PG Research Methods
Assignment 4 'Proposal'

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Introduction

This project is primarily concerned with researching the various forms of signal distortion defined as any change from input to output signal; although it will probably be biased towards the non-linear varieties found in audio equipment that define a units unique sound qualities. These distortions are a byproduct of any signal processing, however some processes such as those found in the various forms of amplification are considered musical while others are considered detrimental to the sound quality.

More specifically the projects intent is to examine the relationship between signal distortions, the generalised subjective response and any musical traits that may or may not trigger this judgement. From hearing much talk about the 'musical' qualities of certain units it seems appropriate to conduct research into the correlations between the signal distortions held responsible and how they correspond with basic music theory.

This research will be accompanied by a practical aspect to the project; a studio recording demonstrating the creative use of distortion. Firstly various pieces of studio equipment will be analysed to gain a working knowledge of their inherent distortions and the recording chain will initially be determined from this information. It will be noted if a given unit doesn't suit its task and is replaced with a subjectively more musical piece of equipment, this will then be examined for possible reasons in the equipment analysis data.

The aims of this project are to improve upon my skills as a studio engineer by having to advance analytical skills through examination of multiple pieces of equipment, their distortion characteristics and also further my understanding of psychoacoustics to determine a 'musical' signal flow. This is a means of learning about a specialist area in an academic and practical manner. Regardless of any findings, I will have gained knowledge in several disciplines and learnt much about the core workings of a studio.

Critical questions

This project will seek to address several critical questions; what are the various forms of distortion? How are they commonly perceived (i.e. noticeability, pleasantness, etc.)? And are there any musically significant relationships?

Research will be carried out on the various types of distortion in order to develop an awareness of how they are formed and an investigation into whether they contain any significant musical relationships. At the same time research will be conducted into the subjective impressions of each distortion under examination.

The fundamental question behind this proposed research project is whether the distortions used creatively in the studio follow musical rules but on a more granular level? This question arose from a previous musical background, some reading on psychoacoustics, and a recently acquired interest in audio processors.

Given the various debates about studio equipment like the 'Tubes vs. Transistors' argument and the fact that many engineers share a generalised preference towards certain equipment topology. It's fair to say that we often consider certain signal processors to be more musically pleasant than others and this presents the main question of why?

Often the response to this question is that its down to the electronics, but of course this response doesn't explain the whole story and can be met with the same question. Eventually we're led to the topic of nonlinear distortions which are an unavoidable byproduct of the circuitry/processing and finally our perception of them.

Research Overview

This project is relatively multidisciplinary with only a few papers specifically focused on distortions and their musical qualities; there are however many books and papers covering electronics, distortions, psychoacoustics and music theory. Below is a summary of the the key research that relates to this project and the authors that have already influenced its direction.

From some reading on music cognition and psychoacoustics, it seems clear that the brain works categorically; an example of this is the phenomena of octave equivalence, this is when a pitch is doubled in frequency but still categorised as the same note. As explained by Jourdain, octave equivalence is near universal and that the various musical scales from around the world are unique divisions of this 'pitch space'.[1] In western music this pitch space is cut up so that each note is an identical rise of 5.9% above the note preceding it and so the scale is said to be equally tempered; this is a modification of the earlier Pythagorean scale which was constructed from ratios to achieve its harmony. Further examples of categorisation can be found throughout music theory, though the main point is that our music is heavily based on maths and so our perception of whether a distortion sounds musical could also be based here.

An example of this can be seen in intermodulation distortion; this is when frequencies interact with each other creating new frequencies at the sum and difference of the input waves. On first impressions one would presume these frequencies to be musically unrelated but its explained by Langevin[2] that this is not so much the case; frequencies that are harmonious such as an interval between the root and 5th often produce other harmonious frequencies, in this case a major 3rd at the sum[3]. From his analysis of different intervals Langevin explains that this could be the reason that large amounts of intermodulation distortion can go virtually undetected by a listener stating that: *'It therefore follows that if the music is harmonious there is a good chance IM products will also be harmonious and not too noticeable'.* This is quite a strong point if we consider how we listen to an acoustic instrument; a listener would not often notice the repeated notes in a triad such as the root an octave higher, however it is quite noticeable if even one note is unrelated because of the introduced dissonance.

