Deep Learning For Time Series Classification

Ali Ismail-Fawaz, Maxime Devanne, Jonathan Weber, **Germain Forestier**

IRIMAS, Université de Haute-Alsace

DALL-E (OpenAI) illustration of InceptionTime

January 2024

Tutorial E-EGC 2024 - Dijon

Outline

Contents

The dream team

Maxime Devanne

Germain Forestier

Ali Ismail-Fawaz

Jonathan Weber

- **Goal of the tutorial**: discover the field of deep learning for time series classification
- **Outline**: a short presentation to introduce the field followed by a practical session on Google Colab
- Deep Learning for Time Series Classification is an active field of research
- slides: `https://germain-forestier.info/e-egc.pdf`

Acknowledgements : The providers of the UCR archive, Mésocentre for providing access to their cluster and the Agence National de Recherche for the Delegation Project.

Open position in our team in 2024

Open position of Associate Professor (Maitre de conférences) in 2014 in our team!

Research: AI / time series (IRIMAS lab, MSD team)
Teaching: Computer Science Engineering School (ENSISA)

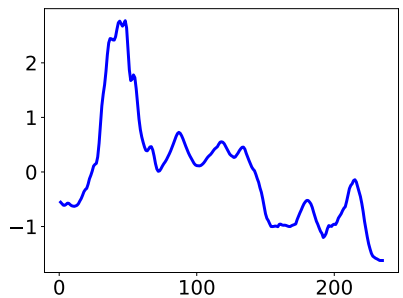
Lac Blanc (massif des Vosges) - MSD team annual hike

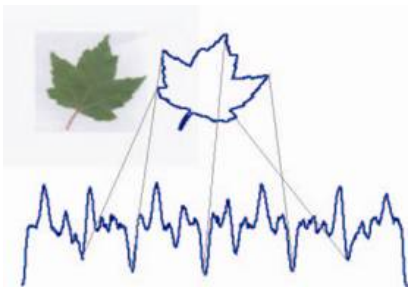
"Mulhouse en tête de liste des villes où concilier travail et logement" (29/11/23)

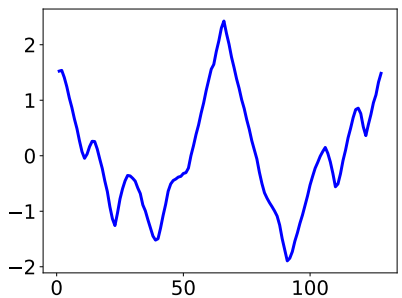
https://www.leparisien.fr/economie/mulhouse-en-tete-de-liste-des-villes-ou-concilier-travail-et-logement-il-y-a-une-energie-et-un-potentiel-enormes-29-11-2023-C5M5YY3J5ZCSLKN7GREIA6KQHM.php

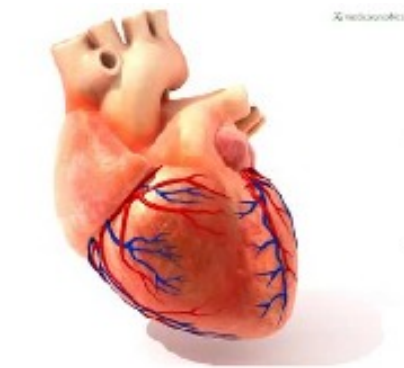
Time series are ubiquitous

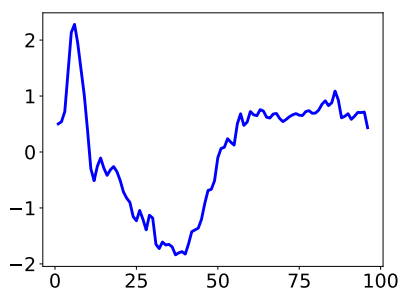
- Type of data present in numerous applicative domains
- Allow to study the evolution in time of a process, a behavior, etc.

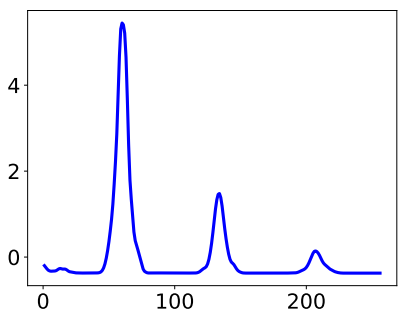












source : `http://timeseriesclassification.com/`

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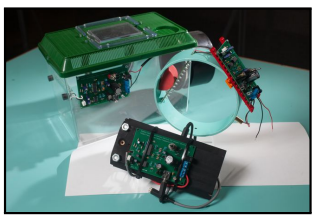

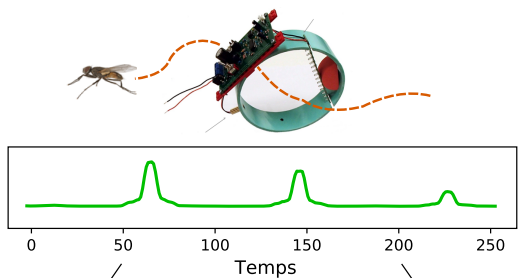

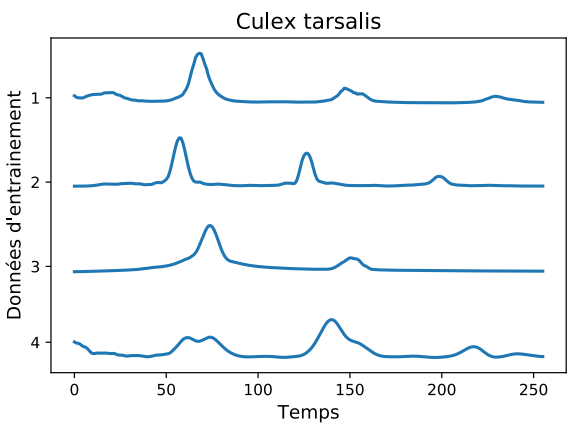

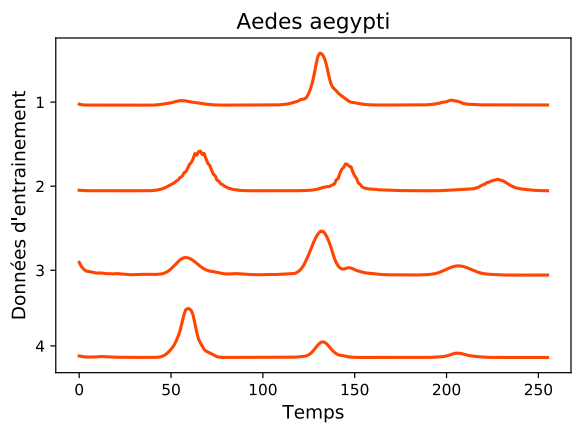

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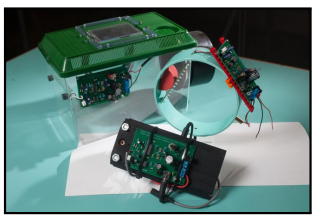

