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Towards a Perceptual Model Of ‘Punch’ In Musical Signals

Steven Fenton & Hyunkook Lee
The University Of Huddersfield, UK

Research Background

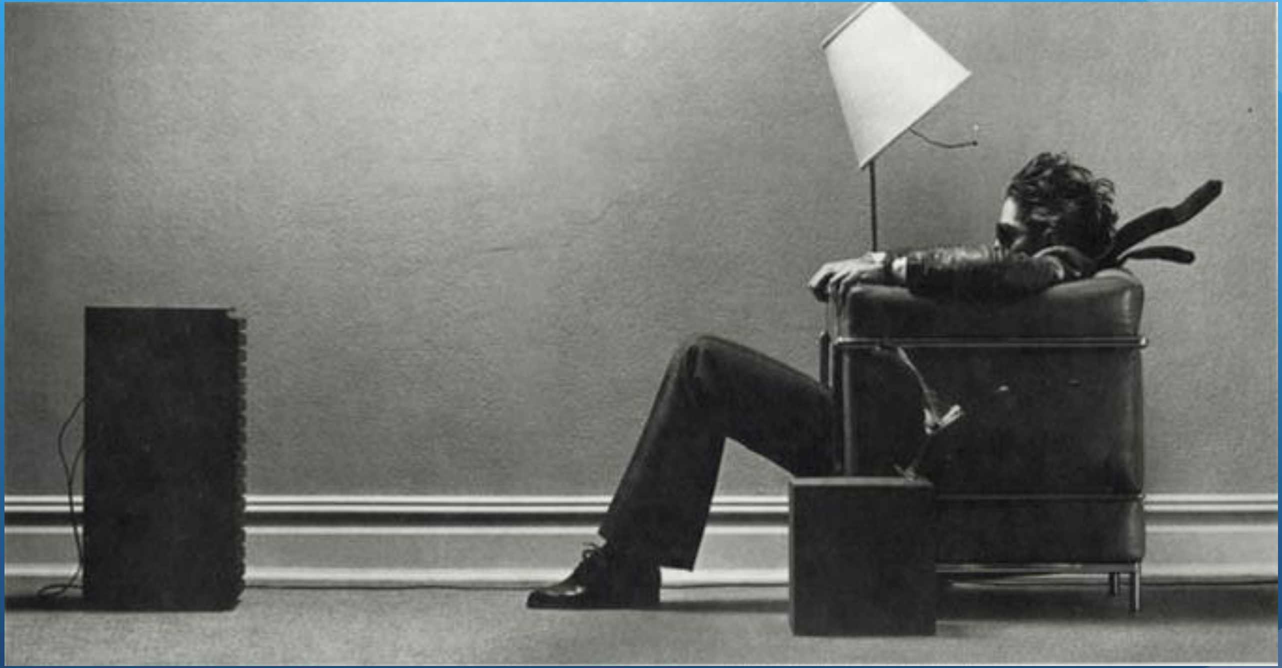
- Part of a wider study on finding new metrics to quantify elements of a complex mix.
- Stress ‘Towards’.
- Application in MIR, auto-mixing and auto-mastering tools
- Tools that are meaningful to both the engineer and musician alike.

Punch – A ‘formal-ish’ definition

- **Semantics** (from Ancient Greek: σημαντικός *sēmantikós*, "significant") is the study of meaning. It focuses on the relation between *signifiers*, like words, phrases, signs, and symbols, and what they stand for; their denotation.
- A term often thrown around but opinions differ on its meaning in a musical sense.
- ‘Thump’ is another one, the clue is in the name
- “Specifies whether the strokes on drums and bass are reproduced with clout, almost as if you can feel the blow.” [1]

[1] Pederson & Zacharov, “The development of a Sound Wheel for Reproduced Sound”, 138th AES Convention, Warsaw, May 2015

Blown-Away Guy - Maxell



Punch – A more formal definition?

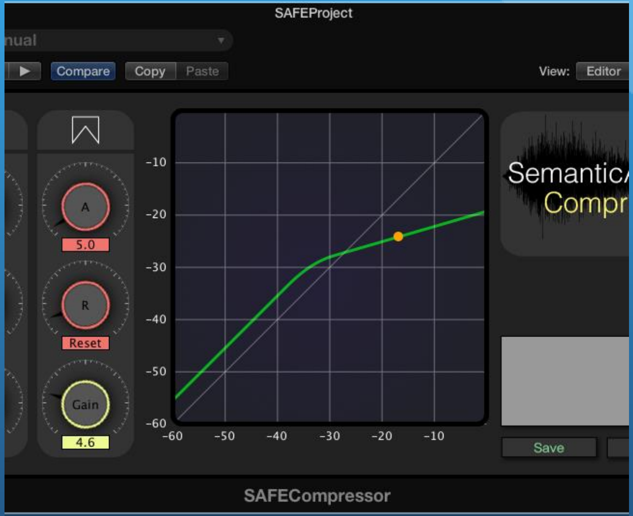
- A characteristic related to dynamics is known as ‘punch’. Punch can be described as a short period of significant change in power in a piece of music or performance. In essence, productions that do not possess any transient information cannot posses punch. Thus, punch is both related to transient change and the energy density at a particular moment in time and duration [2]. Furthermore dynamic change in particular frequency bands contribute to the overall perception of punch perceived by the listener and this is inherently affected by the overall average loudness level at that time [3].

[2]Fenton et al, “Elicitation and Objective Grading of ‘Punch’ Within Produced Music. 136th AES Convention, Berlin, April 2014.

[3] B.Moore, “An Introduction To The Psychology of Hearing”, pp.138-145, 5th Edition, Elsevier, 2004.

