Multimedia Systems

Assignment GA2. Low-Level features and timbre characterization

FEUP

1. Goal

The goal of this assignment is to understand, implement and evaluate a simple set of low-level audio descriptors and analyse their distribution over a collection of sounds, which are samples of isolated notes from musical instruments. Furthermore, we will explore the application of these low-level tasks into the development of a multimedia system.

2. Resources

Available base implementations:

- (Python) Librosa + Code from last week
- MIR.EDU Vamp Plugins for feature extraction (https://github.com/justinsalamon/miredu)

Sound material:

- Samples (isolated notes) from different instruments. ("InstrumentalSounds.zip")

3. Tasks

Task 1

Please review the paper by Peeters (Peeters, 2004)*"A large set of audio features for sound description (similarity and classification) in the cuidado project"*, to make sure that you understand the following descriptors:

Time-domain:
Instantaneous
1. RMS/Energy; 2. Zero Crossing Rate
Global
3. Log-attack time; 4. Temporal centroid; 5. Effective duration

Frequency-domain:
Instantaneous
6. Spectral centroid; 7. Spectral spread; 8. Spectral variation / spectral flux; 9. Spectral flatness

Please pick 2 descriptors by group (one from time-domain and another from frequency-domain), depart from the formula and explain what are the expected values for a sinusoid and white noise.
If they're not implemented in your software library, search online for an implementation that suits your needs.

Task 2

Implement a function to obtain, for a given audio file, the mentioned set of **instantaneous descriptors** (1,2,6-9).
To start, use similar analysis parameters: windowsize = 60 ms, hopsize=10 ms, no zero padding.

Create plots to visualize the extracted instantaneous low-level descriptors and study their evolution for a small set of instrument samples (e.g. percussive, string, wind instrument). Play around with the STFT analysis parameters (windowsize, hopsize, etc.), and try to obtain the best compromise.

Task 3

Implement a function to obtain, for a given audio file, the mentioned set of **global descriptors** (3,4,5), as well as statistics of the previous **instantaneous** (1,2,6-9) descriptors (mean, standard deviation, min, max). Study the values of these descriptors for the previous instrumental samples and analyse how they represent the following aspects: percussive/non-percussive sounds, low-pitch/high pitch, and instrument. In order to do that, you can build 2-D plots visualizing the values of 2 descriptors for the different samples, (the following examples are simply examples. You will have to choose the most appropriate pairs of descriptors for the task):

- Spectral Flux mean vs Spectral Spread mean
- Spectral Flux mean vs Spectral Flatness
- Spectral Centroid mean vs Zero Crossing Rate mean
- Temporal Centroid vs Log Attack Time (you would need to normalize temporal centroid by the duration of each sound).

Task 4

Imagine and describe in a single page (per system), how could you use the previous tasks to build 2 distinct multimedia applications that would classify the above sounds into:

- A: percussive /non percussive (binary classification)
- B: instrument (multi-label classification).

Don't forget to include the following reasoning:

- Would you have to make any manual tasks for the system to work?
- What would be the inputs/outputs?
- What would be the main algorithm?
- How would you classify your system's performance and what metrics would you use?

Note: Machine Learning is not an accepted answer!

Delivery

Deliver your working code and report in a zip file (named GA2_GXX.zip).
Delivery Date: **29/12**

4. References

Bogdanov, D., Wack, N., Emilia, G., Gulati, S., Herrera, P., Mayor, O., Roma, G., & Salamon, J. (2013). Essentia: An Audio Analysis Library for Music Information Retrieval. *ISMIR 2013*, 2–7.

Lartillot, O., & Toiviainen, P. (2007). A Matlab Toolbox for Musical Feature Extraction from Audio. *Proc of the 10th International Conference on Digital Audio Effects DAFx07*, 1–8. http://dafx.labri.fr/main/papers/p237.pdf

Peeters, G. (2004). *A large set of Audio features for sound description (similarity and classification) in the CUIDADO project*.

