

Mozart to Metallica: A Comparison of Musical Sequences and Similarities

Stuart Cunningham, Vic Grout & Harry Bergen

Centre for Applied Internet Research (CAIR), University of Wales, NEWI

Plas Coch Campus, Mold Road, Wrexham, LL11 2AW, North Wales, UK

Tel: +44(0)1978 293583 Fax: +44(0)1978 293168

s.cunningham@newi.ac.uk | v.grout@newi.ac.uk | h.x.bergen@web.de

Abstract

Musical composition is a creative art, but is restricted by the limitations of the finite musical information that can be expressed. Though notation allows expressive qualities to be applied to notes, composition is limited within the realms of the octave; therefore only a limited number of combinations of musical notes are permitted within a measure or musical piece. This restraint combined with trends of the human creative psyche to be influenced by factors in the surrounding environment, means that many musical pieces, though perceived as being greatly different in terms of their style, are often very similarly constructed on a strictly notational basis. This paper uses simple techniques to attempt to provide initial examination of musical pieces, which are perceived to be vastly different in style, and to compare any similarities of sequences of musical notes between them.

This paper contrasts similarities between musical pieces varying across two extremes of musical genre. Results from this investigation show that there are distinct levels of similarity in musical composition between music perceived as being very different; traditional classical music, and more contemporary popular rock.

1. Introduction

Musicology and analysis of musical notation has been a field that has long been studied and the analysis of musical pieces to explore patterns and structure has been of particular interest to both music technologists and composers alike [1, 2, 3]. The number of different styles and genres of music has also grown over time, as both technology and expressive composition has developed to assist the writing of original music. However, although the tools for creation and expression of musical information have developed, the actual language of music has remained static. All music created is restricted within the realms of the musical notes C, D, E, F, G, A, and B and the modifications of these notes (lower and higher octaves, sharps, flats, natural, duration, etc.). Although this may seem a large quantity of different possibilities for composition of sequences limited within these realms, over hundreds of years of music composition it would be an acceptable assumption that sequences of notes can be found within many different original compositions, of

varying genres. Have all the songs already been written? Or at least, more specifically, have all the sequences been written? In which case, music composition is now limited to creative re-arranging of these sequences? This paper analyses several pieces of music, ranging dramatically from the realms of classical music to rock and metal, to demonstrate the existence of similar sequences of music, even between such genres of music, perceived as being dramatically different.

2. Music Notation Searching

Written music score can be stored electronically in a variety of formats, and computers are excellent at performing simple, repetitive tasks, such as comparisons. This means that the development of software has produced a tool which can be fed music score as input, and a number of comparisons can be performed on it. By doing this, it is possible to tailor a search to look for similarities between two musical pieces. Performing searches on a corpus of musical pieces, and with various search options, should reveal trends and interesting detail about music composition, and how it may have developed and grown.

An application was written in Java which processes the musical score information that is present in a MusicXML file. MusicXML is a format which has emerged over recent years, and is designed specifically for easy analysis, storage, and distribution of musical notation information [1, 3, 4]. This application parses the required notational data and stores this in variables and arrays within the program. These variables contain information about the sequences of notes within a measure. This data is then concatenated as required and is ready for processing as a string of data. Comparison is then performed using nested loops, adhering to certain parameters of search, and a count of matches is maintained throughout. It can then be determined what percentage of a musical score, exists in the other score it is being compared with.

The application searches for blocks of musical notes. A block can consist of any sequence of music notation containing multiple musical events. To enhance the effectiveness of a search, blocks are incremented by a note with each iteration, until all search blocks have been used. Therefore, a note, or set of notes, will frequently appear in multiple search blocks.

This particular application of the software searches through measures of music. This means that in the source file, where we are taking measures, we increment by groups of musical notes (the musical measure). Each measure is then looked for in the target file, where the source measure is overlaid on a note step basis.

For example, consider the example illustrated in Figure 1, where we see a file containing six notes and a fixed block size of four notes. The diagram shows how the search block moves throughout the file as the search procedure progresses.