Evaluation / Goals

- Evaluate listeners perception of punch.
- Objective measure.
- Intelligent Processing rather than brute force.
- Another ‘Search’ parameter that can be utilised in music selection.
- Produce a real-time meter – More production tools.



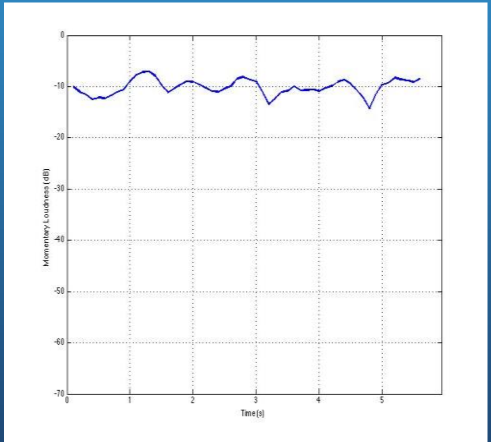
[4]

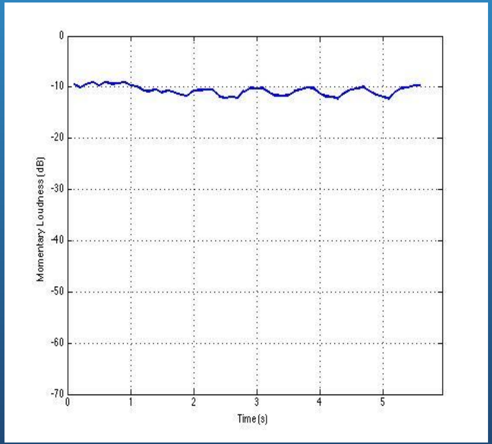
[4] R. Stables, S. Enderby, B. De Man, G. Fazekas, and J. D. Reiss, “SAFE: A system for the extraction and retrieval of semantic audio descriptors,”, The International Society for Music Information Retrieval (ISMIR), 2014.

Audio Example 1

Mr Brightside – The Killers.

Audio Example 1





Mr Brightside – The Killers.

Short term loudness is -10 LU for both excerpts.

Some Measures to start with..

- Crest Factor – Peak To Average
- PLR – Peak to Loudness
  - Can be used to indicate some microdynamic content, eg spikes.
- Dynamic Spread – A statistical approach to quantify the general spread of a time varying loudness signal. [6]. Calculation of the variation about the mean.
- All of these measures are great but have limitations with respect to application to punch. They’re not weighted , they integrate, they rely on peak levels..

[6] |E.Vickers, “Automatic Long-term Loudness & Dynamics Matching”, 111th AES Convention, New York, September 2001.

Better Measures

- Octave Range CF (TT Dynamics Meter).
- IBR (Inter Band Dynamics). [5]
- Loudness range – Quantifies the variation in a time-varying loudness measurement. Based on analysis of the 'Short Term' loudness data. (Formely 'consistency'). Statistical approach eliminating top 5% and bottom 10%.
- Microdynamic –LDR – Developed to quantify the microdynamic loudness variations of an audio signal [6].
- Percentile of difference values between slow and fast loudness level.
- Testing relied on 'inherent' notion of microdynamics by the listeners. Still based on 'loudness' model albeit with smaller window sizes.
- What is punch anyway?

[5] Fenton et al, "Objective Measurement of Music Quality Using Inter-Band Relationship Analysis". 130th AES Convention, London, May 2011.
[6] |E.Skovenborg, "Measures of Microdynamics", 137th AES Convention, Los Angeles, October 2014.

Elicitation of punch.

- Key frequencies of interest
- Nature of the material - Instrumentation
- Temporal / Frequency interaction
- Extraction of key modeling parameters
- Identify any other existing parameters that may also correlate

Dynamics = Punch = Transients

- “Thus, punch is both related to transient change and the energy density at a particular moment in time and duration”

Evaluate listeners perception of punch.

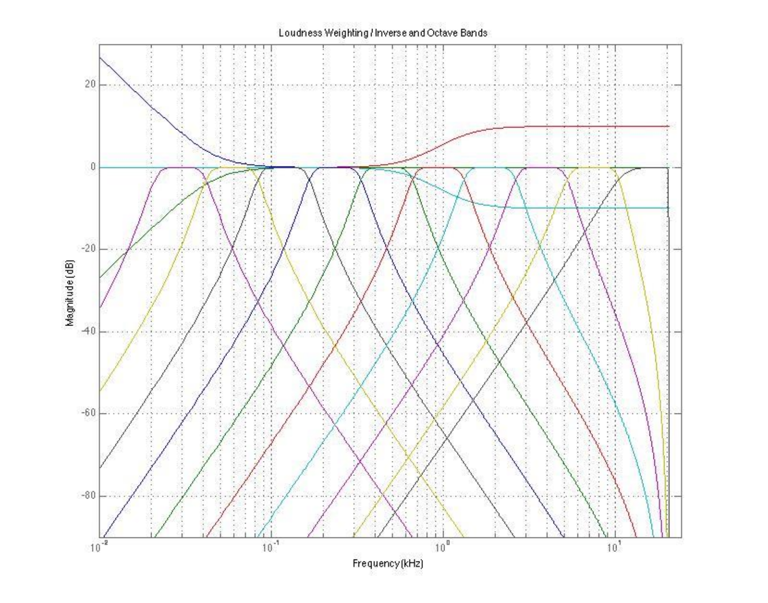
- Controlled experiment using 45 pink noise bursts
- The samples were arranged over 9 octave bands, with temporal attack times of 0, 5, 10, 20, 60ms. A fixed offset time of 40ms was used for all samples.
- The samples were presented in 16bit, mono WAV format.
- Loudness normalisation on the test samples was applied.

