Statistical Analysis of Vocal Folk Music

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Abstract

This study explores the German songs of the Essen Folksong Collection and provides statistical findings from them. The aim has been to study aspects of a contextual nature such as relationships between time domain and pitch domain and the melodic contour at the phrase level. With statistical examinations of melodies a better understanding of several aspects in the music has been achieved and the results are relevant to several fields of music science, such as music cognition and algorithmic composition. The contextual nature of music has been shown by examining ten different aspects. Among the most interesting findings are:

A clear relationship between pitch salience and metrical salience. Notes at salient metrical positions are more likely to have a high pitch salience. A clear relationship between interval size and note length. Large intervals often occur between longer notes and small intervals are more often found between shorter notes. That melodic stairs of one pitch step are more common in a rising formation than in a falling formation. That contour repetition is almost always accompanied by rhythmic repetition at the phrase level. That earlier findings for convex phrase arches is mostly a phenomena of an upward movement in the first phrase of a song and a downward movement in the last phrase of a song.

Contents

1 Introduction

1.1 What are the benefits of statistical analysis in music?

Why can a statistical approach to music, an art form often linked to emotion, be of any use? There seem to be statistical relationships in music wherever you look, and it has been proposed that probable movements in music may be perceived by the listener as pleasurable (Huron, 2006). With a statistical understanding of probabilities in music better predictions about future events can be achieved and statistical results can be used in several fields of music science. Psychological aspects such as expectation and memory can be better understood. As an example sound sequences can be stored in short-term memory for approximately 30 seconds if not repeated (Ahlbäck, 2004; Huron, 2006; Encyclopedia Britannica, 2009) and with an analysis of musical phrase repetition or phrase length this can be directly linked to the structure of music. A statistical analysis can also foster the development in *algorithmic composition* (computer composition of music). Many composition techniques are based on statistical data to model probabilities (Farbood & Schoner, 2001; Nierhaus, 2009; Tanaka et al, 2010) and this data can be used in Markov models, or other generative implementations. Another important field is *music information retrieval* (Temperley, 2006). Retrieval of music information, in particular from audio, will become more accurate with an understanding of statistical probabilities in music. This as the retrieved information will have noise in the form of incorrectly retrieved data and a statistical understanding will aid in removing this noise. Statistics can both confirm relationships within music, and help to provide insights to why these relationships do exist. Let us look at an example to get acquainted with statistical analysis in music and its benefits.

It has been well known that melodies tend to move down after large leaps upwards in pitch, a phenomena called gap fills (Levitin, 2006) or skip reversals (Huron, 2006). To confirm this statistically is fairly easy. The first step is to scan a large set of songs, a database with data in a format that is accessible. Every interval between two succeeding pitches is evaluated and for the intervals that are positive and larger than a certain threshold (as an example a rise of 6 semitones) the notes following that interval are analyzed. If they are on average falling, we have confirmed the theory. However we will not have explained why this is occurring. Is it an expression of style? Or is it perhaps a consequence of the instrument performing the music?

Huron (2006) has analyzed this and his conclusions are that the rule of skip reversal was in fact formulated wrong to begin with. It is not so that large leaps upwards in pitch are automatically followed by a falling pitch. Instead the phenomena can be completely explained by regression to the mean. That is, melodies always tend to move towards the mean pitch where the mean is defined by the earlier notes of the same melody. When the melody is falling after a large leap it is merely an effect of regression to the mean and the statistical evidence Huron has put forward is the following: If a large leap upwards occurs at the lower register of a melody, so that the note which the leap will land on is positioned below the mean pitch of that same melody, it is statistically more probable with a continued upward motion. However, as most large leaps upwards naturally land above the mean pitch this effects cannot be discovered merely by looking at big leaps, disregarding mean pitch. As a conclusion, the phenomena of skip reversal could only be explained when the context in which they occur was taken into consideration. That music is contextual and that the context must always be considered when describing music is an essential thesis in this study.

1.2 Aims

The aim of this study is to reveal statistical relationships that have not been studied before. Simply put the main theory is that *music is contextual*. The idea is that melodies are always of a contextual nature and that simple relationships such as the distribution of intervals do not provide the true probabilities for the next pitch of the melody. Instead a broader context must be analyzed. The context is provided by the earlier parts of the melody and can be of the following nature:

- Where in the melodic range of the melody is the current pitch positioned?
- What is the direction of the earlier pitches?

To make use of the answers to these questions we must know how they affect probabilities in music. This is where this study will be useful as questions of the following nature are answered:

- What are common melodic ranges?
- How does the earlier direction of the pitch affect probabilities for the next note pitch?
- How does metrical position affect pitch probabilities?

Ten different aspects of this nature have been examined and these aspects are presented below in Section *1.3 Outline of the study.*

1.3 Outline of the study

This study explores the German songs of the *Essen Folksong Collection* (Schaffrath, 1995) and provides statistical findings from them. The total number of songs is 5370 and in the statistical examinations different subsets of these songs are used. Ten different aspects have been examined (see Appendix 1 for concepts and terminology):

1. **Ambitus** - The range of the melody as the distance between the highest and the lowest note.
2. **Pitch & Meter** - The distribution of pitches, compared across different meters.
3. **Metrical Salience & Pitch** - How the salience of the metrical positions affect the distribution of pitches.
4. **Intervals & Note Length** - The relationship between note length and interval size.
5. **Double Notes** - The distribution of repeated occurrences of two pitches with the same tone height, for different starting positions in the measure.
6. **Stairs** - The distribution of note sequences, with intervals of one pitch step, with continuous direction, examined for different note lengths.
7. **Contour** - The direction of the melody examined across the pitch domain.
8. **Repetition** - In which ways musical phrases repeat each other.
9. **Phrase Arch** - The contour of the melody examined at a phrase level.
10. **Tonal Resolution** - The pitch distribution at the tonal resolution in the end of each song.

1.4 Background to the studied aspects

Provided below is a brief background to the ten studied aspects.

