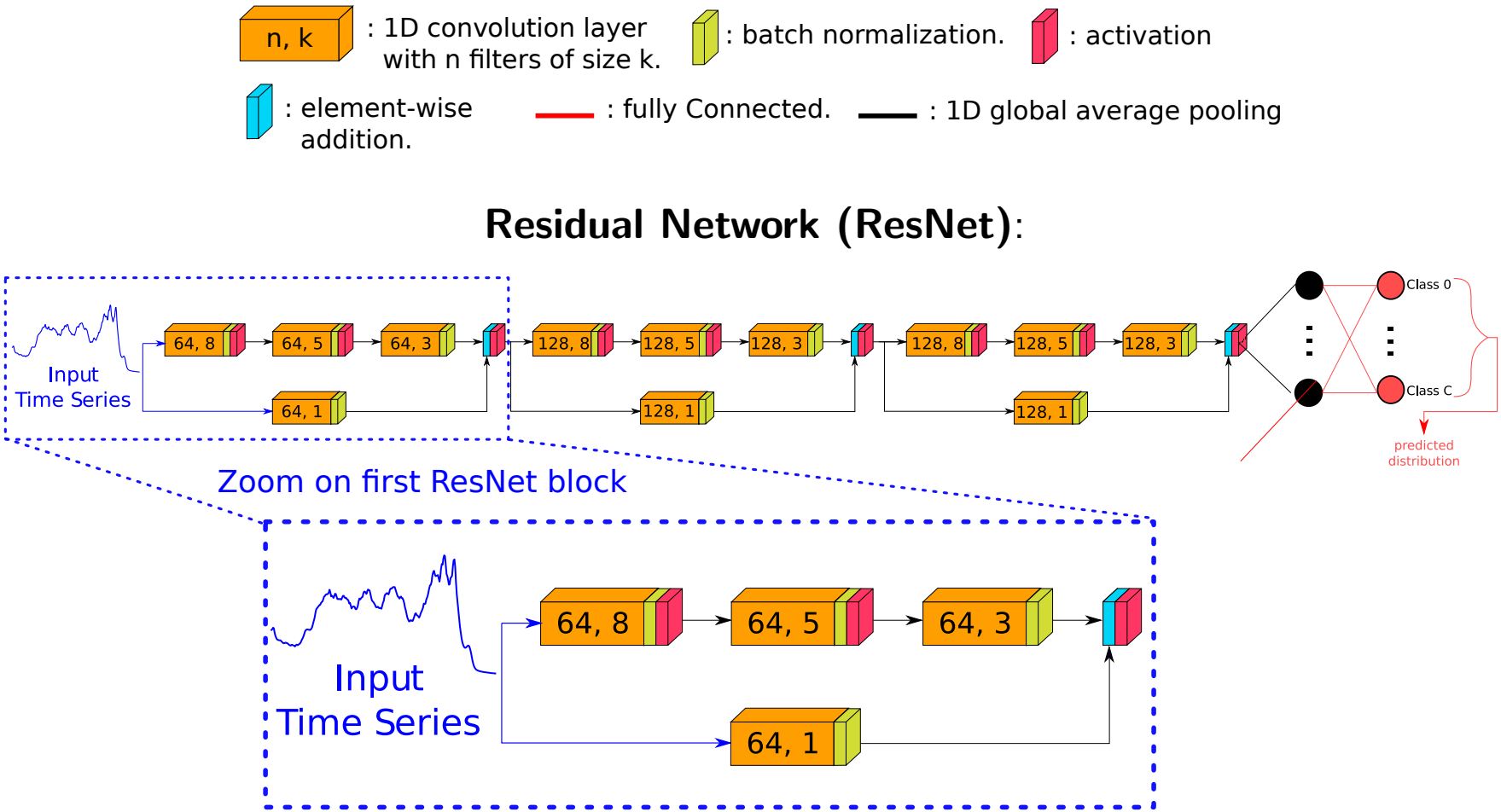

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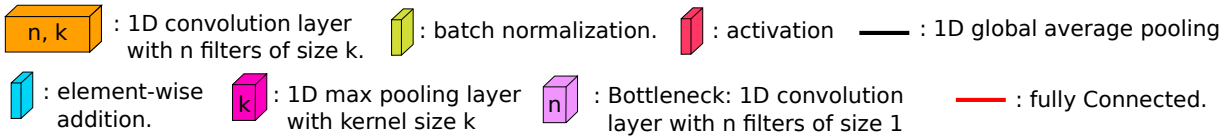
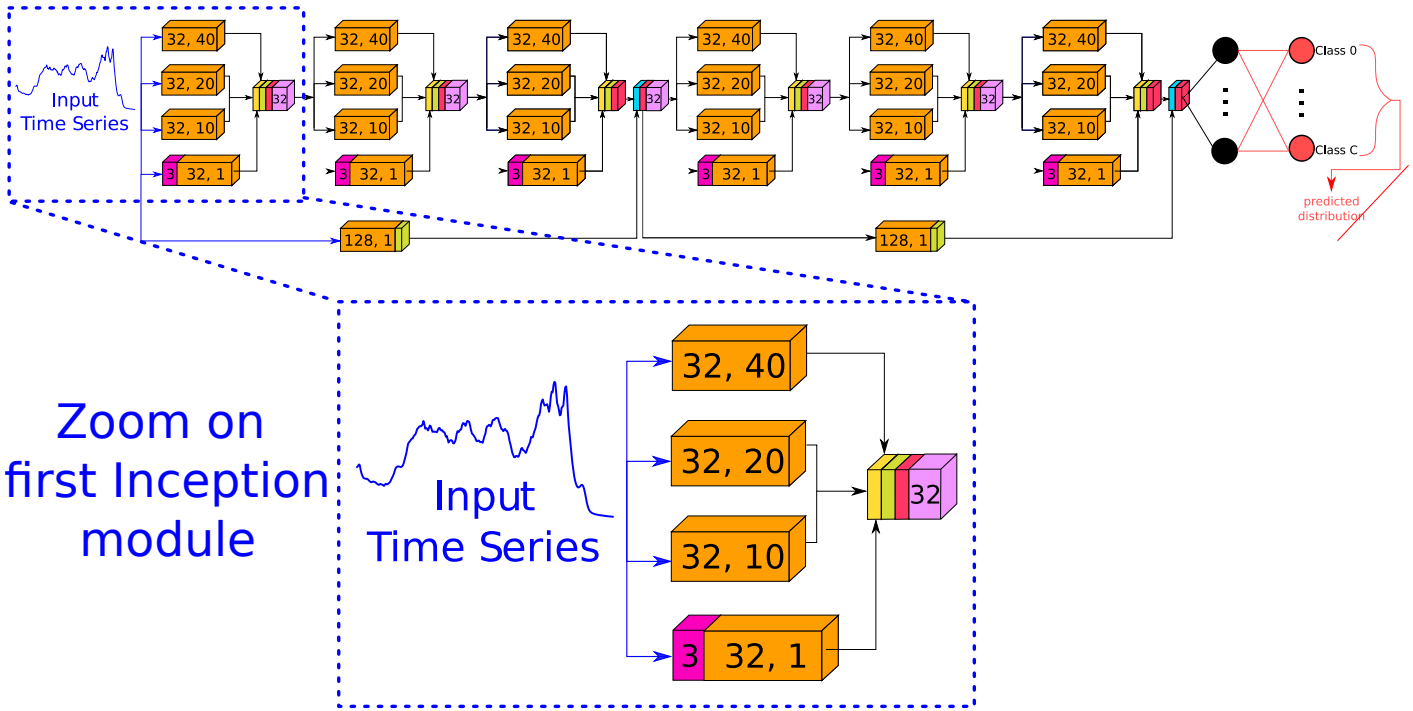
InceptionTime: Ensemble of Inception Models