Loudness Normalisation

- Samples processed with temporal and frequency weighting. The frequency weighting curve was an inverse modified ‘K’ Weighting filter (BS.1770-3)
- Modifications were made to shelving filter G = 10dB rather than 4dB and Fc = 1kHz instead of 1.6kHz.
- These modifications were based on recommendations made by Pestana et al. [7] and through testing.

[7] |Pestana et al, “Loudness Measurement of Multitrack Audio Content using Modifications of ITU-R BS.”, 134th AES Convention, Rome, May 2013

Loudness Normalisation

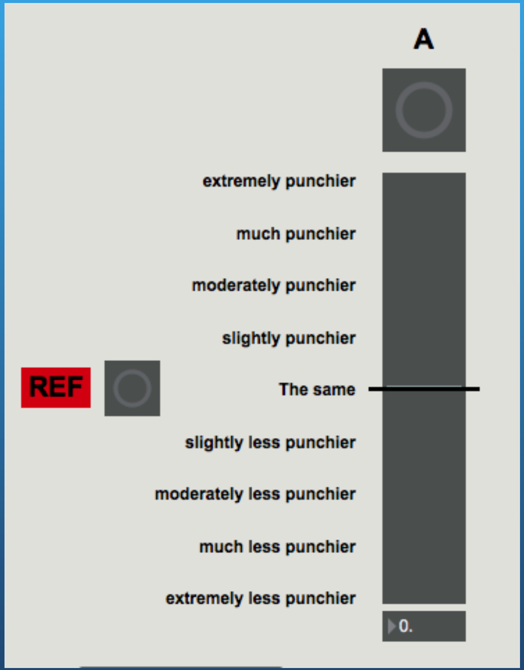


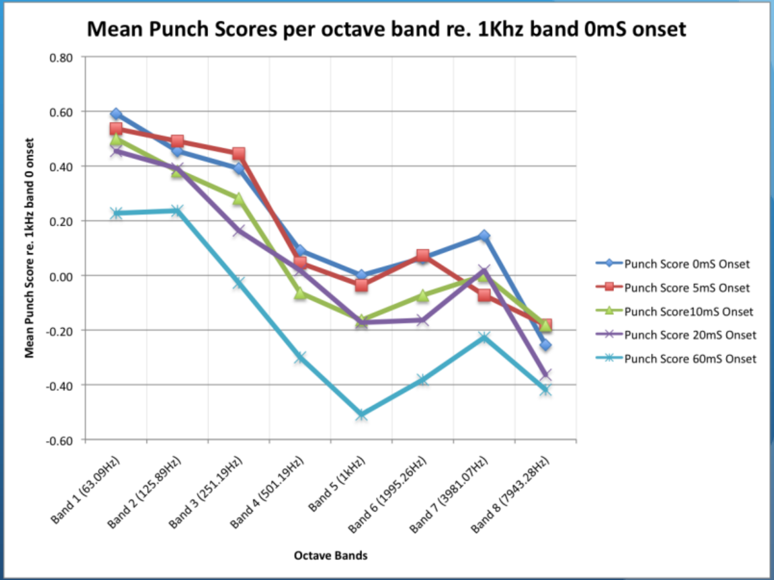
- In addition – temporal compensation was applied.
- Based on the centre frequency of each octave band and the pulse duration.

Listening Test

- An informal listening test took place prior to the main test to briefly evaluate the effectiveness of the loudness normalization algorithm.
- Of the 11 expert listeners that took part, 7 agreed on equal loudness.
- Differences they were hearing were primarily as a result of timbral differences rather than loudness.
- A formal listening test is planned to evaluate the loudness normalisation.
- In comparison, an ITU-R 468-4 filter model was also tested however it was found that the 2kHz-8kHz octave bands were perceptually significantly louder on playback than the lower bands.