Note 1	Note 2	Note 3	Note 4	Note 5	Note 6
Block 1					
	Block 2				
		Block 3			

Figure 1 – Progression of Search Block Through Notes

This can be summarised by the following simple pseudo-code:

```

for (x=1; x<=sourceMeas; x++){
    for (y=1; y<=((tarN-meanN)+1); y++){
        if (sourceBlock==targetBlock) {
            matches++;
        }
    }
}

```

Where *sourceMeas* is the number of measures in the source file, *tarN* number of notes in the target file, *meanN* number of notes in the current source file measure. By recording the number of successful matches of each measure, a percentage of the source file that appears in the target file can be easily obtained.

This means that matches for each measure of the source file can be recorded, even though they may not occur strictly within a measure in the target file. Though this may be seen as not strictly finding exact matches, it does allow for the matching of measures, and effectively components of melody, in the target file.

2.1 Strict Searching

In this search technique the application will search for sequences of musical data where each note in the search sequence must be identical to that of the content of the target block. This gives the most precise and strict search option.

To achieve a match, the notes within the blocks being compared must hold the same pitch, octave, and duration.

Figure 2 shows two measures of music, which would be classed as an identical match during such a search.



Figure 2 – Example of Exactly Matching Measures

2.2 Relative Searching

Through the exact matching process, the note pitch, effectively the name must be the same for a match to be made. However, commonly musicians change the ‘key’ of a musical piece to make it either easier to play or sing [5]. When changing the key of a piece, the notes in a sequence or measure are still relative to each other, though they may be different pitches. However, if a standard formatting is applied to describe the relationship between notes in a sequence, the distance between the notes in a sequence would be the same regardless of the actual note pitch value or the overall key of the piece.

In this case then, it becomes useful to search for the relative relationship of two separate musical sequences. This means that when using a relative search, a melody could be detected successfully as a match, even if it had been transposed into a different key.

This is accommodated by assigning a distance value between notes in a sequence. This could be as simple as assigning a value of 1 to each step in pitch. For example the sequence (A3 B3 B#3 B3) would have a relative distance sequence of (0 2 1 -1), which would match with any other sequence with an identical distance measurement, for example the sequences (C5 D5 D#5 D5) and (E2 F2 F#2 F2).

Figure 3 shows two measures of music, which would be classed as a match, since they have the same distance measurement between notes, even though they have different note values.



Figure 3 – Matching of Relative Measures

2.3 Search Options - Pitch Octaves

If we consider the notes in a musical octave N_t , where N is the note and t is the octave number. In this format, this presents the standard octave format: $\{C_t, D_t, E_t, F_t, G_t, A_t, B_t, C_{t+1}\}$. When analysing sequences and musical melodies, two measures which have the same note pitches or note name, but are in different octave registers may well be perceived to be the same. And, similarly to the relative nature of musical sequences, changes of the

octave value are often employed in music composition to change the timbre or atmosphere of a melodic piece.

When this option is switched on, notes in compared sequences must have the same octave value. For example, the sequence (G3 F#2 E4) would only match successfully with an identical sequence of notes. However, if the octave option is off, then the octaves associated with sequences when they are compared, is ignored. So, if searching for the sequence (G3 F#2 E4), a match is made though octaves values may be different, for example, a valid match for this sequence would be (G5 F#2 E1), or effectively making potential matches (Gx F#y Ez).

This facilitates searches which are exact in terms of octaves, but when this restriction is removed, it means that melodies which employ the same notes, but are shifted up or down the octaves, can still be identified as being similar.

Figure 4 shows two measures of music, which would be classed as a match, since the note pitch values are identical, but the sequences are in different octaves.



Figure 4 – Matching Measures Across Octaves

2.3 Search Options - Duration Types

The length of a note, how long it is played, is commonly an associated musical attribute, known as the duration. If two musical sequences are being compared, the duration of a note may or may not be desired to be taken into account. A sequence of notes might well be considered to be similar if the note pitch and octave are the same, but the duration of some or all of the notes might vary between the two sequences.

In some respects, the same melody might be played much slower or faster, therefore truncating the notes over several measures as they would appear written in musical score. This also helps with any searches where the overall tempo or timing of a piece of music may have been changed.

Figure 5 shows two measures of music, which would be classed as a match, since the note pitch and octaves are identical, though the duration of both sequences of notes is different.



