`Micarraylib`: Software For Reproducible Aggregation, Standardization, And Signal Processing Of Microphone Array Datasets

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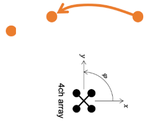
Introduction

Sound Event Localization and Detection

- Machine listening has seen major advances in sound event detection (SED)
  - AST: Audio Spectrogram Transformer (2021)
- In part thanks to large datasets with annotated sound events (like AudioSet)

Large amounts of data will also be needed for Sound Event Localization and Detection (SELD)



- Microphone array hardware and datasets
  - Several useful datasets available online (30+)
  - Very diverse in hardware and content

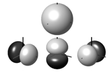

Ambeo®

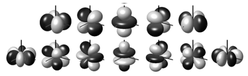

Pyramic (2018)

dataset	no. arr	capsules	length	SELD
DCASE(3) 2019 [5]	1	4	8 Hr	Yes
DCASE(3) 2020 [6]	1	4	13 Hr	Yes
DCASE(3) 2021 [7]	1	4	13 Hr	Yes
LOCATA [8]	4	63	0.5 Hr	Yes
3D-MARCo [9]	7	71	0.2 Hr	No
EigenScape [10]	1	32	11 Hr	No

Datasets with different
- Microphone hardware used
- SELD annotation conventions (or lack of)

Solution: standardization
- Microphone array recordings with B-format (ambisonics)
- SELD annotations with `Soun[D]ata:SpatialEvents`
  - `Label`
  - `Instance No.`
  - `Location`
  - `[start_time, end_time]*N`





`Micarraylib` allows users to access openly-available datasets in standard B-format ambisonics, with `Soun[D]ata:SpatialEvents` annotations

`Soun[D]ata(pre-release)`: https://github.com/soundata/soundata

Under the hood

`Micarraylib`

- After adding the dataset loader to `Soun[D]ata`:
- `Micarraylib`'s dataset object includes the capsule coordinates
- Capsule coordinates are used to compute the spherical harmonics matrix
  - θ = elevation
  - ϕ = azimuth
  - n = order
  - l = degree

$$Y_{n,l}(\theta,\phi) = X_{n,|l|} P_{n,|l|}\cos(\theta) \begin{cases} \sqrt{2}\sin(|l|\phi) & \text{if } l<0 \\ 1 & \text{if } l=0 \\ \sqrt{2}\cos(l\phi) & \text{if } l>0 \end{cases}$$

- The matrix Y is used as B-format encoder (pseudo-inverse matrix):

$$\mathbf{Y}^{\dagger} = (\mathbf{Y}^T\mathbf{Y})^{-1}\mathbf{Y}^T$$ (McCormack et al., 2018)

- Datasets included (so far):
  - 2019 DCASE Task 3
  - 2020 DCASE Task 3
  - 2021 DCASE Task 3
  - LOCATA
  - 3D-MARCo
  - Eigenscape
- ~50 hours of data Total
  - ~30hrs with SELD annotations
- Shared audio format (FOA)

```python
import micarraylib as mc

datadir = '~/datasets'

datasets = [
    mc.datasets.dcase19(datadir),
    mc.datasets.dcase20(datadir),
    mc.datasets.dcase21(datadir),
    mc.datasets.locata(datadir),
    mc.datasets.marco(datadir),
    mc.datasets.eigenscape(datadir)
]

for dataset in datasets:
    dataset.load() # using the soundata API [18]

aggregate = mc.aggregators.aggregate_datasets(
    datasets,
    sr=24000,
)
```

Example use-case

Virtual capsule interpolation

- **Can a microphone capsule's recording be reconstructed using neighboring capsules recordings?**
- **Hypothesis**: such reconstruction is possible using the capsule recordings and space coordinates.
- **Data**: EigenMike data from EigenScape, 3D-MARCo, and LOCATA datasets
  - skip the encoding step; keep recordings in raw A-format

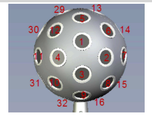
Example use-case (continued)

- **Capturing space info in input data:** intermediate step between A and B format as LeNET input
  - The spherical harmonic matrix multiplies samples recorded by the corresponding capsule.
  - A capsule's samples are missing, and the LeNET architecture is trained to reconstruct it.
- **3 experiments changing the input data:**
  - audio information of a single capsule is missing
  - audio of five neighboring capsules is also missing
  - Input only has samples of 3 capsules resulting in a tetrahedron with respect to the reconstructed capsule
- **Results show:**
  - `micarraylib` is useful and needed.
  - reconstructing a capsule's samples using
  - other capsules' recordings is:
    - possible
    - sensitive to density and physical proximity of recordings available used to reconstruct.

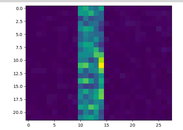
Table of results

Model	MSE (eval)
before training	0.9
exp 1	0.000039
exp 2	0.00013
exp 3	0.0016

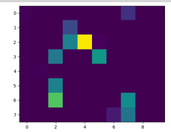
EigenMike capsules



Act in CNN layer 1



Act in CNN layer 2



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