

## TIMBRAL ATTRIBUTES FOR OBJECTIVE QUALITY ASSESSMENT OF THE IRISH TIN WHISTLE

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### ABSTRACT

In this paper we extract various timbral attributes for a variety of Irish tin whistles, and use these attributes to form an objective quality assessment of the instruments. This assessment is compared with the subjective experiences of a number of professional musicians. The timbral attributes are drawn from those developed in the Timbre Model [1].

### 1. INTRODUCTION

The Irish tin whistle is an instrument most often associated with Irish folk music. It is an interesting instrument in that it breaks many of the norms of musical instruments. In particular, there is no consensus among musicians on the merits of more finely crafted, expensive instruments. Many of the great tin whistle players prefer to play inexpensive whistles, believing the sound to be more in keeping with the traditions of folk music rather than the 'sweeter' tones of the more expensive varieties [3].

In its basic form, the whistle consists of a tube (usually metal), which is either cylindrical or conical in shape. A whistle is attached to one end. Different notes can be sounded by blowing through the whistle, and using a different finger pattern on the six holes on the shaft of the instrument. The most common whistle type is in the key of D, which is also the key of most Irish folk music. Air is passed through the whistle opening and strikes the lip of the whistle as it exits the fipple-hole (See Figure 1) [4]. The air jet then rapidly switches between one of two paths: through the bore of the instrument and passing out to the atmosphere, thus setting up a series of acoustic oscillations in the shaft. The effective length of the shaft can be altered by appropriate fingering, as shown in Figure 2.

Altering the effective length of the instrument in this way changes the resonance frequency. This ensures that only the relevant fundamental tone and partials are amplified, to produce the required note. Figure 3 below shows a typical spectral magnitude plot of a D note played on a Generation D tin whistle. It shows a strong

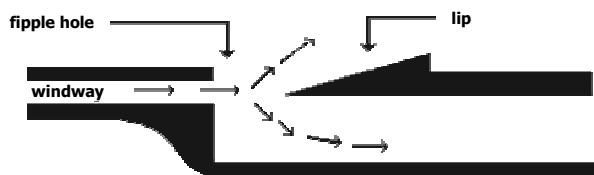


Figure 1: Air jet striking the fipple hole of a tin whistle.

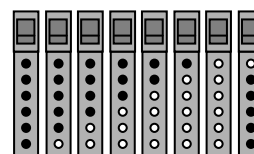


Figure 2: This shows the fingering positions for the tin whistle, playing Doh in the lower register on the left hand side, up to Doh in the upper register, on the right hand side. The black dots indicate closed finger holes, while the white dots indicate open holes.

first partial, followed by a series of harmonics that roll-off at a rate of approximately 8dB/octave. As can be seen, the tin whistle has only a small number of distinct harmonics, relative to other instruments.

### 2. CHARACTERISING MUSICAL INSTRUMENTS

Various approaches towards the characterisation of wind instruments are possible. Acoustic impedance measurements have been applied by [5] to classical and modern flutes. In this approach, an experiment is carried out that characterises the ratio between the air pressure and (the complex) airflow rate, to give a complex impedance measure, which is a function of frequency. This acous-

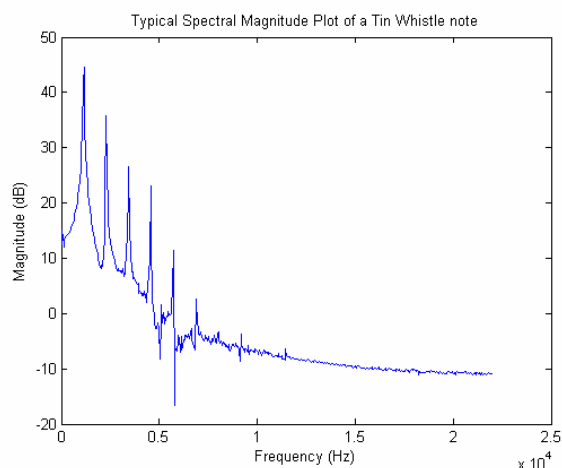


Figure 3: Spectral magnitude of a D note played on a Generation D tin whistle.

tic impedance is a characteristic of the instrument that is independent of the musician. Other approaches focus on analysis/synthesis techniques which seek to parameterise the pertinent perceptual attributes of the instrument and/or its expressive qualities [1,2]. Because of advantages of cost and efficiency, in this paper, a signal processing approach is taken using the recently developed Timbre Model [1].

