APPLYING RHYTHMIC SIMILARITY BASED ON INNER METRIC ANALYSIS TO FOLKSONG RESEARCH

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ABSTRACT

In this paper we investigate the role of rhythmic similarity as part of melodic similarity in the context of Folksong research. We define a rhythmic similarity measure based on Inner Metric Analysis and apply it to groups of similar melodies. The comparison with a similarity measure of the SIMILE software shows that the two models agree on the number of melodies that are considered very similar, but disagree on the less similar melodies. In general, we achieve good results with the retrieval of melodies using rhythmic information, which demonstrates that rhythmic similarity is an important factor to consider in melodic similarity.

1 INTRODUCTION

In this paper we study rhythmic similarity in the context of melodic similarity as a first step within the interdisciplinary enterprise of the WITCHCRAFT [1] project (Utrecht University and Meertens Institute Amsterdam). The project aims at the development of a content based retrieval system for a large collection of Dutch folksongs that are stored as audio and notation. The retrieval system will give access to the collection *Onder de groene linde* hosted by the Meertens Institute to both the general public and musical scholars.

The collection *Onder de groene linde* (short: *OGL*) consists of songs transmitted through oral tradition, hence it contains many variants for one song. In order to describe these variants the Meertens Institute has developed the concept of *melody norm* [2] which groups historically or 'genetically' related melodies into one norm (for more details see [4]). The retrieval system to be designed should assist in defining melody norms for the collection *OGL* based on the similarity of the melodies in order to support the study of oral transmission. In a first step similar melodies from a given test corpus have been manually classified into groups. These melody groups serve as pos-

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[1] What is Topical in Cultural Heritage: Content-based Retrieval Among Folksong Tunes

[2] similar to "tune family" and "Melodietyp"

sible candidates for the melody norms to be assigned in a later stage.

According to cognitive studies, metric and rhythmic structures play a central role in the perception of melodic similarity. For instance, in the immediate recall of a simple melody studied in [8] the metrical structure was the most accurately remembered structural feature. In this paper we demonstrate that melodies belonging to the same melody group can successfully be retrieved based on rhythmic similarity. Therefore we conclude that rhythmic similarity is a useful characteristic for the classification of folksongs. Furthermore, our results show the importance of rhythmic stability within the oral transmission of melodies, which confirms the impact of rhythmic similarity on melodic similarity suggested by cognitive studies.

2 DEFINING A MEASURE FOR SYMBOLIC RHYTHMIC SIMILARITY

This section introduces our rhythmic similarity measure that is based on *Inner Metric Analysis* (IMA).

2.1 Inner Metric Analysis

Inner Metric Analysis (see [2], [5]) describes the *inner* metric structure of a piece of music generated by the actual notes *inside* the bars as opposed to the *outer* metric structure associated with a given abstract grid such as the bar lines. The model assigns a metric weight to each note of the piece (which is represented as symbolic data).

The details of the model have been described in [2] or [1]. The general idea is to search for all pulses (chains of equally spaced events) of a given piece and then to assign a *metric weight* to each note. The specific pulse type underlying IMA is called *local meter* and is defined as follows. Let On denote the set of all onsets of notes in a given piece. We consider every subset $m \subset On$ of equally spaced onsets as a local meter if it contains at least three onsets and is not a subset of any other subset of equally spaced onsets. Let $k(m)$ denote the number of onsets the local meter m consists of minus 1 (we call $k(m)$ the *length* of the local meter m). Hence $k(m)$ counts the number of repetition of the period (distance between consecutive onsets of the local meter) within the local meter. The metric weight of an onset o is calculated as the weighted sum of

the length $k(m)$ of all local meters m that coincide at this onset ($o \in m$).

Let $M(\ell)$ be the set of all local meters of the piece of length at least ℓ. The general metric weight of an onset, $o \in On$, is as follows:

$$W_{\ell,p}(o) = \sum_{\{m \in M(\ell): o \in m\}} k(m)^p.$$

In all examples of this paper we have set the parameter $\ell = 2$, hence we consider all local meters that exist in the piece. In order to obtain stable layers in the metric weights of the folksongs we have chosen $p = 3$. Figure 1 shows examples of metric weights of three melodies of the melody group *Deze morgen* in 6/8. The weights are depicted with lines such that the higher the line, the higher the corresponding weight. The background gives the bar lines for orientation.
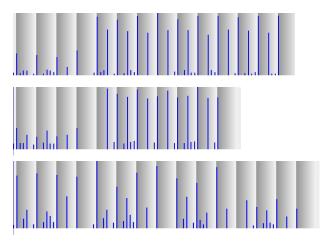

