Computational Ethnomusicology for Exploring Trends in Trinidad Steelband Music Through History

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Abstract. In this paper, we present an interdisciplinary case study combining traditional and computational methodologies to study a selection of Trinidad steelband musical trends over a period of 50 years. In particular, a number of facts and/or trends have been clearly identified in the ethnomusicology literature, while some other hypotheses have been regarded as not immediately addressable with traditional methodologies. Here, we employ Music Information Retrieval (MIR) methods to investigate some of these questions. Our results show that the tempo range measured on our corpus is consistent with values reported in ethnomusicological literature, but reveals no clear change trend over time. On the other hand, our results suggest a change of the use of dynamics in the winning performances of the national Panorama competition. Finally, a tendency for homogenization of the tuning frequency and sound of the steelpans also became apparent, most probably due to the standardization of the manufacture of the instruments.

Keywords: Ethnomusicology, Computational Ethnomusicology, Music Information Retrieval, Trinidad, Steelband, Calypso, Soca, Music archive

1 Introduction

The term *computational ethnomusicology* describes research that applies computational methodologies to address ethnomusicological questions. One of the first works on the subject was published as early as 1978 [2]. Collaboration across disciplines is at the heart of computational ethnomusicology. Some music studies may for instance involve the application of computational methods from other domains, e.g., population genetics [3]; computational linguistics [4]. Of particular interest in the present work is the application of methods developed in the discipline of Music Information Retrieval (MIR), which is being increasingly investigated in the recent years, e.g., [5–11]. In this scenario, MIR methods are typically applied to a corpus of audio recordings of ethnomusicological interest

* This work is supported by AHRC Grant No. AH/N504531/1. and the French Labex Pasts in Present http://passes-present.eu/en

in order to gain insight into the construction and properties of the music [1, 9, 11]. Since the development of existing body of MIR work has primarily been developed focused on Western pop music, its application to ethnomusicological material is technically challenging and is therefore a catalyst for advancing the MIR state of the art [10].

In this paper, we present a case study combining traditional and computational methodologies to study a 50-year period of Trinidad steelband music. Steelband music is a distinctive tradition in the Caribbean island of Trinidad. Its idiosyncratic musical character and its status of national symbol [26, 16], make it a case of particular interest for ethnomusicology, see for example [13–16]. A number of facts and trends have been identified regarding Trinidad steelband music in the ethnomusicology literature, while some other hypotheses formulated have not been addressed with traditional methodologies. We propose here to use MIR techniques, which facilitate the realisation of quantitative and labour intensive studies, in order to investigate research questions and hypotheses arising from the ethnomusicological literature dedicated to steelband music [13–15].

The remainder of this paper is structured as follows. In section 2 we present some elements of background on the tradition of Trinidad steelband music. We then introduce the ethnomusicological questions of interest in section 3. Section 4 is dedicated to the presentation of the corpus of audio recordings used in this study as well as descriptors that we extract from it. The results are then presented in section 5, before discussing them and concluding in section 6.

2 Elements of background on steelband music in Trinidad

2.1 From steeldrum to steelband

Steeldrums, also called steelpans or just pans, were invented in the Caribbean island of Trinidad in the 1940s out of the creative exploration of beating various steel/iron containers such as biscuit tins, old cans and dustbin lids. Since World War II, the 55-gallon oil drum has become the container of choice from which to make steeldrums.

A craftsman, called a *tuner*, is responsible for the steeldrum manufacturing process, which includes several steps, such as cutting, sinking, shaping the concave form of the drum, "grooving" the pan to separate notes, shaping the convex forms of the notes, burning and tuning the steeldrum with the use of sledgehammers and nail sets. Instruments are played with sticks tipped with rubber strips or sponge balls.

Early steelbands were marching road bands in which steeldrums were played while hung from a strap around the player's neck. In reference to the way the pans were carried, these traditional types of steelbands were called "Pan Round the Neck". The main function of these early steelbands was to accompany the street processions of the annual Carnival celebrations.

In the first steelbands, the pitch range was limited. As techniques advanced, steelbands grew into steel orchestras. Throughout the 1950s and the 1960s, ensembles became stationary and pannists started to play sets of steeldrums instead of just one pan per player. The range of the pans was extended and today each group of pans contains most if not all the notes in the equal tempered chromatic scale. As the size of the bands expanded, musical arrangements became more complex giving steelbands the possibility of playing a wider range of music.

