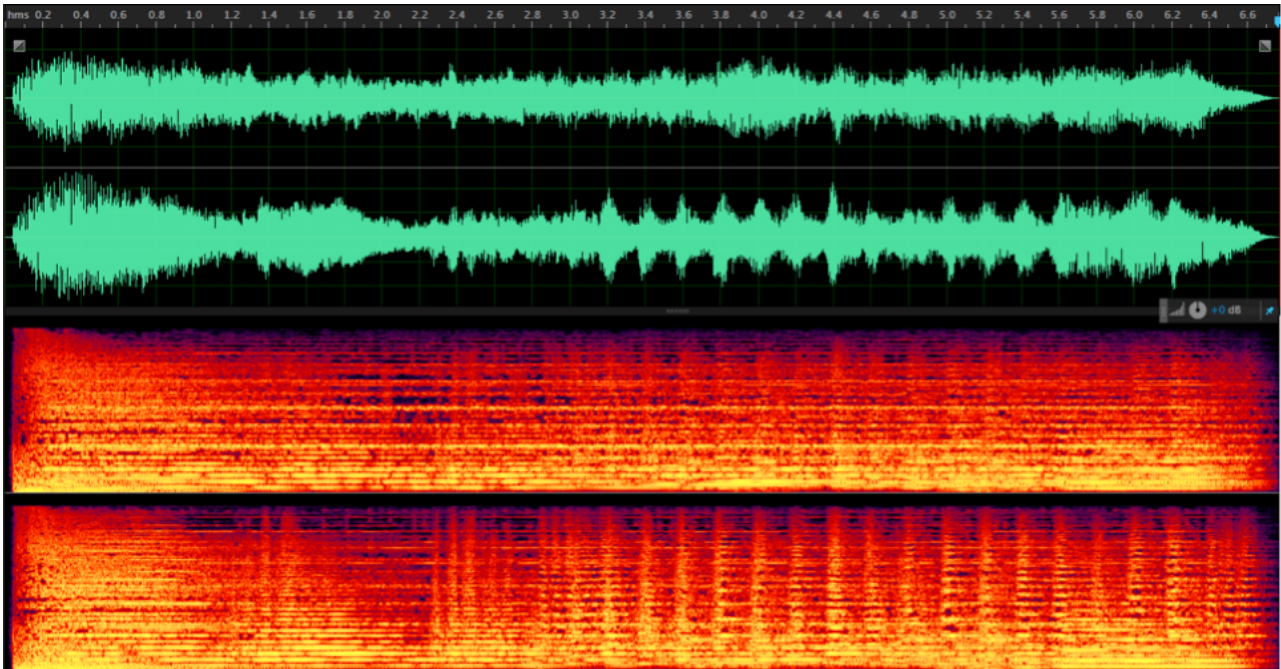# Codecs

TE2071 Assignment 3

Luke Nelson

Introduction

For this assignment, I am going to test whether a CBR (Constant Bit Rate) or VBR (Variable Bit Rate) is better to use when using the MP3 codec to encode. I will be distributing my test via the internet meaning I will be challenged by my test subjects using different listening devices. I will also have to consider the type of sound I encode as the results might vary over longer times and through different types of music. I will use a WAV file as my original to make sure there is no prior encoding done to the track.

CBR vs VBR

WHAT'S THE DIFFERENCE?

CBR stands for Constant Bit Rate. When encoding, the encoder will use a constant bit rate that I select. CBR is useful for streaming as you must adhere to a specified data rate. However, to keep quality in the complex sections, you would have to encode with a large bitrate, wasting bits in the simple sections and making a very large file[1]. VBR stands for Variable Bit Rate. When encoding, the encoder will 'listen' to the track and adapt the bitrate throughout, choosing a higher bitrate for more complicated parts and a lower bitrate (lower quality) for simpler parts. However, you choose a target bit rate that it will aim for.

IF VBR DECREASES THE QUALITY, WHY WOULD YOU USE IT?