Figure 1. Metric weights of similar melodies in 6/8: three examples from the melody group *Deze morgen*

2.2 Defining similarity based on IMA

Rhythmic similarity has been used extensively in the audio domain for classification tasks. In contrast to this, similarity for symbolic data has been less extensively discussed so far. Metric weights of short fragments of musical pieces have been used in [1] to classify dance rhythms of the same meter and tempo using a correlation coefficient. In this paper we measure the rhythmic-metric similarity between two complete melodies. The similarity measure is carried out on the analytical information given by the metric weights. The application of the measure to folk songs in the following section is a first and simple approach in so far as it does not contain the search for similar segments that are shifted in time.

In a first step we define for each of the two pieces the metric weight of all silence events as zero and hence obtain the *metric grid weight* which assigns a weight to all events. The silence events are inserted along the finest grid of the piece determined by the greatest common divisor of all time intervals between consecutive onsets.

In a second step we adapt the grids of the pieces to a common finer grid by adding events e with the weight zero. In the third step, the metric grid weight is split into consecutive segments that cover an area of equal duration in the piece. These segments contain the weights to be compared with the correlation coefficient, we therefore call them *correlation windows*. The first correlation window of each piece starts with the first full bar, hence the weights of an upbeat are disregarded. For all examples of this article we have set the size of the correlation window to one bar of the query.

For the computation of the similarity measure both grid weights are completely covered with correlations windows. Let $w_{i, i=1,...,n}$ denote the consecutive correlation windows of the first piece and $v_{j, j=1,...,m}$ those of the second piece. Let $c_{k, k=1,...,min(n,m)}$ denote the correlation coefficient between the grid weights that are covered by the windows w_k and v_k. Then we define the similarity $IMA_{c,s}$ that is defined on the subsets of the two musical pieces from the beginning until the end of the shorter piece as the mean of all correlation coefficients:

$$IMA_{c,s} = \frac{1}{min(n,m)} \sum_{k=1}^{min(n,m)} c_k$$

3 RESULTS FOR THE TEST CORPUS

Our current test corpus of digitized melodies from *OGL* consists of 141 melodies. In a first classification attempt all melodies have been manually classified into groups of similar melodies.

3.1 Results using $IMA_{c,s}$

Table 1 gives an overview over the results with the similarity measure $IMA_{c,s}$. For each melody group (listed in the first column), an example query is presented (listed in the third column) with the corresponding ranks for all members of the melody group in the fourth column. [3] The last column lists the mean of all group member ranks according to the example query. In addition to the example query we have computed ranking lists using each member of the melody group once as the query. The second column lists the mean over all these ranks of melodies that belong to the group. Hence it represents an average over the distances between the group members.

In the following we investigate for the example queries the reasons for the assignment of a low rank. Some melody groups contain melodies of different meter types. Melodies that are notated with a different meter than the query are responsible for low ranks in the melody group *Deze morgen* (ranks 136, 137, 140 and 141), *Halewijn 4* (ranks 85 and 139), *Halewijn 5* (rank 88), *Frankrijk 2* (all ranks between 100 and 128), *Jonkheer 1* (ranks 96 and 129) and *Moeder 1* (rank 92). For the melody group *Deze morgen* and *Frankrijk 2* we have therefore created subgroups of

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[3] If two melodies have exactly the same similarity distance to the query, they are both assigned the same rank.

Melody Group	Group Mean	Query	Ranks for group members	Mean Rank
Deze morgen	56.48	19914	1, 4, 5, 6, 8, 9, 11, 14, 17, 18, 27, 136, 137, 140, 141	42.94
Halewijn 2	12.58	19201	1, 2, 3, 4, 5, 5, 7, 8, 11, 18, 48	10.18
Halewijn 4	41.11	19107	1, 2, 3, 5, 6, 8, 9, 16, 17, 85, 139	26.45
Halewijn 5	32.53	19106	1, 2, 3, 10, 16, 30, 54, 88	25.5
Frankrijk 1	12.55	19301	1, 2, 3, 4, 5, 6, 6, 6, 6, 23, 33	8.63
Frankrijk 2	54.65	19304	1, 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 18, 20, 21, 22, 23, 24, 25, 26, 28, 29, 30, 32, 35, 62, 77, 78, 79, 95, 97, 100, 103, 105, 112, 114, 120, 121, 122, 123, 128	45.51
Jonkheer 1	51.39	22621	1, 2, 10, 13, 29, 39, 96, 129	39.87
Moeder 1	22.58	33006	1, 2, 3, 4, 6, 9, 10, 11, 13, 17, 92	15.27

Table 1. Query results using $IMA_{c,s}$

melodies belonging to the same meter as displayed in Table 2 showing much better ranking lists.