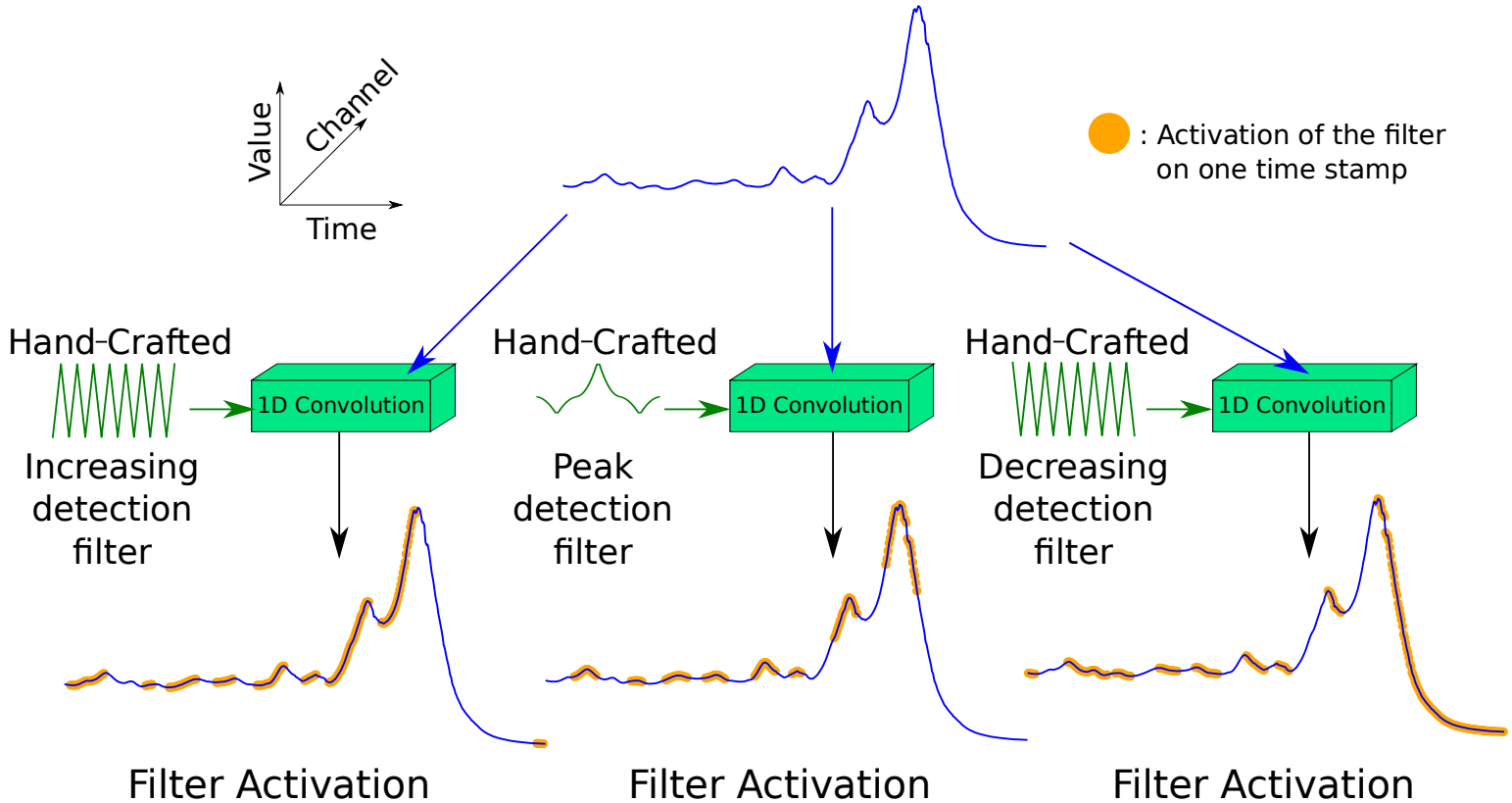
Inception architecture for TSC



Ismail Fawaz, Hassan, et al. "Inceptiontime: Finding alexnet for time series classification." Data Mining and Knowledge Discovery 34.6 (2020): 1936-1962.