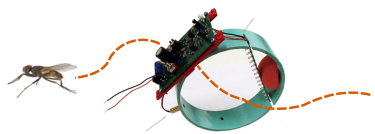

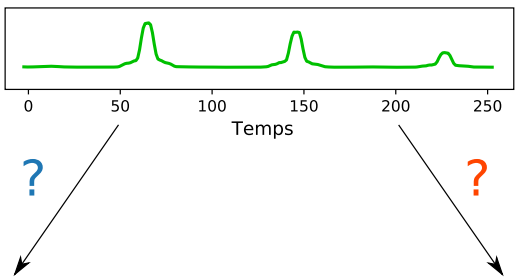

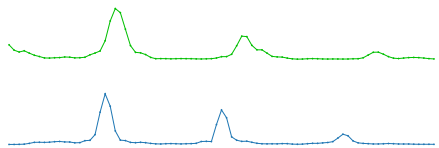

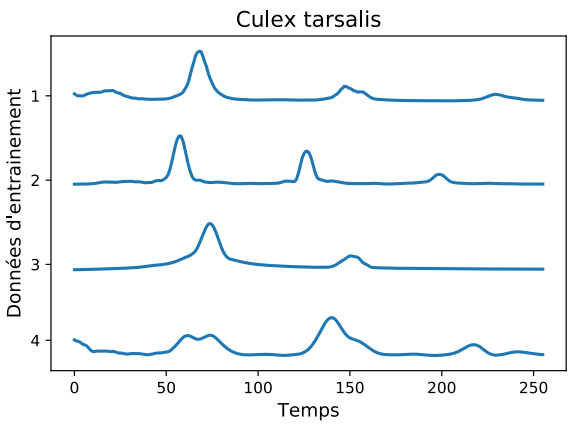

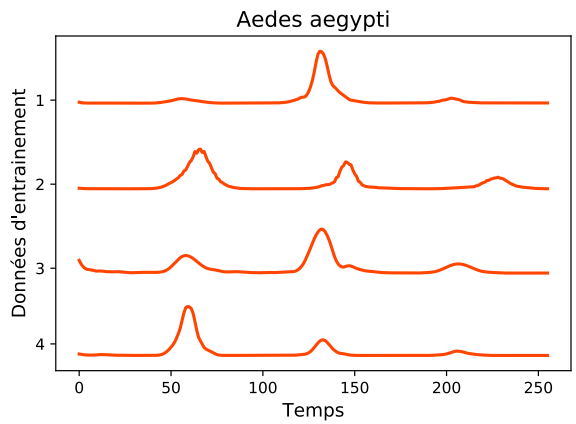

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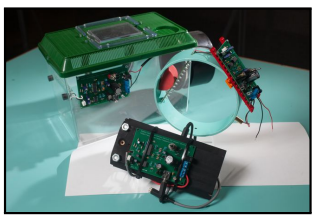

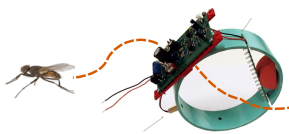

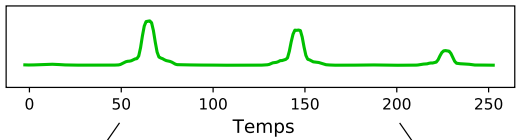

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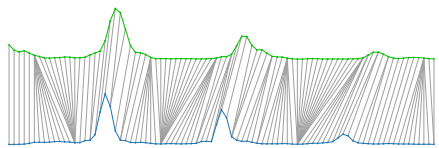
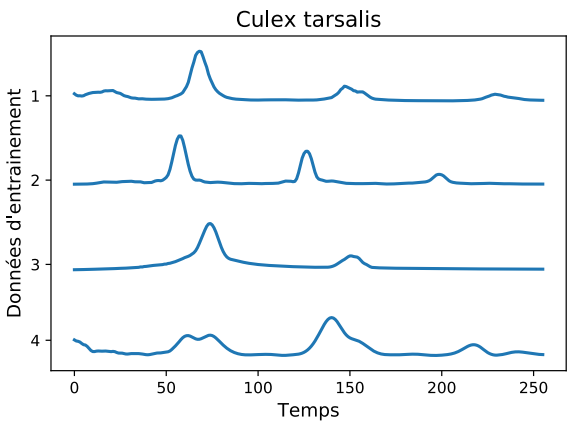
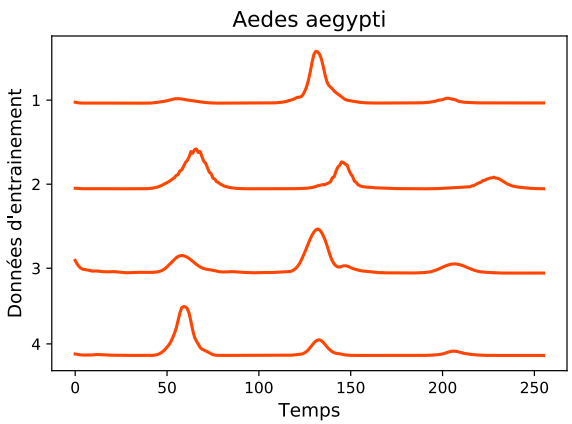


Alignement with
Dynamic Time Warping (DTW)





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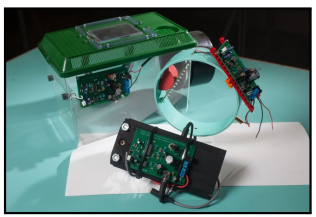