The melody at rank 23 for the group *Frankrijk 1* is notated with doubled note values. Furthermore, low ranks were assigned to melodies that contain a meter change within the piece for *Deze morgen* (rank 27) and *Frankrijk 2a* (ranks 62, 77, 78, 79 and 97). In summary, the main reason for a low rank according to $IMA_{c,s}$ is a very different rhythmic structure expressed by a different meter notation in the transcription. On the other hand, the rhythmic structure seems to be an important component of melodic similarity for many melody groups. For instance, among the first 15 ranks we find 9 out of all 11 melodies for *Halewijn 2*, similar good results are achieved for the groups *Deze morgen 6/8, Halewijn 4, Frankrijk 1, Moeder 1* and *Frankrijk 2b* (see Table 4 for the complete list).

An improvement of this approach could be achieved by shifting the shorter melody along the longer and to search for the most similar submelody. The similarity measure *rhytGauss* from the SIMILE package contains such a routine, hence one might expect better results with *rhytGauss*. While $IMA_{c,s}$ measures the similarity of metric weights that reflect regularity patterns of the onsets of the notes, *rhytGauss* measures the similarity of Gaussifications [4] of

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[4] A gaussification G_R is a linear combination of gaussians centered at the onsets of the given rhythm R. Hence *rhytGauss* can also be applied to unquantized data.

Melody Group	Group Mean	Query	Ranks for group members	Mean Rank
Deze morgen *subgroup 6/8*	16.36	19914	1, 4, 5, 6, 8, 9, 11, 13, 14, 17, 18, 27	11.08
Frankrijk 2a *subgroup 6/8*	31.56	19304	1, 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17,18, 18, 20, 21, 22, 23, 24, 25, 26, 28, 29, 30, 32, 35, 62, 77, 78, 79, 97	24.88
Frankrijk 2b *subgroup 3/4*	10.58	24105	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20	6.81

Table 2. Query results with $IMA_{c,s}$ for subgroups of melodies of the groups *Frankrijk 2* and *Deze morgen*

the onset times (see [3]). In the following section we compare our results to those of *rhytGauss*.

3.2 Comparison of $IMA_{c,s}$ to $rhytGauss$

The SIMILE package (see [7] and [6]) contains the similarity measure *rhytGauss* that is based on cross correlations of Gaussifications. The *rhytGauss* algorithm shifts the shorter of the two melodies along the longer one and takes the maximum of all similarity values as the final similarity value. Since *rhytGauss* takes tempo information into account, all midi files of the melodies from the test corpus have been set to the same tempo.

Melody Group	Query	Ranks for group members	Mean Rank
Deze morgen	19914	1, 2, 3, 4, 5, 6, 8, 11, 12, 13, 16, 17, 117,122, 140, 141	38.625
Halewijn 2	19201	1, 2, 3, 5, 6, 6, 9, 10, 10, 11, 108	15.54
Halewijn 4	19107	1, 2, 3, 64, 95, 95, 95 106, 110, 118, 121	73.64
Halewijn 5	19106	1, 2, 9, 11, 46, 73, 103, 125	46.25
Frankrijk 1	19301	1, 2, 3, 3, 3, 3, 7, 8, 8, 47, 80	15
Jonkheer 1	22621	1, 2, 3, 4, 17, 21, 93, 102	30.375
Moeder 1	33006	1, 2, 3, 4, 7, 8, 15, 18, 37, 46, 131	24.72
Deze morgen *subgroup 6/8*	19914	1, 2, 3, 4, 5, 6, 8, 11, 12, 13, 16, 17,	8.16
Frankrijk 2a *subgroup 6/8*	19304	1, 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 11, 13, 14, 15, 16, 17, 18, 19, 21, 23, 24, 31, 35, 37, 38, 43, 45, 54, 61, 66, 77, 92, 104, 112, 116	32.41
Frankrijk 2b *subgroup 3/4*	24105	1, 2, 3, 4, 5, 5, 7, 8, 11, 13, 140	17.36

Table 3. Query results using *rhythGauss*

The comparison of the mean ranks of the example queries for both methods (see Tables 1, 2, and 3) reveals, with the

exception of the groups *Deze morgen* and *Jonkheer 1*, better (lower) mean ranks for $IMA_{c,s}$.

