Distortion: the sound of distorted electric guitar between perception, spectral descriptors and artificial intelligence

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Abstract: The distorted electric guitar sound is an important aspect when the subject is rock and metal music and it is usually referred to with generic terms like 'sharp', 'rounded', 'glassy' or 'heavy'. However, nowadays we have tools able to analyze a large amount of sonic features and artificial intelligence capable of separating the guitar parts from a master track. Analysis observing those terms and feature classification may be relevant in order to correlate the perception with the measurable aspects of sound. This study, an experimental analysis in progress, aims to investigate the sonic characteristics on the sound of the distorted guitar parts recorded on the songs *Feijão de Corda* (Kiko Loureiro) and *De Joelhos* (Fred Andrade). We used the app *Moises AI* to extract guitar parts from the master tracks and the software *Sonic Visualiser* to perform an analysis using the audio descriptors Loudness, Spectral Centroid and Inharmonicity. We listened to all the tracks repeatedly and took notes about relevant parts. The results were important to understand how the descriptors are related to timbre and features perceived by listening to distorted electric guitar sound and also observed the usability of *Moises AI* on this kind of analysis.

Keywords: Electric guitar. Distortion. Sonic Visualiser. Artificial Intelligence. *Moises* AI.

Distorção: o som da guitarra elétrica distorcida entre percepção, descritores de espectro e inteligência artificial

Resumo: O som da guitarra elétrica distorcida é um importante aspecto quando o assunto é rock e metal, sendo comumente referido com termos genéricos como 'afiado', 'arredondado', 'transparente' ou 'pesado'. Porém, atualmente temos acesso a ferramentas capazes de analisar um grande grupo de aspectos sonoros e inteligência artificial que conseguem separar partes de guitarra de uma gravação masterizada. Análises observando esses termos e as classificações dos referidos aspectos podem ser relevantes para correlacionar percepção e aspectos sonoros mensuráveis. Este estudo também foi realizada a escuta repetida das obras, tomando notas dos pontos mais relevantes. Os resultados foram importantes para a compreensão de como esses descritores se relacionam com o timbre e as características percebidas na escuta do som de guitarra distorcido, além da análise da usabilidade do aplicativo *Moises AI* para extrair faixas sonoras passíveis de análise no Sonic Visualizer.

Palavras-chave: Guitarra elétrica. Distorção. Sonic Visualiser. Inteligência artificial. *Moises AI*.

Introduction

Distortion is a word with a large number of different meanings and it becomes an important aspect when the subject is rock and metal music. Those genres may be recognized by a group of characteristics like heavy drums and bass, keyboards such as Hammond organ and piano, a large variety of vocal timbres, keyboards and even percussion and orchestral elements, when the song is related to some kind of hybridism. However, the sound of the distorted electric guitar is a sonic trademark of most rock and metal music genres (HERBST, 2019). When the subject is metal music, Walser (1993) argues that the most important aural sign of heavy metal is the sound of a distorted electric guitar.

Jimi Hendrix is known, among other characteristics, for his guitar techniques using distortion, saturating his tube guitar amplifiers on high levels and pushing them with pedals like the Fuzz Face. He released his album *Electric Ladyland* in 1968, a year after The Beatles released *Sergeant Pepper's Lonely Hearts Club's Bands*. In both those records, which are references in rock music, the distorted electric guitar is an essential item (LUVIZOTTO; FURLANETE; MANZOLLI, 2006).

The distorted electric guitar is also one of the main elements to identify the 'rock part' in situations of hybridism between rock or metal with other genres as seen in the work of bands like Sepultura, Angra, Rhapsody, Avantasia, Myrath and Nightwish. Pointing to this study's subject, those elements also can be found on instrumental music released by Brazilian guitar players like Pepeu Gomes, Heraldo do Monte, Kiko Loureiro and Fred Andrade.

In the absence of a more appropriate qualification, generic terms have been used to name the characteristics of a distorted guitar sound, frequently explained with associations like 'sharp', 'rounded', 'glassy' or 'heavy'.