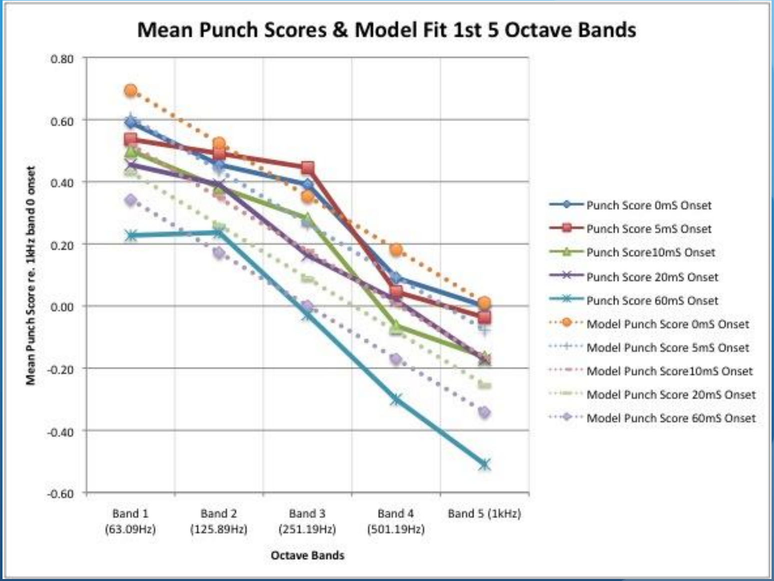
Test Interface & Results



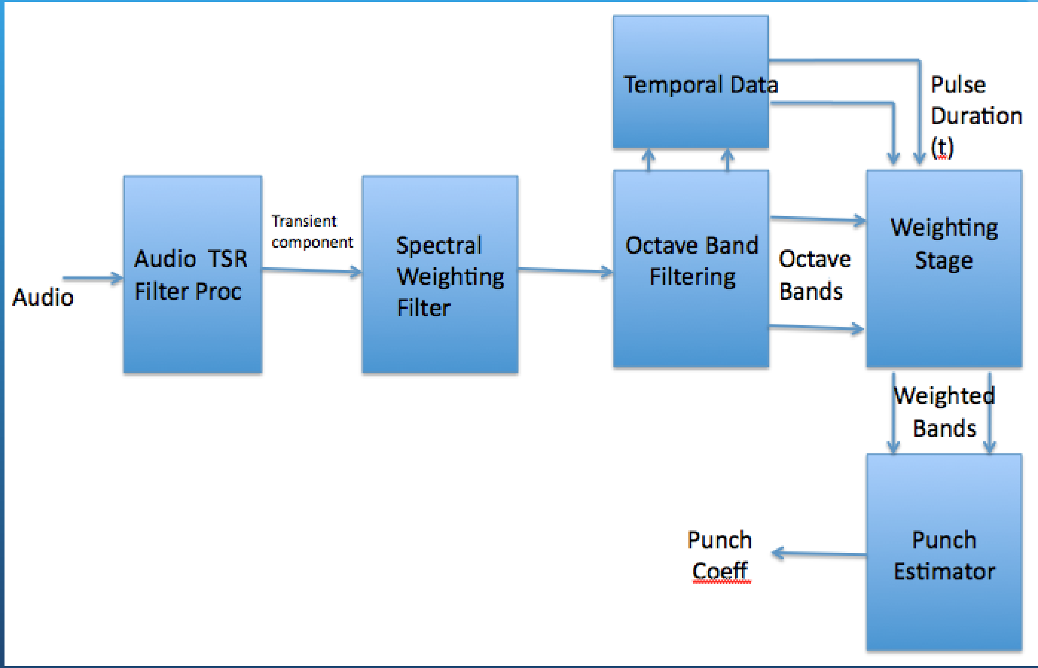


Results

- Upon interviewing the participants after the experiment- the upper bands had been scored higher as a result of their timbral weight or presence. This being particularly relevant to the 4kHz band.
- Through linear regression an Estimated 'Punch' score algorithm was derived.

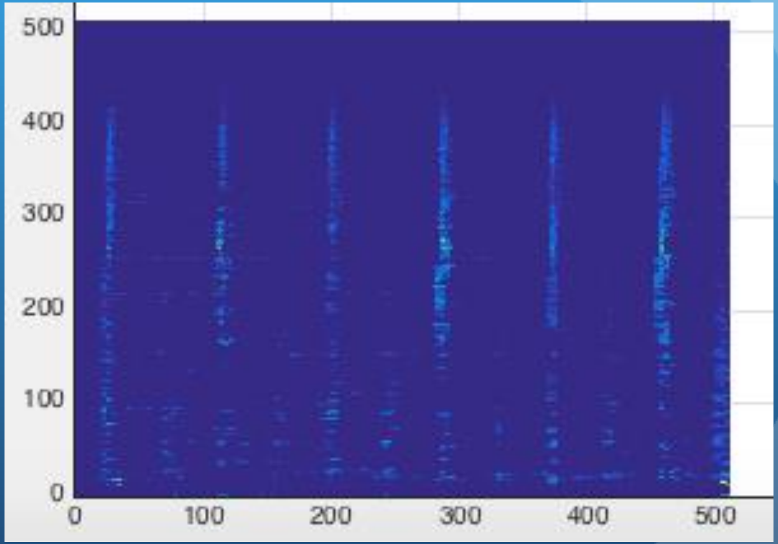


Objective Model



Audio TSR Filtering – Transient Separation

- A multistage approach was adopted based on the 'punch' definition outlined.
- The first stage separates the component parts of the signal.
- The approach adopted is based on median filtering [8].
- Ignores the steady state portion of the signal, unlike a standard integration based meter.



[8] |D. Fitzgerald, "Harmonic/percussive separation using median filtering." Proc. of the DAFx-10, Graz, Austria, Sept. 2010.

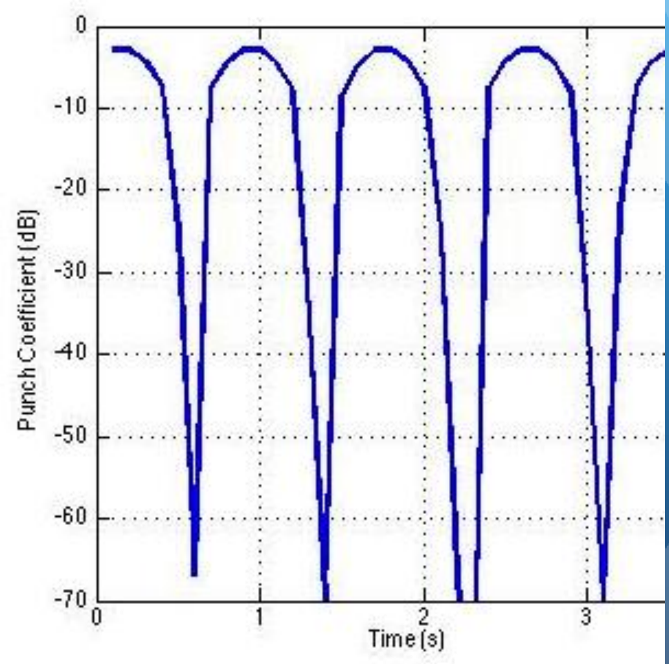
Temporal Data Extraction

- MIR tool box was utilised to extract temporal data relating to attack times and note onsets. [9]
- Utilised within the weighting stage to produce the summed ‘Punch’ score.