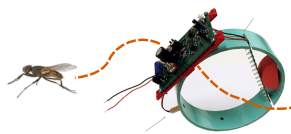

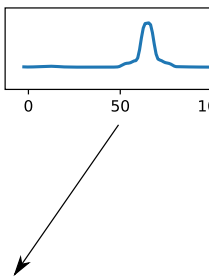

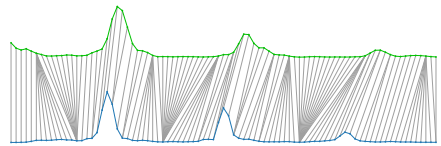

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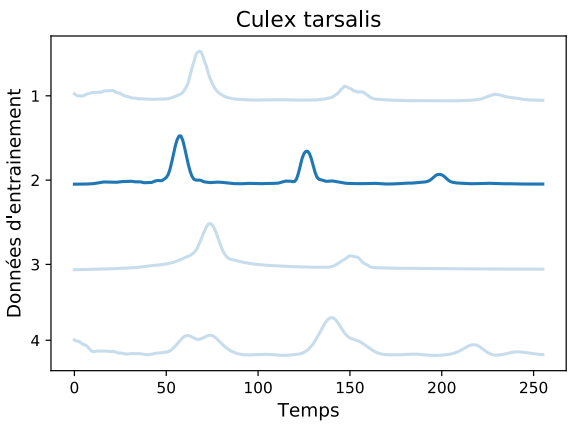

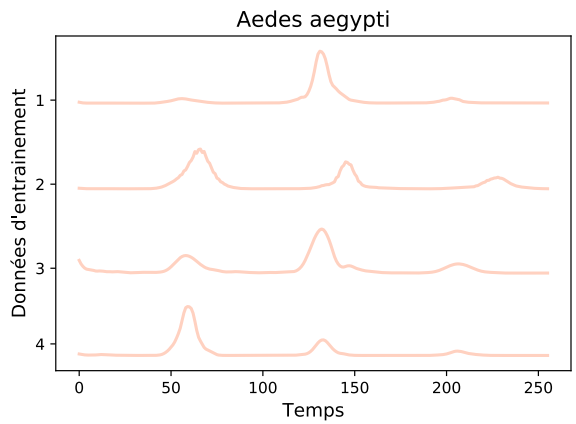

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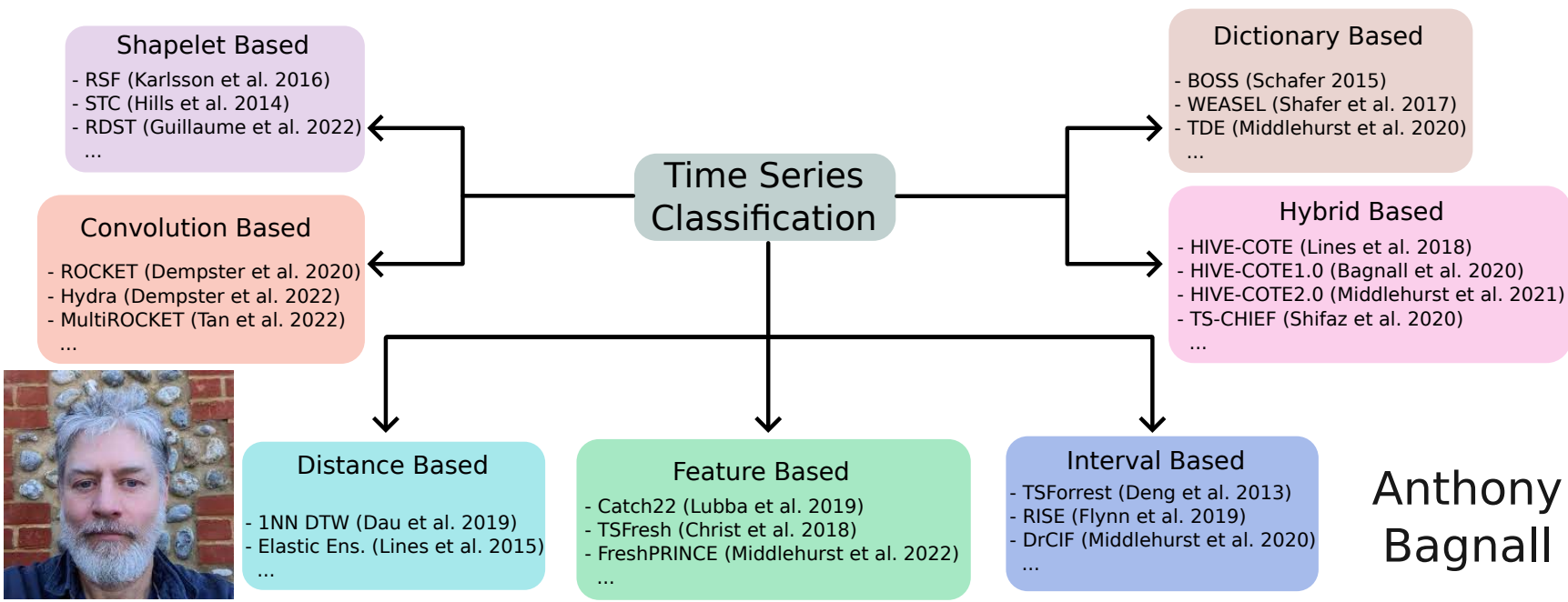
Taxonomy of methods

- Time Series Data can be used for various tasks including:
  - Clustering, representation learning, self-supervised learning, etc.
  - Extrinsic regression, forecasting, imputation, generation, etc.
  - Anomaly detection, similarity search, etc.
- In this talk, we focus on **classification**:



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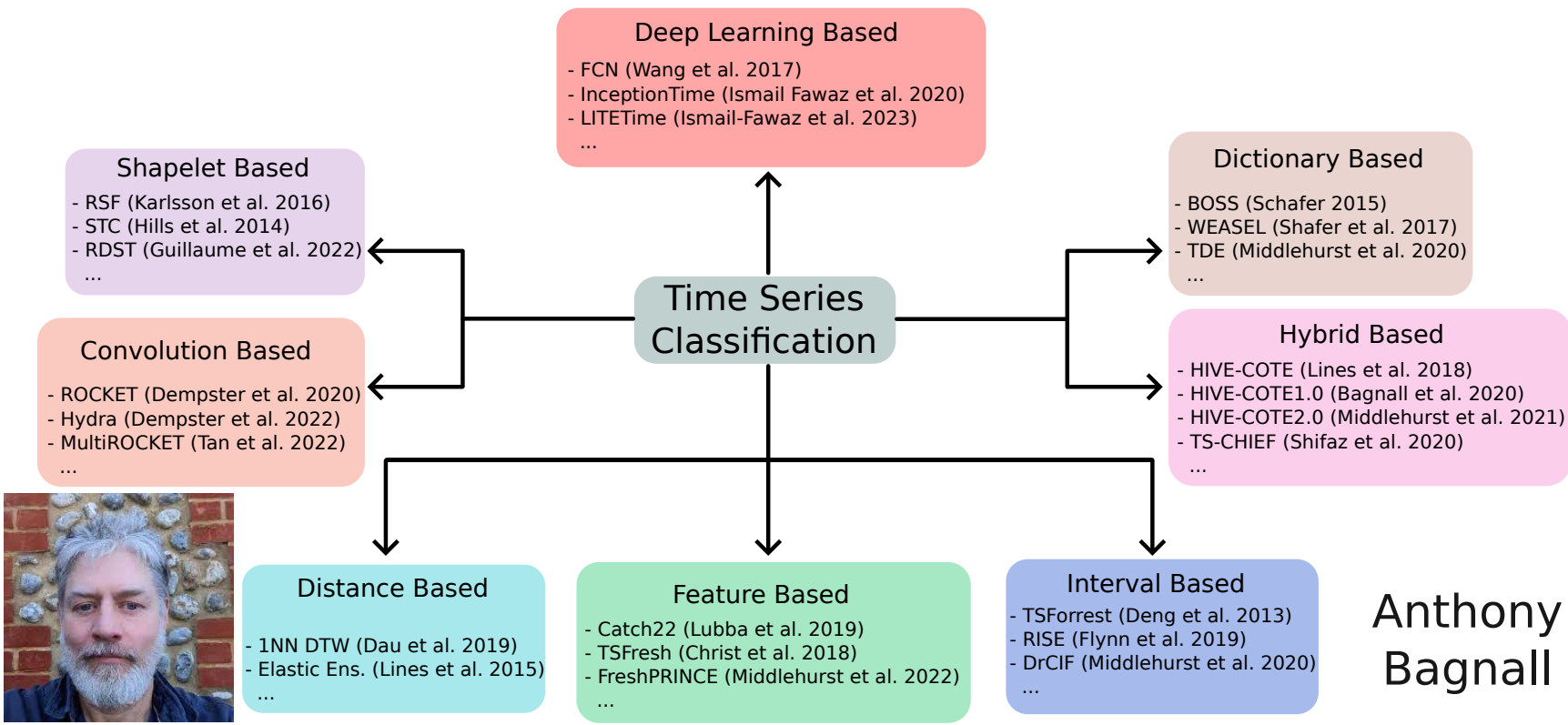

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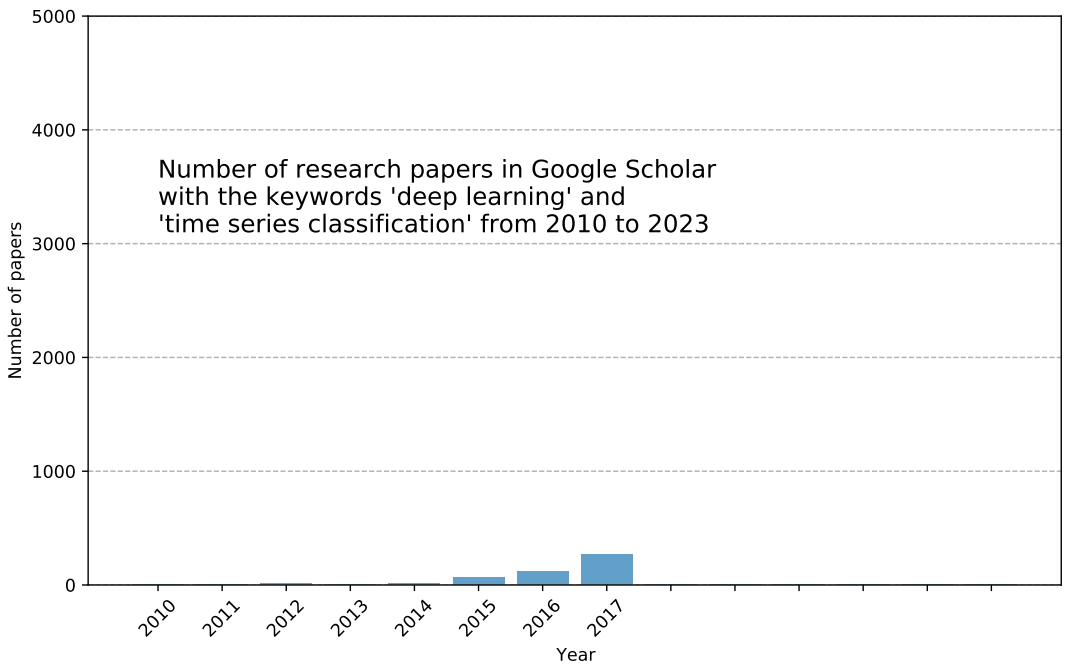
Why Deep Learning ?

- In 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?
- Deep Learning models learn to extract features and perform classification with one set of parameters (end-to-end)