Hand-Crafted Filters

Bridging the Gap Between Random and Fully Learned Filters



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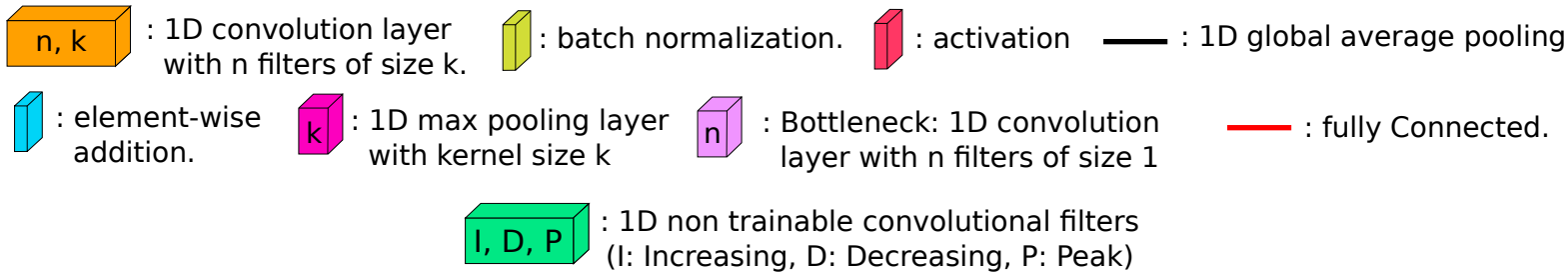
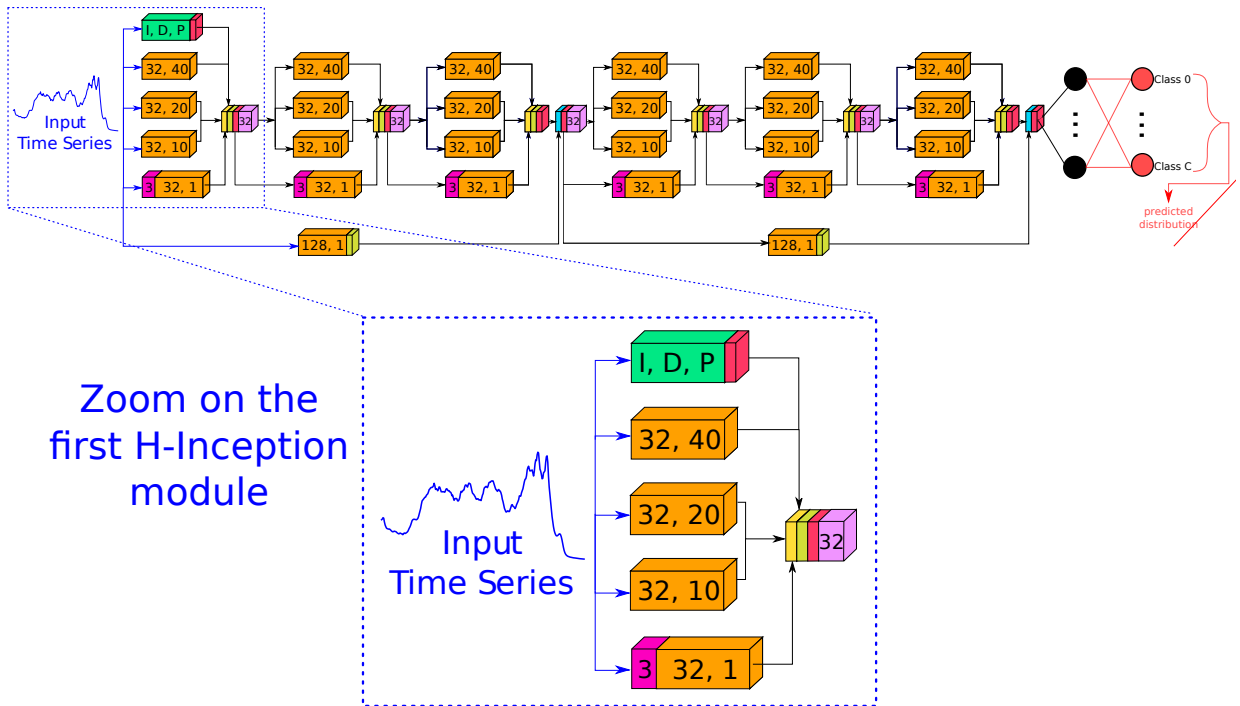
H-InceptionTime: Ensemble of Hybrid Inception Models



Hybrid Inception (H-Inception) Architecture



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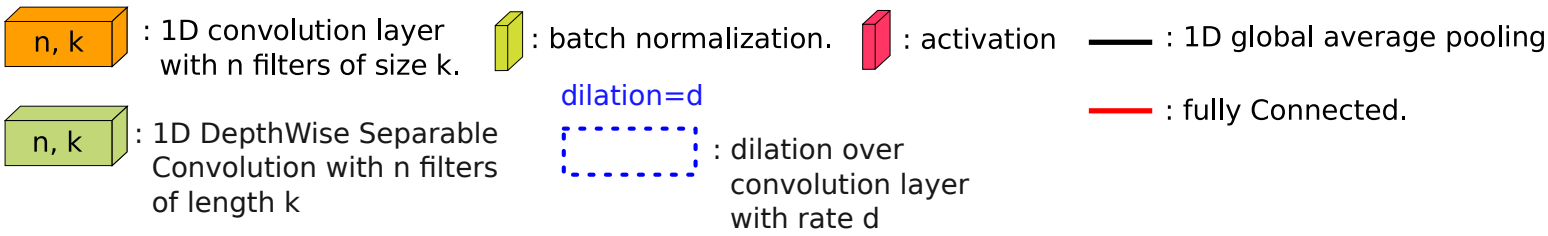
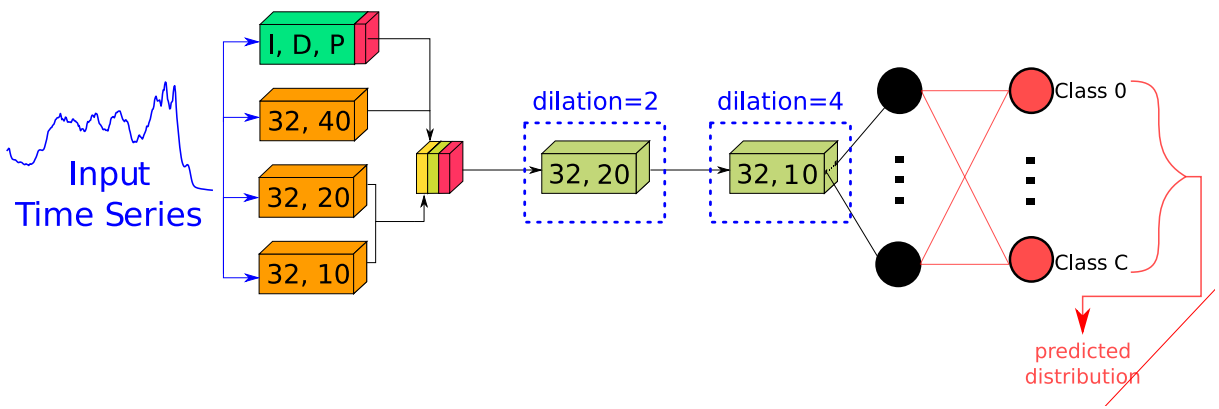
LITETime: Ensemble of LITE Models