Figure 5 – Matching Measures with Different Durations

3. Mozart to Metallica

To fully exploit the ability to compare different musical pieces, it was decided to explore and contrast two genres of music that are perceived to be very different. This would not only make the tests and results highly interesting, but also serves as an insight into how composition techniques and structuring of music might have changed over time. Mainly, the concept is also to see if the two genres, alleged as being so very different, are indeed highly diverse from a purely musicological point of view.

The following choices were made to be used in this investigation. Table 1 shows the choices of music made from the classical genre, while Table 2 details the more contemporary popular rock music choices. For ease of dissemination later, each piece of music has been assigned a unique ID code.

Table 1 - Classical Musical Choices

ID	Composer	Piece
C1	Beethoven	Sym. No. 9 (Op.125) 2nd Mov't
C2	Chopin	Nocturne Opus 15 No.1
C3	Elgar	Pomp & Circumstance March No.1
C4	Mozart	Sym. No. 30 in D 1st Mov't
C5	Vivaldi	Spring (Four Seasons) 1st Mov't
C6	Wagner	The Ride Of The Valkyries

Table 2 - Contemporary Musical Choices

ID	Artist	Song
R1	AC/DC	Highway to Hell
R2	Beatles	Hey Jude
R3	Black Sabbath	Paranoid
R4	Jimi Hendrix	Hey Joe
R5	Metallica	Enter Sandman
R6	Queen	Bohemian Rhapsody

The choice of pieces of music for these tests covers a broad range of perhaps the most recognised names and compositions. This is useful twofold, since the majority of people will be familiar with these musical choices, and also since they have generally been so well accepted and successful, it may be particularly of significance to investigate these pieces over any others.

4. Results of Music Comparison

Each of the pieces of music listed in Tables 1 and 2 were directly compared against each other in this test. By contrasting and comparing several different pieces of music the most interesting and wide scale results could be achieved. To provide a diverse range of results a number of options were invoked over several searches, such as using either strict or relative searches, and the options of ignoring note octaves and durations, as described earlier in this paper.

Once all of these comparisons between the musical pieces had been made, the resulting data was collated into tables for each search carried out. This data is presented for all of the different searches that were carried out. To make the data easier to interpret, charts have been used to present information. However, for the first set of results for each search, the tabulated data is also included to allow the reader to understand the correlation between the raw data, and what is presented in the charts. Measurements are made as a percentage of similarity; measuring how similar one piece of music is to another.

The music ID code presented as ordered vertically are the pieces which are being investigated primarily in a particular search, and is being contrasted against the music listed along the vertical.

For the strict searches, a depth of explanation of results will be presented, but for the relative searches this will be made briefer as it is assumed the reader will be better equipped to interpret the results having read the interpretation of the previous comparisons.

4.1 Strict Search

This comparison looks for exact matches between the musical sequences. The results are tabulated in Tables 3 and 4 below. For ease of interpretation, the results are also presented in a chart in Figures 5 and 6.

To clarify how to interpret the tabulated data, the cell R1, C1, from Table 3, which contains the value '48' should be interpreted as: '48% of the measures in song R1 appears somewhere in song C1'. The average at the end of the row displays how similar, on average that particular song was when compared to all of the musical pieces listed horizontally. As another example, taken from Table 4, the cell located at C3, R4 containing the value '36' should be interpreted by the reader as '36% of the measures in song C3 appears somewhere in song R4'.

Table 3 – Strict Comparison Results (Rock in Classical)

ID	C1	C2	C3	C4	C5	C6	Average
R1	48	31	56	40	31	31	39.50
R2	79	78	81	79	78	78	78.83
R3	28	21	24	22	26	21	23.67
R4	38	38	55	42	38	37	41.33
R5	50	48	51	49	50	48	49.33
R6	77	76	78	75	75	75	76.00

Table 4 – Strict Comparison Results (Classical in Rock)

ID	R1	R2	R3	R4	R5	R6	Average
C1	53	52	52	52	52	56	52.83
C2	20	20	20	22	22	24	21.33
C3	30	32	29	36	30	37	32.33
C4	29	27	28	28	29	29	28.33
C5	28	28	29	29	38	31	30.50
C6	53	53	53	53	53	53	53.00