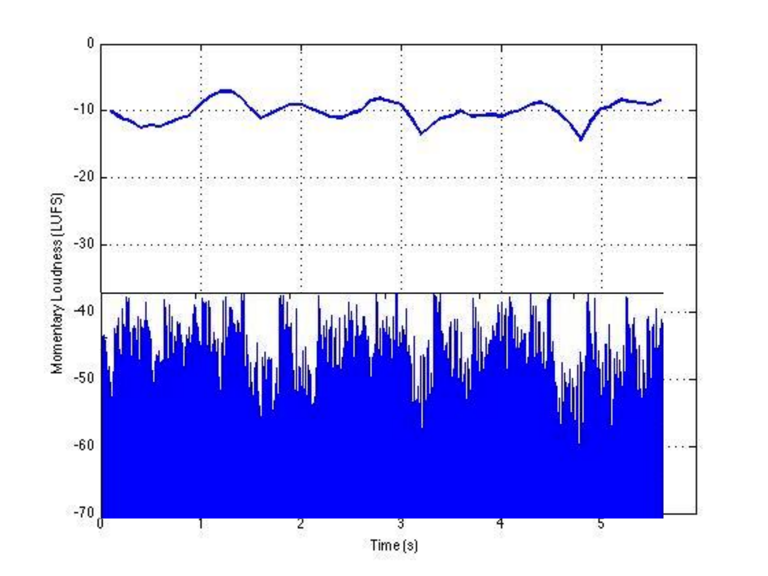
[9] Lartillot, O. & Toiviainen, P. “MIR in Matlab (II): A Toolbox for Musical Feature Extraction From Audio”, ICMIR. Vienna, 2007.

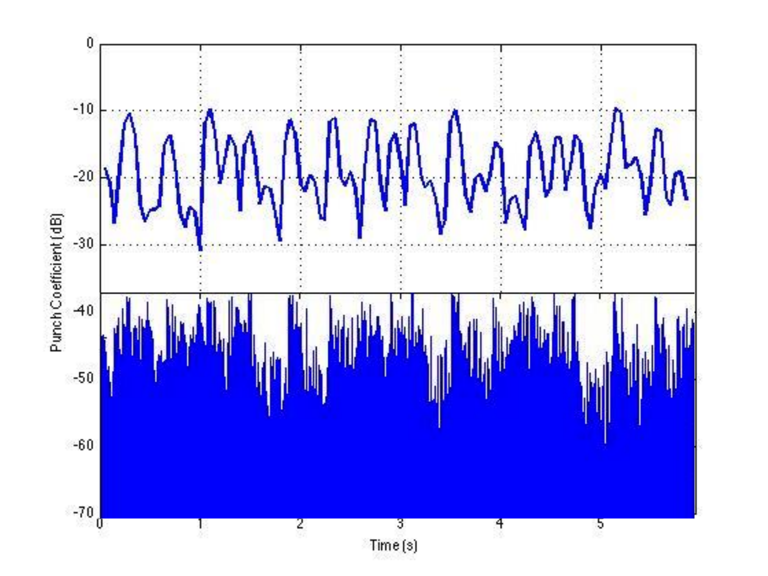
Weighting Stage

- The 0dB output represents full scale.
- Level output is similar to that of the standard loudness model such that if the input stimulus is a full scale digital broad band pink noise burst, the output of the model would be -3dB.