LITE Architecture

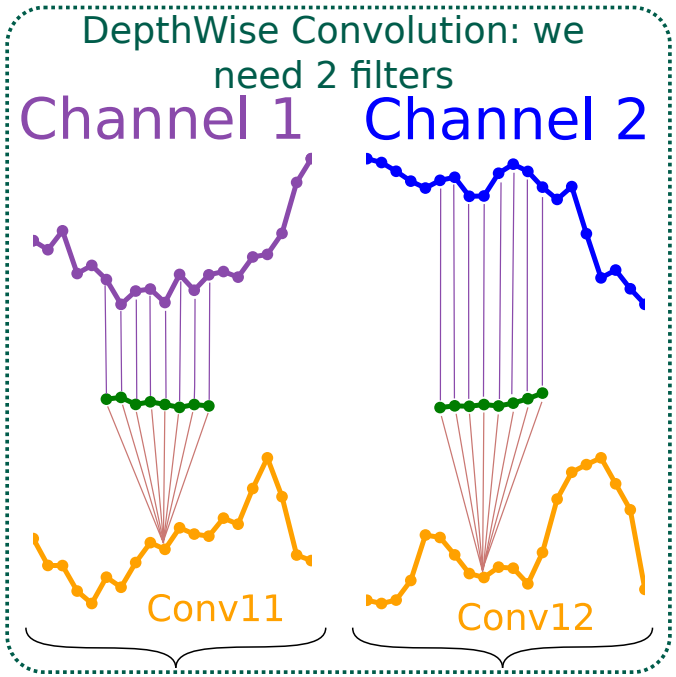


Ismail-Fawaz, A. et al. (2023). LITE: Light Inception with boosTing tEchniques for Time Series Classification. IEEE International Conference on Data Science and Advanced Analytics (DSAA)

Convolutions In LITETime

Standard vs Depthwise Separable Convolutions

Standard Convolution = DepthWise Convolution + Summation



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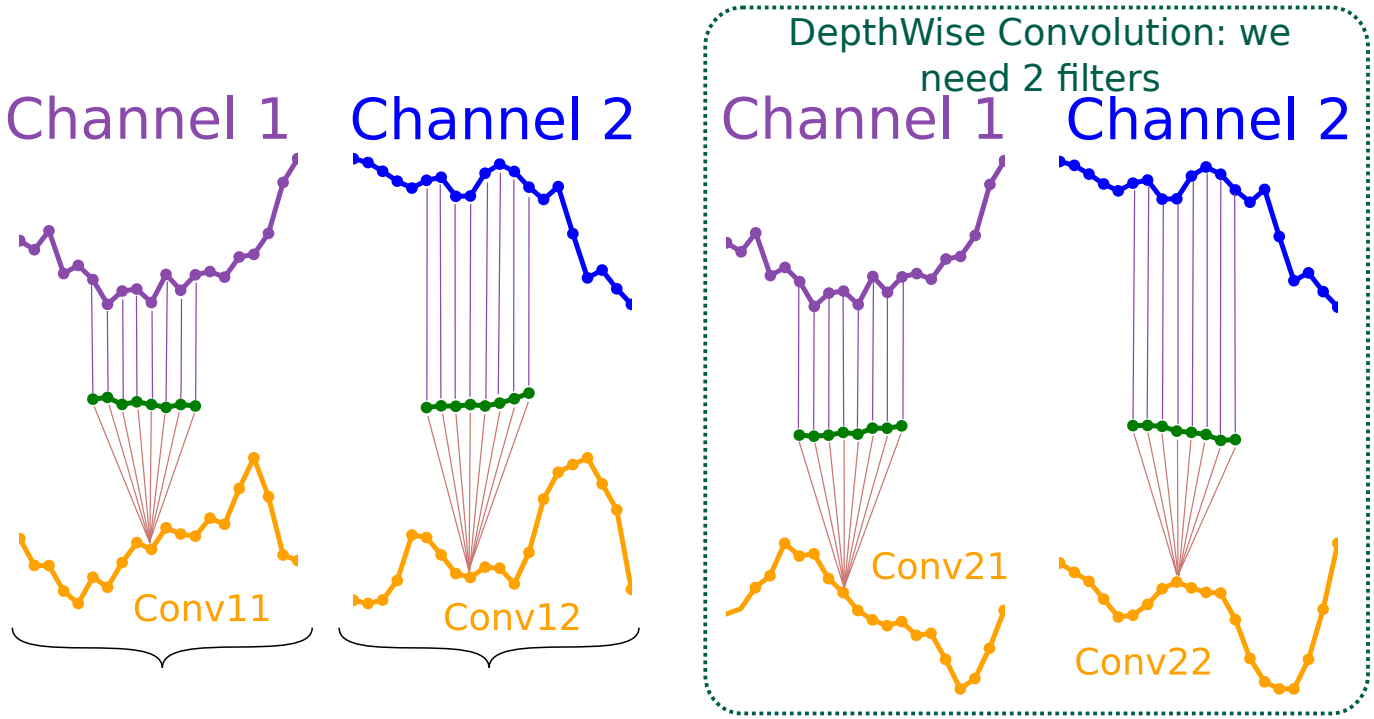