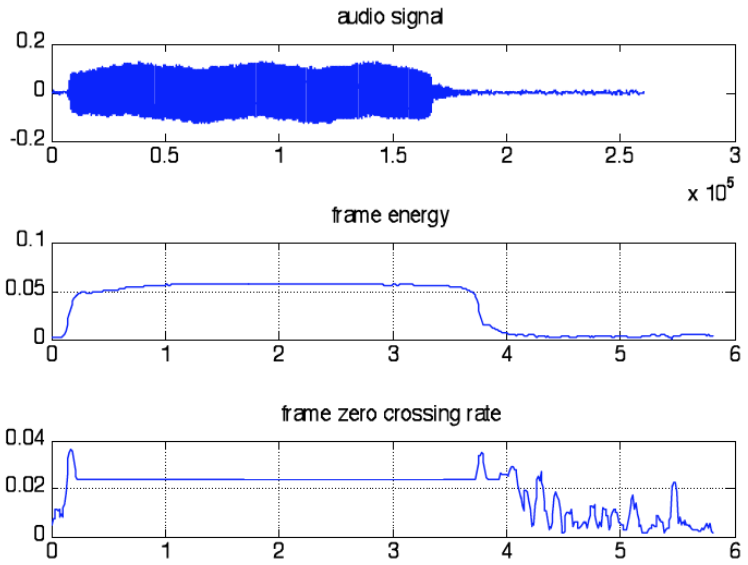
Peeters, G., Giordano, B. L., Susini, P., Misdariis, N., & McAdams, S. (2011). The Timbre Toolbox: Extracting audio descriptors from musical signals. *The Journal of the Acoustical Society of America*, *130*(5), 2902–2916. https://doi.org/10.1121/1.3642604

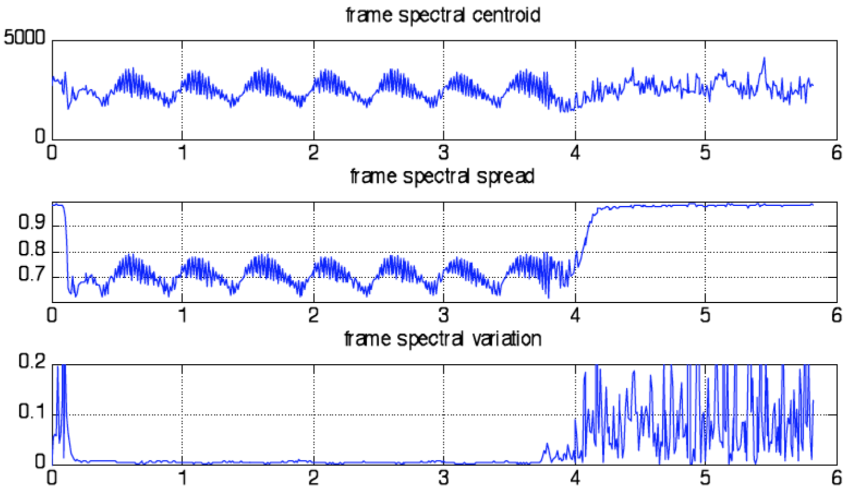
5. Examples

Example of Task 1

Audio file: acco _mf_do4_12.wav

Instantaneous descriptors (square window applied just for testing purposes!!!!):





Global Descriptors:

logAttackTime=-1 (threshold = 20%-80%)
temporalCentroid=2.1131
zcr_mean=0.019278
zcr_std=0.0081513
spec_centroid_mean=2500.4536
spec_centroid_std=496.2628
spec_spread_mean=0.79401
spec_spread_std=0.13328
spec_variation_mean=0.034877
spec_variation_std=0.062566