1. Ambitus, 2. Pitch & Meter, 3. Metrical Salience & Pitch

A thorough analysis of Danish folk songs has been done by Holm (1984) where he studied interval sizes and their distribution, the highest and lowest notes of the music as well as the melodic range (ambitus). Parncutt (1994a & 1994b) has studied listeners' perception of metrical accent for repeating patterns giving credence to the notion of metrical salience based on rhythm. Generally speaking the first position in the meter is the most salient and subdivisions are less salient. On a similar theme, rhythmic organization of a melody may be perceptually more salient than the note pattern according to Dowling (1993), and according to Monahan (1993), listeners will group melodies (performed without accompaniment) based on the rhythmic pattern.

4. Intervals & Note Length, 5. Double Notes, 6. Stairs, 7. Contour

Vos & Troost (1989) have studied the distribution of intervals in Western music and found that small intervals more often descend and that large intervals more often ascend. Tonality has been studied by Krumhansl & Kessler (1982 as cited in Huron, 2006) who let listeners rate the goodness of fit, related to major and minor keys, for different pitches. Notice that the key needed to be established beforehand, an element of uncertainty. By analyzing the *Essen Folksong Collection*, Eerola & Toiviainen (2004) have found a somewhat different distribution. The importance of *contour reversals* was illustrated by Watkins & Dyson (1985) by playing songs with a few notes altered each time. When altered notes occurred at contour reversals listeners were more likely to notice them. It has also been shown by Dowling (1978) that contour is important in our perception of melodies.

8. Repetition, 9. Phrase Arch, 10. Tonal Resolution

That listeners perceive repetition of contour has been noticed by West, Howell & Cross (1985). The repetitive nature of music has been pointed out by other researchers as well, amongst them Huron (2006). Huron has also examined the phrase contour of the songs in the *Essen Folksong Collection*, and found an on average convex contour, sometimes referred to as the *melodic arch*. On a similar theme Craig Sapp showed the author (2011) the most common first three notes and the most common last three notes from the *Tirol Folk Songs* (a subset of the *Essen Folksong Collection*). The most common three-note ending he found was scale notes 3-2-1 and the most common start was 1-2-3 followed by 3-4-5. The author has examined (Elowsson, 2012) the most common three note patterns in 80 000 songs from Themefinder (2011). For the upward motion 1-2-3, 7.5 % of all occurrences were found in the first three notes but for the downward motion 3-2-1 only 1.9 % of all occurrences were found in the first three notes.

2 Preparations

The starting point was to convert the songs of the *Essen Folksong Collection* to the MIDI-format. The songs were originally in a format called *Kern* and they were converted with *Humdrum* (Huron, 1995) in combination with commands from the *Humdrum extras extension*. In this study all songs have been converted to C major or A minor, which as an example for C major means that pitch height C represents the tonic, D represents the second etc.

The MIDI-toolbox (Eerola & Toiviainen, 2004) was used to turn the MIDI-files into a proper format in *Matlab* (2012). Easy-accessible Matlab-files were created for the most common meters and the number of songs is shown in Table 1.

	2/4	3/4	4/4	6/8	Total
Number of songs in Major	1047	921	1295	574	3837
Number of songs in Minor	69	66	138	81	354

Table 1: Matlab files were created for the following meters.

All songs in Table 1 were extracted with and without the human edited phrase slurs of the *Essen Folksong Collection*. Phrase slurs and measure lines were first converted to MIDI-notes to provide the possibility to move them to Matlab with the MIDI-toolbox. They were used in Matlab to align the MIDI files correctly with the meter and to mark up the phrase starts, and then they were removed.

3 Examinations

The songs were examined with simple Matlab commands. This is an example of a short Matlab code to calculate the average length of the notes as depending on the size of the interval.

```
for interval = -12:1:12                              %For each Interval
    len = 0;
    cou = 0;
    for jj = 1:length(nm2)                           %For each song
        song = nm2{jj};
        for ii = 1:(length(song)-1)                  %For each note
            if(song(ii,4) == song(ii+1,4) + interval)   %If correct interval
                len = len + (song(ii,2)+ song(ii+1,2));  %Add length
                cou = cou + 1;                       %Add count
            end
        end
    end
    pitchLen(interval+13) = len/(cou*2);             %Calculate ratio
end
plot(pitchLen)                                       %Plot findings
```

The examinations of the ten different aspects presented in Section 1.3 are described in Section 3.1-3.10. Notice that for a good coherence in the report *considerations*, *results* and a brief *discussion* will be presented for each aspect separately.

3.1 Ambitus

The first examined aspect is the range between the lowest and the highest pitch (ambitus) in the songs. First the number of semitones between the highest and the lowest pitch was extracted from the songs. To be able to display the results as a number of scale tones as well, a separation into scale tones was accomplished by the scheme in Table 2. As an example the ambitus in scale tones became 6, if the ambitus counted in semitones was 10 or 11.

Scale tone	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Semi-tone	1	3	5	7	8	10	12	13	15	17	19	20	22	24
Semi-tone	2	4	6		9	11		14	16	18		21	23	

Table 2: Separation into scale tones from semitones.

The results are summarized in the four diagrams of Figure 1. The two diagrams in the top displays the distribution of the songs as scale steps. The diagram in the top left is for the songs in major mode and the diagram in the top right is for the songs in minor mode. A 7$^{\text{th}}$ degree fitting has been applied to better visualize the results. The two diagrams in the bottom display the distribution of the songs as semitones. The diagram in the bottom left is for the songs in major mode and the diagram in the bottom right is for the songs in minor mode.