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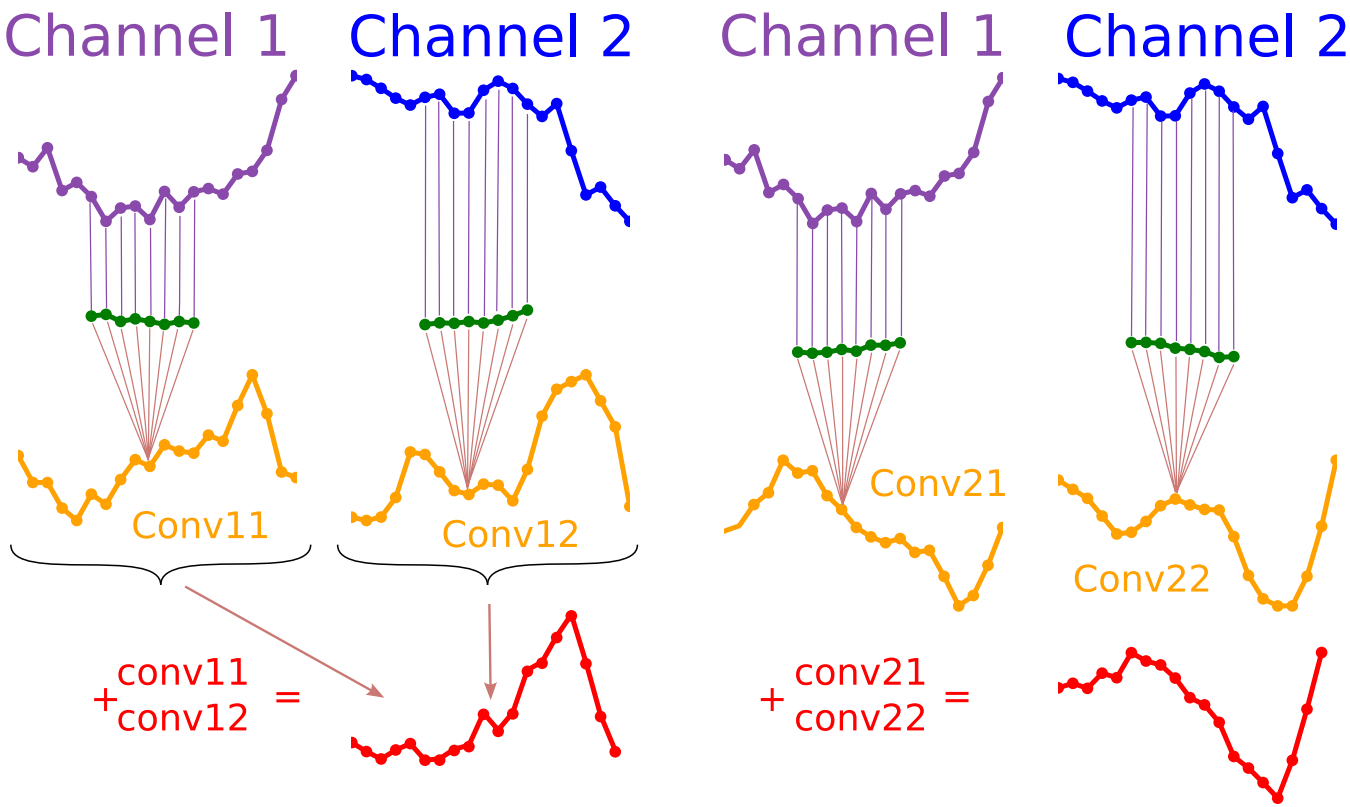