Heaviness, for example, is acoustically described as a result of three elements: piercing treble frequencies, great loudness and harmonic dissonance. Distortion affects all three parameters and it may be the reason why it is commonly associated with the sound of the distorted guitar. (BERGER; FALES, 2005; HERBST, 2018).

In fact, features like pitch, timbre and loudness are perceptual qualities of sound with a certain amount of subjectivity. Perceptually correlated feature extraction and classification may be relevant in order to correlate the perceptual with the scientifically measurable aspects of sound (BULLOCK, 2008). To analyze specific sound features of recorded music in order to provide a better understanding of those characteristics and to complement information extracted from the score, computers have been used to analyze score and digital audio recordings, revealing acoustic and psychoacoustic features (MÜLLER, 2015; ROSSETTI, ANTUNES, MANZOLLI, 2022).

As a part of a bigger research, this experimental analysis in progress aims to investigate the sonic characteristics on the sound of the distorted guitar parts recorded on the pieces *Feijão de Corda* (Kiko Loureiro) and *De Joelhos* (Fred Andrade).

About the method, the first step of this experiment was to test the usability of a distorted guitar track extracted from a master track using *Moises AI*. We used a personal music project, uploaded its master track to *Moises AI* and extracted the lead guitar track, in order to compare this extract with the original lead guitar track, exported directly from the *Logic Pro X* project. After that, we used *Moises AI* to extract the lead guitar tracks of the songs that are the subject of this study: Kiko Loureiro's *Feijão de Corda* and Fred Andrade's *De Joelhos*. Then we used the software *Sonic Visualiser* and utilized the audio descriptors Loudness, Spectral Centroid and Inharmonicity to reveal a few timbre characteristics of those recordings. We also performed a Listening test, where we listened to all the tracks and we took notes about relevant parts.

Moises AI

Ten years ago, when someone asked if it was possible to remove the voice from a song, We used to say that it was the same as asking a baker to remove some eggs from a cake. Nowadays it is beginning to be possible due to the evolution of Artificial Intelligence - AI even the result not being exactly the same is the isolated track from the original session. *Moises AI* is one of the applications able to do that task with a free version and two paid versions. In this study, conducted in 2024, we used the Premium version, which costs US$5.99 monthly.

Softwares like *Moises AI*, that works with source separation, are usually developed using neural-network based machine learning systems and a large amount of training data is required to train them. Pereira *et al*. (2023) published their work on the MoisesDB dataset for musical source separation, which consists of 240 tracks from 45 artists, covering twelve musical genres. They provided individual audio sources organized in a two-level hierarchical taxonomy of stems for each song. According to the authors, it facilitated building and evaluating fine-grained source separation systems, going beyond the limitation of using four stems like, for example, drums, bass, other, and vocals.

In fact, differently from when we started using *Moises AI* two years ago, the current version even recognizes lead guitar; rhythm guitar; acoustic and electric guitars, which were essential to this study.

Even being very useful, the *Moises AI* algorithm, based on an AI that recognizes different instruments, shows some flaws on the track separation. Listening shows that one of the tools is based on the spectral range of the instruments. So, as we will discuss later, a bass solo played on its higher notes may be recognized by *Moises AI* as a guitar track instead of a bass track or a part of the lead guitar track playing chords or the double stops technique may be understood by the AI as a part of the rhythm guitar track.

Despite that, one of the problems on this experimental study was to discover if a distorted guitar track extracted using *Moises AI* would be useful to perform an analysis of sonic features, using the software Sonic Visualiser to observe the descriptors Loudness, Spectral Centroid and Inharmonicity. The next session is about the definitions of those descriptors and what can be inferred from the sound once the researcher has that kind of information.

Loudness, Spectral Centroid and Inharmonicity

According to the American National Standards Institute (1973), Loudness may be described as an attribute of auditory sensation where sounds can be disposed of on a scale ranging from quiet to loud and may be explained as a perception of sound pressure.