By using a lower bitrate, less bits are stored and therefore less memory is used, therefore, VBR can help decrease size of music and movie files. The idea is that in the less complicated bits of music, you shouldn't notice the lowered bitrate. Assessing the effectiveness of VBR is done by measuring the 'quality-to-space ratio'[2]. The LAME encoder tests this as part of it's algorithm, the details of which can be found here: http://wiki.hydrogenaud.io/index.php?title=Recommended_LAME#VBR_.28variable_bitrate.29_settings. However VBR can be more processor intensive and may take longer to encode varying sections of music[3].

SINGLE VS MULTI-PASS

When encoding with a VBR, you can choose to do a 'single pass' or a 'multi-pass'. Both do what they say on the tin: Single Pass analyses and encodes as it goes along, usually taking about half the time of multi-pass. Multi-Pass has one run to analyse the track and then a second to use what it has learned and encode[4]. Depending on how varied the track is, the difference in quality may be negligible, therefore making single pass more beneficial because it is quicker.

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[1] Constant Bitrate - Hydrogenaudio Knowledgebase. 2015. Constant Bitrate - Hydrogenaudio Knowledgebase. [ONLINE] Available at: http://wiki.hydrogenaud.io/index.php?title=Constant_Bitrate. [Accessed 04 January 2015].

[2] Variable bitrate. 2015. Variable bitrate. [ONLINE] Available at: https://www.princeton.edu/~achaney/tmve/wiki100k/docs/Variable_bitrate.html. [Accessed 02 January 2015].

[3] VBR - AfterDawn: Glossary of technology terms & acronyms. 2015. VBR - AfterDawn: Glossary of technology terms & acronyms. [ONLINE] Available at: http://www.afterdawn.com/glossary/term.cfm/vbr. [Accessed 02 January 2015].

[4] Single Pass vs Multi Pass? | Apple Support Communities. 2015. Single Pass vs Multi Pass? | Apple Support Communities. [ONLINE] Available at: https://discussions.apple.com/thread/6043052. [Accessed 02 January 2015].

The Experiment

This section will outline how I planned and executed the experiment and what considerations I had to take whilst preparing it. Near the end, I will also outline my what I will be looking for in the results and how I have engineered the experiment to help present these to me.

SETTING UP THE EXPERIMENT

Choosing the music

I have to choose the music that I use for my test carefully since VBR and CBR might be better at different things. I don't want to just chose one type of music since VBR and CBR might work better or worse over time, similar to a quick or slow attack. Also, one might deal better with a full spectrum for example. There are lots of factors that need testing as CBR and VBR have lots of differences, however, I am going to use five different tracks testing five different possible differences. These are:

- A quickly changing full spectrum sound
- A slow, full spectrum sound
- A slow, quiet or simple track
- A quick, quiet or simple track
- A few extended notes of a piano

When I say 'a full spectrum sound', I mean a sound that has lots of energy across the entire spectrum, for example, an orchestral piece of music or noise.

Choosing the Codec

I have decided to use the MP3 codec in the .mp3 container. MP3 is well know and widely accepted making it very easy to distribute. Since I plan to distribute my test via the internet, this is a very useful feature. When encoding VBR, I need to decide wether to encode with a Single Pass or Multi-pass. As discussed before, the main disadvantage of multi-pass is speed; however since the clips are only 5-10 seconds long and I will be using a very powerful computer to encode, time and processor power are not really issues.
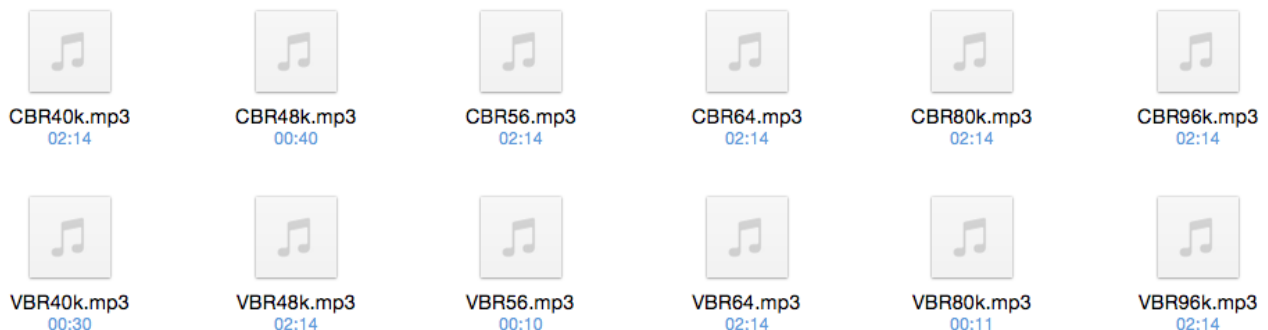
Choosing the Encoder