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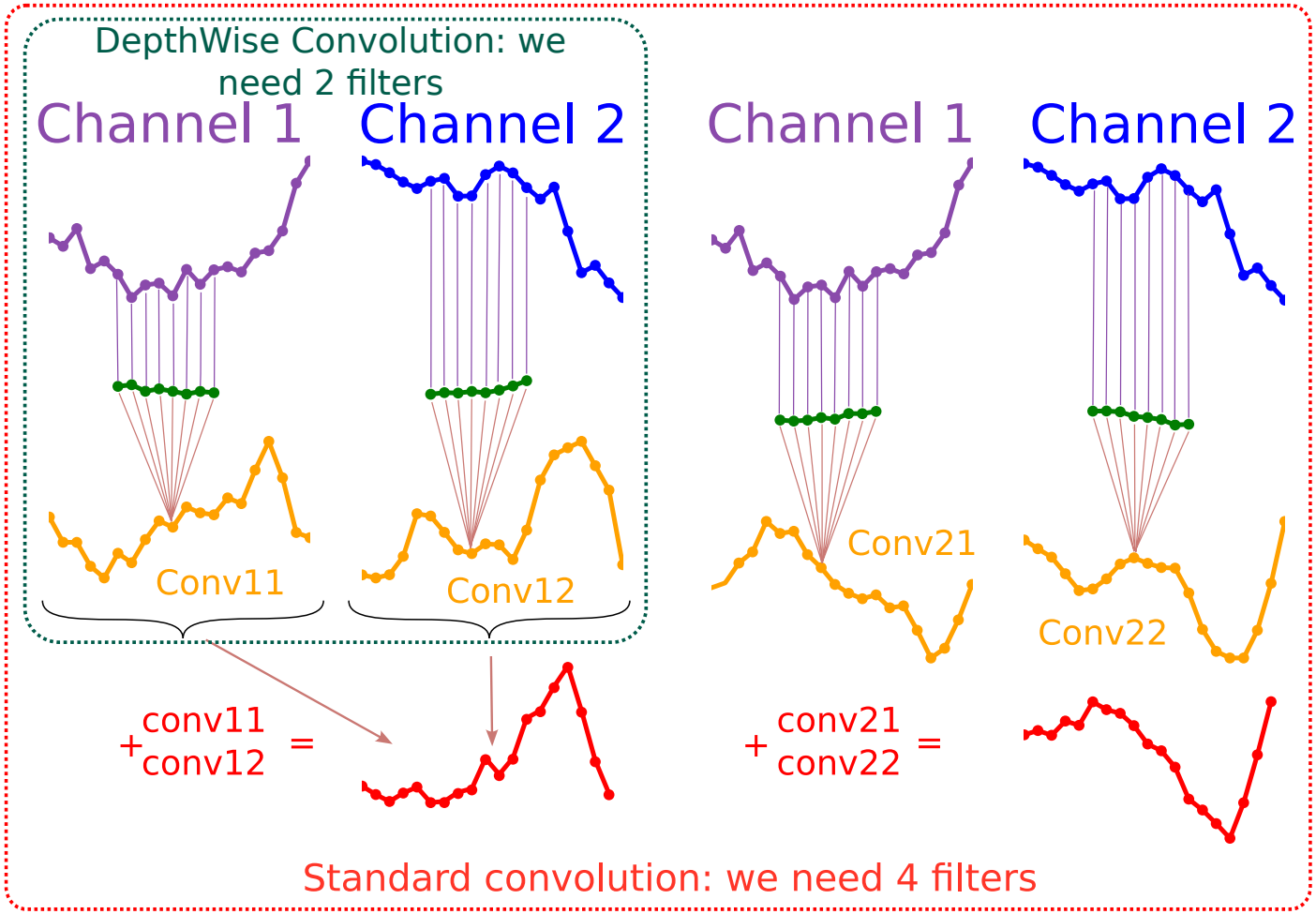
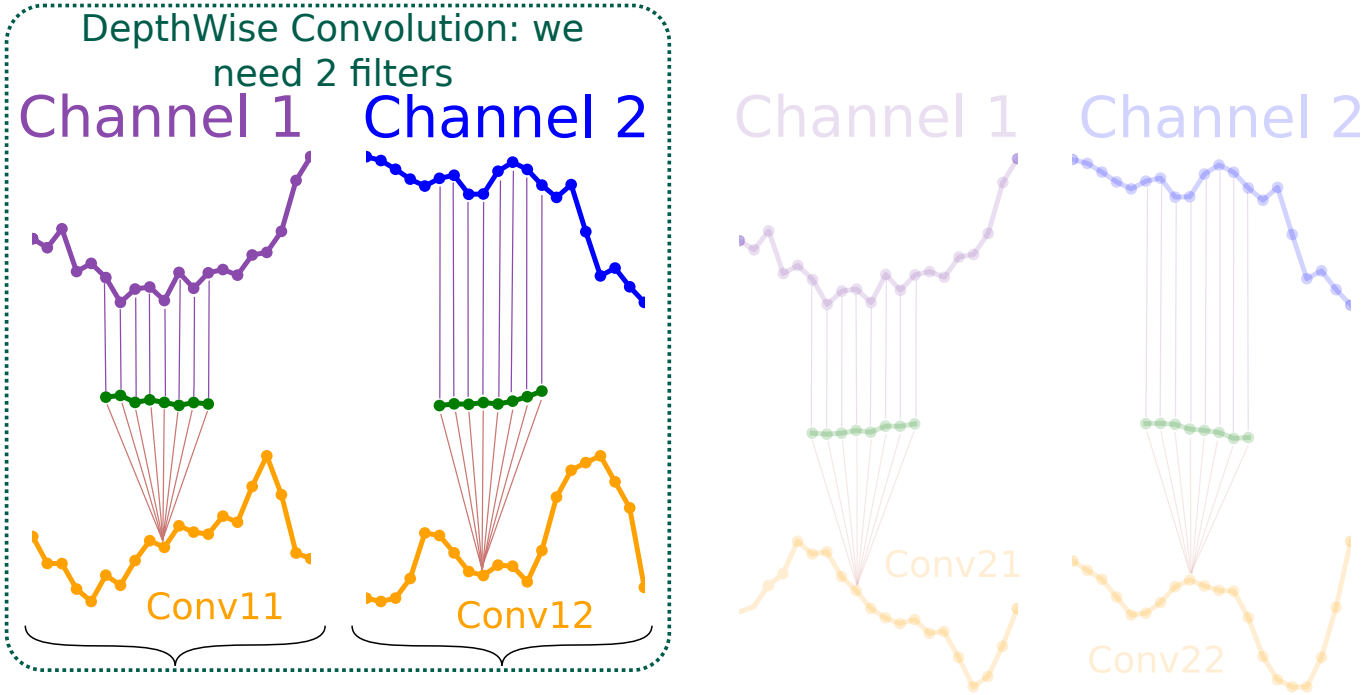


Convolutions In LITETime

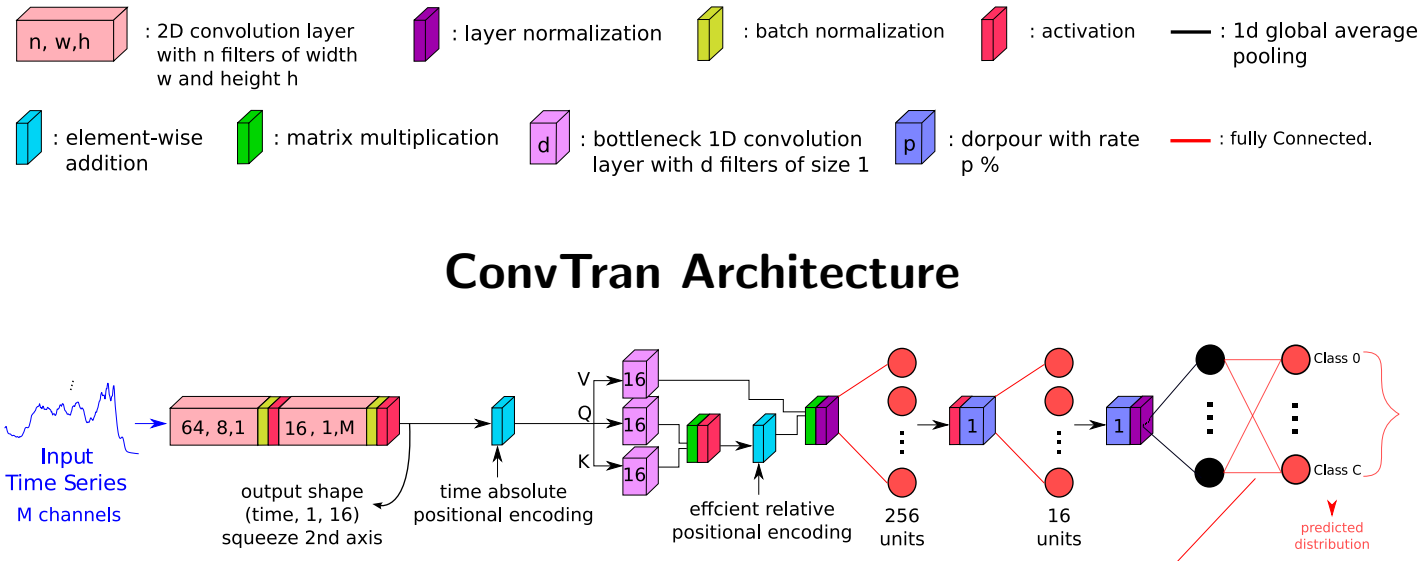
Standard vs Depthwise Separable Convolutions

