`carat`: A toolbox for computer–aided rhythm analysis *

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1 Introduction

`carat` is a toolbox for computer–aided rhythm analysis from audio recordings, that includes a set of ready–to–use tools in order to maximise its usability by the musicological community. It was developed using free and cross–platform tools, and is released under the MIT licence.

Rhythm is an essential component of music and, being primarily an event–based phenomenon, many important tasks can be tackled using computational tools. Computer–assisted musicology has had a substantial development in the last years, and numerous tools exist for analysing different aspects of musical content, either from a symbolic representation [4] or from a digital audio signal [2, 1, 12]. The latter are of special interest in the analysis of traditional and popular musics, and, in general, of all the musics outside the canon of Western notated music. Most of these tools, however, are available as libraries of functions, and therefore their usability is limited to researchers with a solid background in programming. Additional restrictions may arise, like in the case of toolboxes developed for proprietary environments like Matlab.

With `carat` we hope to ease the adoption of computational tools by musicologists, while at the same time making readily available to MIR researchers some recently developed techniques for rhythm analysis, along with musical examples of their applicability.

In order to fulfil these goals, some key aspects were prioritized in the design. First, we strive for a low barrier to entry for researchers in musicology with no background in scientific programming. Therefore, the toolbox seeks to provide some applications that allow the analysis of individual audio files or collections of music data, enabling certain interaction with the user (for instance, visualization and listening of the analysis). The choice of free, open–source and cross–platform developing tools also contributes to a wider accessibility. Another important criterion was designing the functions and processes in the toolbox to be modular, thus allowing users to provide their own functions or to test other workflows for the analysis.

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2 Toolbox

The present work is part of an interdisciplinary collaboration that pursues the development of computer–aided tools for the analysis of musical rhythm from audio recordings. Research topics addressed include: onset detection and classification, automatic beat and downbeat tracking, rhythmic pattern analysis, characterization of micro–timing deviations, among others. Part of this research was carried out in the context of two international collaboration projects, namely IEMP [5] and StaReL [21].

The software tools were implemented in Python [16], using NumPy [13], SciPy [20], Matplotlib [11] and Scikit–learn [19] libraries. In this initial release, the toolbox includes functions and applications to tackle rhythmic pattern analysis [8]. This involves computing an accentuation feature from the audio recording and organizing it into a map of cycle–length rhythmic patterns. This representation enables the inspection of the similarities and differences between patterns, as well as their evolution over time. Through an interactive process, the rhythmic patterns thus obtained can be automatically clustered into groups based on its similarity. Results from different recordings can be aggregated for the analysis of a music collection [7, 17].

The toolbox also allows for the analysis of the micro–temporal deviations of the rhythmic patterns with regards to a regular metrical grid. This is based on the location of onsets and beats, which can be automatically detected or provided by the user as annotation files [14]. The onsets are normalized according to the length of the beat or the rhythm cycle, and an analysis of their deviations is conducted [6].

3 Applications

Pieces from three different different databases were taken as case studies: Uruguayan candombe drumming [18, 9], Brazilian samba [10, 3] and djembe music from Mali [15]. These three corpora belong to the broad category of percussion music of the Afro–Atlantic tradition, and share some common characteristics. They have, however, several substantial musical differences. For instance, the rhythm cycles of candombe and samba are of different length (four and two beats respectively), although their beats are similarly subdivided (four pulses per beat). In Malian djembe music, on the other hand, we find cycles of four beats with ternary subdivision. Thus, the tools provided in the toolbox should be able to manage cycles of different length and beat subdivision.

Figure 1 shows the clustering analysis of the patterns of the *piano* drum in a recording of Uruguayan candombe. The map of bar–length patterns is depicted at the bottom, and the three–dimension representation corresponds to an Isomap mapping. The centroid of each cluster is shown at the right; the obtained clusters match characteristic patterns of the instrument. The program interface allows the user to listen to individual patterns by selecting them on the image, and the number of clusters can be interactively adjusted [17].

Figure 2 shows a comparative analysis of microtiming in the patterns of the *chico* drum in candombe and the tamborim in Brazilian samba. Both instruments articulate four pulses per beat, shown here along a beat–normalized axis. Both patterns exhibit different degrees of compression with respect to an equal subdivision of the beat [6].

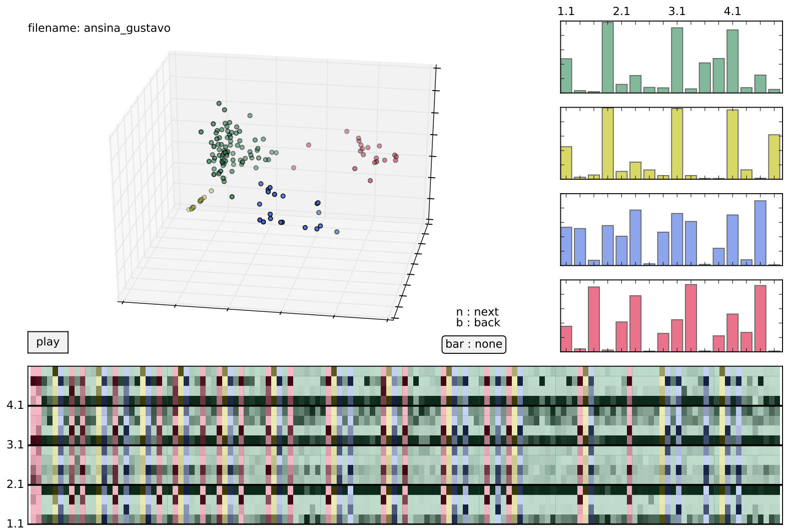

Figure 1: Analysis and classification of *piano* drum patterns

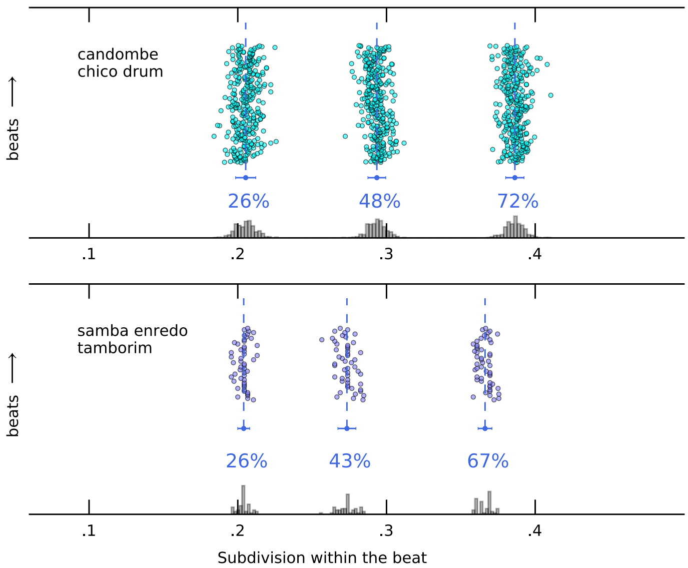

Figure 2: Comparison of microtiming patterns of *chico* drum and tamborim

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