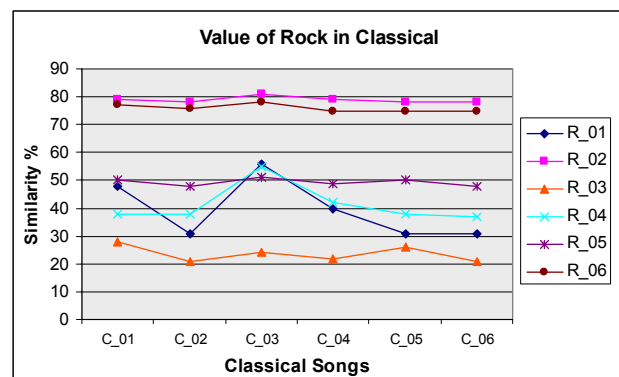


Figure 5 – Strict Comparison Results (Rock in Classical)

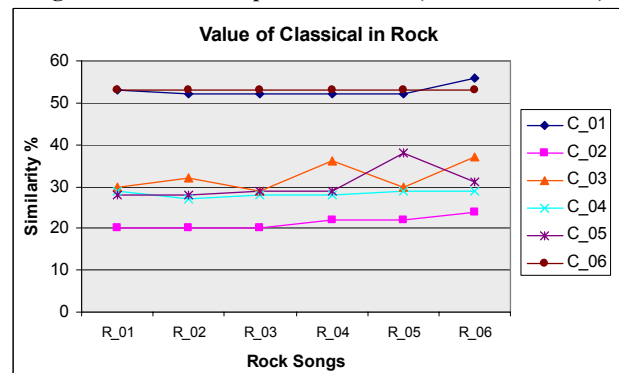


Figure 6 – Strict Comparison Results (Classical in Rock)

The most striking features noticeable in these results, perhaps surprisingly, is the high levels of similarity between some of the musical comparisons. However, since the search procedure takes measures from the source file and overlays them on a stepped by note basis on the target file, this is not so surprising. It is also worth to note that different musical pieces will frequently have varying numbers of measures and notes.

Particularly of interest when comparing the amount of rock measures in classical music, is the large increase in similarity percentage around classical piece C3; Elgar’s “Pomp & Circumstance March No.1”, suggesting that this piece bears a distinct level of similarity against the rock songs. Also of interest are the consistently high levels of similarity of R2 and R6 with all of the classical pieces. This is partly attributable to the large number of measures in these two contemporary rock songs.

To then consider the amount of classical measures appearing in the rock choices, it is noticeable that the trends presented are much more consistent than with the rock measures in classics comparison. It is also interesting to see that for the majority of tests, the similarity levels were between 20 and 30 percent, apart from two files, C1 and C6, which had much greater levels of similarity, every time, against all of the rock choices.

Finally, the overall average similarity of rock in classical is higher (51%), than the overall percentage of similarity between the classical pieces (36%). This suggests that classical pieces are more diverse and complex in their structure than the contemporary music choices. It might also be interpreted that contemporary music is influenced by particular melodies or components occurred in the classics, which may have been inherited in some way, or selected as being the best, most popular techniques which were used in the classics.

4.2 Strict Search – Octaves Ignored

This comparison looks for exact matches between the musical sequences, but this time the search disregards the octave values of notes. The search still takes into account the note pitch and duration. The results are presented in a chart in Figures 7 and 8.

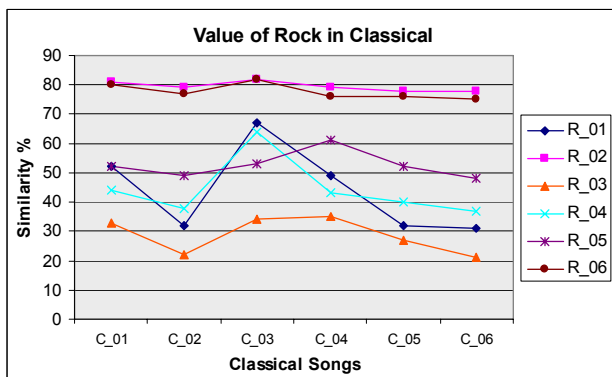


Figure 7 – Strict Comparison Results - Octaves Ignored (Rock in Classical)