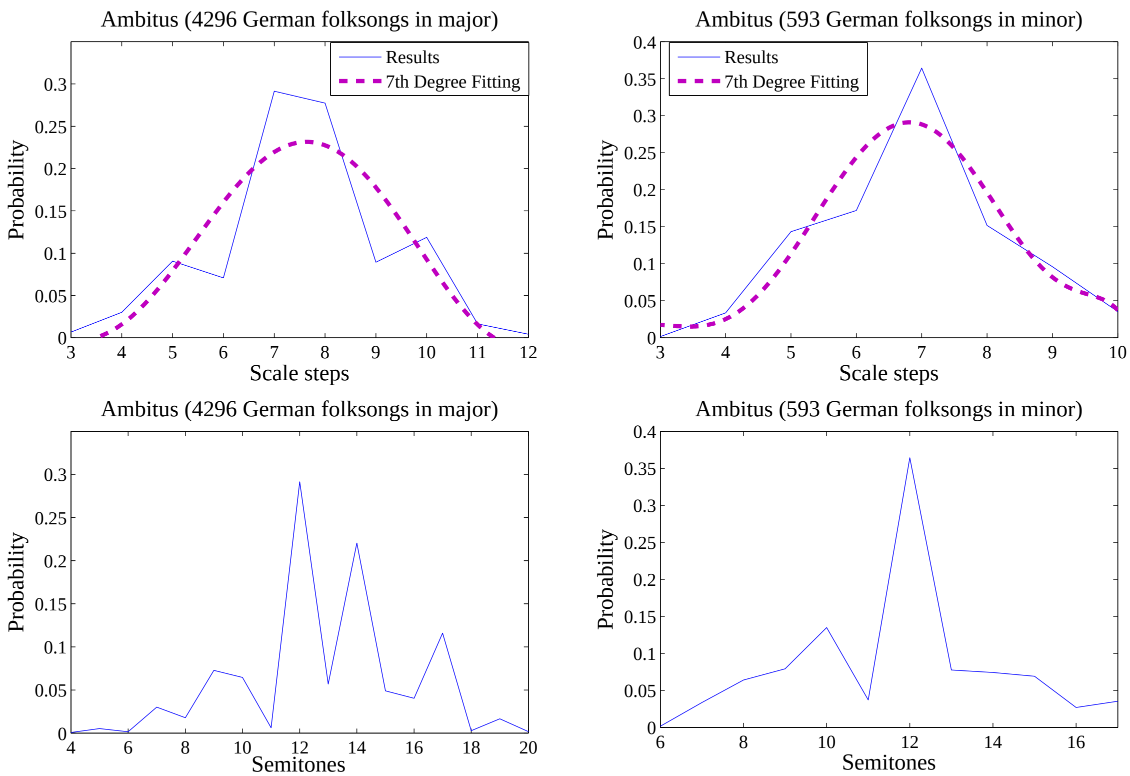

Figure 1: Ambitus in major (left) and minor (right), both displayed as scale tones (top) and semitones (bottom).

It is evident that an ambitus of 7 or 8 scale tones is the most common in major mode (top left diagram of Figure 1) and that an ambitus of 7 scale tones is the most common in minor mode (top right diagram of Figure 1). The findings are in line with earlier findings from Danish folk songs (Holm, 1984). Also notice from the semitone diagrams (bottom diagrams of Figure 1) that the ambitus for songs in minor is smoother than the ambitus for songs in major. Perhaps this is due to the characteristics of the minor scale where in A minor the notes F, F$^{\#}$, G and G$^{\#}$ all occur frequently (Krumhansl & Kessler, 1982 as cited in Huron, 2006; Eerola & Toiviainen, 2004). The tendency for a lower ambitus for the songs in minor mode is somewhat interesting and could be further examined. Perhaps a relationship to the length of the examined melody could be found as well, as it is likely that longer songs have a higher ambitus.

3.2 Pitch & Meter

The number of notes of each pitch (scale tones) as a relation to the total number of notes of each meter was examined for the songs in major mode. The idea was that some meters would perhaps have different pitch distributions than others. The result can be seen in Figure 2. Besides the four meters (4/4, 2/4, 3/4 and 6/8) an average is also displayed (leftmost bar for each pitch)

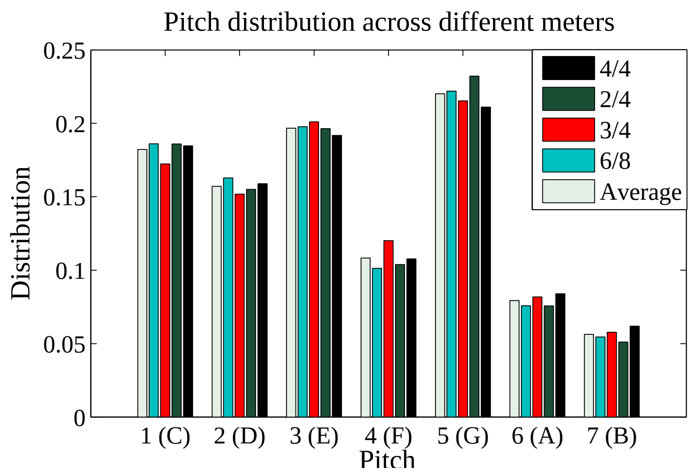

Figure 2: The distribution of pitches across different meters for melodies in major.

The distribution is very similar between the different meters. In conclusion no significance difference in the pitch distribution across different meters was found (Figure 2).

3.3 Metrical Salience & Pitch

The relationship between strong metrical positions and pitch salience was examined. The idea was that the pitches of higher salience (prominence) would more often occur at stronger metrical positions and that pitches of lower salience would more often occur at weaker metrical positions. To be able to demonstrate such a relationship the salience of the pitches as well as the strength of the metrical positions had to be graded in some way. The pitches (within the diatonic scale) were graded according to three different criteria where a lower number means more salient.

- Salience from the circle of fifths: {C = 1, G = 2, D = 3, A = 4, E = 5, B = 6, F = 7}
- Proximity to the tonic chord combined with distance to the dominant chord. First notes belonging to the respective chords were sorted. G which belongs to both chords was given a medium score (4). Lastly F was considered closer to the dominant as it belongs to the seventh chord (G7) and A was considered closer to the tonic as it belongs to the sixth chord (C6). The resulting grading was: {C = 1, E = 2, A = 3, G = 4, F = 5, D = 6, B = 7}
- The total number of notes divided by the number of occurrences of each scale tone within each examined meter (see Figure 2 for this distribution).