Another aspect mentioned as determinant for the perception of ‘Heaviness’ was piercing treble frequencies (BERGER; FALES, 2005), which are highly associated with the impression of ‘brightness’ on a sound and a tool used in digital signal processing called Spectral Centroid. The spectral centroid is the barycenter of the spectrum and it is computed considering the spectrum as a distribution whose frequencies and the probabilities are the values to observe (PEETERS, 2004). Also known as center of spectral mass, Spectral centroid is a measure used to characterize a spectrum, indicating the center of mass of the spectrum location to measure musical timbre (GREY; GORDON, 1978).

The third descriptor, inharmonicity, represents the divergence between the signal spectral components from a purely harmonic signal. Computed as an energy weighted divergence of the spectral components from the multiple of the fundamental frequency, its coefficient ranges from 0 to 1, with 0 being the purely harmonic signal and 1 representing the inharmonic signal (PEETERS, 2004). A note contains a large group of overtones even when perceived as a single pitch. Inharmonicity is a measure to observe how far frequencies of overtones depart from multiples of the harmonic series. It is related to the perception of warmth on musical instruments' sound, especially when they pass through a digital process (KARJALAINEN, 1999).

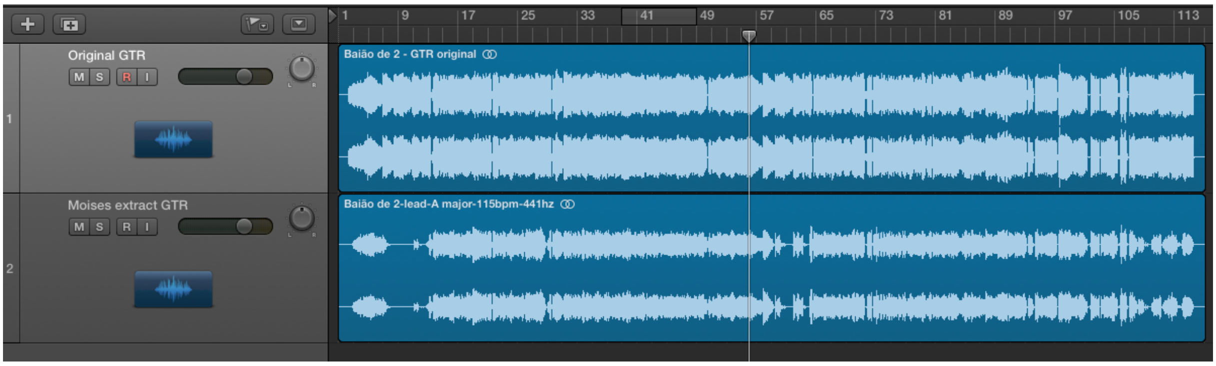
The guitar is a delicate instrument when the subject is inharmonicity. The musician or professional tuner has to take both temperament and string inharmonicity into account when tuning the acoustic, electric or bass guitar. Due to its type of construction, even a guitar precisely built without fret or neck angle errors, inharmonicity can make hard tuning open strings to notes stopped on the fifth or fourth frets. Inharmonicity also demands fine octave adjustments, once the partials go progressively sharp in relation to the fundamental tone of the string.

The overtones are close to the whole number multiples of the fundamental frequency in stringed instruments such as the guitar, due to the size and elasticity of the strings, with elasticity meaning a group of characteristics like thickness, size, tension and stiffness, leading to a state where inharmonicity is inversely proportional to elasticity. In other words, the less elastic the strings are, the more inharmonicity they exhibit (KARJALAINEN, 1999).

With those concepts in mind, the next part of this paper brings the results of the tests and their analysis.