### 2.1. The Timbre Model

The Timbre Model proposes a number of different measures to characterise the envelopes of the partials of a sound. This characterisation takes the form of a number of perceptually significant parameters, such as, spectral envelope, amplitude envelope, and noise parameters. The spectral envelope alone can be used to characterise a particular instrument and is associated with brightness and resonances of the sound [1]. For this research, in which we compare different makes of the one instrument, we choose measures associated with the spectral envelope to assess the qualities of these instruments. We are not concerned here with the expressive qualities evident in the sounds which are mainly due to the performer such as vibrato and tremolo.

Once the partial envelopes have been extracted, a number of spectral measures based on ratios of the partial envelopes are proposed. These include brightness, tristimulus1, tristimulus2, tristimulus3, irregularity and odd/even relation of the partials. As explained in [1], only two out of three of the tristimulus ratios are required. If each partial amplitude is denoted as  $a_k$ , and the sum of all  $N$  partial amplitudes is given as:

$$S_N = \sum_{k=1}^N a_k \quad (1)$$

Subsequently, the various ratios may be calculated as follows:

$$\text{brightness} = \sum_{k=1}^N k a_k / S_N \quad (2)$$

$$\text{tristimulus1} = a_1 / S_N \quad (3)$$

$$\text{tristimulus2} = (a_2 + a_3 + a_4) / S_N \quad (4)$$

$$\text{tristimulus3} = \sum_{k=5}^N a_k / S_N \quad (5)$$

$$\text{irregularity} = \sum_{k=2}^{N-1} \left| a_k - \frac{a_{k-1} + a_k + a_{k+1}}{3} \right| \quad (6)$$

Extraction of the partial envelopes is itself a complex matter. We use a dynamic time warping method to clearly identify the Attack and Release sections of each partial, thus enabling identification of the Attack, Sustain and Release phase of each note. The technique used is explained in [6].

The brightness function is the spectral centroid of the note. Generally speaking, brighter notes will be perceived to have a sweeter sound. The tristimulus measures are an auditory equivalent to the three visual primary colours. It may be seen from equations (3)–(5) that these three values add to unity; therefore one of the three is redundant. Certain instruments favour either the odd or even harmonics, giving rise to an even or jagged spectrum and this is the basis for the measures of equation (6).

### 2.2. Application of the Timbre Model to the Tin Whistle

Being a simple instrument, the tin whistle has relatively few partials. Indeed, our experiments have found from examination of the spectrograms of each note, that only low partials up to about the fifth or sixth are most significant. This is unsurprising, as it is commonly known that tin whistles are usually only played with other instruments that have richer tones, e.g. the fiddle, to add depth. For this reason, when calculating the tristimulus measure for the tin whistle, we use only tristimulus1 and tristimulus2. Furthermore, we include irregularity (equation (6)) rather than the odd/even measure [1] due to the small number of partials. Experiments supported this view, as measures for tristimulus3 and odd were low for all instruments and so did not illuminate significant differences in their timbres.

### 2.3. The Sounds

The sounds were recorded in uncompressed format in a quiet room using a standard microphone with a mini-disc recording system at 44.1 kHz (CD quality). The instruments were played by a professional Irish traditional musician. Five different tin whistles were used, the Generation D, Feadóg D, Clarks D, Hohner C, and Shaws D. A one octave scale was recorded in the key of each instrument. Four of the whistles are relatively cheap to purchase (around €5) whereas the Shaws whistle is about four times this cost.

## 3. RESULTS

In all of these results, the brightness, tristimulus, and irregularity parameters are calculated for each note, and then averaged over all notes in the octave for each whistle. There are therefore five plots in each section, one for each of the whistles used. It should be noted that the plots proceed from the Start of Attack to the End of Release for all notes.

### 3.1. Brightness Measures

Figures 4 and 5 display plots of the average brightness function for each of the 5 whistles. The brightness value during the attack is high for all whistles. However, the Generation D and Feadóg whistles display a value of above 2 for the duration of their notes. The Hohner whistle also fluctuates around 2 for its duration while the Clarks and Shaws whistles drop to between 1.5 and 2. The Generation D and Feadóg whistles, therefore, display a stronger brightness value for the duration of their notes.

