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Searching musical representative phrases using similarities

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Abstract: A new method to find representative phrases from a musical score is given. Fuzzy similarity relations between phrases are defined and applied.

Keywords: Fuzzy Similarities, musical phrases, t-norm.

1. Introduction

Zadeh [4], [5] similarity relations are Fuzzy relations on a universe E, S:ExE→[0,1] verifying the following three properties:

1) Reflexivity: S(a, a) = 1 for all a in E. An object is similar to itself.
2) Simmetry: S(a, b) = S(b, a) for all a, b in E
3) Min-Transitivity: Min(S(a, b), S(b, c)) ≤ S(a, c) for all a, b, c in E.

The similarity fuzzy relations are useful to compare objects of a universe, to classify objects, to pattern matching, to make Fuzzy inference with the Fuzzy compositional rule, etc. The similarity fuzzy relations generalise the classical equivalence relations, so important to define crisp partitions of a set. It is known that a α-cut of a similarity is a classical equivalence relation, so it is possible to consider a similarity as an equivalence relation with many granularities, allowing to put several racks to define new partitions of a universe.

The similarities are negations of a distance that satisfy the Max triangular inequality: S(a, c) ≤ Max(S(a, b), S(b, c)).

Similarities are especial cases of T-indistinguishabilities [3], the chosen t-norm is the minimum.

A similarity operator is a similarity relation on the real interval.

The term musical motive (from the Italian *Motiu*) is related with a short musical phrase on which a compositor develops a whole musical score. A motive is a melodic element with importance in the rest of the work, and allows making variations on it to generate more musical phrases.

This paper uses the criteria of [1] to search for musical motives, based on the analysis of different parts (phrases) to find a motive of a score with a "fuzzy pattern machine" model that uses similarity operators to compare phrases.

2. Algorithm to search for musical motives

It is used a pre-searching method described by Overill [1] as a starting point for the musical motives searching algorithm. A musical score is separated into phrases that are compared to each other to evaluate a similarity degree of every couple of phrases, allowing to identify the phases that are candidates to be motives.

The algorithm in pseudocode is the following:

a) A score is separated in phrases.
b) It is evaluated a similarity degree of every couple of phrases.
c) Every phrase is evaluated as a candidate of motive aggregating or conjunting the similarity degrees with other phrases.

Note that it is possible to make a tuning of the process depending on the separation of phrases.
The pre-search takes into account the following criteria:

1) The comparison of the notes duration
2) The variation of tones into a phrase
3) A distance of the intervals between notes into a phrase.

The following definitions are given to establish a notation and to describe the processes.

Definition 1. Phrases and notes

A phrase of a score is an ordered set of notes.
A note is represented by a three-dimensional point (x, y, z) standing for tone, figure and the interval with the next note tone.

A note n_i is the spatial point p_i = [(tone, figure, interval with the next note tone)]
Let $P^n = \{ p_1, p_2, \ldots, p_n \}$ be a set of ordered points (notes) in space.

P^n represents a succession of points that represent a musical phrase.

Figure 1. A few phrases of Invention # 1 of J. S. Bach

Definition 2. Distance between ordered notes

Let P^n be a phrase with n ordered notes. A function computing the n-1 distances between the n notes is defined by $D: P^n \rightarrow R^{n-1}$ as follows:

$$D(P_n) = [d(p_1, p_2), d(p_2, p_3), d(p_{n-1}, \ldots, p_n)] \quad (1)$$

Where d is a distance, for example the Euclidean distance.

Definition 3. A similarity S of phrases

Let S_{real} be a similarity operator $Sr : R \times R \rightarrow [0,1]$ defined by

$$Sr\ (a, b) = (rmax - d(| a - b |) / rmax \quad (2)$$

where the range rmax is | a_maximum – b_maximum | (3)

A function between vectors of real numbers $Sv : R^n \times R^n \rightarrow R^n$ is defined by

$$Sv\ (\{x_1, x_2, \ldots, x_n\}, \{y_1, y_2, \ldots y_n\}) = \{ Sr(x_1,y_1), Sr(x_2,y_2), \ldots, Sr(x_n, y_n) \} \quad (4)$$

To define a similarity degree $S: P^n \times P^{n'} \rightarrow [0, 1]$ of two musical phrases P^n and $P^{n'}$ it is computed a conjunction operator V on the similarity degrees of the distances between notes given by D.