Analysis and results

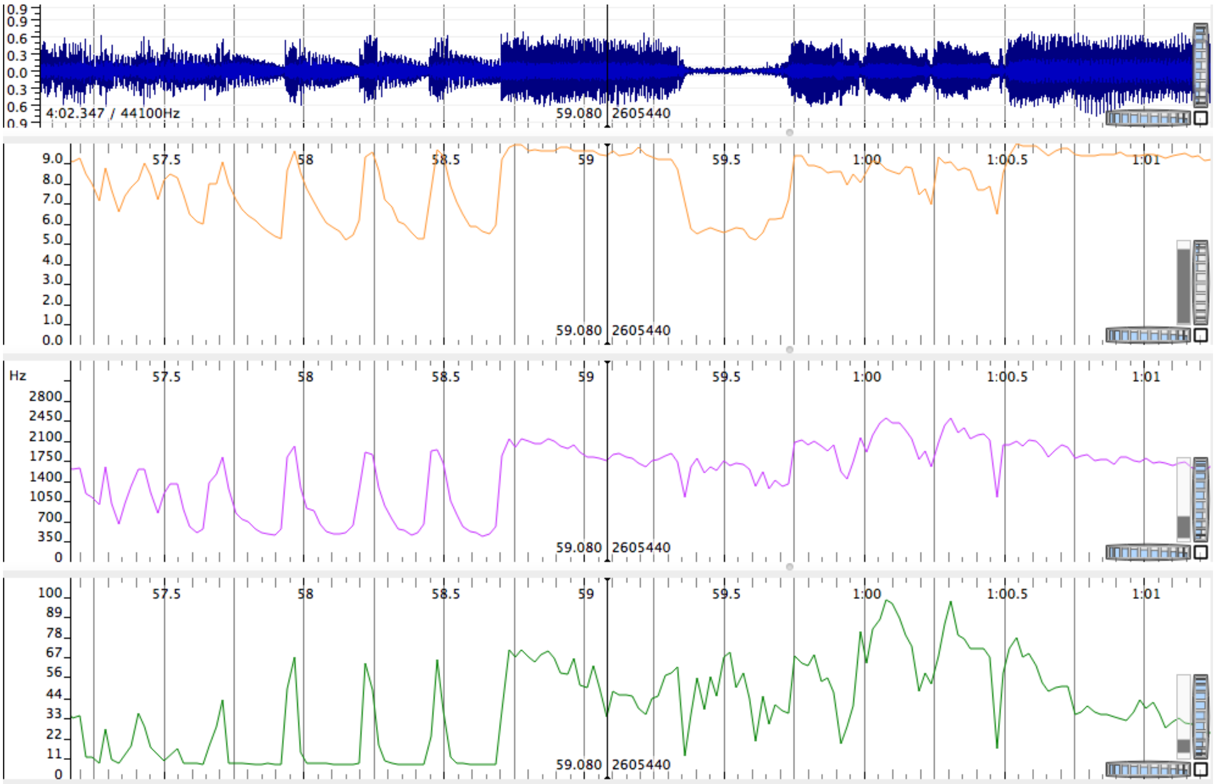
To test if distorted guitar tracks extracted from a master track could be useful to our analysis we used a personal music project as a reference track. The goal was to compare the original lead guitar track with the one extracted from its master using *Moises AI*. Both tracks were exported from the *Logic Pro X* project with 44.100kHz and 24 bits. Then the Master track was uploaded to *Moises AI* to separate the lead guitar from Master track and so we had two lead guitar tracks named Original GTR and Moises *AI* extract GTR. The Example 1 shows both tracks on the Logic Pro X screen.