The metrical positions were sorted into four groups based on metrical salience (Parncutt 1994a; Parncutt 1994b) as described in Table 1. Lower means more salient so group 1 is the most salient.

Salience group	4/4 meter	2/4 meter	3/4 meter	6/8 meter
1	{1,3}	{1}	{1}	{1,4}
2	{2,4}	{2}	{2,3}	{3,6}
3	{1.5,2.5,3.5,4.5}	{1.5,2.5}	{1.5,2.5,3.5}	{2,5}
4	{16^{th} notes}	{16^{th} notes}	{16^{th} notes}	{16^{th} notes}

Table 3: Metrical positions (numbered as beats) sorted into groups based on metrical salience, where group 1 is the most salient etc.

The relationship between pitch and metrical salience was computed as the average score of the graded pitches in each metrical salience group. That is, the average score of the pitches (according to the three different grading criteria) that were positioned on the strongest metrical position was computed as a total score for that metrical position. The average score of the pitches (according to the three different grading criteria) that were positioned on the second strongest metrical position was computed as a total score for that metrical position etc. The results can be seen in Figure 3. Notice that the score gets higher the weaker the metrical positions are. This means that there is a relationship between metrical salience and pitch salience. The results were similar over all examined meters, salient scale tones are positioned more often at metrically salient positions. The relationship is significant for all three examined gradings of the pitches. That is, the relationship exists independently of if you regard pitch salience as something that can be derived by the *Circle of Fifths,* a *Tonic/Dominant* scheme or *Weighted* by how common the pitches are.

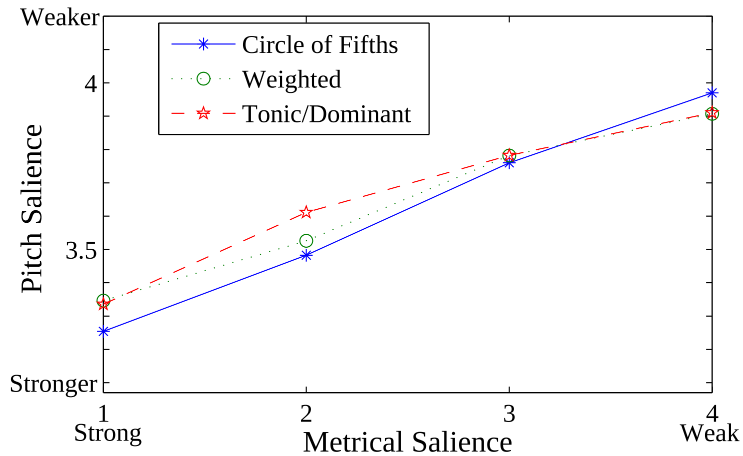

Figure 3: The relationship between metrical salience and pitch salience as an average of all examined meters.

To get an overview of how the relative pitch distribution changes across the measure a distribution for 4/4 meter is displayed as well in Table 4. A positive score means that the pitch is relatively more common at that position as compared to the other pitches. A negative score means that the pitch is relatively less common at that position as compared to the other pitches.

Beat/Pitch	C	D	E	F	G	A	B
1	0.31	-0.13	0.08	-0.26	0.00..	-0.04	-0.34
1.5	-0.28	0.23	-0.21	0.45	-0.07	0.08	0.25
2	-0.10	0.07	0.10	-0.01	-0.03	0.01	-0.08
2.5	-0.24	0.17	0.01	0.42	-0.29	0.24	0.17
3	0.02	0.08	0.05	-0.12	0.01	-0.08	-0.13
3.5	-0.14	-0.05	-0.30	0.44	0.08	0.12	0.26
4	-0.02	-0.06	-0.17	-0.10	0.23	-0.02	0.11
4.5	-0.32	-0.03	0.05	0.47	-0.17	0.03	0.60
16^{th} notes	-0.10	0.20	-0.06	0.21	-0.27	-0.02	0.55

Table 4: Relative distribution of scale tones at metrical positions in 4/4 meter and major mode.

We find that salient pitches (C, E, G) are overrepresented and that scale tones of low salience (B, F) are underrepresented on salient metrical positions (beat 1 and 3). For the less salient positions (16^{th} notes) the opposite is true. We also find that notes belonging to the dominant chord but not the tonic chord (B and D) are more common towards the end of the measure whereas C is most common at the first position in the measure.

3.4 Intervals & Note Length

The average note length was examined for different intervals, ranging from a falling interval of one octave to a rising interval of one octave. The songs in 4/4 meter in major mode were used in this examination and the code is displayed in the beginning of Section 3. In this examination a quarter note has the length 1, an 8^{th} note (which is half the length of a quarter note) has the length of 0.5 etc. The average of the length of both notes in each interval was used. The theory was that there would be a relationship between the size of the intervals and length of the notes. An important aspect in visualizing the results was a cubic fitting. This as the results becomes very noisy for unusual intervals. The results can be seen in Figure 4. Interval size is represented by a number. Falling intervals have negative numbers (as an example a falling minor third is represented by -3).

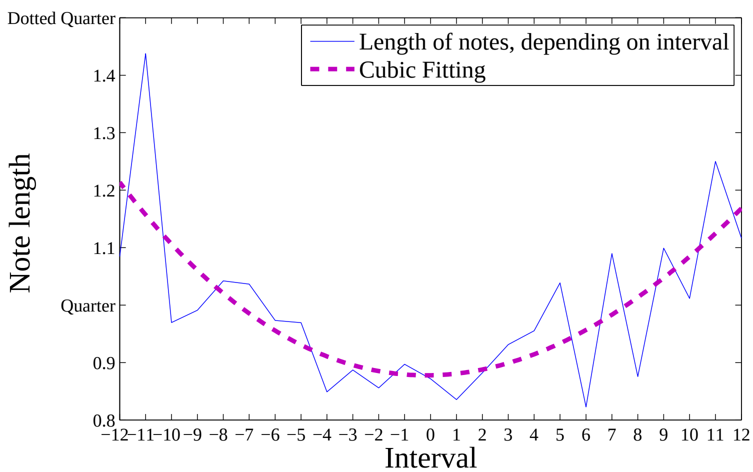

Figure 4: The average note lengths for different intervals. *Note length* is the average note length of the two notes that constitute the interval.