Another example can be seen in the case of the missing fundamental[4]. This occurs because our brains recognise the harmonic structuring of a note and fills in the missing frequency regardless of whether it actually exists; algorithms are already being used in commercial products to extend the bass response of bandwidth limited systems[5] and again shows how inter-linked our perception of sound is with structuring and relationships.

1 Jourdain, R. (1997) *Music the Brain and Ecstasy* – 1st Edition p68 & 69, Harper Collins, US.
It states on p69 that the only exception to octave equivalence being truly universal are certain aboriginal groups who never sing in octaves, but seldom sing out of a single octave range.

2 Langevin, R. (1963) *Intermodulation Distortion in Tape Recorders* – AES Journal, Volume 11, Issue 3.

3 E.g. The notes A and E are a musical 5th, they are at 55hz and 82hz respectively. [55+82 = 137] C# is at 138hz and is the major 3$^{rd.}$. The difference of 1hz is virtually undetectable and the brain will still categorise 137hz as a C#.

4 Howard & Angus (2006) *Acoustics & Psychoacoustics* - 1st Edition p203, Focal Press, UK.

5 Gan & Oo (2008) *Harmonic and Intermodulation Analysis of Nonlinear Devices Used in Virtual Bass Systems* – AES eJournal, paper 7403.

Russell Hamm[6] discusses other nonlinear distortions in his paper *Tubes vs. Transistors* and talks about the perceptual response to them maintaining focus on harmonic distortion. This distortion is observable by passing a sine wave through a piece of equipment and as the waves shape is distorted, additional frequencies that are related by octave. If one imagines this effect on a complex signal the results would be equally intricate. However Hamm shows the importance of this simple analysis and how it allows an insight into the different perceptual effects that additional harmonics and their relative levels produce.

Hamms paper however is limited to harmonic distortion (measured in %THD values) which is a system long criticised by engineers due to its inability to explain of the audibility of such byproducts.[7] As Trumbull explains in his response that there are many other factors to consider when dealing with the audibility of such distortions like masking, not discounting Hamms work he uses the example of transients to demonstrate this by suggesting that:

'Any strong transients such as the attack of a drum beat (and percussion attack transients in general) do not last longer than a few milliseconds, and the harmonics associated with these attack transients will not be significant in relation to the magnitude of the actual attack transient itself[8].'

Earl Geddes and Linda Lee are a more recent and authoritative voice on the subject of perceptual distortions with several papers now published that share Trumbulls opinion. Their papers from 2003[9] explain a theory that the perceptual response to a systems non-linear distortion are actually the sum of an underlying transfer function; these papers also show that their theory works by predicting the generalised perceptual outcomes in the experiments they conducted. However their most recent paper from 2006[10] presents a few practical problems explaining that our perceptions of the underlying linear distortions are greatly effected by level intensity due to our nonlinear hearing mechanisms. This is a fair criticism of their own work however the implications of their papers are still that a generalised perceptual response can be derived. Given this theory it is possible that in some equipment the underlying transfer function is made up from more musically correlated arithmetic than another and could sway our subjective judgement.

Originality

This projects originality lies in its approach of finding generalised guidelines that engineers can follow when faced with the need to choose a suitable unit for a given task in the studio. Knowing the properties of a piece of equipment and what to listen for when using it can contribute to a better recording; this is the driving force behind the project and so an attempt will be made to present the information in a concise manner for easy reference. From reading it seems quite possible that music theory, being based on our perceptions of harmony, could have knock on effects in the field of audio electronics. The fact that so many engineers discuss the musicality of equipment, it seems surprising that few have actually compared the subjective response to distortions with music theory and so I feel this area could do with the further research of which I hope to contribute.