Ex.1: Control tracks comparison on Logic Pro X

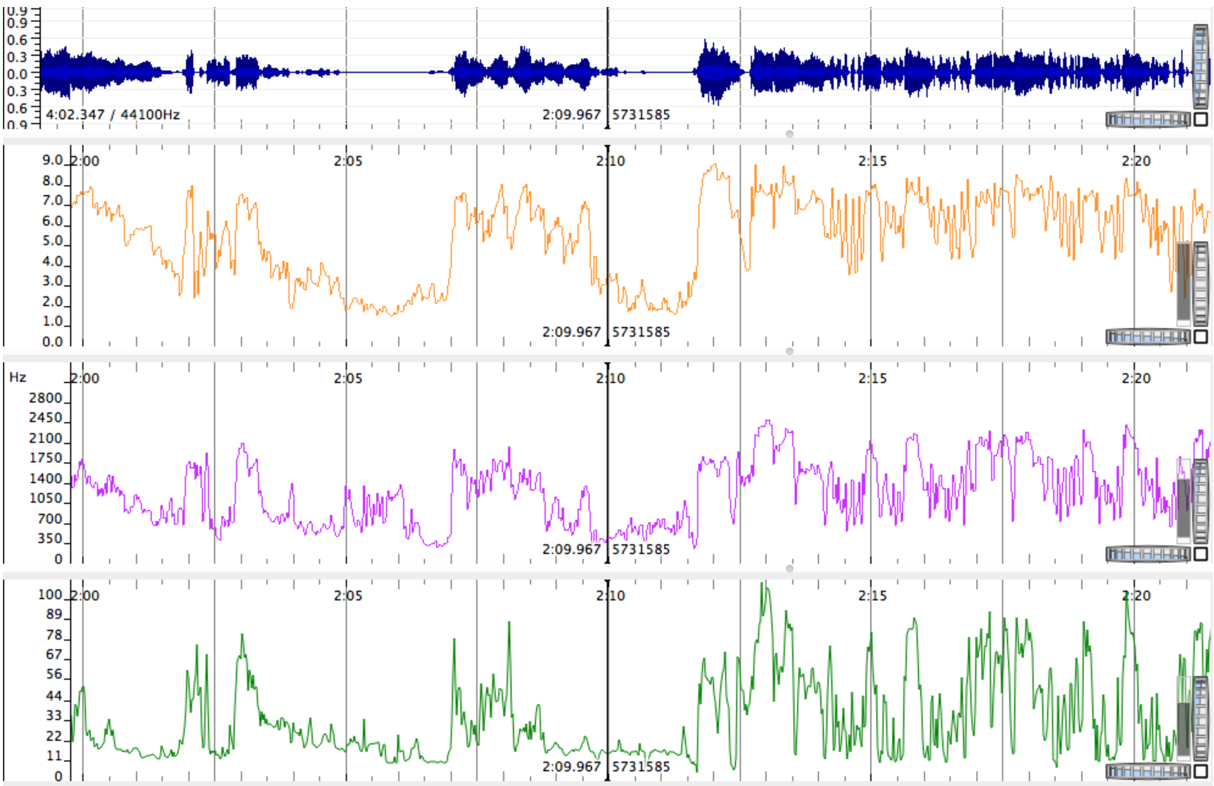
That representation of the waveform presents time on the horizontal axis and intensity on the vertical axis. The first thing noticed is the difference on the output level, with the original track being visually louder, confirming the perception of the listening analysis. Also, as mentioned before, it shows that Moises recognized a lead guitar playing double stops as rhythm guitar and not extracting them to the lead guitar track, as we can see around the compass 9 for example.

The second step was the analysis of both tracks using the software *Sonic Visualiser*, a free and open-source application designed to study and analyze recorded music. Based on previous experience and the three elements affected by distortion and described as determinants to the perception of ‘heaviness’ (BERGER; FALES, 2005), the chosen descriptors, as mentioned before, were Loudness, Spectral Centroid and Inharmonicity. The Example 2 is the *Sonic Visualiser* screen of the Original GTR track analysis, with the Waveform on top followed by Loudness (orange), Spectral Centroid (purple) and Inharmonicity (green). The values and colors will be the same on all track analysis.



Ex.2: Original lead guitar Sonic Visualiser analysis

The Example 3 shows the Sonic Visualizer screen analysis to the control track extracted using *Moises AI*. It is on the same page in order to facilitate the comparison between the tracks. As mentioned before, the disposition, values and colors are the same: waveform on top followed by Loudness (orange), Spectral Centroid (purple) and Inharmonicity (green).



Ex.3: *Moises AI* extracted lead guitar Sonic Visualiser analysis

It is possible to observe a relevant difference from one track to the other, specially between 2:08 and 2:12 seconds, where the original track shows an intense movement while the one extracted using *Moises AI* goes to a quiet and slow movement on all descriptors screen. That part is one of the moments where *Moises AI* recognized chords played on the lead guitar as rhythm guitar and didn't extract that guitar part to the correct channel.

