Statistical Indications of Notational Style in Composers' Additions of Performance Marks in Solo Piano Scores

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Notated Music as a Document Genre

- Music notation is highly privileged in Western art music.
- As a symbolic language, music notation is selective, incomplete, and ambiguous; as a diegetic representation, music notation is not a precise image of a musical performance but rather the declaration of a sometimes imprecise space within which performances can occur (e.g. see Cole, 1974, pp. 127-130; Rastall, 1983, pp. 1-11).
- From the viewpoint of document theory (O'Connor, Kearns, & Anderson, 2008), the meaning of music notation arises from a relationship between structure, function, and context of use.

Musical Texts and Performance Annotations

- This research adopts the view that a score consists of two coordinated but separate communication channels: the musical text and a collection of annotative performance marks.
- This view borrows a distinction from Goodman's (1976) discussion of notation in the arts but rejects his semantic orientation in favor of a structural approach:
    - The channels are defined by largely disjoint vocabularies.
    - Performance marks exhibit highly variable temporal densities.

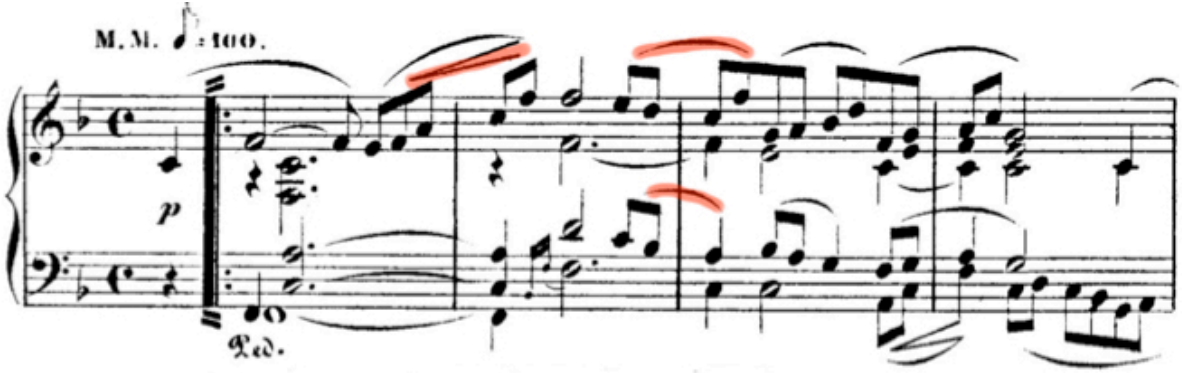
Godowksy and Notational Styles

Leopold Godowsky, 1870-1938, was a Polish American pianist and composer with a self-professed tendency to dense interpretive annotations:

> The thoughful attention given to the interpretative directions of my compositions has resulted in a profusion of expression marks, pedal indications, and fingerings. Though they may appear on the surface as too minute and elaborate, I believe the serious student will find them essential and illuminating. (Godowsky, 1925, "Addendum", para. 1).

Two Editions of Träumerei

A



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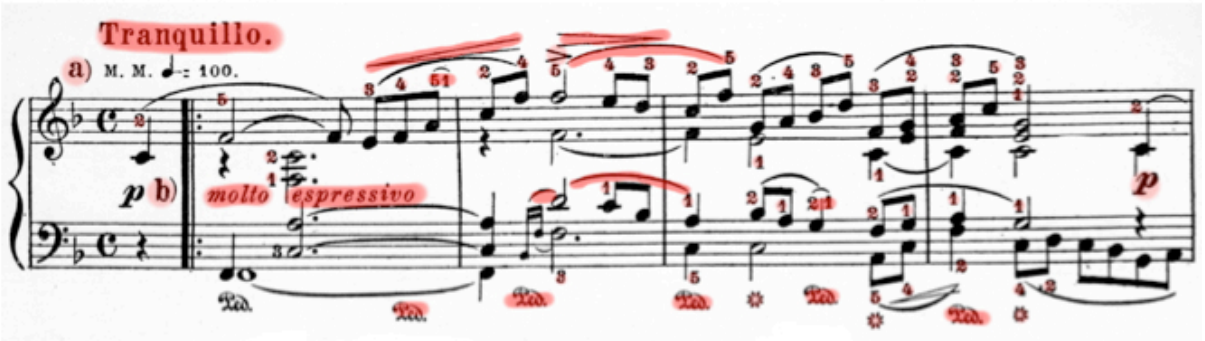


Adapted from Schumann, R. (1839). *Kinderszenen.* Leipzig, Germany: Breitkopf & Härtel; and Schumann, R. (1915). *Childhood Scenes.* (L. Godowsky, Ed.). St. Louis, MO: Art Publication Society. Sloboda (1980) provides a similar example from one of Mozart's piano sonatas but seems to highlight the editor's role in choosing between too few and too many performance marks in preparing editions of standard works.