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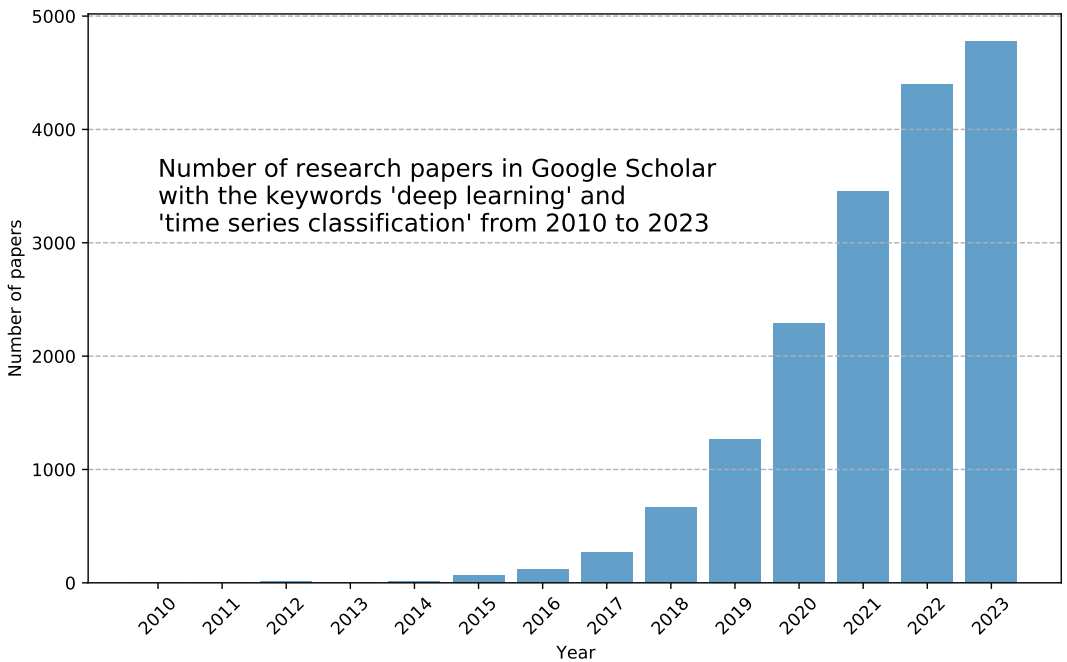
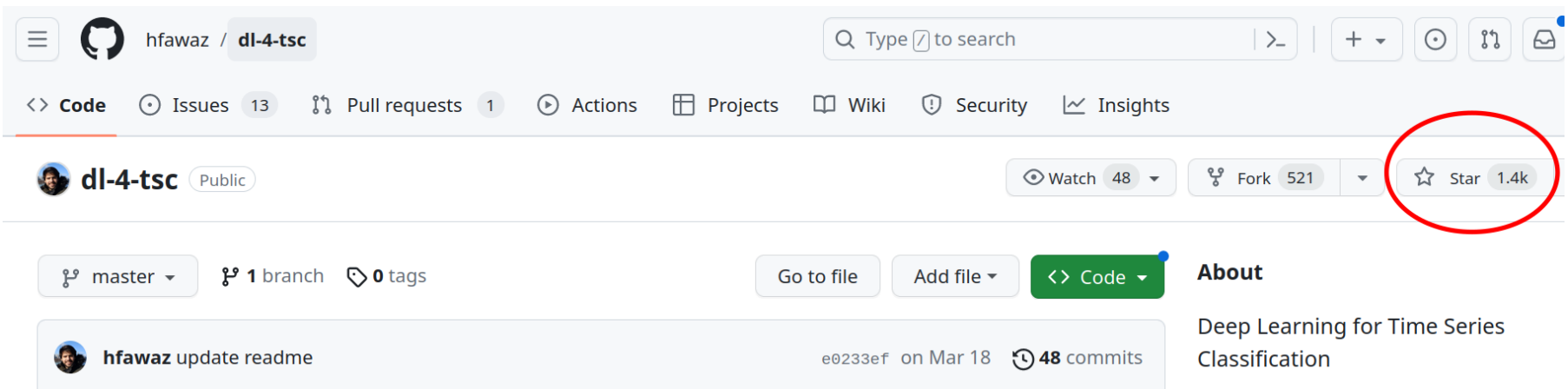


DL4TSC - 2019

In **2019**, we presented a study of **Deep Learning for Time Series Classification** (cited more than 2.7K times (GoogleScholar)) [1].

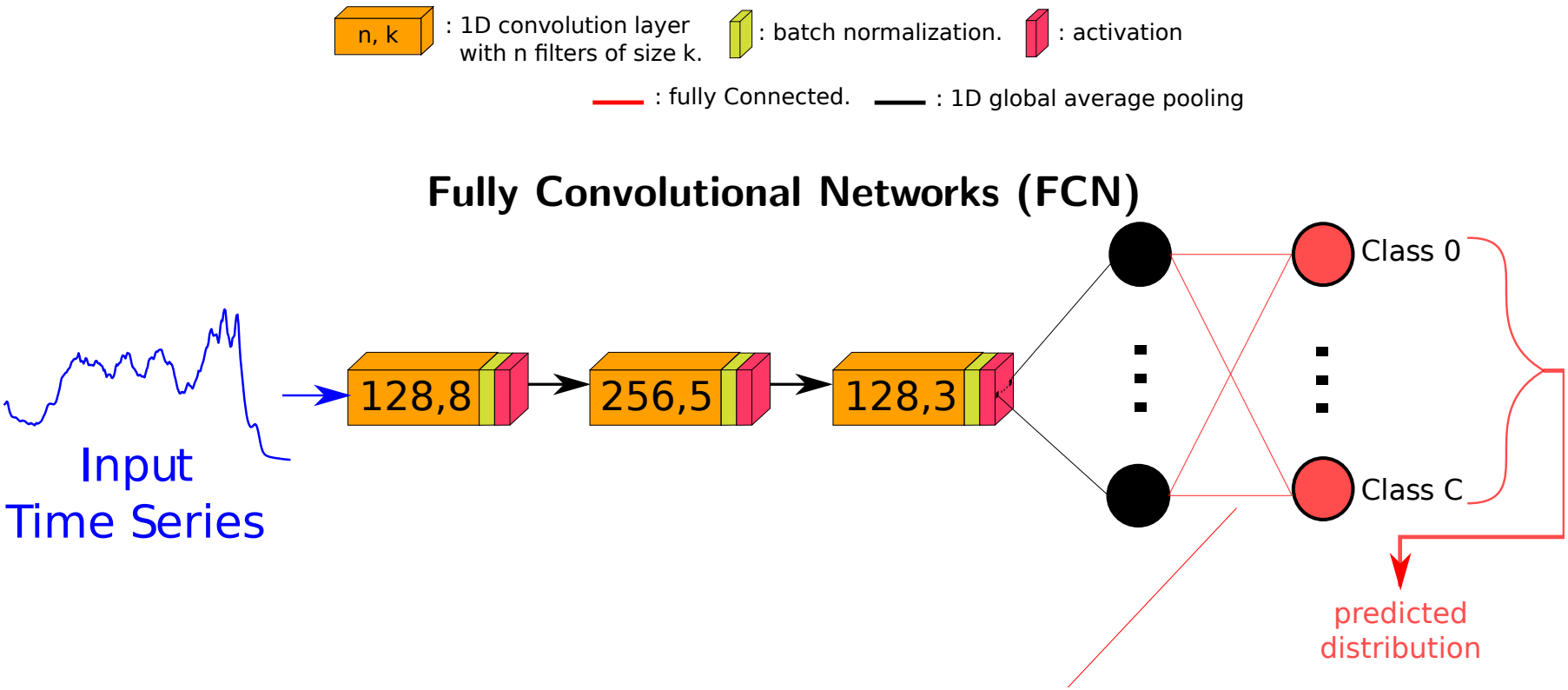
- We selected models with enough details (or available code) to reproduce the model's architecture
- We benchmarked all the models on the UCR archive [2]
- We published the code on Github for reproducibility and got very positive feedback (>1.4K stars)