We observed that the original guitar track has a higher spectral density, corroborating with the results that appeared on Logic Pro X. As can be seen on Example 2, on the original lead guitar track the Loudness pane on Sonic Visualiser points the highest peaks above 9.0. The guitar track extracted using Moises *AI* presents lower peaks than the original one, barely touching the mark 9.0 on the meter scale, as shown on Example 3.

The lowest peaks are even farther than each other, with notes above 9.0 on the original track while the *Moises AI* extract floating around 2.0 and 4.0. However, it is possible to see a similarity in the curve's behavior, which leads to the understanding that, even without being exactly the same, it is possible to conduct an experiment on Loudness using tracks extracted using *Moises AI*.

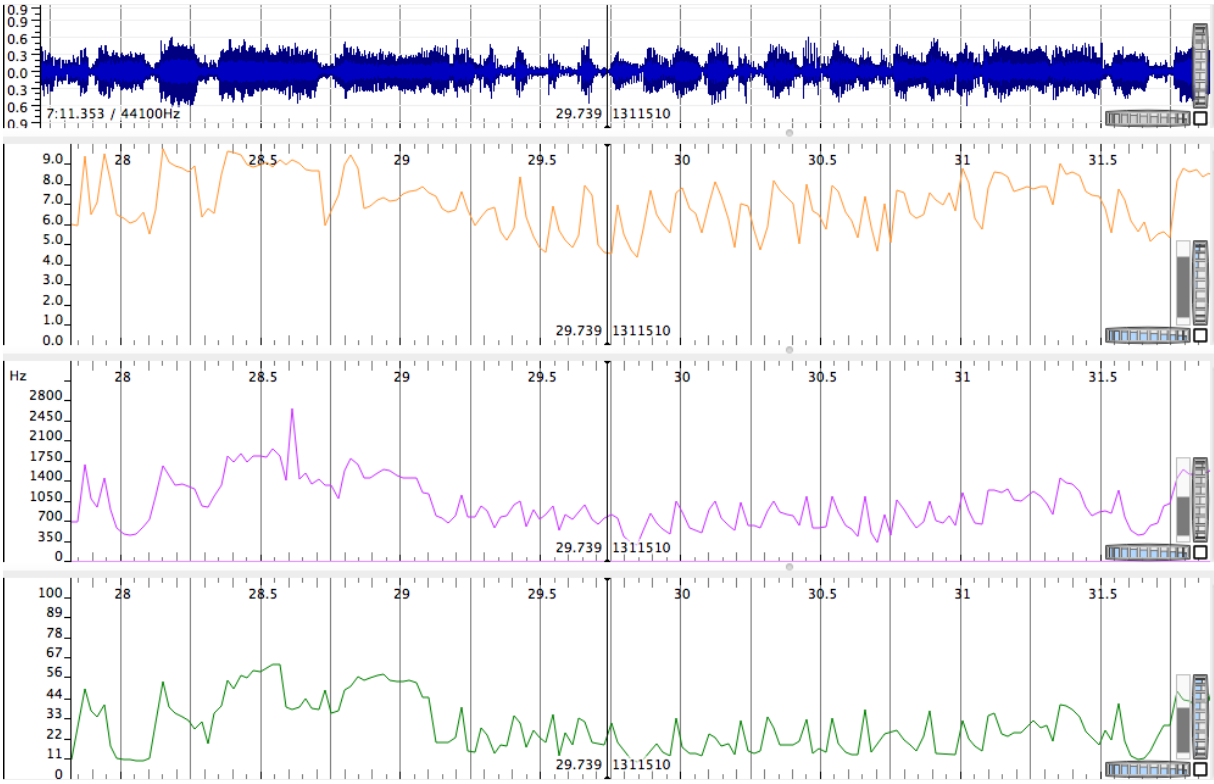
The second descriptor, Spectral centroid, confirms the loss of high notes on the listening test. The original track starts at 2100 Hz on the first part of the curve seen on the screen while the *Moises AI* extracted track stays around 700 Hz at the same point. The Spectral centroid analysis shows different curves, providing some insecurity to use sounds extracted using *Moises AI* to the main objective of this study, however, that decrease observed on the Spectral centroid level may be related to due to the cutting of the higher frequencies of the guitar partials, which happens when *Moises AI* extract the guitar track from the master track.

