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# nmf\_audio\_benchmark: Benchmarking NMF algorithms on audio tasks

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### Take home message

Introducing `nmf_audio_benchmark` [1], an open-source toolbox for benchmarking NMF algorithms and variants on audio tasks.

[github.com/ax-le/nmf\\_audio\\_benchmark/](https://github.com/ax-le/nmf_audio_benchmark/)

### NMF - Nonnegative Matrix Factorization

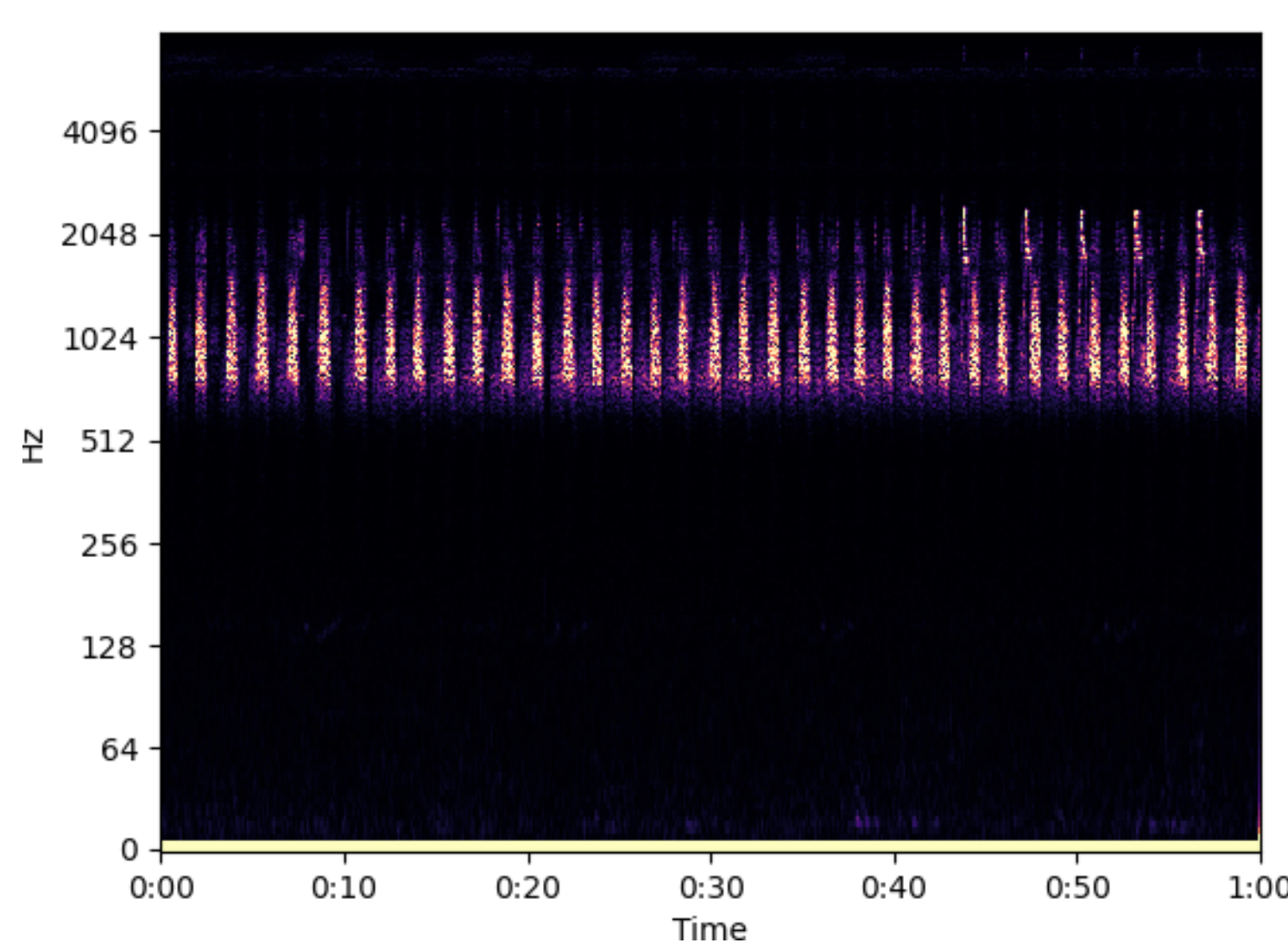
NMF is an unsupervised learning technique that factorizes a matrix  $V$  into two nonnegative matrices  $W$  and  $H$ , such that [2]:

$$V \approx WH \quad (1)$$

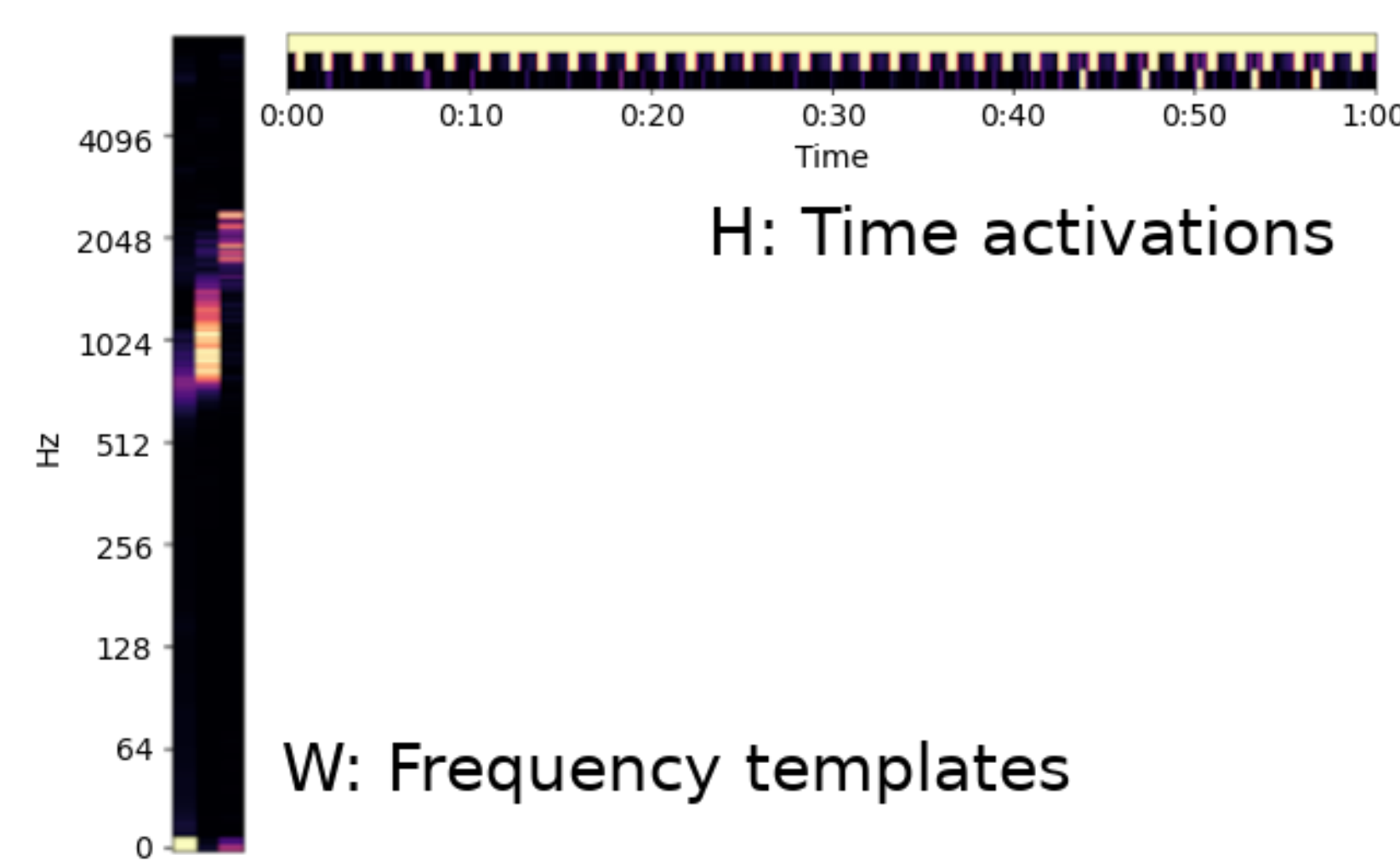
This is obtained by minimizing some distance function  $d(\cdot)$  between  $V$  and  $WH$ :