2.2 Panorama competition and steelband sound

In the newly independent republic of Trinidad and Tobago (Aug. 1962), the Panorama steelband competition was created in 1963 in the frame of a nation-building policy fostering masquerade, calypso traditional narrative ballads[3] and steelband music as carnival arts [12, 15]. Through this institutional policy — interweaving cultural politics and carnival music forms [12] — the state sponsored Panorama competition has become the most prestigious steelband stage performance in Trinidad.

Every year, approximately 30 large conventional steelbands, each composed of a hundred players for the most, take part in the annual Panorama competition. The Panorama rules require that steelbands play an arrangement of a calypso or a soca tune from the current carnival season. The selected tune is arranged in order to display the bands skills. The winner is proclaimed Panorama Champion. Owing to both its prominent and prestigious position, the Panorama competition has had a prime influence on the development of steelband music. One of the consequences of this phenomenon has been the promotion of the arranger and the tuner as key figures of the steelband movement.

With the rising importance of the arrangers, the steelband music development incorporated elements of European repertoires, such as the symphonic sonata form, as well as adaptations of Afro-Trinidadian repertoires and musical procedures (cyclical forms, polyrhythmic texture, call-and-response) [16]. By the end of the 1960s, calypso or soca steelband arrangements displayed features that were yet to become conventions: "theme and variations" formal structure including introduction, verse, chorus, variations on the original melody (first variation, second variation), key modulations, melody in minor mode, cyclical "jam" sections, coda [16, 13]. These conventions still structure todays steelbands arrangements.

With the rising importance of the tuners, the manufacture of the steeldrums evolved. Through the development of melodic steeldrums (based on diatonic scales) followed by the elaboration of fully chromatic ones (1950s), the unique sound of steelband was shaped over time: "compared to the early days of the steeldrum, the sound of todays instrument is far more refined, mellower in tone, and there is a much wider range of pitches utilized" [14].

3 Research questions

We now present the research questions that we investigate in this paper. In particular, we are interested in the potential changes in tempo, dynamic range

[3] Calypso is a style of caribbean music that originated in Trinidad and Tobago. For a more detailed description of Calypso, see for example [25]

and sonic properties of Trinidad steelband music over time. Does the tempo tend to be faster in more recent pieces? Do arrangers use increasingly large dynamic ranges? Has there been a change in the sonic properties of steelbands? We detail further these research questions in the following.

Our first research question relates to the change of tempo over time. In particular, the hypothesis suggesting that tempo has increased over time seems to emerge from ethnomusicological works. Guilbault writes that in the post-independent era: "pan calypsos were performed in an upbeat tempo in the 1960s equivalent to 112, and in the mid-1970s, reaching 126" [12]. Following a similar idea, Dudley mentions Panorama competition constraints as being responsible for "placing a premium on speed" [15]. Overall, these works suggest that the canonical tempo range may have changed over the decades and that the competitive nature of the panorama competition may be a force pushing towards ensembles to play with higher speed.

Secondly, we investigate the use of musical dynamics over time. Based on the premise that the tunes performed in the Panorama competition are arranged so as to display the bands' skills, and that a fine control of the musical dynamics requires a high level of musicianship, it can be hypothesised that the use of large dynamics is a valuable asset for winning the Panorama competition. Expanding on the idea that the competitive nature of the event relates to an increase in virtuosity of the performances over time, we investigate a possible change of the range of dynamics used in the panorama competition in the following sections.

A final aspect of interest in our study is the sonic properties of the steelband. Aho articulates a link between the development of the Panorama competition and the change of the steelband sound [14]: "Although there is no empirical evidence to verify the observation, it seems quite likely that as the steelband began to engage in sponsored musical competition with audiences including middle-class people, they sought to maintain and increase the latter's interest and support by striving for a smoother, more refined sound, a wider range of notes". Complementary to Aho's idea, Dudley articulates a dynamic link between the change of steelband sound and the steeldrum manufacture improvements: "the transformation of the steeldrums timbre is almost invariably portrayed as an improvement of the instrument" [16]. The emulation between tuners channeled through the Panorama competition constraints led to a refinement of the steeldrum timbre transforming a "vulgar underclass pastime into national instrument" [16]. Building on these observations, we seek to investigate whether computational methods can help identify a change of the sound of the steelband, as a result of the improvement of the manufacture of the steeldrums.

4 Methodology

We now attempt to address the ethnomusicological research questions presented in section 3 with the aid of computational methods. In the remainder of this section, we describe the audio recording corpus we use for study (section 4.1), then present the descriptors we automatically extract from the audio recordings (section 4.2 to section 4.5).