DepthWise Separable Convolution = DepthWise + PointWise Convolution



Deep Learning for Multivariate Time Series

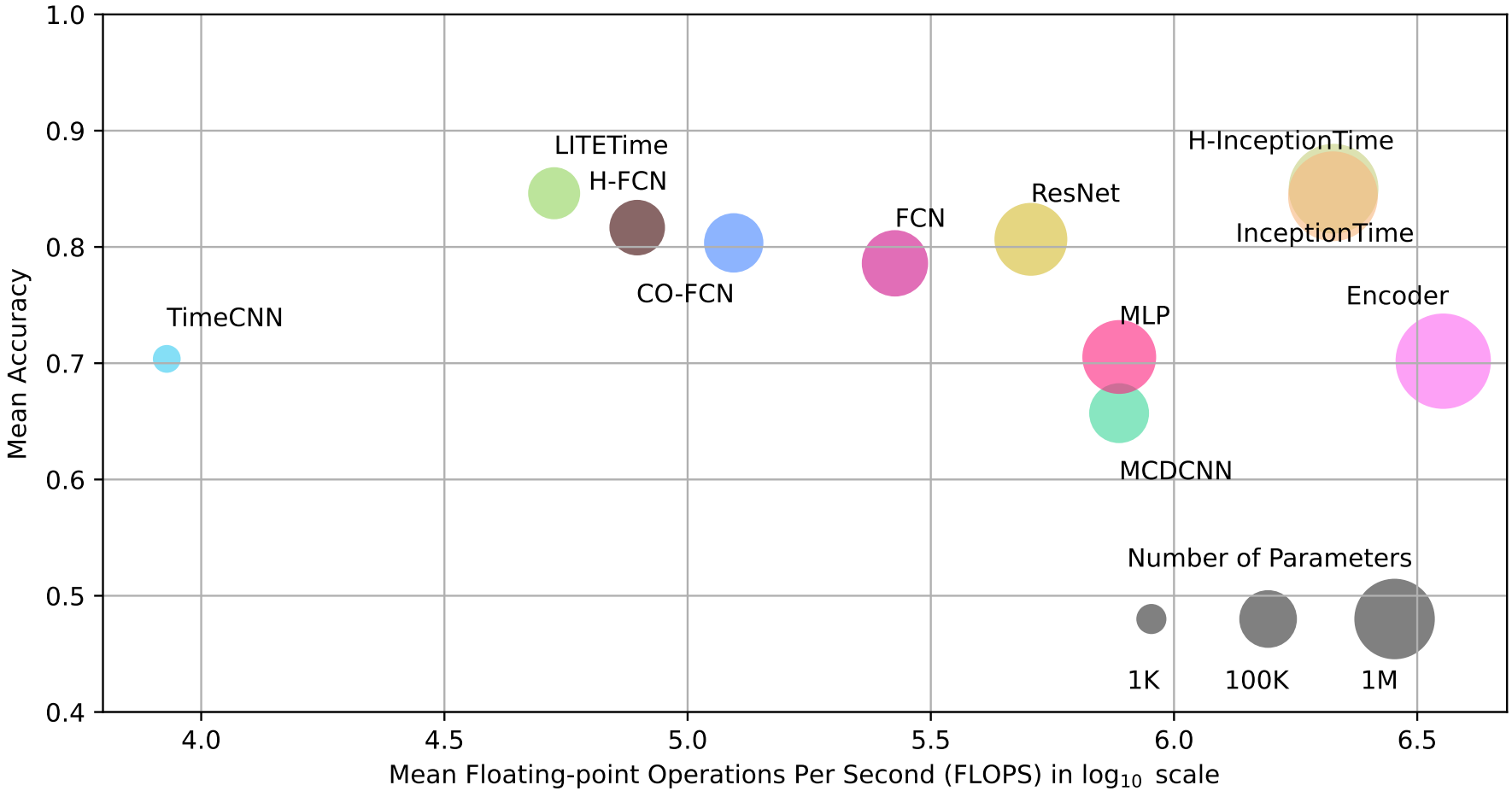
Architecture using Transfomer:



- Foumani, Navid Mohammadi, et al. "Improving position encoding of transformers for multivariate time series classification." Data Mining and Knowledge Discovery 38.1 (2024): 22-48.

Comparing all the architectures

We created a dynamic website (updated regularly) to compare all these architectures in terms of performance and complexity:

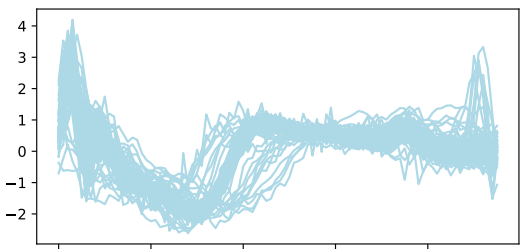


Try it out on : `https://msd-irimas.github.io/pages/dl4tsc/`

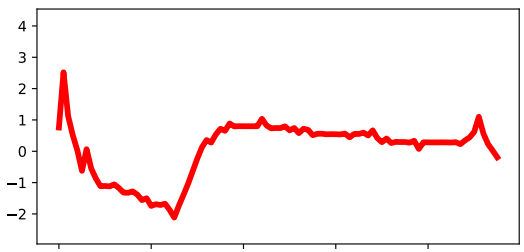
Regularization Techniques: Data Augmentation

How to create synthetic time series ?