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6 Hamm, R. (1973) *Tubes Versus Transistors-Is There an Audible Difference* – AES Journal, volume 21, Issue 4.

7 Trumbull, R. (1974) *More about "Tubes Versus Transistors" and -Comments on Tubes Versus Transistors" and Author's Reply* – Journal of the AES, Volume 22, Issue 1.

8 Trumbull, R. (1974) *More about "Tubes Versus Transistors" and -Comments on Tubes Versus Transistors" and Author's Reply* – Journal of the AES, Volume 22, Issue 1.

9 Geddes & Lee (2003) *Auditory Perception of Nonlinear Distortion* – AES eJournal, paper 5891
Geddes & Lee (2003) *Auditory Perception of Nonlinear Distortion; Theory* – AES eJournal, paper 5890.

10 Geddes & Lee (2006) *Audibility of Linear Distortion with Variations in Sound Pressure Level and Group Delay* – AES eJournal, paper 6888.

Methodology

It is expected that the proposed methodology will change to an extent to cover other fields as they are studied over the coming year and a half, however below outlines the present idea.

Research will be conducted into the various categories of distortion and their correlations with music theory which will also be compared to a generalised perceptual response. After this the testing of studio equipment for various distortions will be carried out with audio analysis tools and rated on a scale of 'musicality' according to the artefacts they produce. The analytically most musical units will be used for the an initial signal chain when recording, however if they don't audibly work they will be replaced and the practical reason for such a subjective response will be sought. My justification for this approach is because much like song writing, the goal of creating a good recording should be based upon theoretical rules and then follow subjective tastes.

An interesting development could also be to analyse a signal from its source as it endures various distortions in the signal path and observe how the signal changes at points considered subjectively musical. For example an electric guitar could be checked by taking a direct signal and comparing the clean output at several stages; after effect units, after running through an amplifier and being picked up by multiple microphones in a room, after preampfification and the recording medium, and finally after the summed processing. This could be a practical way of finding subjectively pleasant distortions in that listening to the different stages and subjectively narrowing down the stages of signal processing down to those that sound the most musical could help point towards the possible distortions that are held responsible for this musicality.

As explained THD values mean little with many calling for a new measurement of distortion that is perceptually based, intermodulation distortion in this respect looks to be more relevant to our perception of sound and musically related but these measurements still lack meaning as some sounds will be flattered while others will not. Looking into the level differences at different intervals in a pice of equipment and cross examining the levels of the dissonant frequencies could yield some results that may prove interesting.

Conclusion

This project is intended as a way to research the field of distortion and apply this knowledge to the studio in order gain further experience and new skills. Analysing and testing multiple pieces of equipment and knowing their unique properties will prove extremely helpful as a studio engineer. A side aim is also to improve upon my existing knowledge of signal flow and so having to patch many pieces of equipment from around the various studios will prove a good way to do this. The recording aspect will allow for the use of various units around the studios that I have not had opportunity to hear yet because there is no substitute for practical experience, it will also add to my portfolio which is an important factor in getting studio work.

Time Line

This project will be researched along with the other modules over the coming year and a half before it must be submitted and so the time line is relatively vague on specifics, especially as unexpected changes from fresh information cant be predicted.

January – August
Research on various distortions and their perceptual outcomes.

September – January
Research audio analysis methods and during the first half of the MA's second year. Continue research on distortions and learn new topics that might be implemented.

February – May
Test equipment in the various studios for their different distortion properties. Continue research on distortions and analysis, start a new semester and learn new topics that may be implemented.

June – August
Continue research, record one to four demonstration tracks, analyse subjective deviations from planned signal flow made during the recording for potential reasons and write the project.

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References A-Z

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