Research Question

Do performance marks structurally encode distinctive notational styles?

In other words, to what extent can the contextual patterns of performance marks in notated music identify the Godowskys from the Schumanns?

Selecting and Coding the Sample

- Nineteenth-century piano sonatas
- Modern "urtext" editions

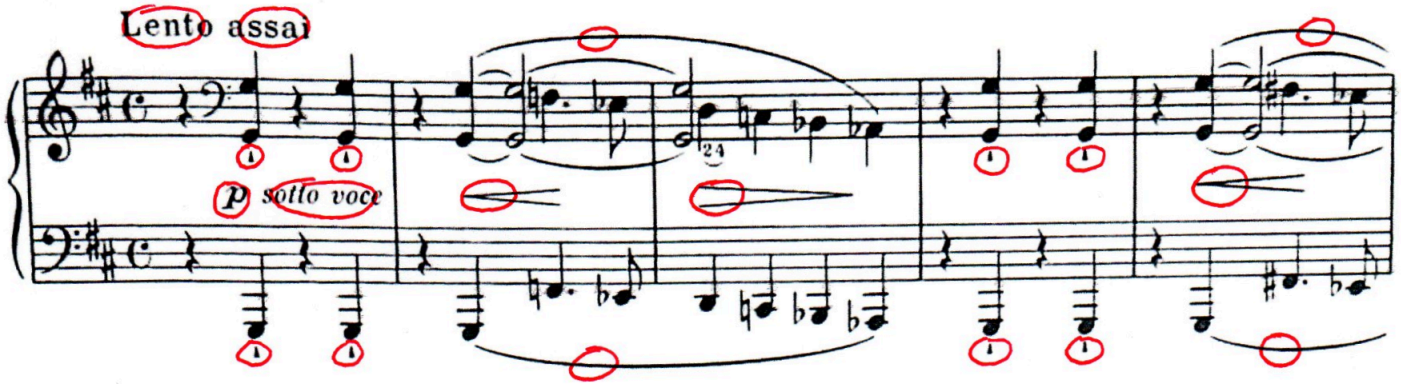
- Performance marks only (textual and graphic tokens)
- Fingering omitted but pedal marks included
- Lexical coding (i.e. individual tokens)
- Detailed coding manual developed during mark-up
- Conservative stop rules and lemmatization for textual tokens

(for details see Buchanan, 2016)

Scores Coded for the Study

Work Id	Common Title	Composer	Date	Edition
LVB8	Piano sonata no. 8 in C minor, op. 13 ("Pathétique")	Beethoven, Ludwig van	1798	Henle HN32
LVB14	Piano sonata no. 14 in C-sharp minor, op. 27, no. 2 ("Moonlight")	Beethoven, Ludwig van	1801	Henle HN32
LVB21	Piano sonata no. 21 in C major, op. 53 ("Waldstein")	Beethoven, Ludwig van	1804	Henle HN34
LVB23	Piano sonata no. 23 in F minor, op. 57 ("Appassionata")	Beethoven, Ludwig van	1805	Henle HN34
LVB29	Piano sonata no. 29 in B-flat major, op. 106 ("Hammerklavier")	Beethoven, Ludwig van	1818	Henle HN34
FC1	Piano sonata no. 1 in C minor, op. 4	Chopin, Frédéric	1828	Henle HN942
FC2	Piano sonata no. 2 in B-flat minor, op. 35	Chopin, Frédéric	1839	Henle HN289
FC3	Piano sonata no. 3 in B minor, op. 58	Chopin, Frédéric	1844	Henle HN290
JB1	Piano sonata no. 1 in C major, op. 1	Brahms, Johannes	1853	Henle HN38
JB2	Piano sonata no. 2 in F-sharp minor, op. 2	Brahms, Johannes	1852	Henle HN38
JB3	Piano sonata no. 3 in F minor, op. 5	Brahms, Johannes	1853	Henle HN38
FL1	Piano sonata in B minor	Liszt, Franz	1853	Henle HN273
FL2	Après une lecture du Dante from Années de pèlerinage ("Dante Sonata")	Liszt, Franz	1858	Henle HN174
ANS1	Piano sonata no. 1 in F minor, op. 6	Scriabin, Aleksandr Nikolayevich	1892	Henle HN1107
ANS3	Piano sonata no. 3 in F-sharp minor, op. 23	Scriabin, Aleksandr Nikolayevich	1897	Henle HN1109
ANS5	Piano sonata no. 5, op. 53	Scriabin, Aleksandr Nikolayevich	1907	Henle HN1111
ANS7	Piano sonata no. 7, op. 64 ("White Mass")	Scriabin, Aleksandr Nikolayevich	1912	Henle HN747
ANS9	Piano Sonata no. 9, op. 68 ("Black Mass")	Scriabin, Aleksandr Nikolayevich	1913	Henle HN855