There is a clear relationship. The intervals are generally larger between longer notes and smaller between shorter notes (notice the concave pattern with short note lengths for small intervals).

3.5 Double Notes

The aim was to show how patterns of repeated "double notes" with the same pitch and note length are distributed over the measure. An example of a song built around two notes of the same pitch followed by two new notes of the same pitch etc. is "Twinkle, Twinkle, Little Star". The idea was that formations of these double notes would be more inclined to start at certain positions in the measure than others. The examinations were done for quarter notes and 8^{th} notes and melodies in 4/4 meter in major were used. In figure 5 we see the results for quarter notes. Notice that the stronger metrical position {1,3} take precedence over {2,4}, and that there are no occurrences at {1.5,2.5,3.5,4.5}.

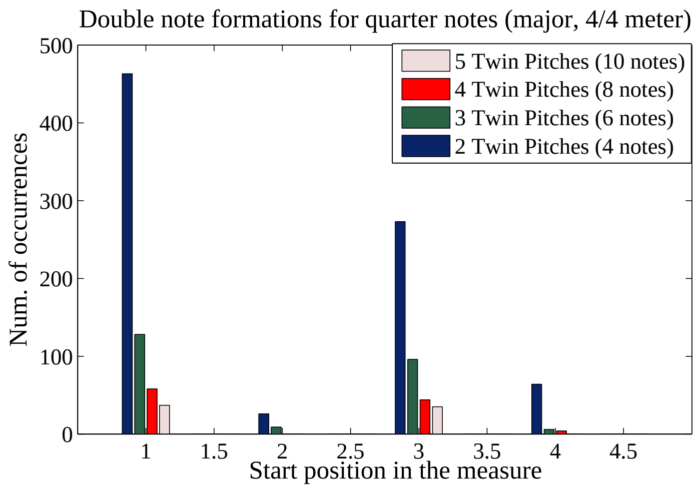

Figure 5: The number of double notes (two repeated pitches followed by two new repeated pitches etc.) for quarter notes with start position for the whole formation displayed across the measure.

For 8^{th} notes no further examinations were done beyond 4 notes (2 twin pitches) as so few examples was found and the statistical data became uncertain. The results can be seen in Figure 6.

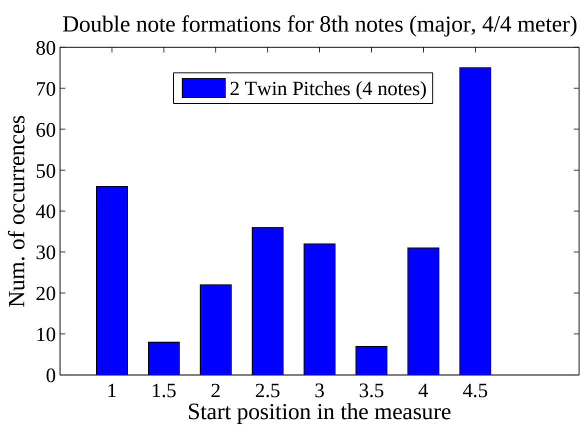

Figure 6: The number of double notes (two repeated pitches followed by two new repeated pitches etc.) for 8^{th} notes with start position for the whole formation displayed across the measure.

For the 8^{th} notes the results are harder to interpret. There are fewer matches overall and there seems to be a repeating pattern for the first four 8^{th} notes and the last four 8^{th} notes of the measure. One possible interpretation is that double note formations have a tendency to begin on metrically salient positions also for 8^{th} notes. They may start an 8^{th} note before but not an 8^{th} note after the metrically salient position to include that position early on in the double note formation.

3.6 Stairs

The idea was to find formations of notes with similar length that occur as falling or rising stairs. This means that the intervals would rise one scale step or fall one scale step for each note. As different note lengths were examined the context of note length as affecting the tendency for stair-formations could be analyzed. To make the results generally applicable the total number of repeated notes of the different note lengths is used and the findings for the different note length becomes a ratio between the number of found stairs and the number of total occurrences. A comparison between rising and falling stairs is also interesting and therefore results are plotted for falling and rising stairs, as well as for the sum of the two. The examined songs were in major and had a $4/4$ meter. The result can be seen in Figure 7. Notice that rising stairs (R) are more common than falling stairs (F) and that stair formations are generally more common for shorter note durations.

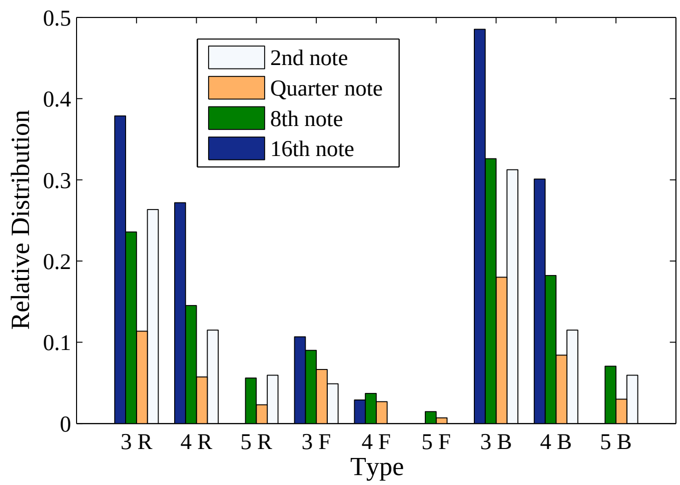

Figure 7: Relative distribution for stairs of varying length, with varying note lengths. R = Rising, F = Falling, B = Both, {3,4,5} = Number of notes in the formation.