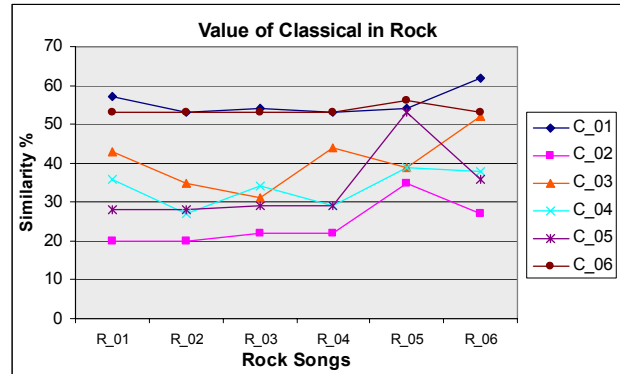


Figure 8 – Strict Comparison Results – Octaves Ignored (Classical in Rock)

If we look first at Figure 7, we observe that in this set of comparisons C3 again shows a high level of similarity when all of the rock music choices are compared against it. The amount of variance when compared to the same set of results when the octaves were significant has increased, with greater deviation between the rock songs. An example of this expansion of difference can be seen by comparing the trends of R1 and R5 in particular in Figures 5 and 7. Additionally, R3 had increased similarity against C3 and C4 when the octave values are disregarded.

Figure 8 again shows an increase in similarity for the majority of tests, when compared to the previous, octave aware, set of comparisons. This is noticeable with a peak in trends for R5. This could suggest that for this particular piece of music, Metallica’s “Enter Sandman”, there is a particular relationship between it and the classical pieces, and that sections of the classical music are quite similar, but generally placed in different octaves.

Overall the average similarity of rock in classical is higher once again (54%), than the overall percentage of similarity between the classical pieces (40%), and this is a higher average value, 3% and 4% higher respectively, of similarity that the previous test, which required octaves to be the same. This would suggest that overall the shifting of melodies into other octaves is not a hugely significant factor when comparing sequences of audio. Perhaps predictably though, it does also indicate that by making a search more flexible and open, that more matches will indeed be found.

4.3 Strict Search – Duration Ignored

This comparison looks for exact matches between the musical sequences, but discounts the note duration information in measures and search blocks. The results are presented in a chart in Figures 9 and 10.

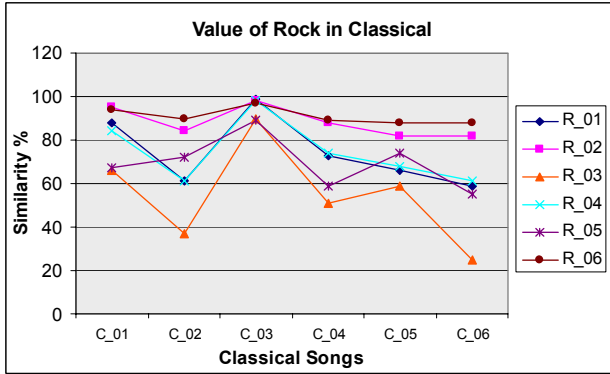


Figure 9 – Strict Comparison Results - Duration Ignored (Rock in Classical)

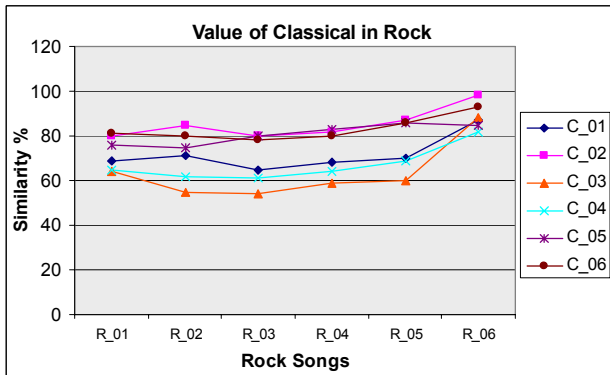


Figure 10 – Strict Comparison Results – Duration Ignored (Classical in Rock)

Figure 9 again demonstrates that across a series of strict tests, with various options, the piece C3 has the highest similarity against all of the rock pieces. In this case the percentage of rock measures present in C3 is exceptionally large, with similarity measures of 99, 98, 90, 98, 89, and 97 percent. Another point of note is that R2 and R6 have more variance across their comparisons with all of the classical pieces.