Example Mark-up: Liszt's Sonata in B Minor



Adapted from Liszt, F. (1973). *Klaviersonate h-moll.* Munich, Germany: G. Henle Verlag.

Corpus Token Summary

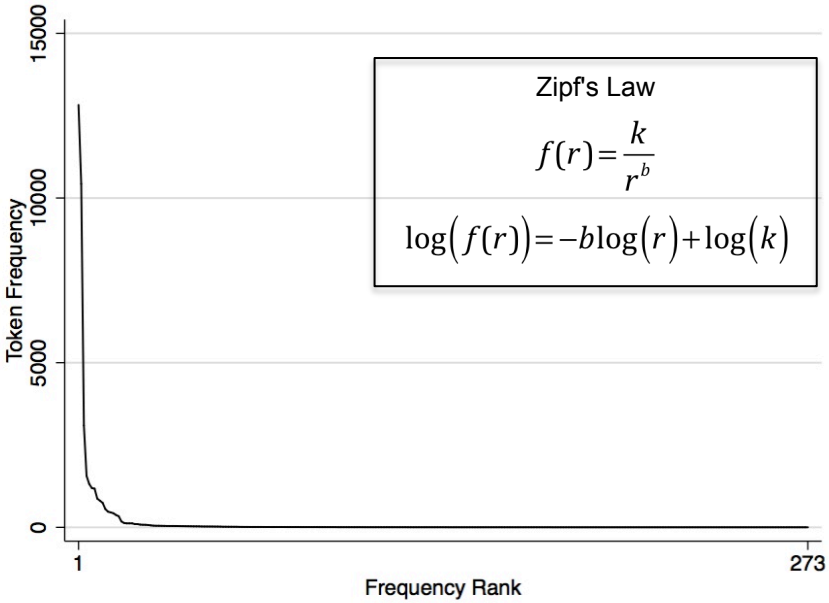
Common Tokens (All Works)

Token Type	Rank	Frequency
accent-dot	1	12826
slur	2	10430
hairpin-cresc	5	1314
hairpin-dimin	6	1191
p	10	743
f	11	556
cresc	13	454
pp	14	428
		27942
Corpus Token Count (273 Types)		39519

Top-Ten Combined Tokens

Token Type	Rank	Frequency
accent-dot	1	12826
slur	2	10430
accent	3	3094
ped-ext	4	1562
hairpin-cresc	5	1314
hairpin-dimin	6	1191
accent-wedge	7	1174
accent-tenuto	8	872
sf	9	807
p	10	743
		34013
Corpus Token Count (273 Types)		39519

Corpus Token Distribution



(Nicholls, 1987; Piantadosi, 2014; Zipf, 1929, 1932)