$$\arg \min_{W, H \geq 0} d(V, WH) \quad (2)$$

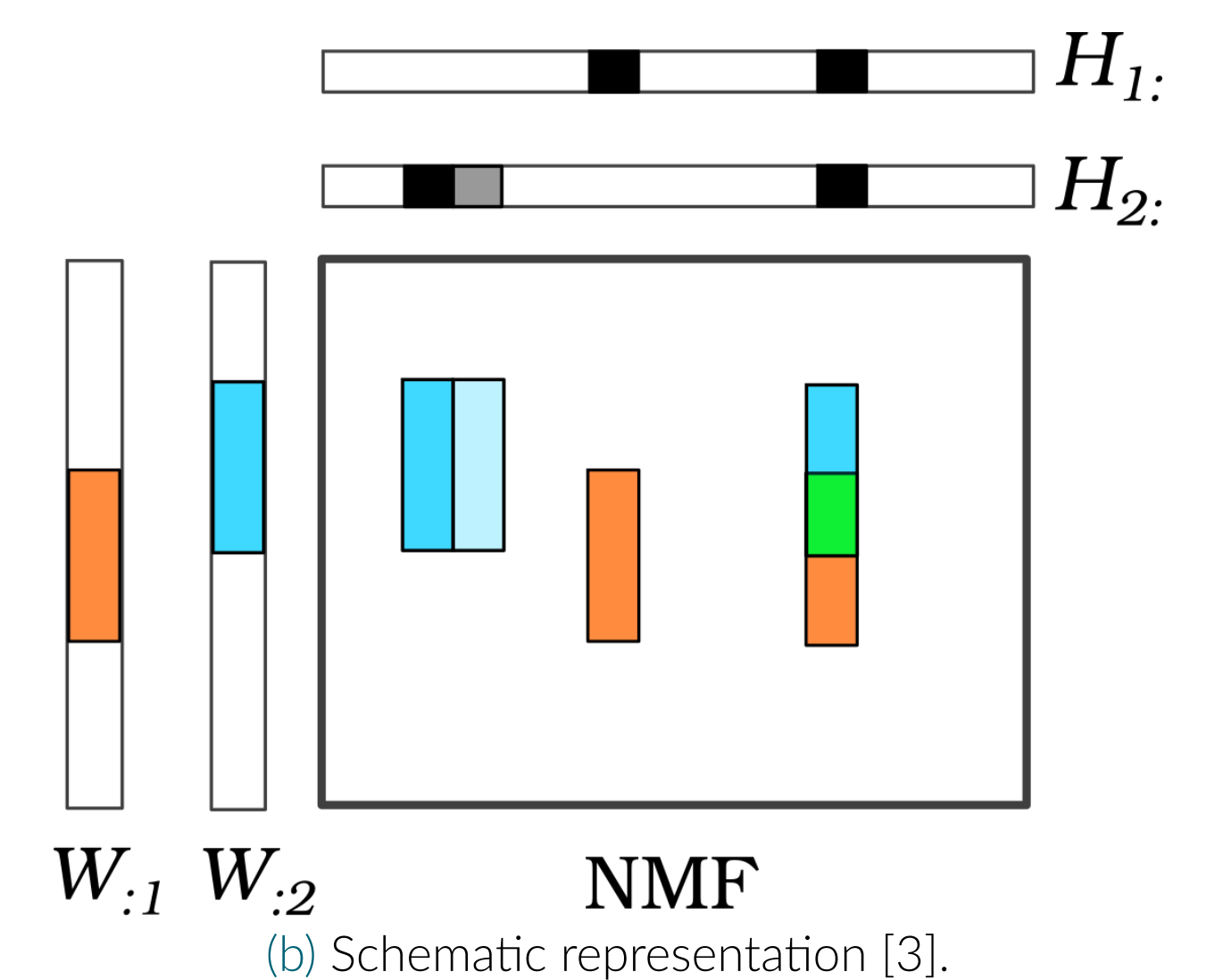
For instance, using the Euclidean distance, the optimization problem becomes:  $\arg \min_{W, H \geq 0} \sum_{i,j} (V_{ij} - (WH)_{ij})^2$