$$S (P^n_i, P^{n'}_j) = V\ Sv (D(P_{ni}), D(P^{n'}_j)) \quad (5)$$

V is a t-norm operator (a conjunction operator) [2] by extended to be n-ary to be a conjunction of n values through the associative property of t-norms:

$$T(x_1, x_2, \dots, x_n) = T(x_1, T(x_2, T(\dots, T(\dots, x_n)))) \quad (6)$$

3. Experiments and results

An example is given to show the algorithm behaviour. It is evaluated the Figure 1. J. S. Bach and the first phrase are compared with the rest of phrases to evaluate it as a possible motive.
The score is separated in length 8 phrases P^n.
The figures are represented as follows: [0 = semi quaver, 1 = quaver, 2 = quarter note', 3 = half note, 4 = halt note].
Then the first phrase of Figure 1 is:

$P^n = [(C5,1,2), (D5,1,2), (E5,1,1), (F5,1,-3), (D5,1,2), (E5,1,-4), (C5,1,7), (G5,1,0)]$

The ten initial phrases of the schore are represented by $P^{n'}_i$. Note that the initial 5 phases of every voice are chosen displacing a note from the previous phrase. The initial sciences are omitted.

$P^{n'}_1 = [(C_6,2,-1), (B_5,2,1), (C_6,2,2), (D_6,1,-7), (G_5,1,2), (A_5,1,2), (B_5,1,1), (C_6,1,-3)]$
$P^{n'}_2 = [(B_5,2,1), (C_6,2,2), (D_6,1,-7), (G_5,1,2), (A_5,1,2), (B_5,1,1), (C_6,1,-3), (A_5,1,0)]$
$P^{n'}_3 = [(C_6,2,2), (D_6,1,-7), (G_5,1,2), (A_5,1,2), (B_5,1,1), (C_6,1,-3), (A_5,1,2), (B_5,1,0)]$
$P^{n'}_4 = [(D_6,1,-7), (G_5,1,2), (A_5,1,2), (B_5,1,1), (C_6,1,-3), (A_5,1,2), (B_5,1,-4), (G_5,1,0)]$
$P^{n'}_5 = [(G_5,1,2), (A_5,1,2), (B_5,1,1), (C_6,1,-3), (A_5,1,2), (B_5,1,-4), (G_5,1,7), (D_6,2,0)]$
$P^{n'}_6 = [(C_4,1,2), (D_4,1,2), (E_4,1,1), (F_4,1,-3), (D_4,1,2), (E_4,1,-4), (C_6,1,7), (G_4,2,0)]$
$P^{n'}_7 = [(D_4,1,2), (E_4,1,1), (F_4,1,-3), (D_4,1,2), (E_4,1,-4), (C_4,1,7), (G_4,2,-12), (G_3,2,0)]$
$P^{n'}_8 = [(E_4,1,1), (F_4,1,-3), (D_4,1,2), (E_4,1,-4), (C_4,1,7), (G_4,2,-12)(G_3,2,-), (-,S3,0)]$
$P^{n'}_9 = [(F_4,1,-3), (D_4,1,2), (E_4,1,-4), (C_6,1,7), (G_4,2,-12), (G_3,2,-), (-,S3,-), (-,S1,0)]$
$P^{n'}_{10} = [(D_6,1,2), (E_4,1,-4), (C_4,1,7), (G_4,2,-12), (G_3,2,-), (-,S3,-), (-,S1,-), (G_6,1,0)]$

The distances $D(P^n)$ between notes of every phrase are the following:

$D(P^n) = [$	2.00	2.24	4.12	5.83	6.32	11.70	9.90	]
$D(P^{n'}_1) = [$	2.24	1.41	9.22	11.40	2.00	2.24	1.41	]
$D(P^{n'}_2) = [$	1.41	9.22	11.40	2.00	2.24	4.12	4.24	]
$D(P^{n'}_3) = [$	9.22	11.40	2.00	2.24	4.12	5.83	2.83	]
$D(P^{n'}_4) = [$	11.40	2.00	2.24	4.12	5.83	6.32	5.66	]
$D(P^{n'}_5) = [$	2.00	2.24	4.12	5.83	6.32	11.70	10.63	]
$D(P^{n'}_6) = [$	2.00	2.24	4.12	5.83	6.32	11.70	9.22	]
$D(P^{n'}_7) = [$	2.24	4.12	5.83	6.32	11.70	19.92	16.28	]
$D(P^{n'}_8) = [$	4.12	5.83	6.32	11.70	19.92	16.28	0.00	]
$D(P^{n'}_9) = [$	5.83	6.32	11.70	19.92	16.28	0.00	0.00	]
$D(P^{n'}_{10}) = [$	6.32	11.70	19.92	16.28	0.00	0.00	12.00	]