Stairs are more common for faster note lengths if the total number of repeated notes of the different note lengths are taken into consideration. As quarter notes and 8^{th} notes were the most common, the statistical findings for these two are the most reliable. Here we find that for all nine types, the 8^{th} note stair is more common than the quarter note stair if the relative frequency of occurrence of repeated 8^{th} notes and quarter notes is taken into consideration. We also find that for all nine types where the 16^{th} notes are represented they are more common than the quarter note stairs.

Stair formations tend to occur more often as rising than falling. This is especially interesting as it is the opposite of what have been found to be true for intervals in general, that small intervals more often descend than ascend (Vos & Troost, 1989). There seems to be something special with stairs that makes them more common as rising[1].

3.7 Contour

As it has been shown by Dowling (1978) that contour is important in our perception of melodies different aspects of contour in melodies were examined. To be able to display the results based on position in the meter a decision was made to only use the most common metrical positions. As the songs were in 4/4 meter (major) this meant 8 positions an 8^{th} note apart from each other. Contour was examined for *contour reversals*, *direction* and *good continuation*.

3.7.1 Contour Reversals

As *contour reversals* seem to be perceptually important (Watkins & Dyson, 1985) these were examined separately. Each time the contour of the melody changed direction (from falling to rising or rising to falling) the pitch at which the direction changed (the lowest/highest pitch) was noticed. The result, a distribution of contour reversals, can be seen in Figure 8. The results are displayed for each semitone where 1 represents C, 2 represents C#, 3 represents D etc. Notice that for the two notes in C major that are non-pentatonic, 6 and 12 (F and B), there are large differences in the tendency to be minimum and maximum pitch at contour reversals. Pitch 12 (B) occurs 7 times more often as a minimum pitch than a maximum pitch and pitch 6 (F) occurs almost 5 times as often as a maximum pitch than as a minimum pitch. Why does this happen? Both of these extremes are found for notes that are non-pentatonic. The answer may then be that non-pentatonic pitches often function as contour reversals towards the scale tone that is one semitone away, but almost never functions as contour reversals towards the scale tone that is two semitones away.

[1]Perhaps stairs can be perceived as moving more clearly towards a specific goal for a rising contour than a falling contour, making rising stairs more useful to the composer.

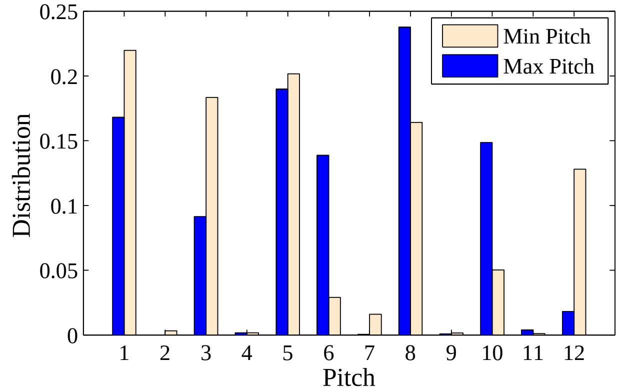

Figure 8: The distribution of *contour reversals.*

Another interesting result is that a succession of three notes in a row far from the tonic in C major 6, 8 and 10 (F, G and A) are all maximum pitches. A succession of four notes in a row close to the tonic 12, 1, 3 and 5 (B, C, D and E) are all minimum pitches. Why does this happen? Here a conclusive answer is harder to give. Perhaps the disharmony of pitch 10 and 12 (A and B) with the tonic chord constitutes a melodic barrier, making movements away from the barrier more probable.

3.7.2 Direction

In a similar way as *contour reversals* the *direction* of the melody was also examined. For each note it was examined if the direction of the melody from that note was falling, rising or steady. The result can be seen in Figure 9.

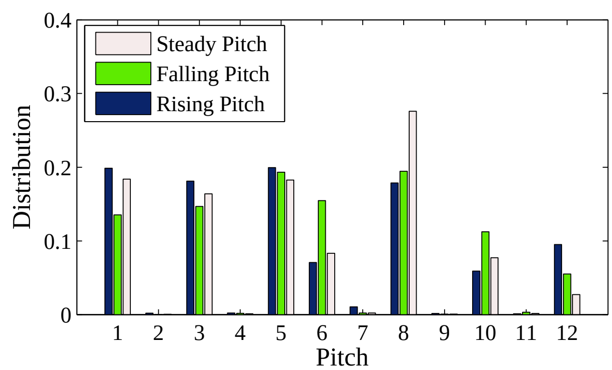

Figure 9: The distribution for the subsequent *direction* from different pitches.

The tendency that could be observed for *contour reversal* is once again apparent. Pitch 12 (B) tends to move upwards and pitch 6 (F) tends to move downwards. A similar explanation (non-pentatonic notes moving one semitone) may be applied here as well. Overall the findings for *direction* are less clear than the findings for *contour reversal*. Interesting is also the tendency for 8 (G) to be steady. One explanation may be that G belongs to the two most common chords I (tonic chord) and V (dominant chord). G can therefore occur repeatedly and still belong to the chord. The higher tendency for 10 (A) to fall may be explained by the movement to the steady G and the movement away from the earlier proposed barrier that A and B forms.

3.7.3 Good Continuation

If a new direction of the melody had been established (falling to rising or rising to falling) by an interval of one pitch step, it was examined if the melody continued to move in that direction, one pitch step at the time. The result is displayed as a ratio where higher than one means a higher probability to *continue* in the same direction and lower than one means a higher probability that the melody *changes* direction than continues in the same direction. The result is displayed in Figure 10. A quadratic fitting was applied to better visualize the results. The dotted line represents an equal probability. As can be seen, new intervals of one pitch step tend to continue in the same direction but as 3-5 notes have passed in the same direction the probabilities are instead higher for a change of direction.