4.1 Music corpus

Section 2.2 highlights the prominent role played by the Panorama competition in the steelband music tradition of Trinidad. Based on this premise, we select recordings of Panorama performances as our corpus of study for its representativeness.

All digital recordings used in this paper are part the "CNRS - Musee de l'Homme" sound archives[4], which are accessible via the Telemeta platform[5] [18]. This musical data includes field recordings as well as published recordings, which are a mixture of digitised analog recordings and digital recordings. In particular, we assembled a corpus made of recordings of most of the steelband calypsos/socas performed by the winners (position 1, 2, 3) for each yearly Panorama competition between 1963 and 2015[6]. In other words, the corpus covers the entire lifespan of the Panorama competition, from 1963 to today. We assume that this Panorama champions database reflects the musical trends for this period as these arrangements/compositions were judged as the best of the Panorama competition in their respective years. As a result, this corpus contains 94 pieces, each piece being typically 8-10mins long, totalling about 14hrs of audio data.

4.2 Tempo

In order to address the question of a change of tempo in winning Panorama pieces, we estimate the tempo value for each track using state of the art algorithms implemented in the *madmom* library [19]. In particular, we employ the algorithm proposed by Böck et. al. in [20]. Since the Panorama competition is restricted to steelband arrangements of soca and calypso tunes, it can be expected that musical pieces will be played at a medium tempo, about 110-130 BPM (cf. section 3). We therefore restrict the possible tempo range to 80-160BPM in our computations. The main benefit of imposing this constraint is that it prevents the occurrence of octave errors in the tempo estimation.

4.3 Dynamics range

Another research question we are concerned with in this paper is concerned with the changes in the use of dynamics by Panorama winners. Note that the term "dynamics" is understood in the musical sense here, that is to say to describe the loudness at which performers play music, e.g. *piano* or *forte*. More specifically,

[4] `http://archives.crem-cnrs.fr/`
[5] `http://telemeta.org/`
[6] Although we intended to include all winners for every year, some of these recordings are not present in the archive

we are interested in the dynamic range used in the panorama competition, i.e. the difference between the loudest and quietest part of a given piece.

For each track, we compute the loudness using the ITU 1770.3 standard [21]. Following this specification, the audio recording is first divided in L blocks of 400ms length with 75% overlap. By computing the loudness for each block, the changes in loudness in a piece are captured in $\mathbf{l} = (l_1, \cdots, l_L)$, where l_i denotes the loudness of the i^{th} block. The loudness range may then be defined as the difference between the loudest and quietest point in the track $R = \max(\mathbf{l}) - \min(\mathbf{l})$.

It is clear that this measure is very sensitive to the presence of, e.g., silence in the audio. Moreover, the recordings in our corpus sometimes include a presentation of the performers by the competition speaker at the end and/or the beginning of the recording. In order to guarantee that we effectively assess the range of dynamics used in the music and incorporate robustness against recording artifacts, we first trim the silence at the beginning and at the end of the recording. Secondly, in order to get rid of speaker announcements and applauses, we then trim an extra 30s at the beginning and at the end of each track. The loudness of the resulting track is denoted as $\hat{\mathbf{l}}$. The musical dynamics range is then computed as $\hat{R} = \max(\hat{\mathbf{l}}) - \min(\hat{\mathbf{l}})$.

4.4 Tuning Frequency

The A 440Hz is regarded as the current Western standard tuning frequency. However, even in Western musical traditions the tuning frequency used by performers and ensembles has evolved through history and still exhibits some variability nowadays. In fact it is not unusual to encounter tuning frequencies that differ from A 440Hz. Since the process of manufacture of steelpans has evolved in Trinidad and Tobago over the past few decades (cf. section 3), we hypothesise that this may have impacted the tuning frequency used by ensembles. In order to test this hypothesis, we use the vamp plugin implementation[7] of the algorithm proposed by Mauch et. al in [22] for estimating the tuning frequency of each recording.

4.5 Dissonance

Following a rationale similar to section 4.4, and according to the existing ethnomusicological hypotheses described in section 3, we seek to estimate whether or not the evolution of the manufacture of the steelpans has resulted in measurable differences in the timbre properties of the instruments.

The recording conditions can vary significantly from one recording to the next in our corpus of study. It is therefore to be expected that an estimate of timbre computed from such a recording would be influenced by both the timbre of music and the recording conditions. In order to quantify properties of the steelband sound, we chose to compute the *dissonance* feature extracted by the

[7] `http://www.isophonics.net/nnls-chroma`

Essentia library [23] because it relies on the comparison of pairs spectral peaks [24] and is therefore expected to be less sensitive to recording conditions than spectral shapes estimates such as MFCCs[8].