I I will use the LAME encoder to encode all my tracks. As mentioned before, the LAME encoder files performs many tests[56] on it's VBR created files, hopefully giving them a standing chance against VBR In quality. Some suggest that this is one of the best VBR encoders[7]. However, it is a very good CBR encoder as-well. Lame is also a very flexible encoder having many many options built into it's audacity compatibility; however it can also be run on its own[8] and can be modified with several switches, allowing almost infinite tweaking.

Choosing the Bit Rate

I did some independent testing on the Star Wars theme tune. I exported the track several times using both CBR and VBR over a range of bit rates, starting at 96kbps and going down as low as 40kbps. I listened to part of the original WAV version of the track and then to part of both versions of the same bitrate. I was listening for the point where I could tell the difference between the original and the encoded versions. At first, I thought that 56kbps was the limit as you can start hearing artefacts right from the start of the track. After noticing this, I listened to the whole of both of the 64kbps versions and noticed that there were still artefacts at this higher bitrate. Therefore, I have decided that instead of encoding the entire track lower and making the difference to both more noticeable, I have decided to encode my test clips at the slightly better bitrate and pick the 'worst' section of the better version. This will make the test slightly more realistic as the test clips will be of closer quality to those that people would actually listen to in real life.

CBR40k.mp3	CBR48k.mp3	CBR56.mp3	CBR64.mp3	CBR80k.mp3	CBR96k.mp3
02:14	00:40	02:14	02:14	02:14	02:14

VBR40k.mp3	VBR48k.mp3	VBR56.mp3	VBR64.mp3	VBR80k.mp3	VBR96k.mp3
00:30	02:14	00:10	02:14	00:11	02:14

My test files

5 LAME - Hydrogenaudio Knowledgebase. 2015. LAME - Hydrogenaudio Knowledgebase. [ONLINE] Available at: http://wiki.hydrogenaud.io/index.php?title=Recommended_LAME#VBR_.28variable_bitrate. 29_settings. [Accessed 05 January 2015].

6 LAME - Hydrogenaudio Knowledgebase. 2015. LAME - Hydrogenaudio Knowledgebase. [ONLINE] Available at: http://wiki.hydrogenaud.io/index.php?title=Recommended_LAME#Technical_information. [Accessed 05 January 2015].

7 Which is the Best MP3 Encoder for Podcasts? | Richard Farrar. 2015. Which is the Best MP3 Encoder for Podcasts? | Richard Farrar. [ONLINE] Available at: http://www.richardfarrar.com/which-is-the-best-mp3-encoder-for-podcasts/. [Accessed 05 January 2015].

8 Lame Installation - Audacity Wiki. 2015. Lame Installation - Audacity Wiki. [ONLINE] Available at: http://wiki.audacityteam.org/wiki/Lame_Installation#Using_LAME_without_Audacity. [Accessed 03 January 2015].

Compare against original?

I found that comparing against the original made me more able to hear the differences and artefacts. I want the test subjects to be able to listen to both A and B at the closest possible bitrate to real life as possible to show that MP3 encoding is not terrible.

What am, I looking for?

Alongside what people think sounds best, I will also be looking at file size and encoding time. When I prepare the clips, I will log down the time and file size along with the difference to the WAV file.