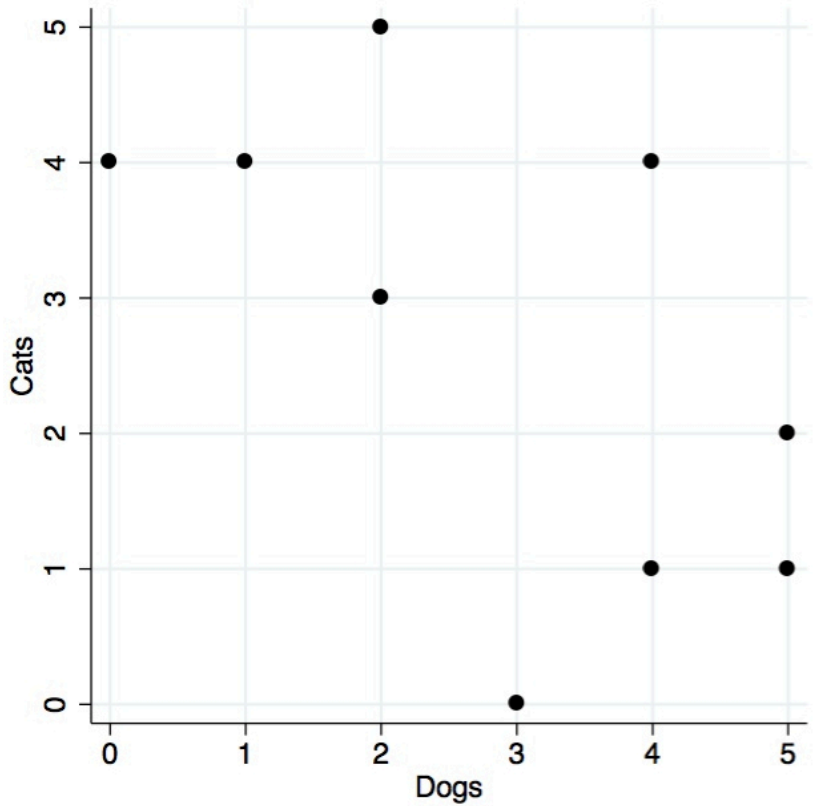
Vector-Space Document Models

- The vector-space model projects a corpus of documents into a common Cartesian *n*-space where each member document is represented by an *n*-element vector encoding raw or, more often, weighted document attributes.
- The model supports algebraic methods for computing well-behaved document similarity measures and is a foundational approach to document classification and clustering.

(Manning, Raghavan, & Schütze, 2008, p. 110-116)