5 Results

In this section, we analyze the descriptors introduced in section 4 to address the ethnomusicological research questions detailed in section 3.

5.1 Tempo

Let us first consider the tempo. Panorama steelband performances typically do not feature significant tempo change over the course of a piece. We therefore produced a single tempo estimate per piece. The results are shown in Fig. 1 (a). First of all, it appears that most of the pieces are played at a tempo in the 110-150 BPM, consistent with observations made in the literature [13]. One may note that there are a few estimates below the 110BPM mark. After manual inspection, we found that these estimates correspond to errors in the algorithmic tempo estimation. In these cases, the computational estimate correspond to a tempo that is 2/3 of the correct value.

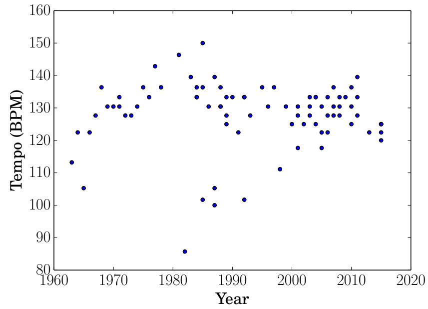
Leaving the erroneous outliers estimates aside, we see no clear trend in this data. The Pearson correlation between tempo and time is $r = 0.03$ ($p = 0.79$). As a conclusion, even if the Panorama competition places "a premium on speed" [15], our results provide no evidence to support the hypothesis of a trend of increasing tempo of winning Panorama performances.

5.2 Dynamics range

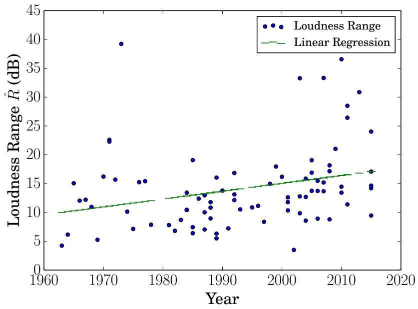
Fig. 1 (b) shows the value of $\hat{R}$ computed for each track of the Panorama winners corpus. It appears that most of the estimates lie in the 5-20dB range, with the addition of some outliers above 20dB. Overall there seem to be a trend for a slow but steady increase of the dynamics range over time. Linear regression suggests a significant positive correlation between $\hat{R}$ and time, $r = 0.28$ ($p = 0.009$).

Because the computation of the loudness range is very sensitive to outliers, we also computed the loundness Inter-Quartile Range (IQR), which is robust against outliers and show results in Fig 1 (c). The loudness IQR measures the interval between the 75th and 25th percentiles, thereby indicating the range covered by the most frequently occurring values. As such it provides an indication of the overall dispersion of loudness values. The results shown on Fig. 1 (c) suggests that the distribution of loudness IQR does not seem to significantly change over time. The Pearson coefficient also reveals the absence of a linear correlation ($p = 0.53$).

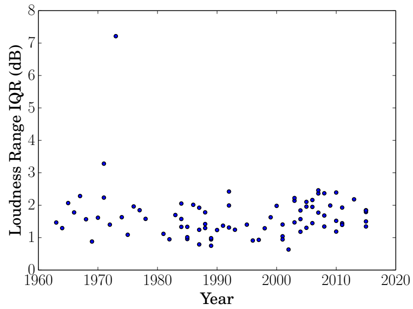
[8] `http://essentia.upf.edu/documentation/reference/std\_Dissonance.html`



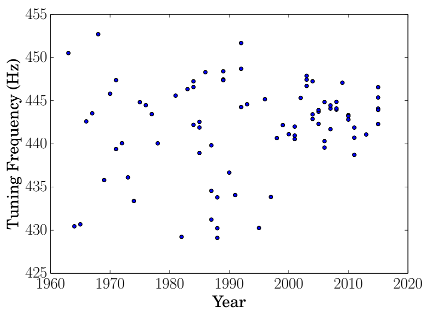
(a) Tempo



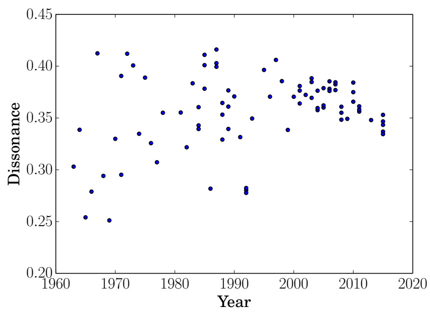
(b) Loudness Range with linear regression ($r = 0.28$,$p = 0.009$)