To the proper observation of the inharmonicity analysis, the vertical axis was adjusted to show values between 0 and 100, with 0 being the purely harmonic signal and 100 (valuing actually 1) representing the inharmonic signal.

Inharmonicity analysis showed a relevant similarity between the tracks, with the exception of the part recognized by *Moises AI* as rhythm guitar. From 2:12 to 2:16 second they are pretty close and that cut is the main riff of the song, which means that most relevant information is still there, although the researcher still has to perform a listening analysis to understand the nuances of the performance on the recorded song. It also makes it possible to observe the inharmonic characteristic of the distorted electric guitar sound.

Despite the differences observed, specially on spectral centroid and inharmonicity, the insecurity about the usability of *Moises AI* for our analysis is mitigated by the listening test, where we were able to easily identify the song even with the higher notes loss and the lack of some lead guitar parts. This comparative test performed on a reference track led our research to understanding that it is possible to use distorted guitar tracks extracted using *Moises AI* to our Sonic Visualizer analysis in order to observe the sonic characteristics of the guitar tracks which are the main subject of this study, which will be detailed from now on.

The example 4 shows the analysis of the song *Feijão de Corda* (Kiko Loureiro). The version analyzed was taken from the live concert Instrumental Sesc Brasil. The excerpt analyzed was chosen because it's the end of the intro, which ends around 29 seconds and the beginning of the main theme, which appears on the rest of the screen.