When we analyse Figure 10 we can see a notable difference between the results presented in the other strict tests in Figures 8 and 6. In this particular comparison, the trends of all classical songs are similar, and the numerical similarities are also relatively closely correlated, across all of the rock songs with which they have been compared. This may indicate that when duration is removed classical music compositions bear a standard form of similarity with rock pieces, and that there may be some ratio or formula which could be applied to calculate such relationships.

Overall the average similarity of rock in classical is equal in this test (75%), than the overall percentage of similarity between the classical pieces (75%). This indicates that the duration attributes of notes is fairly significant when comparing sequences of music. However, to match purely the sequence of notes pitches in a melody, the removal of the duration assists in finding a

greater number of matches. This also indicates again, that by making a search more generic, more matches will be found.

4.4 Relative Search

This comparison looks for relative matches between the musical sequences, which also accounts for the octave and duration attributes of each note in a sequence. The results are presented in Figures 11 and 12.

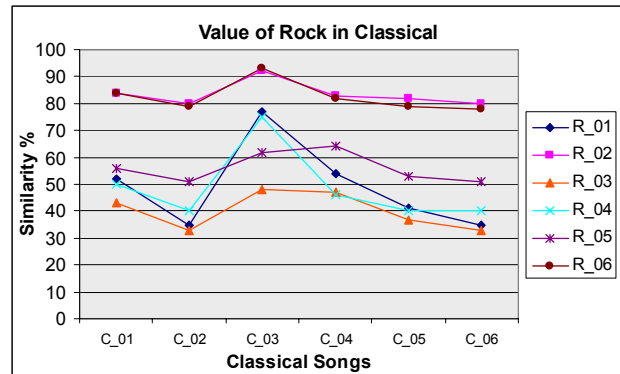


Figure 11 – Relative Comparison Results (Rock in Classical)

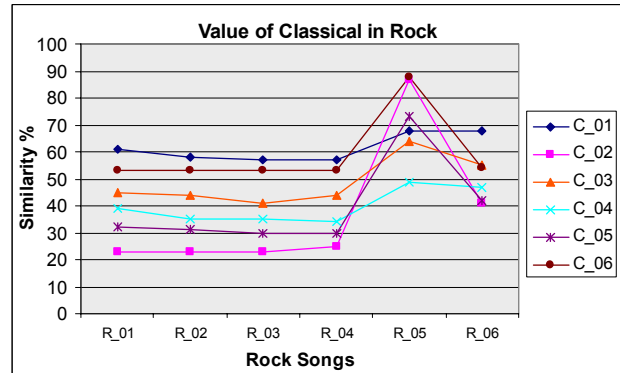


Figure 12 – Relative Comparison Results (Classical in Rock)

Figure 11 shows peaks of the trends again at C3, and also shows high levels of similarity at C4 for a number of the rock pieces. Additionally, there is a very close correlation between results for R2 and R6, which is echoed by the trends of lower similarity, in R3 and R5. This may suggest that when comparing the relationship between melodies relatively, there is a much more normalised relation between the two genres of music.

Clearly, the most interesting features evident in Figure 12 is the close similarity of trends for all of the classical pieces, and the common rise in similarity between all of the classics to R5 and R6. All of the classical songs have a high level of similarity to both of these pieces, which themselves vary significantly in size. This suggests that the measure present in “Bohemian Rhapsody” by Queen and “Enter Sandman” by Metallica, have very similar musical progressions and structures to a range of classical

pieces, in particular Wagner’s “*Ride of the Valkyries*” and Beethoven’s “*9th Symphony*”.

Overall the average similarity of rock in classical is much higher in this test (60%), than the overall percentage of similarity between the classical pieces (48%).

4.5 Relative Search – Octaves Ignored

This comparison looks for relative matches between the musical sequences and disregards octave attributes associated with notes in sequences. The results are presented in a chart in Figures 13 and 14.