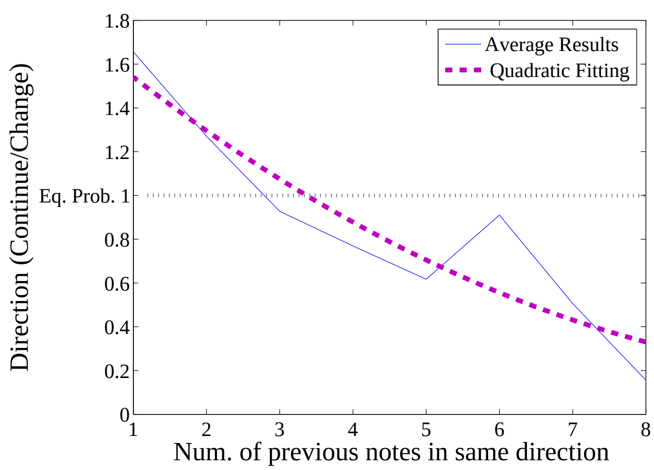

Figure 10: The probabilities for intervals to continue in the same direction after x number of intervals of one pitch step in that direction.

The probability to continue in the same direction when a new direction has just been established were high both for rising and falling contours (Figure 10 display the average result for both contours). They however differed between the 4^{th} and the 6^{th} note. Perhaps the fact that rising stairs are more common than falling stairs (Figure 7) offers an explanation here. The higher scores for rising contour between the 4^{th} and the 6^{th} note would in that case be a result of a predisposition to these rising stair lengths. Overall the findings can be summarized in the following way:

If a new direction has been established by an interval of one pitch step, new intervals of one pitch step tends to continue in the same direction. As 3-5 notes have passed in the same direction the probabilities are instead higher for a change of direction.

The decrease in probability as more notes are added in the same direction can probably be connected to the ambitus (Figure 1, Section 3.1). The melody can only continue in the same direction for a certain number of notes before the melodic range is reached. For each note added in the same direction the probabilities to reach the melodic range increases. As was pointed out in the introduction, with the role of regression towards the mean pitch (Section 1.1), different aspects of the melody must be taken into consideration. This is a similar case where regression to the mean can also be applied in a meaningful way.

3.8 Repetition

The phrase information in the *Essen Folksong Collection* opens the possibility for interesting examinations. Each phrase start and each phrase end is notated in the songs and this was used to examine how phrases repeat each other. The phrases were examined for repetition in the time domain and in the pitch domain. When examining repetitions between phrases it had to be decided what actually constituted a repetition. In the time domain the phrase was said to be a repetition if the notes of the phrases started at the same position in the measure and had the same length as the notes of an earlier phrase in the song. In the pitch domain, contour was examined and the phrase was said to be a repetition if each interval of the phrase had the same contour. The examined songs were in major and had a 4/4 meter. The most important result is summarized in Figure 11. The probability (between 0 and 1) for phrase repetition represents how likely it is for any given phrase of a song to be a repetition of an earlier phrase. This means that if one phrase repeats another in a song of two phrases it is counted as 0.5, representing a 50 % probability for a randomly chosen phrase to be a repetition. For a song of three phrases where they all repeat each other the result would be 0.67. Notice that rhythm repetition (R) is twice as common as contour repetition (C). Notice also (by comparing $R\&C$ with C) that repetition of both rhythm and contour ($R\&C$) is almost as common as only contour repetition (C).

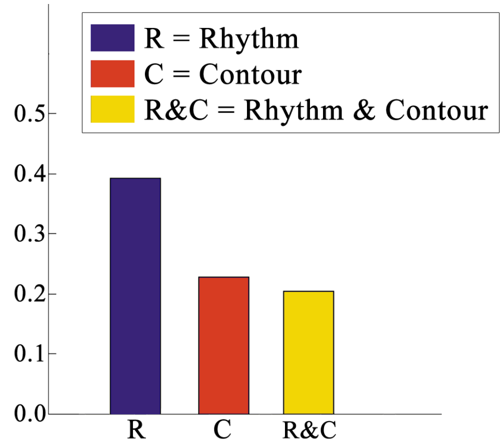

Figure 11: Probabilities for phrase repetition.

We find that about 40 % of any randomly chosen phrase in the data was a rhythmical repetition of an earlier phrase. For repeated contour the probability was close to 20 %. Almost all contour repetitions (C) are rhythm repetitions as well ($R\&C$). The results can be interpreted in the following way: If we have a repetition, one of two cases, which have about the same probability is likely be true. Either it is a rhythmical repetition or it is a repetition of both rhythm and contour. That contour is so rarely repeated on its own is interesting as it in a way contradicts the notion that listeners can perceive repeated contour independently (West et al, 1985). However it has been repeatedly claimed (Dowling, 1993; Monahan, 1993) that the rhythmic organization is perceptually more important.

3.9 Phrase Arch

Huron (2006) has done some interesting examinations of phrase contour. The findings were a rising contour in the beginning of the phrase and a falling contour in the end of the phrase as described in the background section (Section 1.4). In the examinations presented below Huron's conclusions have been tested by tracking how the phrase contour changes over the course of the song. The first and the last phrase were examined separately as it was expected that these phrases would produce the most interesting results. Another change in the examination technique as compared to Huron was done to produce more generally applicable results. The phrases were not separated based on their length. Instead, the first five notes and the last five notes were examined separately for all phrases. If a phrase had less than five notes the missing notes were disregarded. The songs were in major and had a 4/4 meter. Figure 12 is the result for the beginning of the phrases. It can be seen that the contour on average rises about 0.4 semitones if all phrases are taken into consideration (solid blue line). If we however disregard the first phrase there is no rising contour (dotted green line). This is because the rising contour in the beginning of the phrases was a statistical effect of a strong rising contour in the beginning of the first phrase (dashed red line). The contour in the first phrase rises approximately 2.5 semitones.

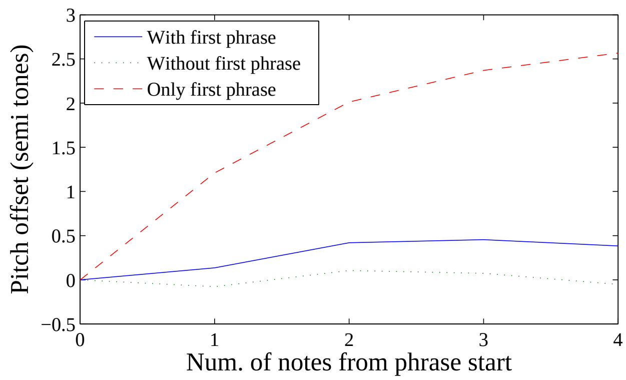

Figure 12: The average contour for the start of each phrase.