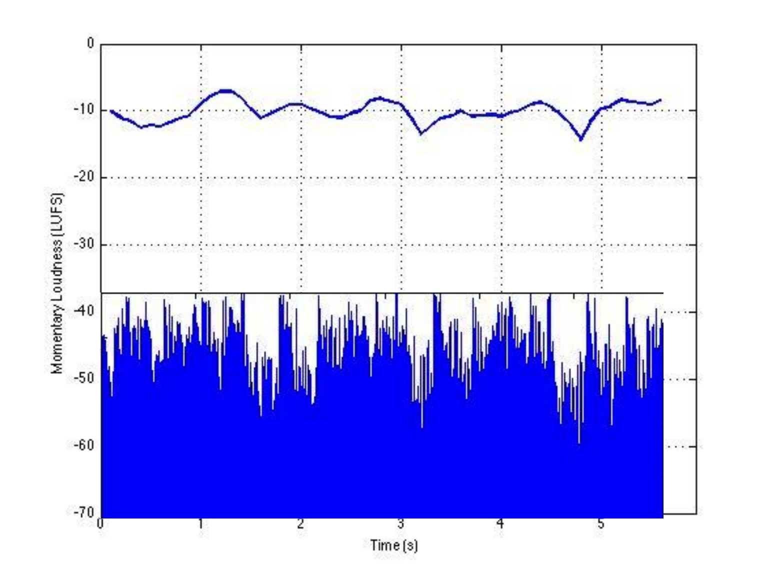


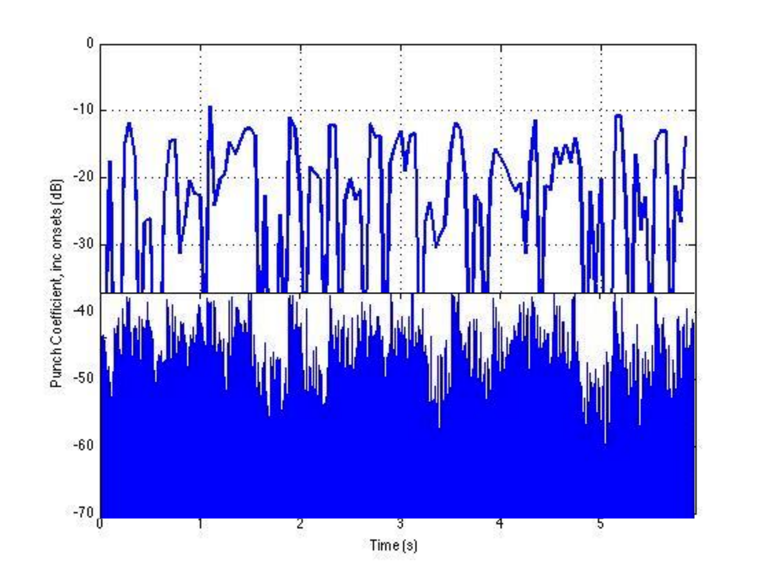
Punch Measure





Punch Measure

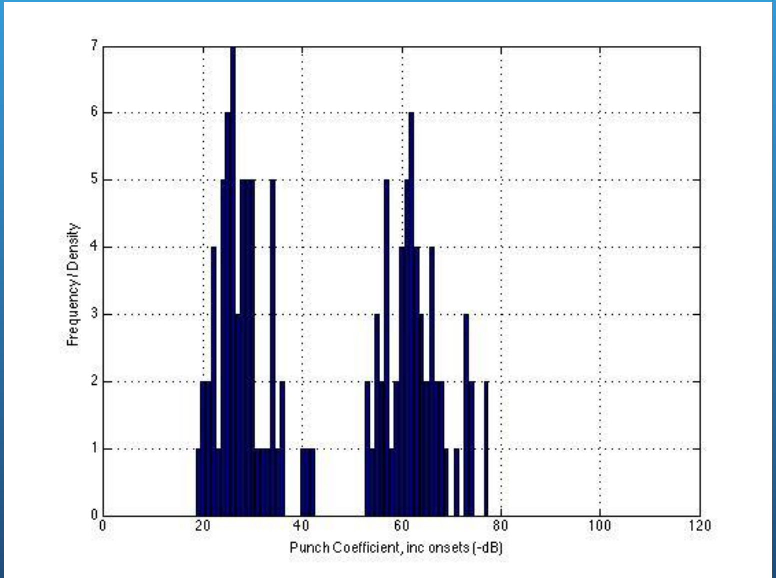


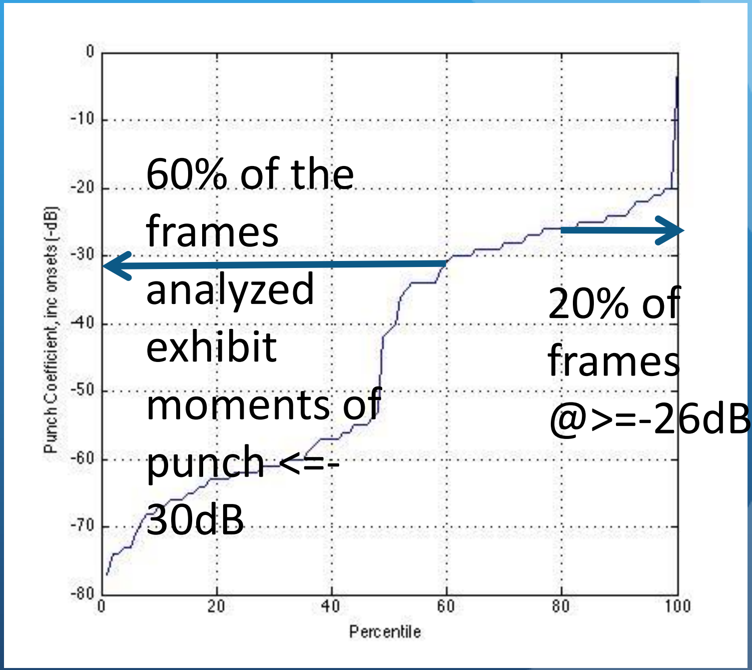


Punch Profiling

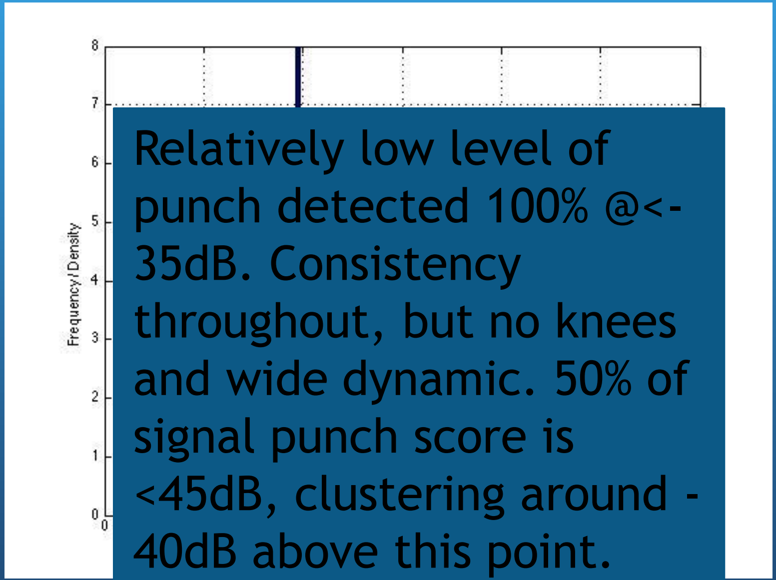
- The previous output measure could be used in conjunction with a loudness meter to aid in mixing.
- For track comparison, a statistical approach can be adopted, based on a frame by frame analysis of the punch coefficient.