(c) Loudness Range IQR



(d) Tuning Frequency



(e) Dissonance

Fig. 1: Audio features for the winning Panorama performances. Each dot represents the estimate computed from one track of the Panorama winners corpus (1963-2015). The estimates presented are: (a) the tempo (cf. section 4.2), (b) and (c) the Loudness range with linear regression ($r = 0.28$,$p = 0.009$) and Loudness range IQR respectively (cf. section 4.3), (d) the tuning frequency (cf. section 4.4) and (e) the dissonance measure (cf. section 4.5).

The conclusions that can be drawn from these observations are two fold. First, it appears that winning Panorama performances are played at a remarkably consistent loudness level, as suggested by the typical loudness IQR of 1-2dB. Since the IQR is measured piece by piece, it can be assumed that the recording conditions are consistent within one recording. The small loudness IQR may then be interpreted as a high level of dynamic consistency in the steelband performance. On the other hand, the loudness range employed in the same winning performances seems to have been increasing over time — see Fig. 1 (b). Moreover, it is interesting to note that the typical dynamic range is of the order of 10-20dB, i.e. an order of magnitude larger than the IQR. This suggest that the winning pieces feature very large variations of dynamics on a very small time scale, and almost no variations on a longer time scale. In other words, it suggests that the large dynamics variations observed may correspond to short crescendos, short drops of dynamics, or short stops etc. Note that the instances of very large loudness range (e.g. 30dB and above) may be explained by the presence of short stops in the music: the dynamics then vary from silence to the loudest point in the piece, hence a very large dynamics range.

5.3 Tuning Frequency

We now focus on the tuning frequency, set by the tuner during the manufacture of the pans, as an indicator of the change of the steelpan sound. Fig 1 (d) shows the tuning frequency estimates for each track of the panorama winning performances corpus, computed according to the method described in section 4.4. It appears that the distribution of tuning frequency seems to have narrowed around the turn of the 21st century. Indeed, in the last two decades, the tuning frequency seems to be confined in the 440-450Hz range while it was spanning the 430-450Hz range until the late 1990's. This result tends to support the hypothesis of a form of standardisation, and therefore homogenisation, of the steelpan manufacture specifications.

5.4 Dissonance

In complement to section 5.3, the dissonance estimates computed according to the method described in section 4.5 are shown in Fig. 1 (e). This descriptor is computed as a proxy to evaluate the sound of the steelbands.

An observation similar to the case of the tuning frequency can be made here: the variability has gradually decreased over time, so that the spread of dissonance values in the 2000's is significantly smaller than in the 1960's. In other words, this audio descriptor also suggests a trend towards the homogenisation of the sound of steelbands over time.

6 Discussion and Conclusion

This paper presents an interdisciplinary case study of a selection of ethnomusicological hypotheses regarding musical trends in the Trinidad steelbands performances over time. Choosing the Panorama competition winners for their representativity of the musical tradition of Trinidad and Tobago, we assembled a corpus of recordings covering a period of over 50 years. Starting from research questions and hypotheses stemming from the ethnomusicological literature, we employed MIR methods to compute descriptors related to the musical properties of interest from the audio recordings. Our results show that the tempo range measured on our corpus is consistent with values reported in ethnomusicological literature but do not show any clear trend of increasing over time. On the other hand, our results suggest a possible change in the use of dynamics in the winning performances of the national Panorama competition. Finally, a possible tendency for homogenisation of the sound of the steelbands is suggested by our results. We hypotheise that this tendency may be due to the standardisation of the manufacture of the instruments.

In this paper we propose to investigate a selection of ethnomusicological hypotheses via the use of computational methods to analyse a corpus of audio recordings of live musical performances. Music recording corpora used for ethnomusicological research typically are either ethnographic recordings or field recordings (both in our case), which are produced in very heterogeneous conditions that are mostly uncontrolled. In addition, it is often not possible to evaluate the impact of these recording conditions on the properties of the musical recordings. Though not all audio features are equally affected, the estimates produced by MIR tools on such corpora may only have limited reliability. Results of computational analyses carried out on such a corpus should therefore be interpreted with due care. In conclusion, this case study suggests some answers to our hypotheses and should therefore be regarded as a starting point from which to develop further investigations.

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