[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



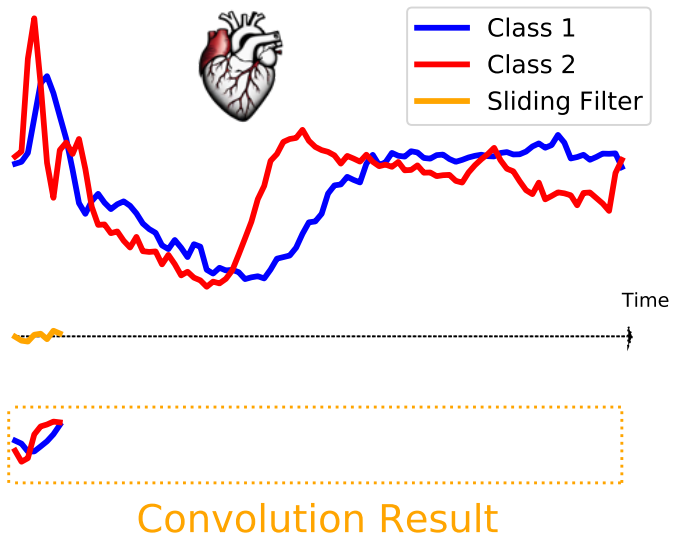
https://msd-irimas.github.io/pages/dl4tsc/

Wang, Z., Yan, W., & Oates, T. (2017, May). Time series classification from scratch with deep neural networks: A strong baseline. In 2017 International joint conference on neural networks (IJCNN) (pp. 1578-1585). IEEE.

Why Deep Learning ?

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

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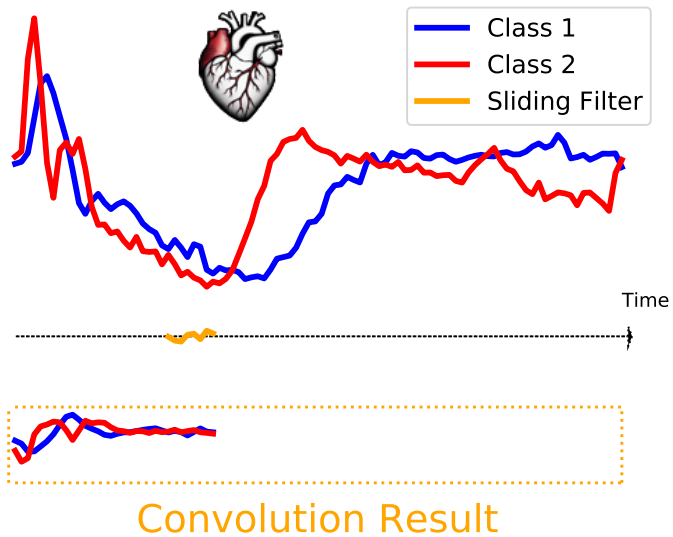

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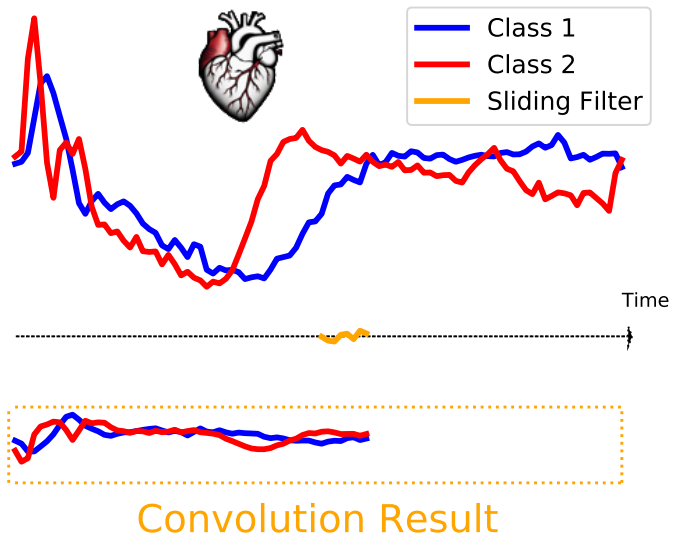

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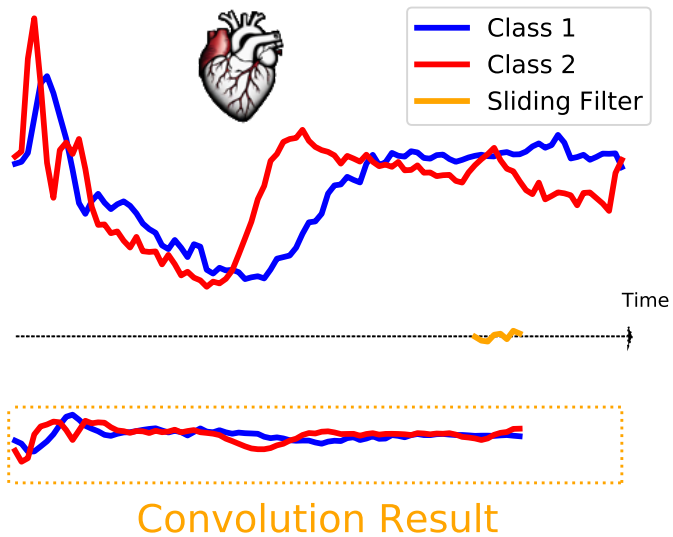

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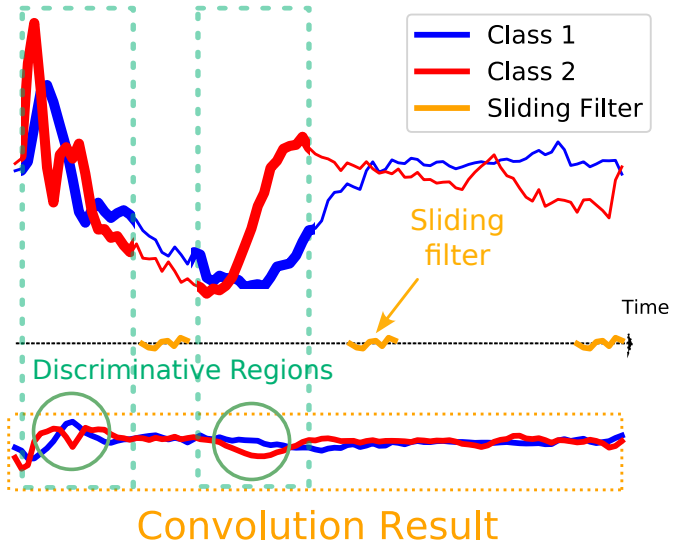