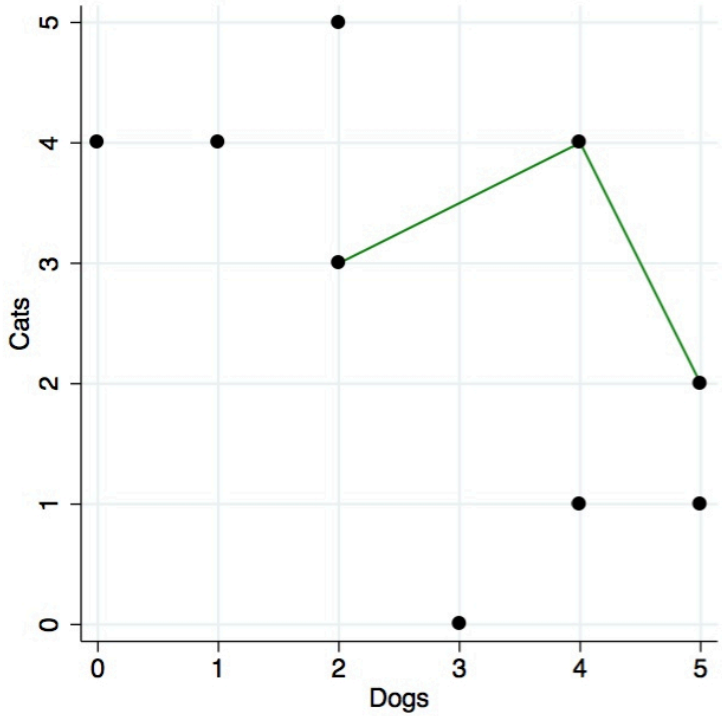
Vector-Space Models of Token Frequency

	Dogs	Cats
D1	4	4
D2	4	1
D3	5	2
D4	2	3
D5	2	5
D6	1	4
D7	0	4
D8	3	0
D9	5	1

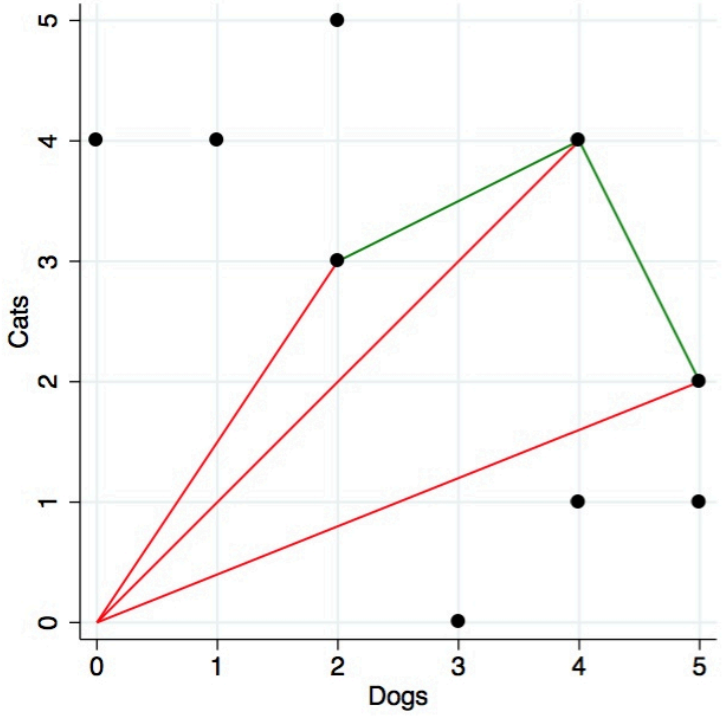


Distance Metrics in Vector-Space Models

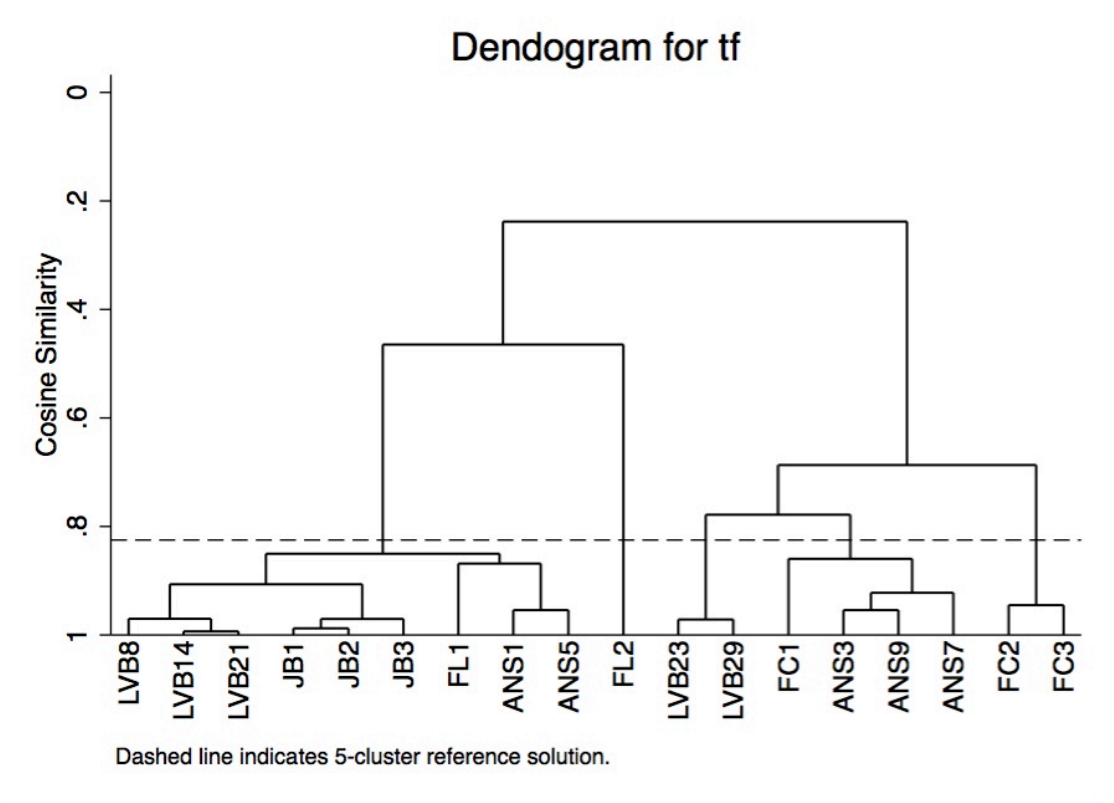
Euclidean



Euclidean vs Angular



Hierarchical Vector Clustering



Note: Agglomerative hierarchical clustering with complete linkage and cosine similarity metric.

Evaluating Composer Clustering

- The Rand index can be used to compare two clustering solutions and is based on the fraction of all possible document pairs whose classifications agree between the two solutions (Rand, 1971). The Composer Rand Index (CRI) adapts this method to compare an empirical clustering solution with a theoretical reference solution consisting of pure composer-based groups.
- For agglomerative clustering with raw token frequencies, the CRI at the nominal 5-cluster level was 0.67.