### 3.2. Tristimulus1 Measures

The timbre of the tin-whistle is characterised by a fundamental with only a few harmonics. For this reason, we compare the tristimulus1 and tristimulus2 values for each whistle only. Tristimulus1 is plotted against tristimulus2 to show the relative strength of the fundamental compared with the first three partials for each whistle. Figures 6 and 7 illustrate these results. In Figure 6 (a), for the Generation D whistle, it can be seen that there is a good balance between the fundamental and low harmonics for the duration of the tone. This is also true of the Feadóg whistle as shown in Figure 7. The Clarks D (Figure 6 (b)) and Shaws D (Figure 6 (d)), on the other hand, show a much stronger fundamental with tris-

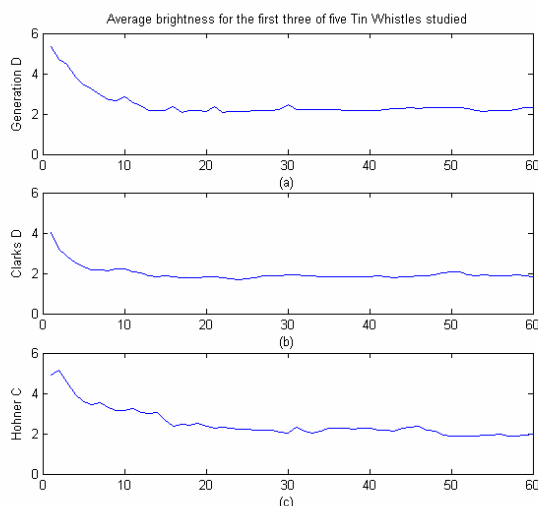


Figure 4: Plots (a) to (c) show the average brightness for the Generation D, Clarks D, and Hohner C whistles respectively.

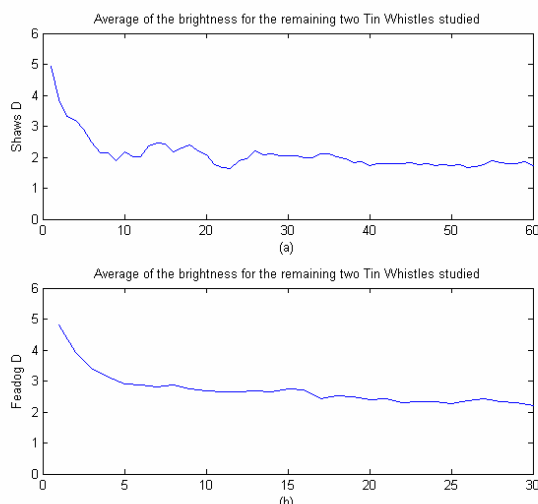


Figure 5: Plots (a) and (b) show the average brightness for the Shaws D and Feadóg D whistles respectively. (Note the duration of the Feadóg D is shorter than the other whistles.)

timulus1 dominating the plots. Finally, the Hohner C (Figure 6 (c)) exhibits a better balance but is not as good as the Generation D and Feadóg whistles.

The mean and standard deviation of the tristimulus values are shown in Table 1 for the various instruments. For this calculation, only tristimulus values in the sustain portion of each note were considered. The standard deviation results for both tristimulus measures are not markedly different for any of the instruments, indicating that this may be a characteristic of the tin whistles. The average value of tristimulus1 is higher in the Clarks and the Shaws whistle and these whistles also suffer from a lower value of tristimulus2. This indicates that there is more energy concentrated in the fundamental, relative to the other partials, and this indicates a poorer balance across harmonic amplitudes for these two whistles.

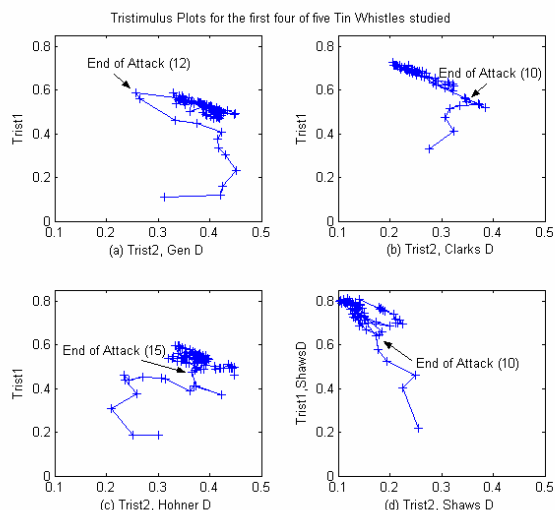


Figure 6: Plots (a) to (d) show the average tristimulus for the Generation D, Clarks D, Hohner C and Shaws D whistles respectively. Tristimulus1 is plotted against tristimulus2. The End of Attack is indicated, along with the ordinate of this point in brackets.