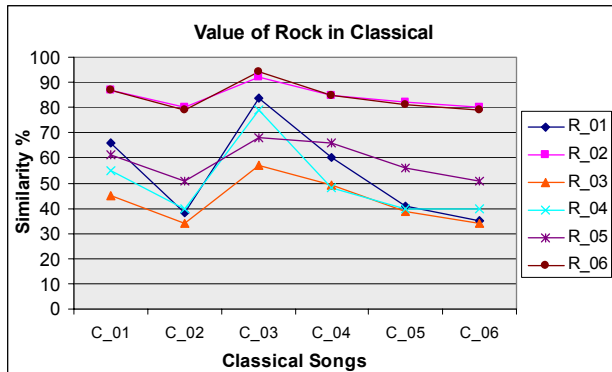


Figure 13 – Relative Comparison Results - Octaves Ignored (Rock in Classical)

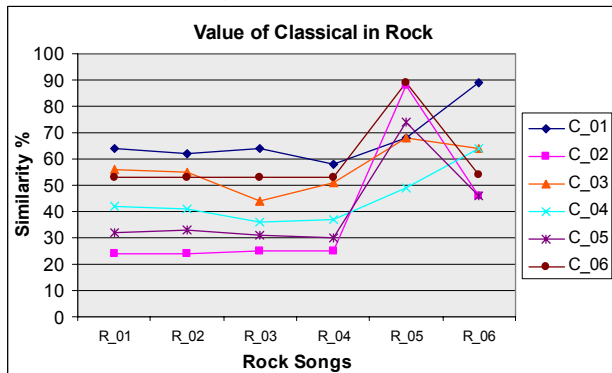


Figure 14 – Relative Comparison Results – Octaves Ignored (Classical in Rock)

Figure 13 shows similar results to Figure 11, but as with the octave ignored strict search, the results have been truncated from the same search that included octave values. This trend may begin to suggest that the difference in octaves is not highly significant when compared to sequences in classical songs.

Figure 14 again slightly expands the range of results from the previous relative search that ignored the octave values. The most intriguing difference though, is that the majority of all classical songs now show a higher similarity to R6, suggesting that there might be a significant relationship between the classical pieces and R6; an interesting point, given that R6, “*Bohemian Rhapsody*” contains an operatic section.

Overall the average similarity of rock in classical is much higher in this test (62%), than the overall percentage of similarity between the classical pieces (51%). Interestingly, this is the first set of results where the overall average percentage of classical measure in rock songs has been higher.

4.6 Relative Search – Duration Ignored

This comparison looks for relative matches between the musical sequences, and disregards the duration element of notes in sequences. The results are presented in a chart in Figures 15 and 16.

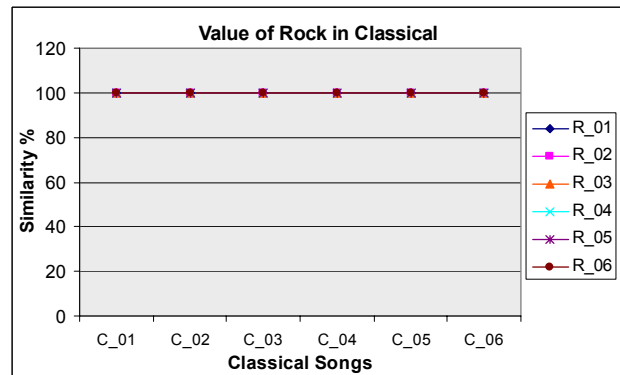


Figure 15 – Relative Comparison Results - Duration Ignored (Rock in Classical)

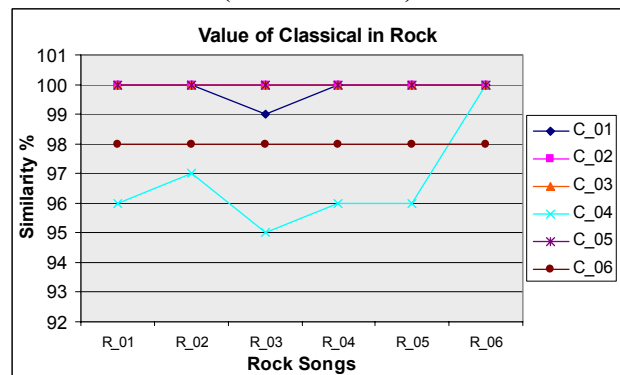


Figure 16 – Relative Comparison Results – Duration Ignored (Classical in Rock)

Figure 15 demonstrates that 100% of all the rock measures appear in all of the classical pieces.

Figure 16 shows very similar sets of results, except for the very subtle variances for C4, Mozart’s “*Symphony Number 30*”. C4 varies slightly across the range of rock pieces, indicating that it is perhaps one of the most musically diverse pieces being compared.