PREPARING THE MUSIC - METHODOLOGY

To prepare the clips for distribution, I first needed to pick a track that suits one of my pre- set criteria:

- A quickly changing full spectrum sound
- A slow, full spectrum sound
- A slow, quiet or simple track
- A quick, quiet or simple track
- A few extended notes of a piano

Below, I will outline how and why I chose each track.

Clip 1 - A quickly changing full spectrum sound

Clip 1 is a section of Alex Clare's song, Too Close. The section I have chosen to test is in the climax of the song. It is quite an active part which should test the encoder's ability to assess the required bitrate quickly and make a good judgement.

Clip 2 - A slow changing, full spectrum sound

Clip 2 is also a section of Alex Clare's song, Too Close. I have chosen this section form the introduction of the song. This part slowly builds in volume but there are electronic instruments across the spectrum, from bass to treble. This sample should test the encoder's ability to learn over time but it also needs to be sensitive at the start of the song to not cut too many of the low power frequencies out.

Clip 3 - A slow, quiet or simple track

Clip 3 is another Alex Clare song, this one is called I Won't Let You Down. It is a soft piano and vocals track with simple chords. This one shouldn't be too hard for the encoders, however, they will have to be sensitive to the gentle track. If they are too harsh to keep file size down, they may ruin the quality.

Clip 4 - A quick, quiet or simple track

Clip 4 is a track I made in GarageBand using some built in loops. The loops were .aiff uncompressed. I then made them into a short piece. The aim of this track was to quickly change but still be quiet and gentle, challenging the encoder.

Clip 5 - A few extended notes of a piano
The last clip is just a few sustained piano notes. This should be easy for the encoder but the VBR encoder might be too harsh. This should test wether it's 'learning' will reinforce for all notes.

The Alex Clare songs have been downloaded from the following web address:
http://files.philippe46.org.ua/media-data/music/Alex%20Clare%20-%20The%20Lateness%20Of%20The%20Hour%20%282011%29/

Clips 4 and 5 were made by myself using Apple Garageband[9].

All WAV files are 16-bit PCM. All MP3 files have a target bitrate of 64kbps and are encoded in 'Joint-Stereo' mode.

<div align="center">

**** SPOILER ALERT ****

</div>

If you are planning on trying my experiment for yourself, do not go onto the next page yet as it has the answers as to which clip, A or B was CBR and VBR. No cheating!

You can find my test here:
http://penguin.uclan.ac.uk/~lnelson/TE2071.html

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[9] Apple (United Kingdom) - GarageBand for Mac. 2015. Apple (United Kingdom) - GarageBand for Mac. [ONLINE] Available at: https://www.apple.com/uk/mac/garageband/. [Accessed 4 January 2015].

Filename	File Type	CBR /VBR	Original clip Filename	Length (Seconds)	File Size (KB)	File Size Decrease (KB)	Encoded % of original
1O.wav	WAV	-	04. Too Close .flac	16	2,809.9	-	-
1A.mp3	MP3	VBR	04. Too Close .flac	16	128.2	-2,681.7	21.9
1B.mp3	MP3	CBR	04. Too Close .flac	16	131.1	-2,678.8	21.4
2O.wav	WAV	-	04. Too Close .flac	15	2,648.4	-	-
2A.mp3	MP3	CBR	04. Too Close .flac	15	120.9	-2,527.5	21.9
2B.mp3	MP3	VBR	04. Too Close .flac	15	115.4	-2,533.0	22.9
3O.wav	WAV	-	12. I Won't Let You Down .flac	12	2,036.9	-	-
3A.mp3	MP3	VBR	12. I Won't Let You Down .flac	12	101.9	-1,935.0	20.0
3B.mp3	MP3	CBR	12. I Won't Let You Down .flac	12	93.1	-1,943.8	21.9
4O.wav	WAV	-	Luke's Track.aif	19	3,392.5	-	-
4A.mp3	MP3	VBR	Luke's Track.aif	19	162.5	-3,230.0	20.9
4B.mp3	MP3	CBR	Luke's Track.aif	19	154.4	-3,238.1	22.0
5O.wav	WAV	-	Piano notes.if	10	1,787.0	-	-
5A.mp3	MP3	CBR	Piano notes.if	10	81.7	-1,705.3	21.9
5B.mp3	MP3	VBR	Piano notes.if	10	83.1	-1,703.9	21.5