Punch Profiling

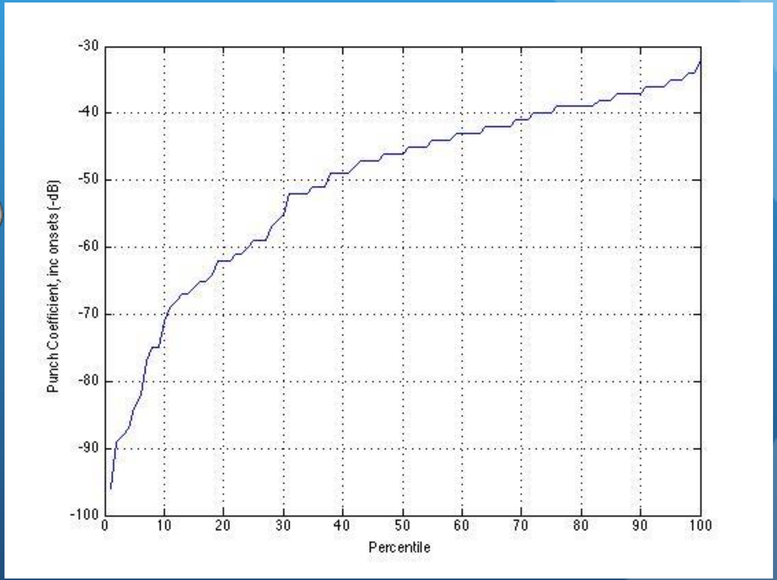




Punch Profile Examples



Relatively low level of punch detected 100% @<-35dB. Consistency throughout, but no knees and wide dynamic. 50% of signal punch score is <45dB, clustering around -40dB above this point.



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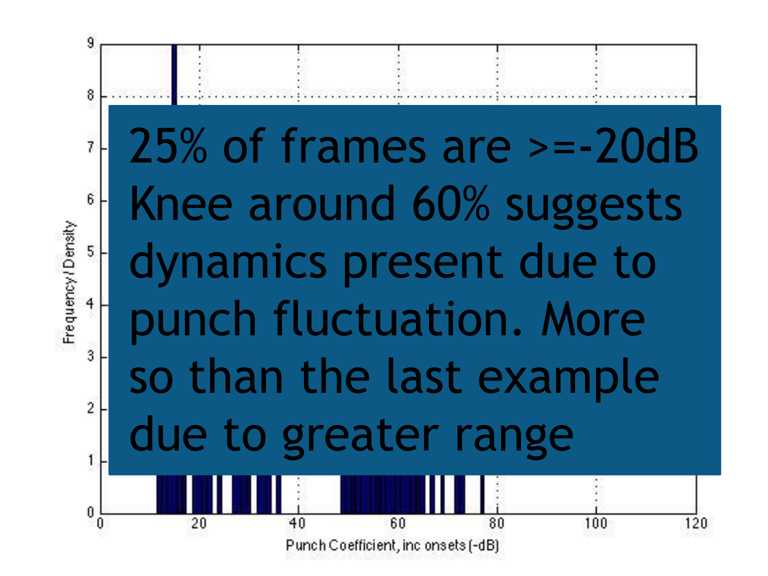
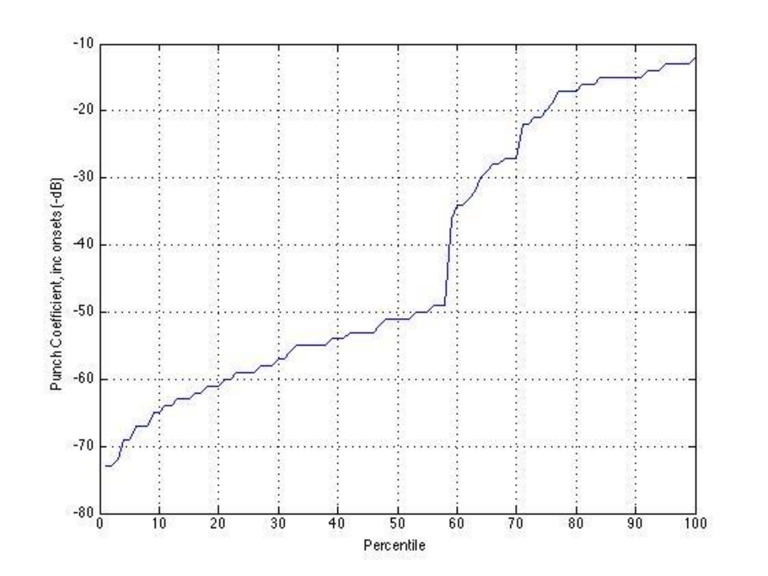
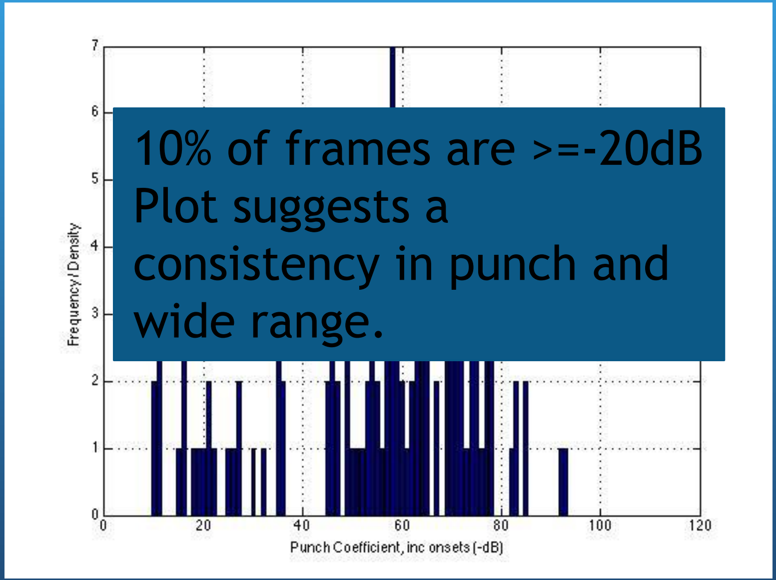