Overall the average similarity of rock in classical is much higher in this test (100%), than the overall percentage of similarity between the classical pieces (99%). It is expected that this high percentage set of results is due to the large number of measures in many of the compositions, the percentage value being rounded, and

the fact that this is a relative search which ignores note duration. This is the least strict search of all those covered in this paper. The duration attribute seems to play a significant role in separating rock from classical music.

5. Discussion of Results

Different musical pieces have more parts and differing lengths than others. Hence, there is often a difference in the number of measures available to search in each of the different files. The obvious difference is that classical songs generally have a greater number measures than the rock songs. This is primarily attributable to most classical pieces being performed by an entire orchestra, with many instruments, whereas rock songs are more traditionally limited to a much lower number of musical parts.

On the whole, the percentage of similarity in tests has been of varying levels, but tending to average towards values of around 50%. Although this does not absolutely qualify all rock musical pieces as being very similar to classical pieces, it should not be dismissed through being perceived as a high value. After all, we know that music composition is limited to eight notes within an octave, with any alterations. Given that all musical compositions are tied to this, it should be expected that a reasonable degree of similarity would be found in any comparison. This being taken into account though, the octave values would be expected to reduce this level of similarity. However, when searches were performed with and without analysing the octaves, there were only slight increases in similarity encountered, suggesting that this has little value in accounting for any dissimilarities, and would propose that most music composition centres around the same set of octaves, the majority of the time.

Perhaps the most interesting discovery when changing options in searches was that the duration element seemed to be the most constraining for detecting matches. When note duration was neglected, the percentage of similarity generally showed enhancement. Note duration, from these sets of tests, seems to be the largest factor separating classical and contemporary rock music, in terms of their musical attributes. This could well account for the human perceptive difference in the musical style, as classical music is normally less intensive, with notes of longer durations, than the up-beat, and often frantic streams of notes encountered in contemporary rock.

6. Conclusions & Future Work

The application developed to support this avenue of investigation supports many more search options than have been addressed in this paper. For example, other note elements can be chosen to be included or ignored in searches, such as alterations of notes, ornaments and duration dots.

Another useful feature available is the ability to specify the size of the search block, in notes, rather than being limited to using the current measure of the source file. This is a particularly interesting feature, as it allows more precision and degrees of granularity to be added to any search and comparison work.

In future, a larger number of comparisons needs to be undertaken with a greater sample of music across different styles and genres, to further test the techniques employed, and substantiate the theories proposed in this paper.

It should be noted that although the comparisons carried out in this work were from genres perceived to be radically different, the tests were still limited to a fairly small number of pieces within two genres. It does not necessarily mean that these similarities, trends and theories will necessarily apply to comparisons across, and within, other genres of music. Clearly, further and more diverse testing is required to ascertain any absolute conclusions in this field.

However, that said, it does appear from the majority of results and tests, that the classical and contemporary rock genres, may not be so radically different after all. It may then be the case that the way in which human hearing interprets the colour and timbre of a piece of music, is more significant to helping classify musical style, than the actual notes and sequences being played. Surely to classify music in the strictest sense, it should be done on a notational, musicological scale, and not by the human perceptive system, which is open to misinterpretation and huge deviation between listeners? Creating new music may well be much more focused on the performance and interpretation of music now, rather than on the creative writing and composition process.

7. References

- [1] Cunningham, S., 2003, Music File Formats and Project XEMO, MSc Dissertation, University of Paisley, Scotland, UK.
- [2] Dannenberg, R. B., Hu, N., "Discovering Musical Structure in Audio Recordings", Proceedings of Music and Artificial Intelligence: Second International Conference (pp. 43-57), ICMIA, Edinburgh, Scotland, UK, 2002
- [3] Cunningham, S., 2004, Suitability of MusicXML as a Format for Computer Music Notation and Interchange, Proceedings of IADIS Applied Computing 2004 International Conference, Lisbon, Portugal.
- [4] Good, M., 2001, MusicXML: An Internet-Friendly Format for Sheet Music. IdeAlliance: XML 2001. Florida, USA.
- [5] Károlyi, O., *Introducing Music*, Penguin, 1991.

8. Acknowledgments

Thanks to Dr. Rich Picking, Dr. Derek Turner and Prof. Marcin Paprzycki.