DISTRIBUTION

I have decided to distribute my test over the Internet. I will create a website which will have my clips (three for each of my five tests) and a small form to fill in for each one. The user will be able to listen to the clips in any order they would like. They will also have playback controls, allowing them to pause, rewind and seek through the clips. They will know the original version but the encoded versions will just be called A and B. I will mix up whether A or B is the CBR or the VBR for each test. This will make it a blind test meaning user's can't choose to prefer CBR or VBR and bias results. The user will then be asked a couple of questions asking which closest to the original, A or B and

how close it was. I have been looking at the way SoundExpert[10] runs its tests as they are all online. I tried to find out how other people did their blind listening tests by visiting the LAME website[11], however none of the links[12][13][14] worked, leaving only SoundExpert for me to base my experiment on.

Problems with this method

One problem with this method is that everybody will be listening to the tracks on different devices with different speakers and at different device sample rates. My website could be viewed on a mobile phone, on a smart TV with a 5.1 surround sound system, on a laptop with small speakers or even a desktop with headphones. This will mean that even the exact same clip will sound different per-person. This means the Device Under Test (DUT)[15] would not just be the encoder, it would also be the user's device. However. Between tests of the same user, the setup will stay the same. To try and minimise the differences, I will use SoundExpert's advice and advise users to do the following before beginning the test:

"It is recommended:
• to use headphones for listening
• to switch off all sound enhancers like SRS or Dolby
• to set equalizer to flat position
• to set the volume you normally listen your music" - *Direct quote from SoundExpert*[16].

Although results may differ slightly, the difference between devices will be negligible.

Benefits over other methods

Allowing users to listen to A and B multiple times will make sure they have made an informed decision rather than an instinctive click. The clips are also quite short, if they are not paying attention they may 'miss' the sound or not listen properly to gain an accurate perception.

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[10] Audio quality ratings of sound equipment and technologies - SoundExpert. 2015. Audio quality ratings of sound equipment and technologies - SoundExpert. [ONLINE] Available at: http://soundexpert.org. [Accessed 03 January 2015].

[11] LAME MP3 Encoder :: Related Links. 2015. LAME MP3 Encoder :: Related Links. [ONLINE] Available at: http://lame.sourceforge.net/links.php#Comparisons. [Accessed 02 January 2015].

[12] http://ff123.net/

[13] http://www.rjamorim.com/test/

[14] http://www.listening-tests.info/

[15] Page 2 - How It Works - Audio quality measurements in the digital age. (n.d.). [PDF] Available at: http://soundexpert.org/documents/10179/11017/se_howitworks.pdf/3a12bec5-9857-4fe2-9937-dab099801fe6 [Accessed 03 January 2015].

[16] Page 3 - How It Works - Audio quality measurements in the digital age. (n.d.). [PDF] Available at: http://soundexpert.org/documents/10179/11017/se_howitworks.pdf/3a12bec5-9857-4fe2-9937-dab099801fe6 [Accessed 03 January 2015].

COLLECTING THE RESULTS

The forms I put alongside the clips are Google Forms[17]. They are embedded in iFrames. This allows me to distribute a well made form that will not break and is easy to use. It is also easy for me to create and makes the results very accessible. The results are sent instantly into a spreadsheet, each sample gets it's own page.

The Results

I managed to get 31 responses from my family, friends and some other people.

Time to Encode
In my testing, encoding was done before I could even see the dialog box appear. If I were to properly test this part, I would use much longer pieces of music since the difference at this length is negligible.