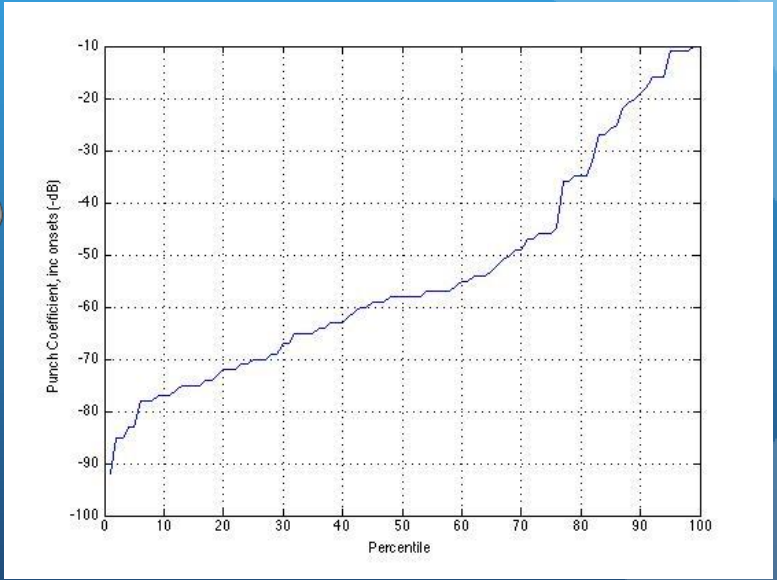
25% of frames are >=-20dB
Knee around 60% suggests dynamics present due to punch fluctuation. More so than the last example due to greater range



Punch Profile Examples

10% of frames are >=-20dB
Plot suggests a consistency in punch and wide range.





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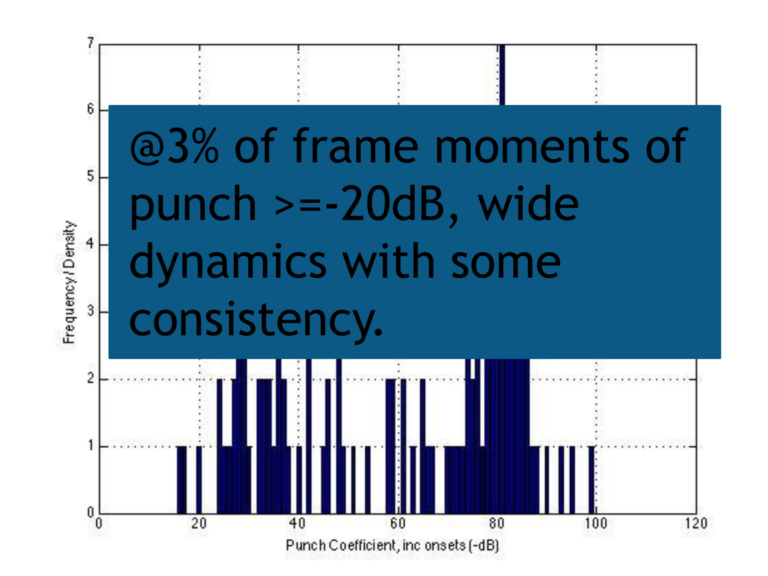

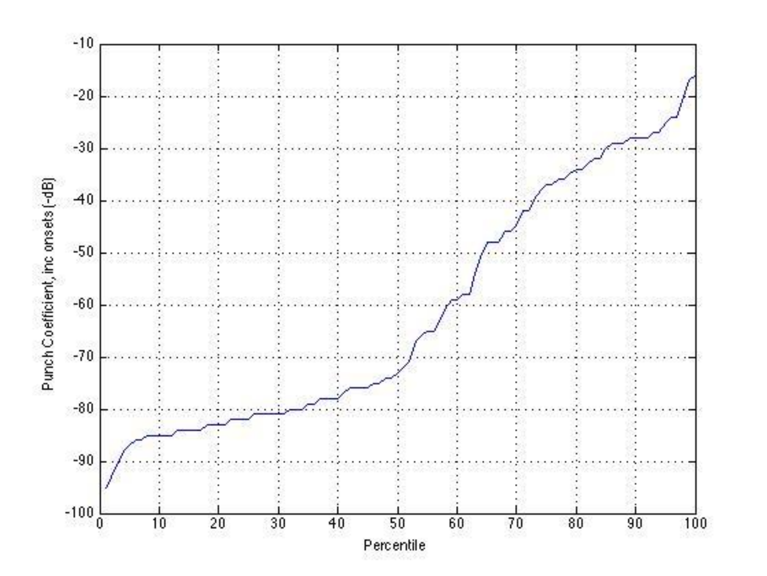

Further Work

- Bring the residual/harmonic into the equation.
- Smooth the detection envelope / ignore spurious spikes of little interest.
- Test with various median filter window sizes.
- Compare to LDR and other promising models.

Thankyou