(a) NMF example.



W: Frequency templates



### Why this toolbox?

**TL;DR:** help researchers in MIR to easily use NMF / help researchers in numerical optimization to test their new NMF models on audio.

#### 1. NMF models still constitute an active research domain

Goal: easy and consistent tool to evaluate a new the model.

In particular, avoid having to re-implement the evaluation process for a standard task.

#### 2. Bridge (again) Audio and Low-Rank Factorization communities.

Goal: reinvigorate the use of NMF in audio processing (long-standing method [4, 5, 6], still used recently [3, 7, 8])

#### 3. In some contexts, NMF is still relevant

It may help when dealing with a **limited set of data** (common in Ecoacoustics), or "Out-of-distribution" data (NMF is unsupervised). In addition, NMF is a frugal and interpretable method!

### What is the state of the toolbox now?

As of now, some tasks are already implemented in the toolbox:

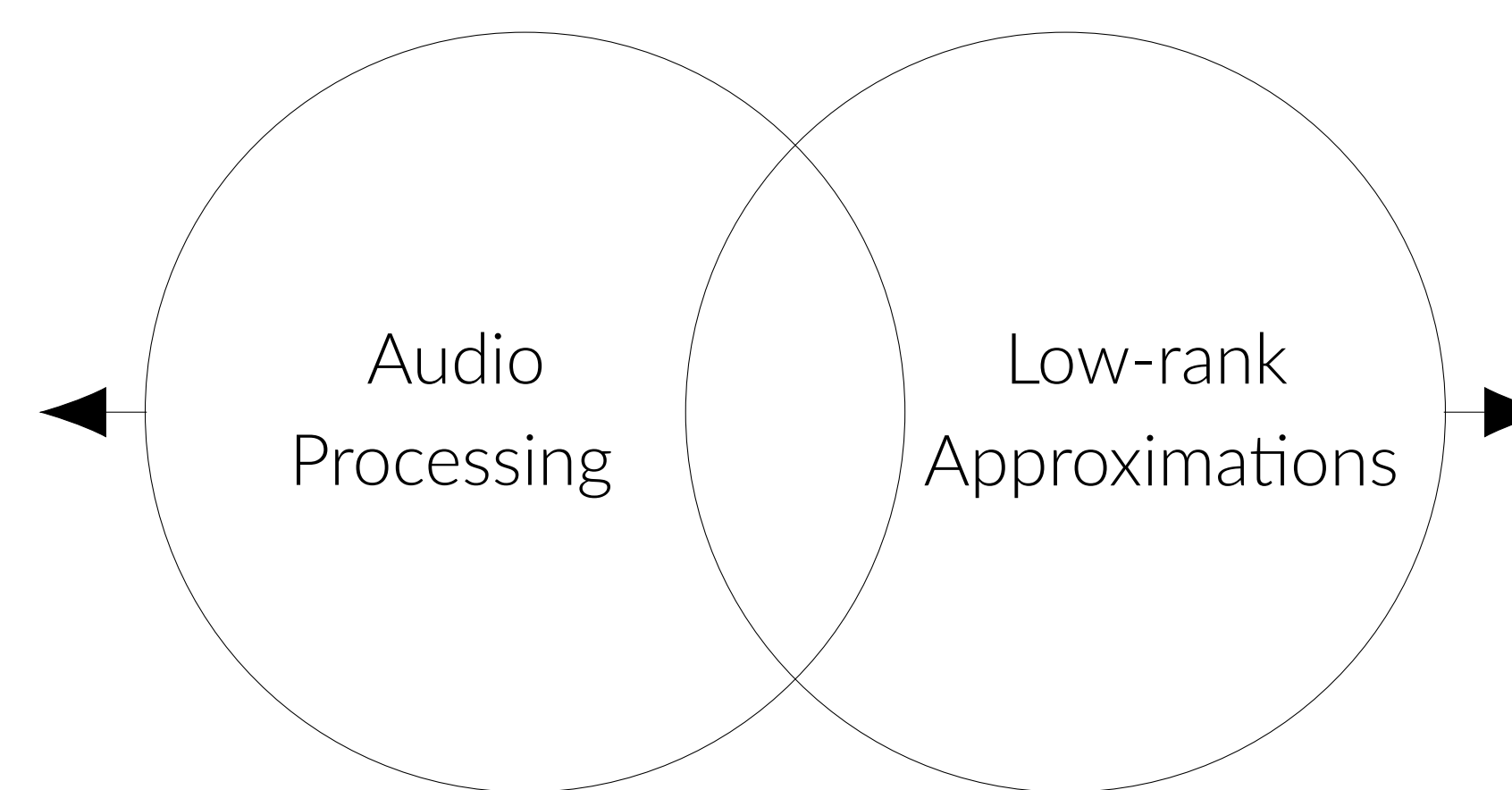
MIR:

- Music Transcription
- Blind Source Separation
- Music Structure Analysis

Ecoacoustics:

- Blind Source Separation
- Source Count
- ... and more to come!

For now, datasets include MAPS, MusDB18, SALAMI, and RWC Pop for MIR, and AnuraSet for Ecoacoustics.



For now, several NMF are implemented:

- $\arg \min_{W, H \geq 0} \|X - WH\|_2^2$  (Euclidean-NMF)
- $\arg \min_{W, H \geq 0} d_{KL}(X, WH)$  (KL-NMF)
- $\arg \min_{W, H \geq 0} d_{IS}(X, WH)$  (IS-NMF)

Details about KL- and IS-NMF in audio processing: [9].

Sometimes (soon!), Sparse-NMF [10] and minimum-volume NMF [11].

### Toolbox details

The toolbox is fragmented in **algorithms**, where NMF models are defined, **tasks**, defining how to post-process  $W$  and  $H$  and defining metrics, and **datasets**, defining the dataloaders. The toolbox relies on the `doce` [12] package to run experiments. It is developed in Python.

### Future work

Audio Processing:

- **Enhanced tasks** (in particular, the Transcription task).
- **Adding new tasks** (ex: sound event detection).
- **Expand datasets.**

Low-Rank Factorizations:

- **Constrained models** (minimum-volume, simplex-structured, sparse, orthogonal, ...)
- **Coupled NMF & tensor models** (ex: CP decomposition for multichannel processing).
- **Computing NMF on GPUs** instead of CPUs.

### Off-topic, for ATIAM students: Internship proposal

I propose an internship directly based on this toolbox for the ATIAM students that may be in this room.

The idea will be to use coupled NMF models in a multi-channel context, with different features (ex: factorizing simultaneously STFT, CQT, Mel, ...).

Come talk to me or reach me at [axel.marmoret@imt-atlantique.fr](mailto:axel.marmoret@imt-atlantique.fr) if interested!

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