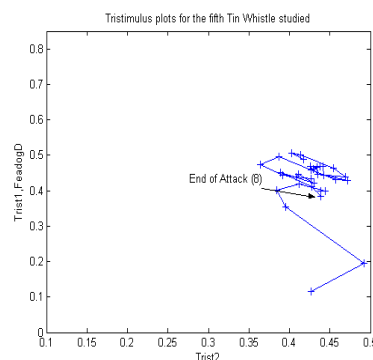


Figure 7: This show the average tristimulus for the Feadóg D whistle. Tristimulus1 is plotted against tristimulus2, and as before, the End of Attack is indicated, along with the ordinate of this point in brackets.

Tin Whistle	$\bar{T}_1$	$\langle T_1 \rangle$	$\bar{T}_2$	$\langle T_2 \rangle$
Generation D	0.52166	0.16259	0.38794	0.15098
Clarks D	0.67097	0.16074	0.25806	0.15224
Hohner C	0.53509	0.2013	0.37605	0.1869
Shaws D	0.7557	0.14867	0.14476	0.094288
Feadóg D	0.45373	0.1518	0.42539	0.13269

Table 1: This table shows the mean and standard deviation of the tristimulus values for each of the tin whistles studied.

### 3.3. Irregularity Measures

The average irregularity for the 5 tin whistles is shown in Figure 8. This measures the average spectral irregularity or 'jaggedness',

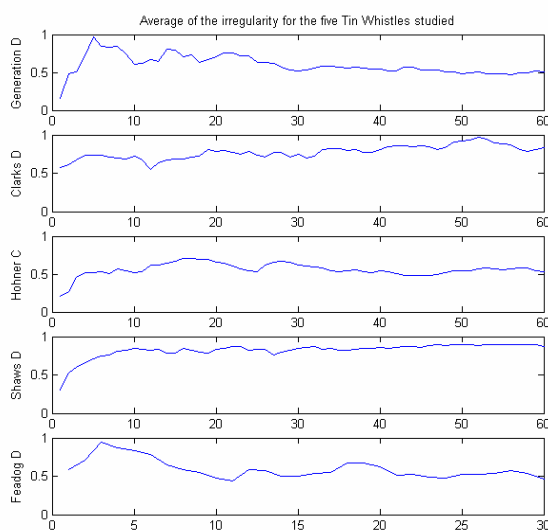


Figure 8: From top to bottom these plots show the average irregularity for the Generation D, Clarks D, Hohner C, Shaws D and Feadóg D whistles respectively.

for each whistle, a feature of timbre found to be one of the most perceptually salient for instrumental tones [2].

The main observation from the plots is that both the Generation D and Feadóg whistles have a decreasing irregularity after an initial peak during the attack phase, after which the irregularity settles at around 0.5. The other three whistles have less irregularity in their attacks after which it rises to around 0.5 in the Clarks and Hohner whistles. The Shaws whistle shows a very high irregularity for the sustain portion of the note.

#### 4. CONCLUSIONS

The timbral qualities of 5 Irish tin whistles have been analysed using spectral measures or brightness, tristimulus, and irregularity developed in the Timbre Model. The Generation D and Feadóg whistles showed the most similar results with both being distinctive for their high values for brightness, balance for tristimulus, and similar curve shapes and values for irregularity. The tristimulus results for these whistles reconfirm the results for brightness, where the influence of the low partials contributes to a centroid calculation for a brighter sound. The results also explain the duller timbre of the Clarks and Shaws whistles while the Hohner whistle is closer in brightness to Generation D and Feadóg. The similarity in irregularity results for the Generation D and Feadóg whistles would possibly relate to the stronger presence of the low harmonics whereas the results for the other three whistles possibly reflect the absence of low harmonics. Moreover, the high value in these three whistles is due to the relationship of a strong fundamental to weak harmonics especially as the tone progresses. We can conclude, therefore, that the Generation D and Feadóg whistles are the brightest and contain stronger low harmonics. These results would appear to agree with the subjective assessment of most professional tin whistle players, the majority of whom choose the Generation D whistle for performances in order to produce a clear bright sound. This would appear to indicate that the Timbre Model is a useful predictor of subjective quality. Future work intends to

explore more rigorously potential applications of the Timbre Model to other instrument families.

#### 5. ACKNOWLEDGEMENTS

The authors wish to thank Mr. Roy Galvin, a former All Ireland champion tin whistle player, for his professional assessment and playing of the tin whistle sounds recorded for this research.

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