Example of Task 2

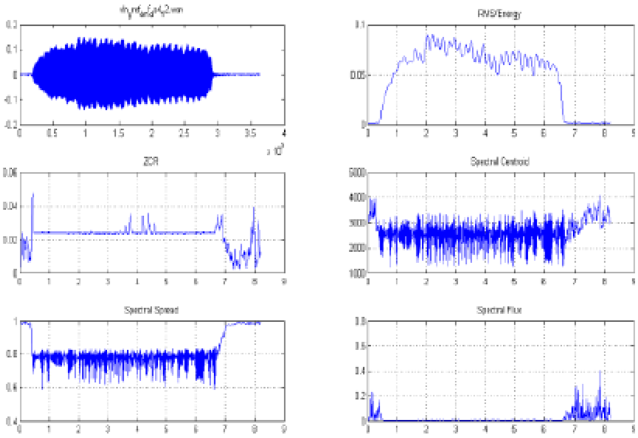


Figure 1. Low Level Features for Violin

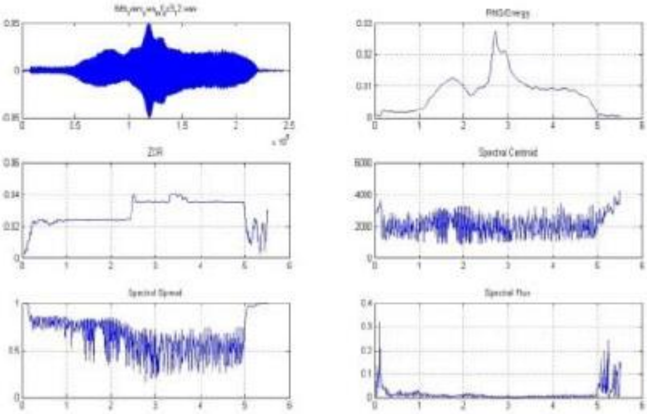


Figure 2. Low Level Features for Tuba

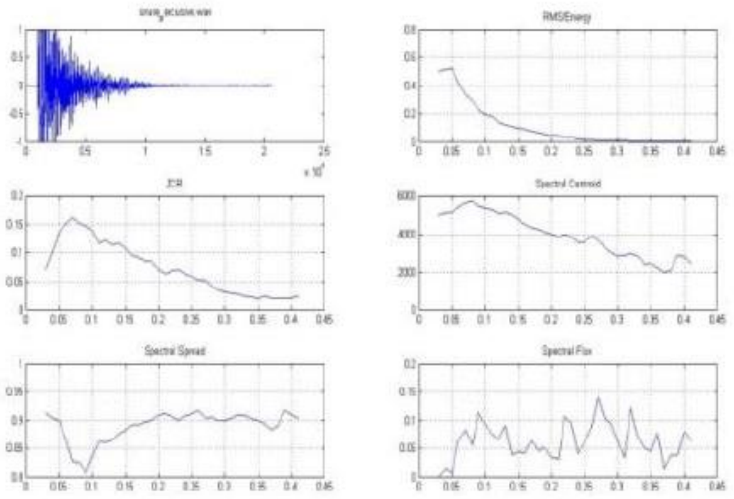


Figure 3. Low Level Features for Snare

Example of Task 3 (Bad example, as it's not easy to discriminate between classes)

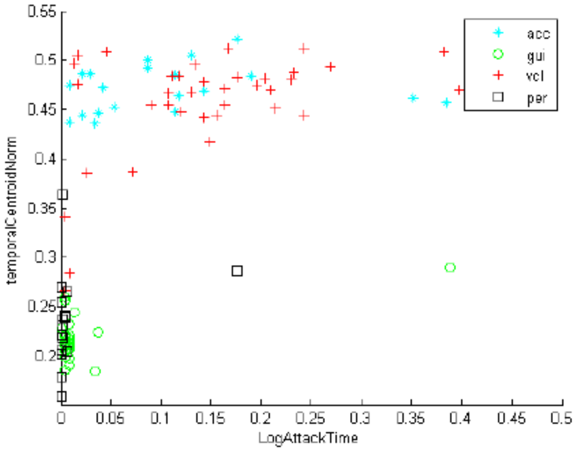


Figure 4. *Log-Attack Time* (mean) vs *Temporal Centroid* (normalized)