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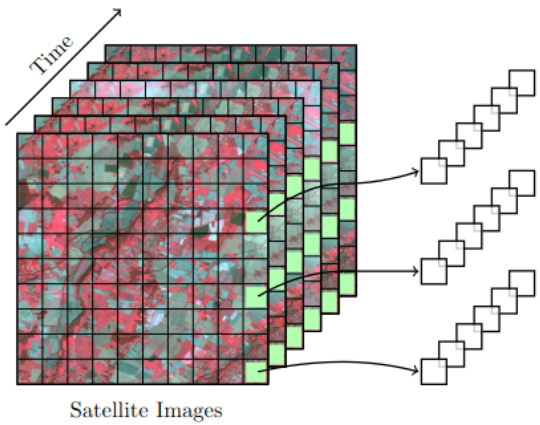
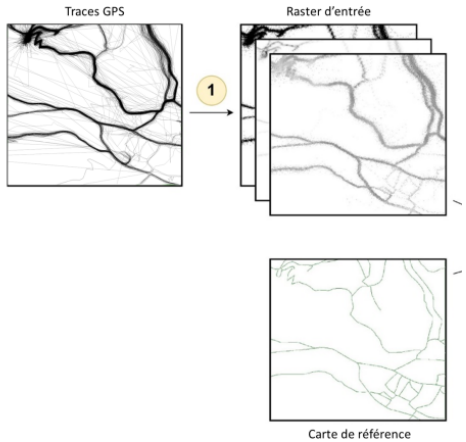
Applications

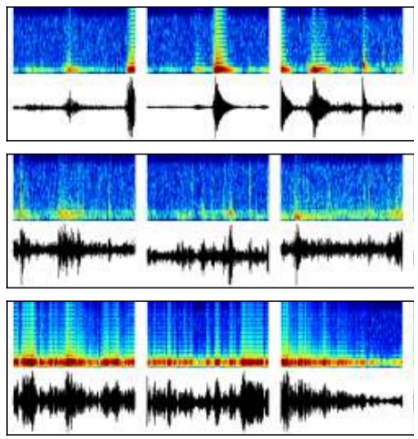
Applications:



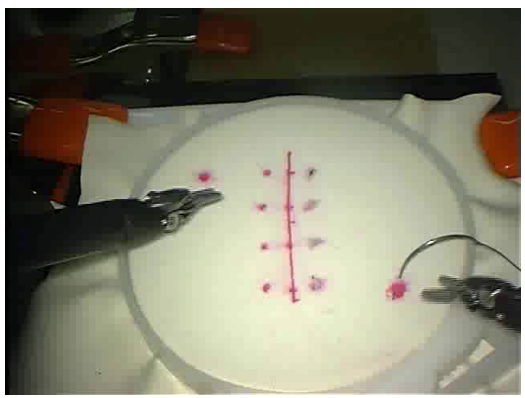
Series of Remote Sensing Images



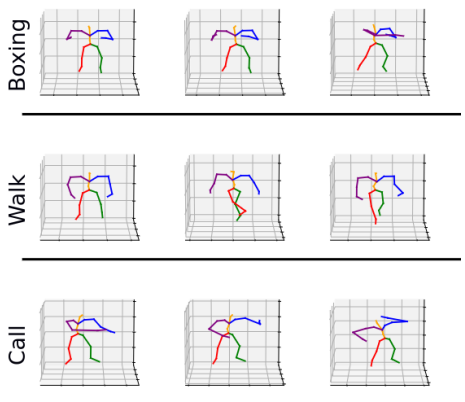
Generating Hiking Maps



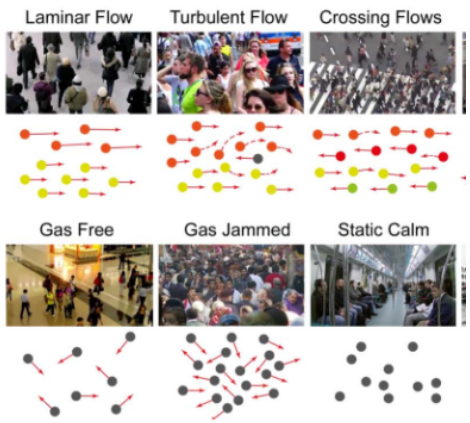
Seismology



Surgical Data Science



Body movements



Crowd movements

Applications

Crop dataset:

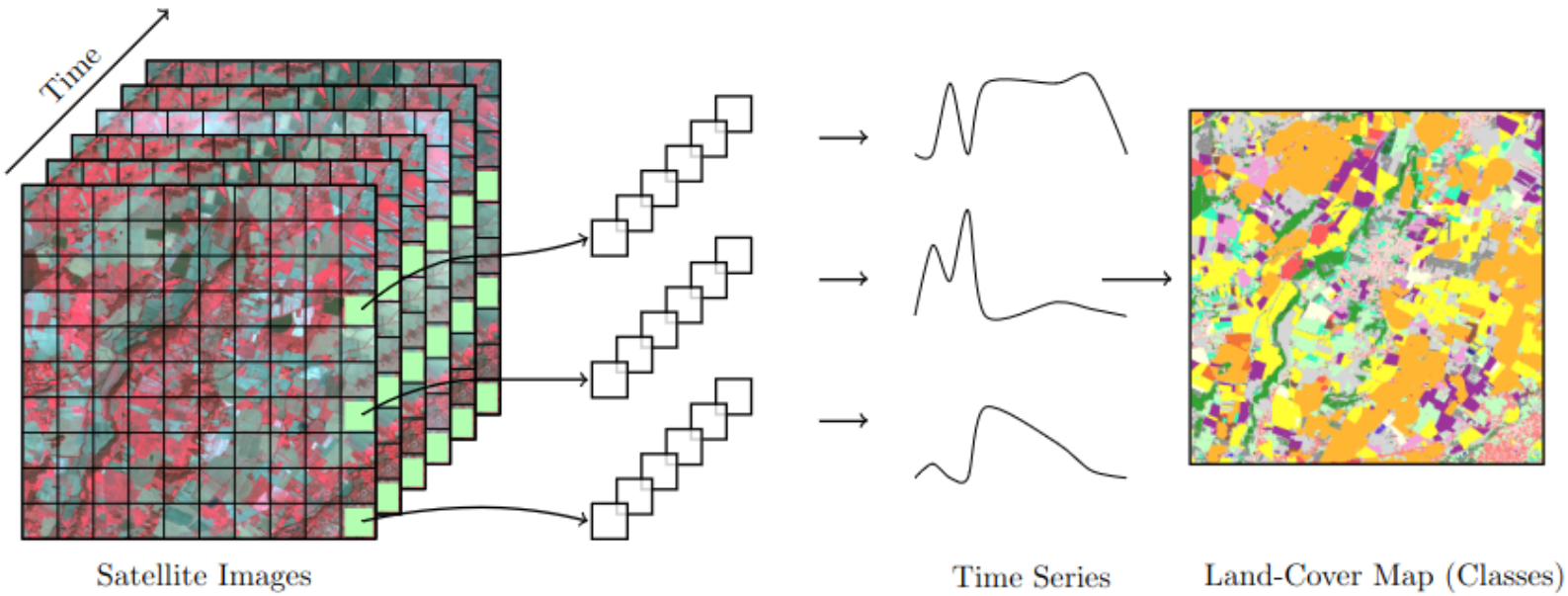
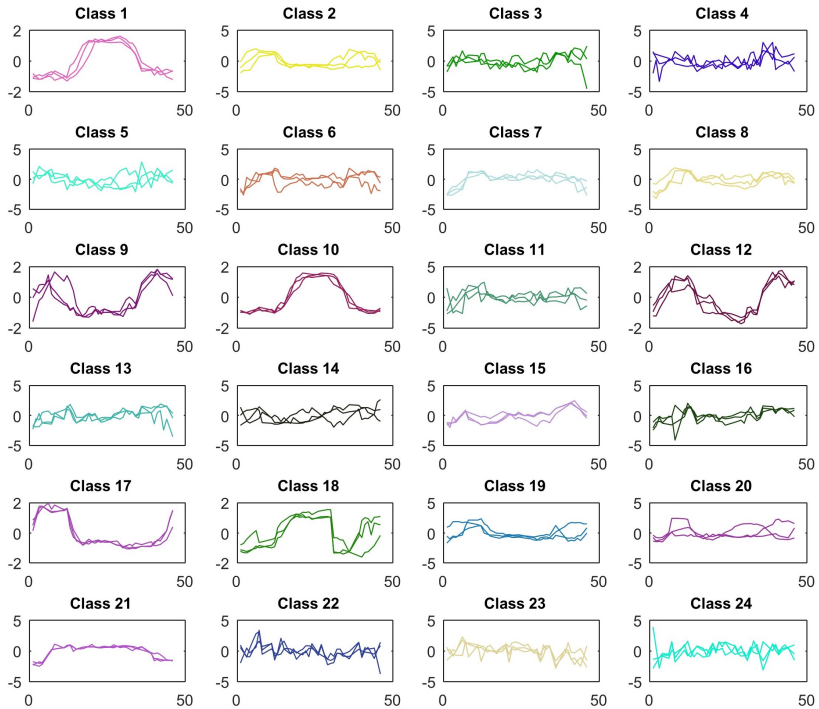


Figure 2: Production of a time series datasets from satellite image series.

Tan, C. W., Webb, G. I., & Petitjean, F. (2017, June). Indexing and classifying gigabytes of time series under time warping. In Proceedings of the 2017 SIAM international conference on data mining (pp. 282-290). Society for Industrial and Applied Mathematics.

Applications

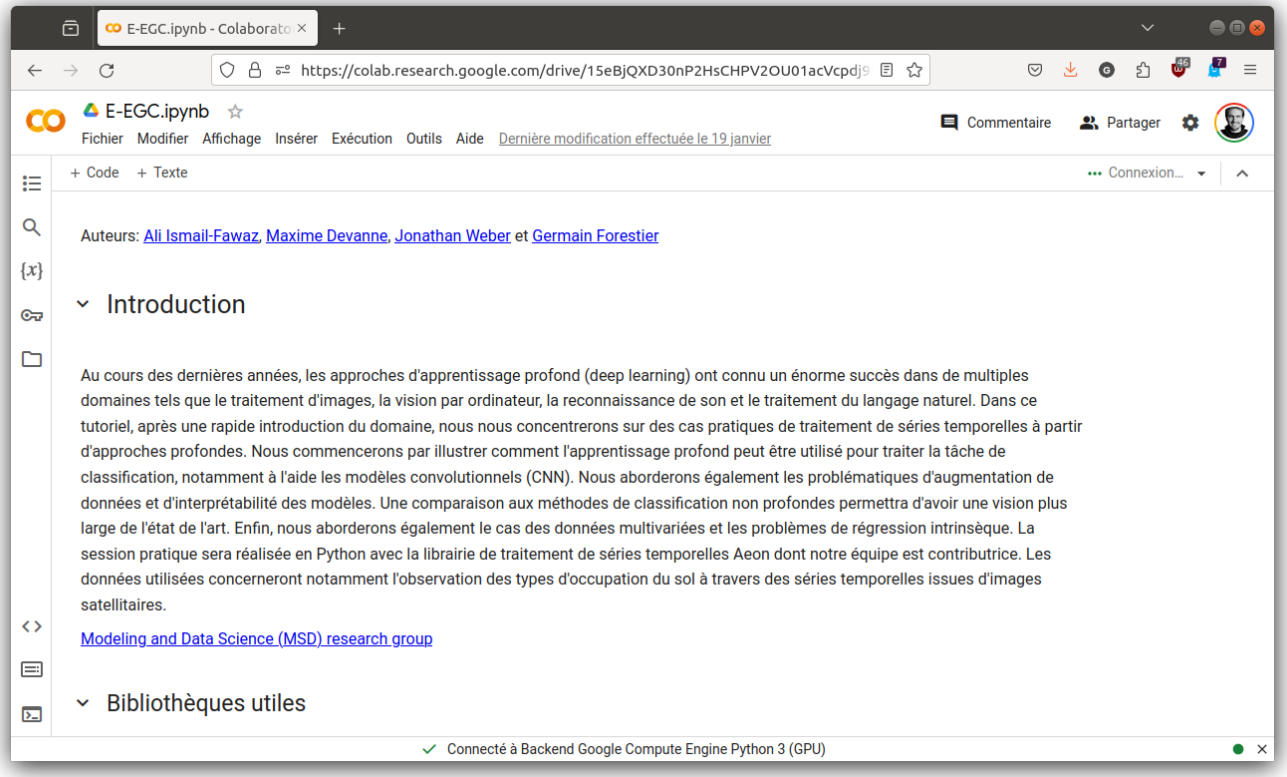
Crop dataset:



Tan, C. W., Webb, G. I., & Petitjean, F. (2017, June). Indexing and classifying gigabytes of time series under time warping. In Proceedings of the 2017 SIAM international conference on data mining (pp. 282-290). Society for Industrial and Applied Mathematics.

Applications

Lets code!



`https://germain-forestier.info/e-egc.pdf`

`https://colab.research.google.com/drive/15eBjQXD30nP2HsCHPV2OU01acVcpdj9l?usp=sharing`

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