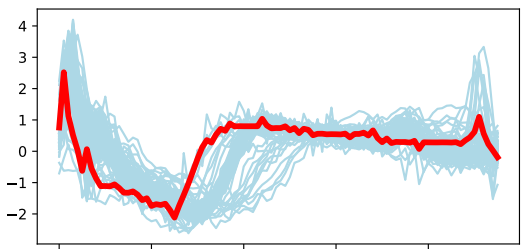
- We averaged a set of time series and took the average as a new synthetic object
- We used weighted averages to generate multiple synthetic objects



Set of time series



Average time series



Augmented dataset

- Petitjean, F., Ketterlin, A., & Gançarski, P. (2011). A global averaging method for dynamic time warping, with applications to clustering. Pattern Recognition, 44(3), 678-693.
- Forestier, G., et al. "Generating synthetic time series to augment sparse datasets." 2017 IEEE International Conference on Data Mining (ICDM). IEEE, 2017.
- Ismail-Fawaz, A. et al. " ShapeDBA: Generating Effective Time Series Prototypes using ShapeDTW Barycenter Averaging." ECML/PKDD Workshop on Advanced Analytics and Learning on Temporal Data, 2023

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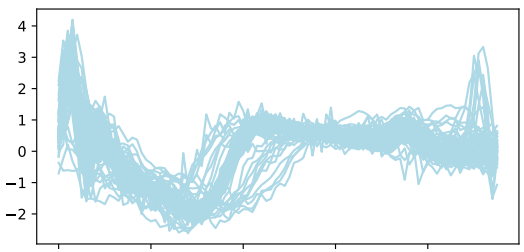

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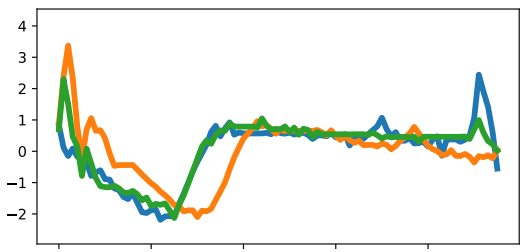
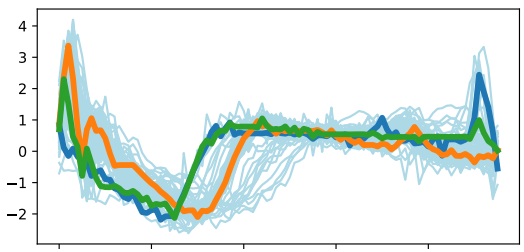


Weighted average time series



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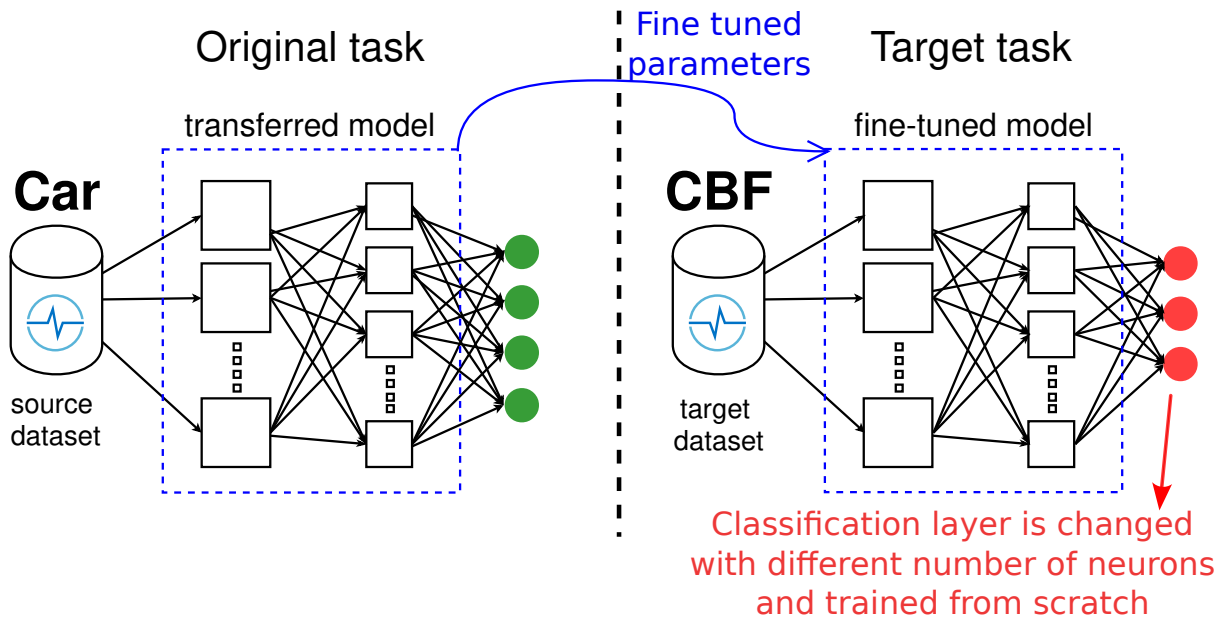
Regularization Techniques: Transfer Learning

Transfer Learning:

1. Train a base network on a source dataset
2. Transfer the learned features (the network's weights) to a second network and adapt the last layer (class-dependent)
3. Re-train or fine-tune the transferred network on a target dataset



- Ismail Fawaz, H., Forestier, G., Weber, J., Idoumghar, L., & Muller, P. A. (2018). Transfer learning for time series classification. IEEE International Conference on Big Data.
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Lets code!

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https://github.com/aeon-toolkit/aeon-tutorials/tree/main/KDD-2024/Slides/Part7deep-learning.pdf

https://github.com/aeon-toolkit/aeon-tutorials/tree/main/KDD-2024/Notebooks/part7_deep_learning_based.ipynb

https://msd-irimas.github.io/pages/dl4tsc/