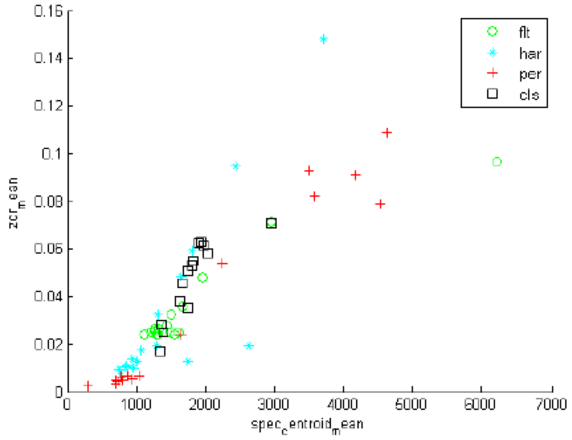
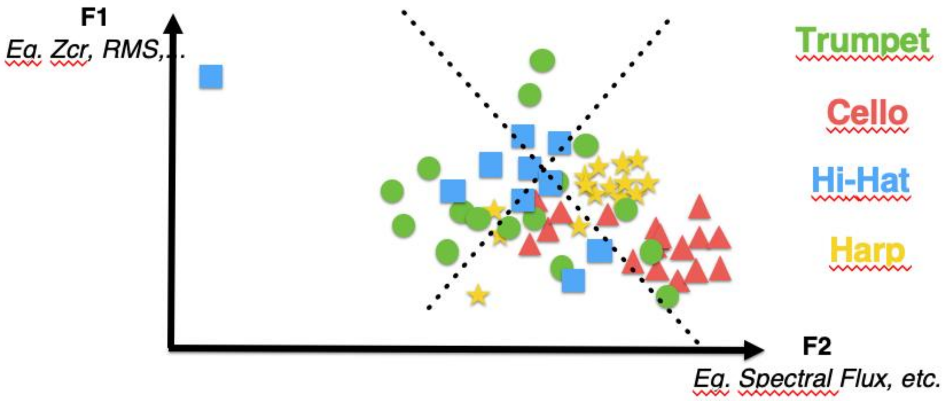


Figure 5. Spectral Centroid (mean) vs ZCR (mean)

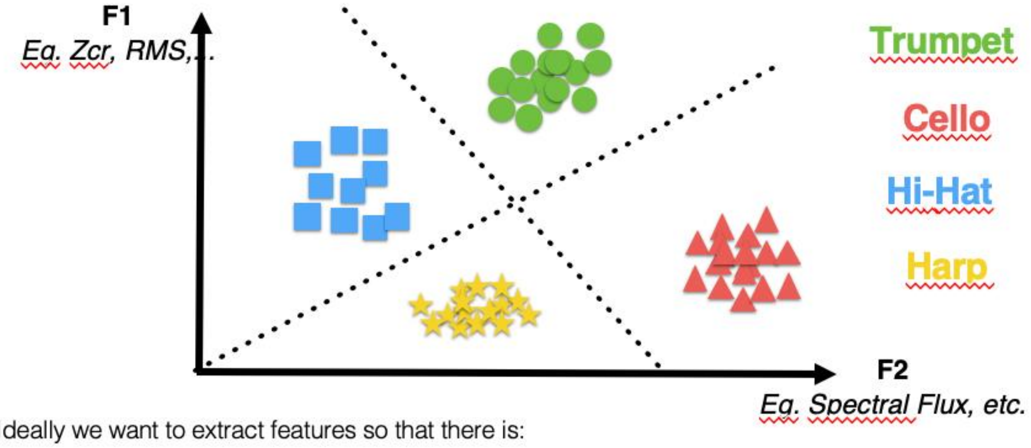
Theoretical basis for Task3 and Task5

Bad Situation



In practice a poor choice of features (F1,F2) can mean it's very difficult to meaningfully separate the data

Ideal Situation



Ideally we want to extract features so that there is:

high intra-class similarity (tight clusters)

high inter-class distance (easy to draw decision boundaries)

Find features that allow to separate the data (visually)