File Size
Both CBR and VBR use a very similar amount of space at this length. Both reduce file size by around 21%. The best reduction was done by CBR with a file just 20% the size of the original. The worst was VBR with 22% the original size.
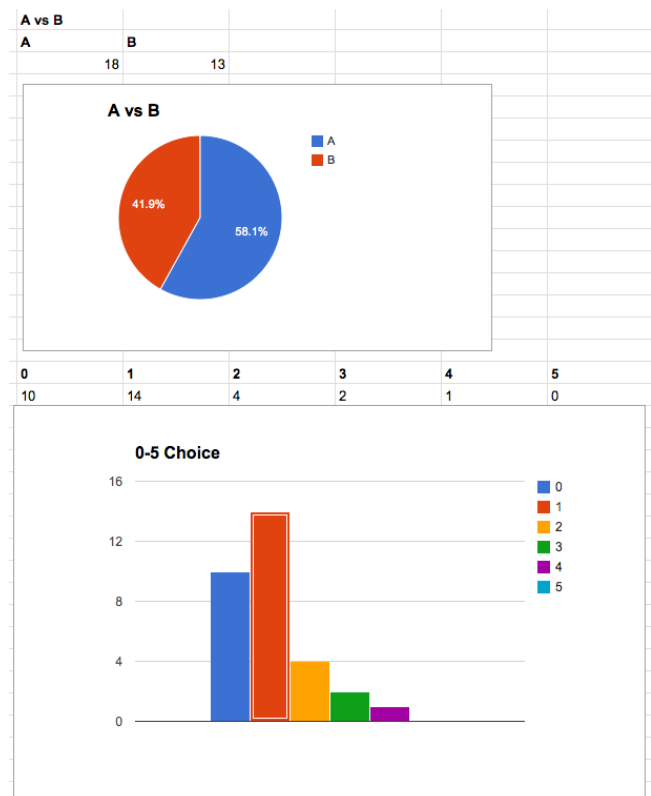
THE CLIPS

Clip 1
For clip one, to me, A and B sounded fairly similar but there were some extra artefacts in B. People seem to have picked up o them, the general trend being marking A as a 1. There were no fives at all but someone did mark A as a 4. VBR is the winner here.

The results for Sample 1 in chart form

Clip 2
Clip 2 was a difficult one. The results were very varied. B was the clear winner meaning the VBR was Better

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17 Google Forms - create and analyze surveys, for free. . 2015. Google Forms - create and analyze surveys, for free. [ONLINE] Available at: http://www.google.co.uk/forms/about/. [Accessed 13 January 2015].

Clip 3

This test was very close. There is no clear A/B split and the results are all very low, 0-2 meaning there is not much difference. I think both did a good job on this.

Clip 4

A (VBR) is the clear winner in this test but again, low scores. There is not much difference.

Clip 5

These clips are almost identical and the survey reflects this, only 0's and 1's.

CONCLUSION

Method	# Wins	Clip 1 FS	Clip 2 FS	Clip 3 FS	Clip 4 FS	Clip 5 FS	Clip 1 SV	Clip 2 SV	Clip 3 SV	Clip 4 SV	Clip 5 SV
CBR	4	1	1	0	0	0	0	0	1	0	1
VBR	7	0	0	1	1	1	1	1	1	2	1

As you can see from the table above, VBR is the clear winner, however, neither are really that good at 56kbps. It seems VBR can handle the differences better across the board whilst CBR stays constantly poor across all tests.

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11. LAME MP3 Encoder :: Related Links. 2015. LAME MP3 Encoder :: Related Links. [ONLINE] Available at: http://lame.sourceforge.net/links.php#Comparisons. [Accessed 02 January 2015].
12. Page 2 - How It Works - Audio quality measurements in the digital age. (n.d.). [PDF] Available at: http://soundexpert.org/documents/10179/11017/se_howitworks.pdf/3a12bec5-9857-4fe2-9937-dab099801fe6 [Accessed 03 January 2015].
13. Page 3 - How It Works - Audio quality measurements in the digital age. (n.d.). [PDF] Available at: http://soundexpert.org/documents/10179/11017/se_howitworks.pdf/3a12bec5-9857-4fe2-9937-dab099801fe6 [Accessed 03 January 2015].

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