Token Frequency Weighting Functions

Local Weighting

Log Frequency

$$f(tf_i) = \log(1 + tf_i)$$

(Berry & Browne, 2005)

Concave Down

$$f(tf_i) = tp_i \left(\log \frac{1}{tp_i} \right)$$

(Campbell et al., 1997)

Global Weighting

Inverse Document Frequency

$$f(tf_i) = tf_i \times \log\left(\frac{N}{n_i} \right)$$

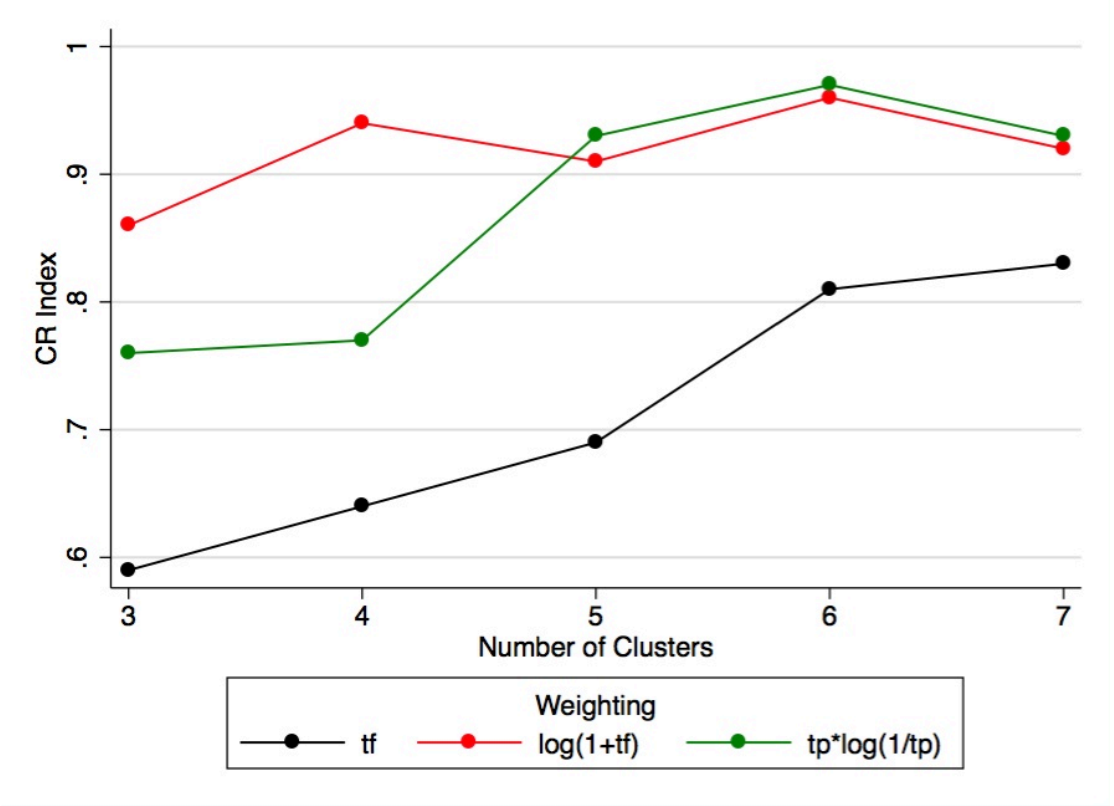
(Berry & Browne, 2005)