Table 1: Distance D(Pn) between notes of every phrase

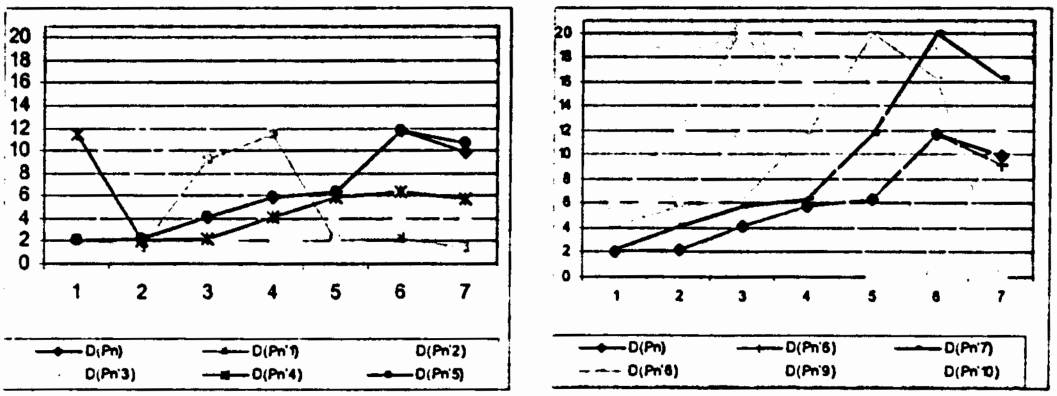

Figure 2. Distance $D(P^n)$ between notes of every phrase

The next step is to compute the similarity between every couple distances $D(P^n)$ using the main t-norm conjunction operator V: minimum, product and Lukasiewicz.
A visible result is that the first phrase is almost similar to the phases 5 and 6.

D(P^n)								Minimum	Product	W
D(Pn'_1)	0,993	0,352	0,977	0,859	0,846	0,881	0,739	0,766	0,739	0,062
D(Pn'_2)	0,984	0,336	0,807	0,799	0,894	0,887	0,791	0,844	0,791	0,007
D(Pn'_3)	0,801	0,322	0,747	0,942	0,901	0,939	0,838	0,805	0,747	0,000
D(Pn'_4)	0,741	0,493	0,993	0,948	0,953	0,986	0,852	0,883	0,741	0,356
D(Pn'_5)	1,000	0,980	1,000	1,000	1,000	1,000	1,000	0,980	0,980	0,980
D(Pn'_6)	1,000	0,981	1,000	1,000	1,000	1,000	1,000	0,981	0,981	0,981
D(Pn'_7)	0,993	0,480	0,948	0,953	0,986	0,852	0,773	0,824	0,773	0,329
D(Pn'_8)	0,942	0,265	0,901	0,939	0,838	0,625	0,874	0,727	0,625	0,000
D(Pn'_9)	0,894	0,137	0,887	0,791	0,611	0,725	0,677	0,727	0,611	0,000
D($P^{n'}_{10}$)	0,881	0,138	0,739	0,564	0,712	0,826	0,677	0,942	0,564	0,000

Table 1. Similarity of phrases using the t-norm V minimum, product ad Lukasiewicz

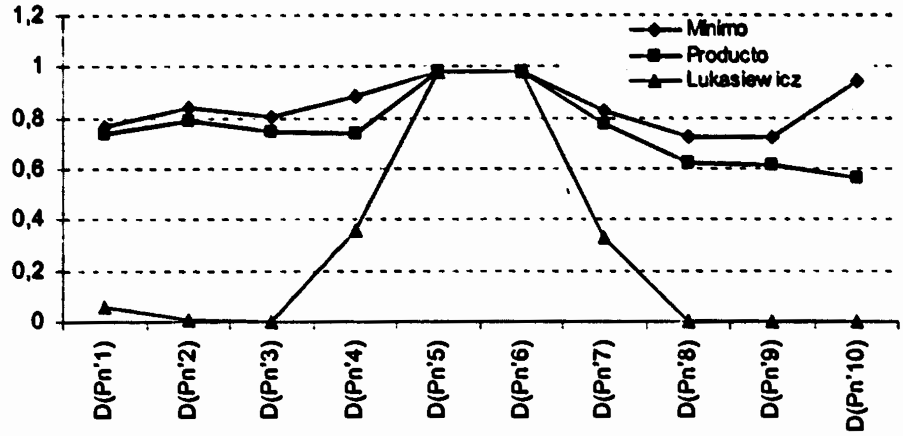

Figure 3. similarities of the phrases with the first phrase

4. Conclusions and further work

A method to search musical motives using similarities is given. In the example, the first phrase seems to be a good representative motive when using the Zadeh, product and Lukasiewicz logic. However the n-ary Lukasiewicz t-norm tends to zero, and so the similarity of the first phrase with others is much lower when the punctual similarities are not high.

A first immediate further work is to consider an aggregator operator (operators between t-norms and t-conorms), for example, an arithmetic mean, instead of conjunction operator to define the similarity of phrases. Some other similarity operators, different that 1-euclidean distance, will be considered and tested. This paper is a small part of a huge project towards assistance musical composition.

5. References

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