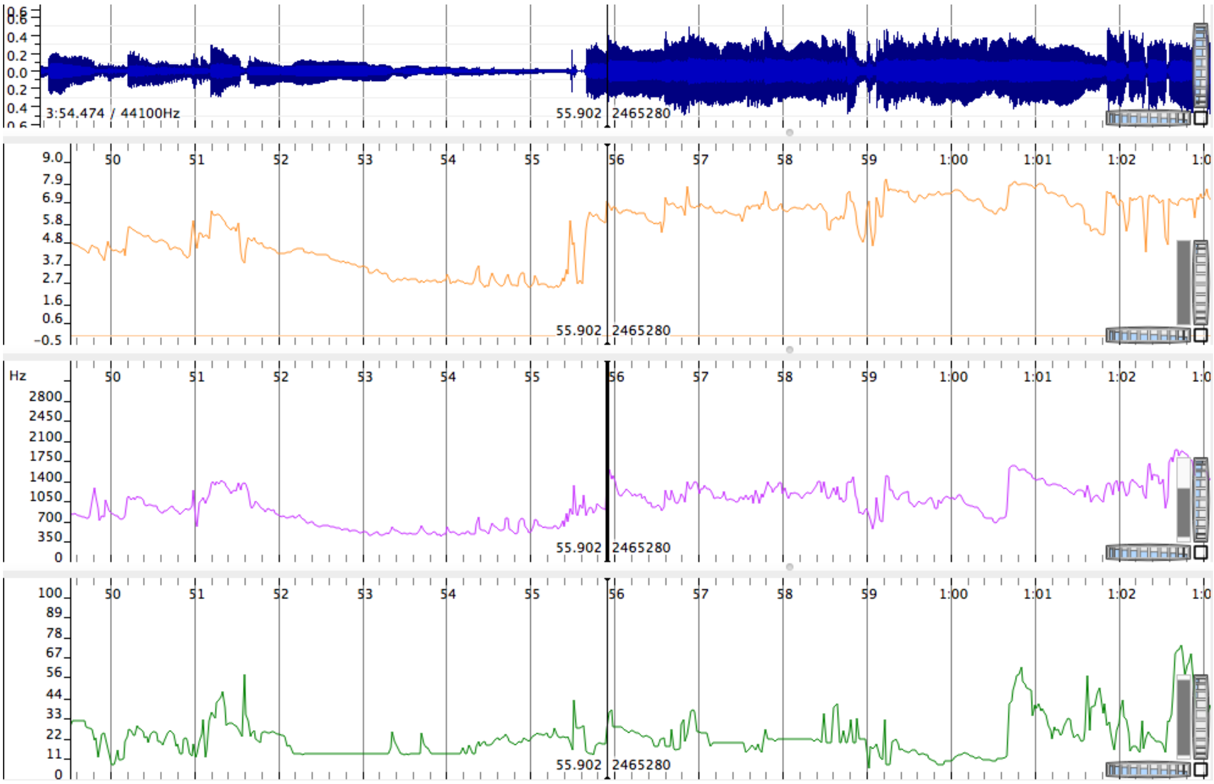


Ex.4: Feijão de Corda (Kiko Loureiro) - Sonic Visualiser analysis

Different from the control track, this one has a lot of moments where Loureiro played chords and they all were recognized by *Moises AI* as lead guitar. Listening test shows that it is due to the instrumentation on that concert with bass, drums, and just one guitar player. Not surprisingly, the waveform appears to be closer to the *Moises AI* extract version of the reference track and the Loudness descriptor flows between 6.0 and 9.0, which agrees with the listening test, where we perceived that the track was still on a similar level to its master track.

Spectral centroid analysis reaches points between 2450 Hz and 2800 Hz, in the same way that it did on the reference track, corroborating with the listening test, which shows some higher notes loss but is still full of treble. It also shows less inharmonicity than the both reference tracks.

On the Example 5 we can analyze the guitar played on the song *De Joelhos* (Fred Andrade), which sounds less distorted than *Feijão de Corda* and the reference track on the listening test. The version analyzed was taken from his DVD Guitarra Pernambucana, recorded live at the studio as a quartet instrumentation with bass, drums and two guitars, one electric and one 12 stringed acoustic.



Ex.5: De Joelhos (Fred Andrade) - Sonic Visualizer analysis

Like *Feijão de Corda*, *De Joelhos* did not have problems on the *Moises AI* extraction, with all the guitars appearing on the lead guitar track, even having an acoustic guitar on the instrumentation. *Moises AI* accurately separated the distorted electric guitar from the acoustic guitar.

The analysis shows less loudness than the other tracks, flowing between 3.0 and 7.0 on the quieter moments and reaching 8.0 on louder parts, which can be explained by Andrade's approach and interpretation on the record of a song that is almost an instrumental ballad.

Spectral centroid goes from 700 Hz to 1750 Hz, with less treble appearing on the listening test too, probably due to the use of a semi-hollow guitar, which can be seen on the DVD. To connect with generic terms mentioned at the beginning of this paper, Andrade's timbre sounds less 'piercing' and more 'mellow' than Loreiro's, a characteristic that clearly appears on this part of the analysis.

The inharmonicity analysis shows a curve that is likely Feijão de Corda, with less inharmonicity than the reference tracks. On the listening test, there are moments when Andrade plays with more intensity on his vibrato technique, another strong feature of rock and metal guitar playing, which may contribute to the way inharmonicity curve appears on the analysis.

Conclusions

This study objective was to investigate the sonic characteristics on the sound of the distorted guitar parts recorded on the pieces *Feijão de Corda* (Kiko Loureiro) and *De Joelhos* (Fred Andrade), as a part of a bigger research.

On the Loudness analysis, Loureiro's guitar appears to be more compressed than Andrade's, always showing more intensity on the observed curve. It also reaches higher levels on the Spectral centroid analysis, which corroborates with the listening test, where Andrade's guitar sounds more 'mellow' while Loreiro's sounds more 'sharp'. This is the correlation between the perception and the measurable aspects of sound like Spectral centroid that we were searching for, as mentioned at the beginning of this paper. The inharmonicity analysis showed similarity on both tracks, corroborating with the literature concepts about the characteristics of this property on the guitar sound and its warmth perception.

This study was relevant to understand how the descriptors Loudness, Spectral centroid and Inharmonicity are related to features perceived by listening to distorted electric guitar sound and also observed the usability of *Moises AI* on this kind of analysis.

As mentioned before, this is an experimental analysis and the research is still in progress. We will continue the study performing the same analysis on a group of pieces recorded by guitar players in order to improve the understanding of the distorted guitar sound acoustically and sonically.

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