Row Entropy

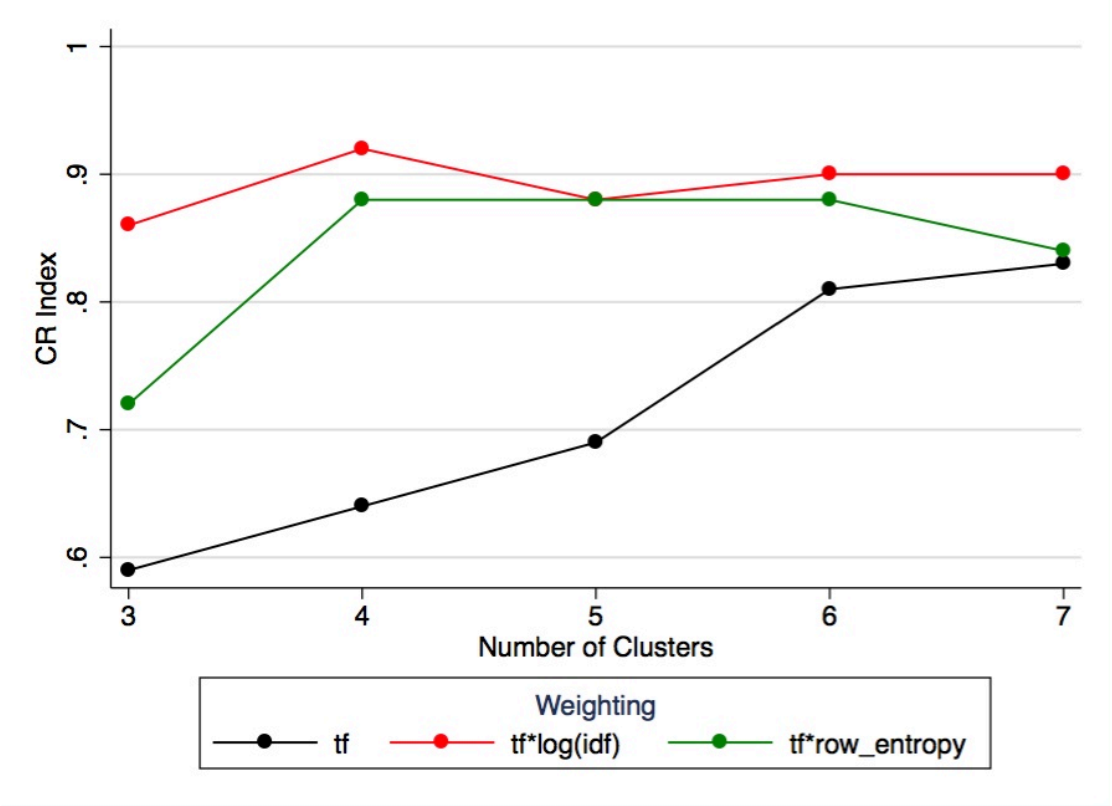
$$f(tf_i) = tf_i \times \left(1 + \frac{\sum_j \left(tp_{i,j} \log(tp_{i,j}) \right)}{\log N} \right)$$

(Dumais, 1991)