Melody Group	Query	$IMA_{c,s}$	*rhytGauss*
Deze morgen 6/8	19914	9 (12)	10 (12)
Halewijn 2	19201	9 (11)	10 (11)
Halewijn 4	19107	7 (11)	3 (11)
Halewijn 5	19106	4 (8)	4 (8)
Frankrijk 1	19301	9 (11)	9 (11)
Frankrijk 2a	19304	31 (36)	26 (36)
Frankrijk 2b	24105	10 (11)	10 (11)
Jonkheer 1	22621	4 (8)	4 (8)
Moeder 1	33006	9 (11)	7 (11)

Table 4. Comparison of the number of melodies ranked among the first 15 hits (for *Frankrijk 2a* among the first 40 hits). Numbers in brackets refer to the total number of melodies belonging to the melody group.

The greatest difference between the ranking lists of the two measures can be observed in the results for the melody groups *Halewijn 4* and *Halewijn 5*. For instance, the low ranks of 103, 73 and 46 in the group *Halewijn 5* according to *rhytGauss* correspond to much higher ranks according to $IMA_{c,s}$ (3, 30 and 16).

With the exception of the groups *Deze morgen* and *Jonkheer 1* the similarity measure $IMA_{c,s}$ obtains on average better results than *rhytGauss* despite the fact that the latter includes the search for the most similar subset in the longer melody. The comparison of the ranks assigned to the same melody shows that *rhytGauss* assigns to 17 melodies a considerably higher rank[5] than $IMA_{c,s}$ (on average 20.65 ranks better). However, $IMA_{c,s}$ assigns to 30 melodies a considerably higher rank than *rhytGauss* (on average 49.9 ranks better).

The comparison of the number of songs that are found within the top 15 matches (top 40 matches for *Frankrijk 2a*) as listed in Table 4 shows no great differences between the two methods compared (with the exception of *Halewijn 4*). Hence the difference between the methods seems to apply to melodies that are more distant to the query.

4 CONCLUSION

Our results show that rhythmic similarity is an important ingredient of the similarity between melodies that have been classified into groups of similar melodies.

A further refinement of our proposed rhythmic similarity measure is the search for the most similar submelody within the longer melody by shifting the metric weight of the shorter melody along the weight of the longer melody. With the current approach of $IMA_{c,s}$ the additional phrases of the longer piece have in some cases a great impact on the weight of the entire piece and may change the metric weight of otherwise similar parts. In a further development we could test whether using the analysis of the sub-

melody (defined by the length of the shorter melody) leads to better results than using the subset of the weight of the entire piece. The comparison with the *rhytGauss* measure indicates on average better results for $IMA_{c,s}$. However, the compared methods agree on how many melodies are very similar to the query. A more detailed investigation of the examples that were ranked very differently will help to clarify which similarity measures are the most appropriate for which query type within the retrieval system to be designed within the WITCHCRAFT project. Preliminary findings using $IMA_{c,s}$ on a larger corpus including 1100 melodies from the Essen Folksong collection indicate promising results for the application of rhythmic similarity to Folksong research. Hence we conclude that rhythmic similarity is an important ingredient of melodic similarity.

6 REFERENCES

[1] Chew, E., Volk, A., and Lee, C. "Dance Music Classification Using Inner Metric Analysis", *Proceedings of the 9th INFORMS Computer Society Conference*, Kluwer, 2005, pp. 355-370.

[2] Fleischer (Volk), A. *Die analytische Interpretation. Schritte zur Erschließung eines Forschungsfeldes am Beispiel der Metrik*. dissertation.de - Verlag im Internet Gmbh, Berlin, 2003.

[3] Frieler, K. "Beat and Meter Extraction using Gaussified Onsets". *ISMIR Proceedings*, Barcelona, 2004.

[4] van Kranenburg, P., Garbers, J., Volk, A., Wiering, F., Grijp, L.P., Veltkamp, R. C. "Towards Integration of MIR and Folk Song Research" *ISMIR Proceedings*, Vienna, 2007.

[5] Mazzola, G. *The Topos of Music*. Birkhäuser, 2002.

[6] Müllensiefen, D. and Frieler, K. "Cognitive Adequacy in the Measurement of Melodic Similarity: Algorithmic vs. Human Judgements". *Computing in Musicology 13*, p. 147-177, 2004.

[7] Müllensiefen, D. and Frieler, K. *The SIMILE algorithms documentation 0.3*. White Paper, 2006.

[8] Sloboda, J.A. and Parker, D.H.H. "Immediate recall of melodies". In Hower, P., Cross, I. and West, R. (eds), *Musical structure and cognition*, London, Academic Press, p.143-167, 1985.

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[5] with a difference of more than 10 ranks