The result for the end of the phrases can be seen in Figure 13. The contour on average falls about 0.65 semitones if all phrases are taken into consideration (solid blue line). If we however disregard the last phrase there is a smaller rising contour (dotted green line). This is because the falling contour in the end of the phrases partly was a statistical effect of a strong falling contour in the last phrase (dashed red line). The contour of the last phrase falls approximately 2 semitones.

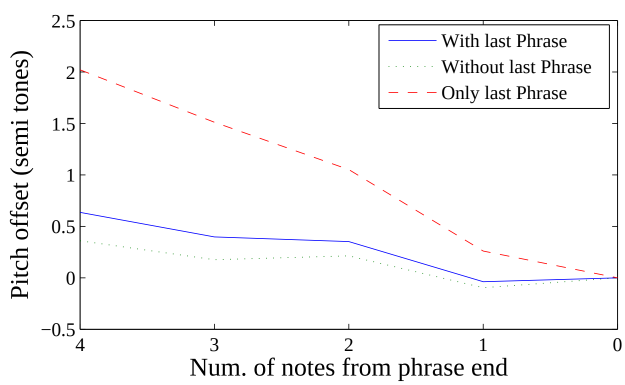

Figure 13: The average contour for the end of each phrase.

This is one of the most interesting findings of the study. Earlier findings for a rising contour in the beginning of the phrase (Huron, 2006) may instead turn out to be a rising contour in the beginning of the song. What seemed to be a falling contour in the end of the phrases may instead turn out to be a falling contour in the end of each song.

3.10 Tonal Resolution

The end of each song at which the melody resolves at the tonic is interesting to examine. The examination is done in the pitch domain for a few of the last notes in major and 4/4 meter. If the melody did not end at the tonic that song was disregarded. The number of occurrences of each of the scale tones were counted as the melody approached the tonic in the end. The result can be seen in Figure 14 where a darker square means a higher number of occurrences. Notice that a falling motion is common in the end of the songs, visualized by the thicker arrow. A rising motion towards C also occurs (thinner arrow) but is not as common.

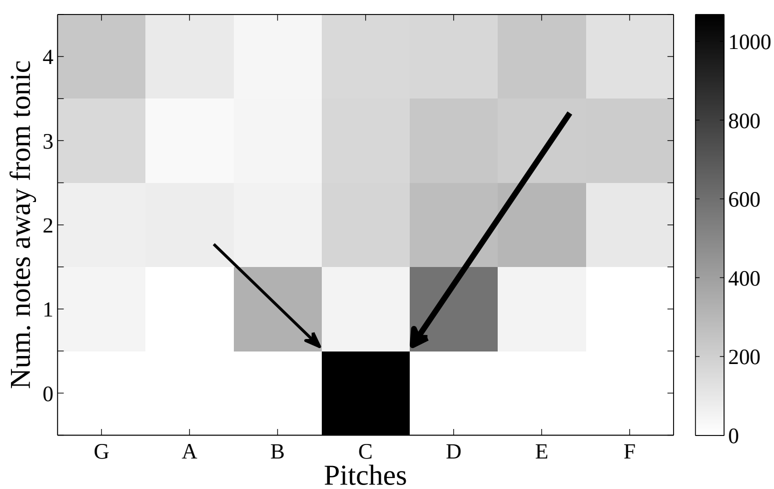

Figure 14: The pitches of the last notes of the songs. Arrows visualizes common movements.

4 Conclusions

Melodies have been examined with the aim to find contextual relationships. The relationship between pitch and time has been examined and it has been shown that they relate to each other in several ways. Salience in one domain tends to be followed by salience in the other, and longer notes tend to be accompanied by larger intervals. The frequency of occurrence of certain formations such as stairs or double notes also depends on note length. Phrases have been examined as well and here pitch and time also relate to each other, as contour repetition is almost always accompanied by rhythmic repetition. It can be concluded that to get a good understanding in the pitch domain the time domain must also be taken into consideration. In a similar way, to get a good understanding in the time domain the pitch domain must also be taken into consideration.

Contextual relationships have been found in other areas as well. There seems to be a difference between the pentatonic notes of the scale and the non-pentatonic notes concerning contour. It has also been shown that to get a good understanding of phrase contour the position of the phrase in the song must be taken into consideration. A strong upward movement in the first phrase and a strong downward movement in the last phrase have been found. Besides showing the contextual nature of music some of the findings are interesting on their own. Among the most interesting findings are:

- A clear relationship between pitch salience and metrical salience.
- A clear relationship between interval size and note length.
- That stairs are more common in a rising formation than in a falling formation.
- Findings that the melody tends to continue in the same direction when a new direction with small intervals has recently been established.
- That contour repetition is almost always accompanied by rhythmic repetition at the phrase level.
- That earlier findings for convex phrase arches seem to mostly be a phenomena of an upward movement in the first phrase of a song and a downward movement in the last phrase of a song.

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Appendix 1

The following concepts are important to understand:

- *Note length* - The length of a note. A note with a length of half the measure is called a half note, a note with a length of a quarter of the measure is called a quarter note etc.
- *Measure* - Consists of a repeated pattern of beats.
- *Meter* - The perceived number of beats and the note length of each beat in the measure.
- *Phrase* - A musical sentence consisting of several notes.
- *Pitch* - Note height, a logarithmic interpretation of the fundamental frequency.
- *Interval* - The distance between to subsequent pitches.
- *Tonic* - The first scale degree which means that a song in C major has C as the tonic. The tonic is perceived as a resolution and most songs end on the tonic. The tonic chord is perceived in a similar way.
- *Dominant* - The fifth scale degree which means that a song in C major has G as the dominant. The dominant is perceived as unstable and the dominant chord is perceived in a similar way.