CR Indices for Local Weighting Functions



CR Indices for Global Weighting Functions

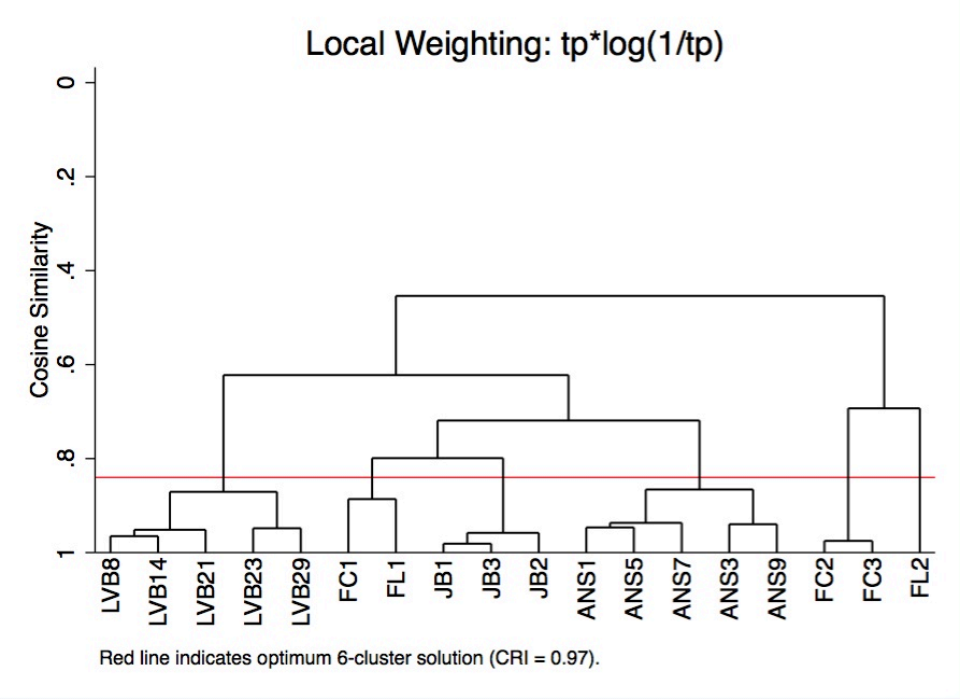


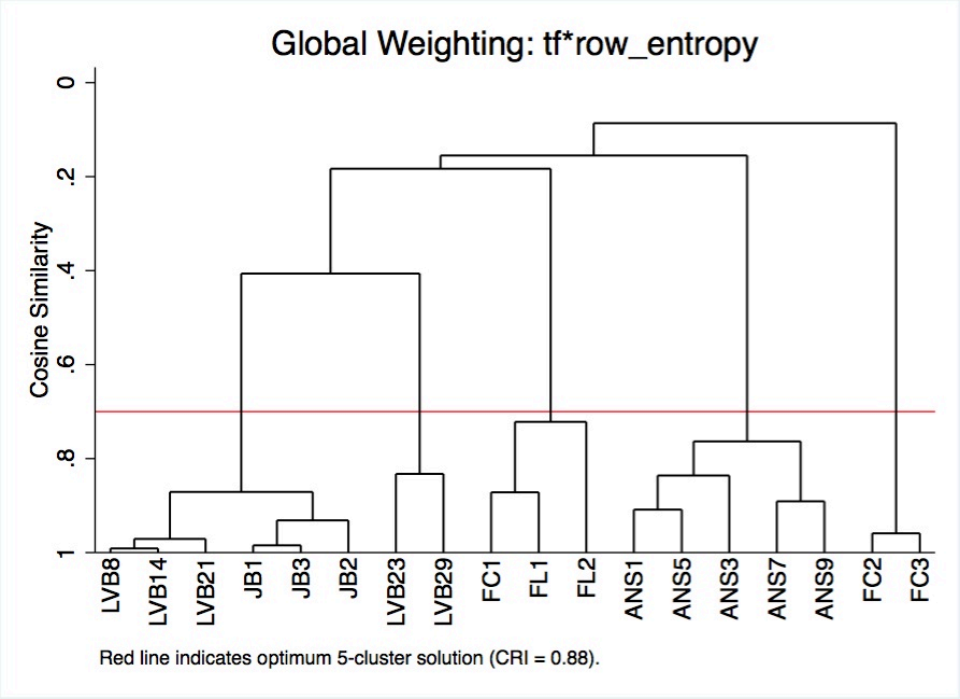
Overall Evaluation for Hierarchical Clustering

Weighting	N = 3		N = 4		N = 5		N = 6		N = 7	
	CR Index	C-H Index	CR Index	C-H Index	CR Index	C-H Index	CR Index	C-H Index	CR Index	C-H Index
Raw Frequency										
tf	0.59	11.81	0.64	11.63	0.69	11.50	0.81	11.60	0.83	11.25
Local Weighting										
log(1+tf)	0.86	4.59	0.94	4.23	0.91	3.84	0.96	4.35	0.92	4.26
tp*log(1/tp)	0.76	6.11	0.77	5.69	0.93	7.37	0.97	8.10	0.93	8.01
Global Weighting										
tf*log(idf)	0.86	6.82	0.92	8.08	0.88	8.13	0.90	9.54	0.90	10.09
tf*row_entropy	0.72	6.06	0.88	10.01	0.88	14.24	0.88	13.57	0.84	13.53

Note: Agglomerative hierarchical clustering with complete linkage and cosine similarity metric. Indices at each level of clustering are Composer Rand Index and Caliński-Harabasz Index (Caliński & Harabasz, 1974; Milligan & Cooper, 1985). Yellow highlights indicate optimum solutions as judged by the researcher.

Optimum Weighted Clustering





Note: Agglomerative hierarchical clustering with complete linkage and cosine similarity metric. Optimum clustering per Composer Rand Index.

The Future for This Research

- More scores, more composers, more musical forms, more instruments.
- Studies of multiple editions of the same work over time to identify historical trends.
- Exploration of statistical methods for identifying combinations and sequences of tokens indicating higher-order syntactic structures.
- Empirical performance studies to examine correlates of performance marks in performance variability.

Expanding the Digital Future for Music Libraries

- Digitization of scores in machine-readable formats that completely capture the notation structure and its metadata (e.g. see Music Encoding Initiative at music-encoding.org).
  - Projects to collect and organize born-digital scores.
  - Projects to explore the creation of digital editions of historical scores (Fujinaga, Hankinson, & Cumming, 2014).
- Management of datasets from empirical projects: data, program code, supporting documentation (Porter & Serra, 2014).
- Workshops on Digital Libraries for Musicology (DLfM)

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