Multidimensional timbre analysis of melody

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Perceptual importance of timbre

- Timbre described as the most important and relevant feature of auditory events.
- We show acute memory for timbral qualities (Schellenberg *et al*, 1999).
- We have an immense ability to distinguish timbres in everyday life.
- Timbre has been implicated in the mechanism of absolute pitch perception.

Timbre analysis: Western Music

Secondary role of timbre in the analysis of western tonal music:

Reasons

- Unlike pitch and rhythm, timbre is difficult to notate.
- Dominance of harmonic pitch relations as musical structuring force in WTM.

However…

- Timbre does play an important role in WTM.
- Is exploited by composers, particularly in 20th century compositions.

Timbre analysis: non-western music I

In absence of harmony as principle way of structuring music could timbre play a stronger role?

Evidence from ethnomusicology:

- "…*has western music lost something by eliminating the melodic possibilities inherent in smaller, less regular intervals which music of other cultures still value?*" (Theodore Finney, 1947: p720)

- Ethnomusicologist, David Morton (1976) described the Thai musical tradition as having "*…developed melodic possibilities rather than harmonic ones*"
- (Morton, 1976: p22).

Timbre analysis: non-western music II

In absence of harmony as principle way of structuring music could timbre play a stronger role?

Evidence from perceptual studies:

- Grouping by timbre similarity; adjacent sounds group in preference to others (Bregman, 1990).
- Expressive changes increase perceptual salience of pitch events (Gjerdingen, 1993).
- Pitch-timbre interaction in musical sequences (Beal, 1985; Crowder, 1989, Semal & Demany, 1991; Krumhansl & Iverson, 1992)

Characterising timbre: ordinal point of view

- Cannot be satisfactorily related to a single physical dimension like:

  Pitch → frequency.

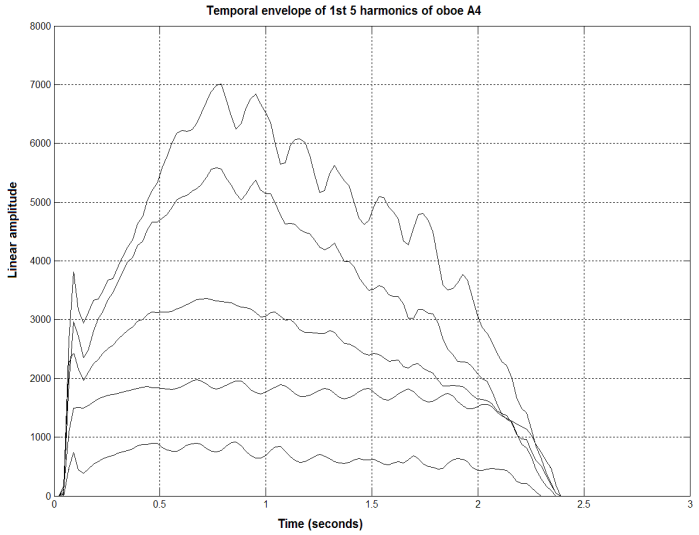
  Rhythm → duration/time.

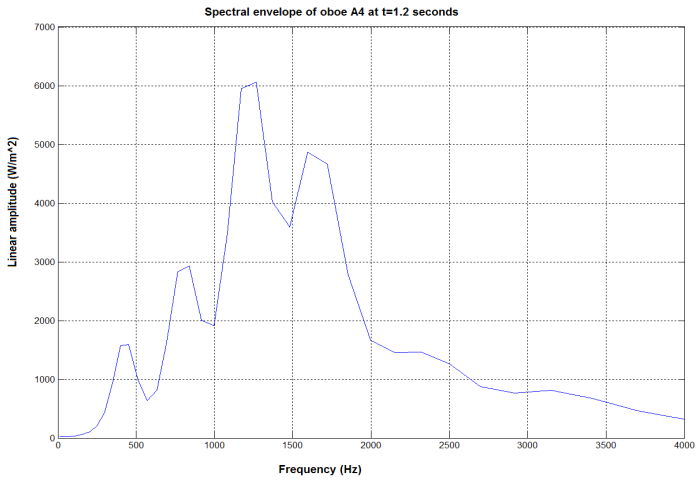
Thus…

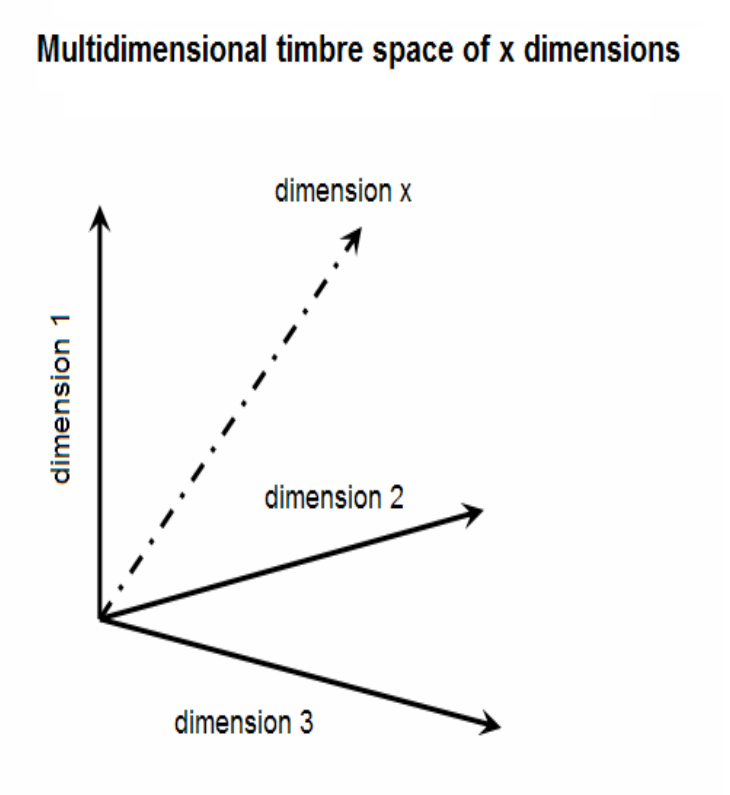
- It is described as **multidimensional** and
- sounds create a **multidimensional timbre space**.

- **Spectral** and **temporal** descriptors of timbre →describe the multidimensional timbre space.

Multidimensional timbre space







Name	Type	Physical Correlate	Perceptual Correlate	Description
Spectral centroid	Spectral	Energy concentration in low/high spectral area	Brightness/ Dullness	Balance of energy in spectrum.
Irregularity	Spectral	Fluctuating energy between adjacent partials	Richness	Amplitude variation of adjacent components.
Roughness	Spectral	Beating of overlapping partials	Harshness/ Smoothness	Inharmonic and noise components in spectrum.
Harmonicity	Spectral	Harmonic/ Inharmonic	Cohesive/ Diffuse	Ratio of harmonic to inharmonic spectral components.
Attack/ Decay times	Temporal	Slope of attack and decay	Instrument identification	Time taken to reach max. amp from 0 (attack).

Timbre analysis of melody: Aims

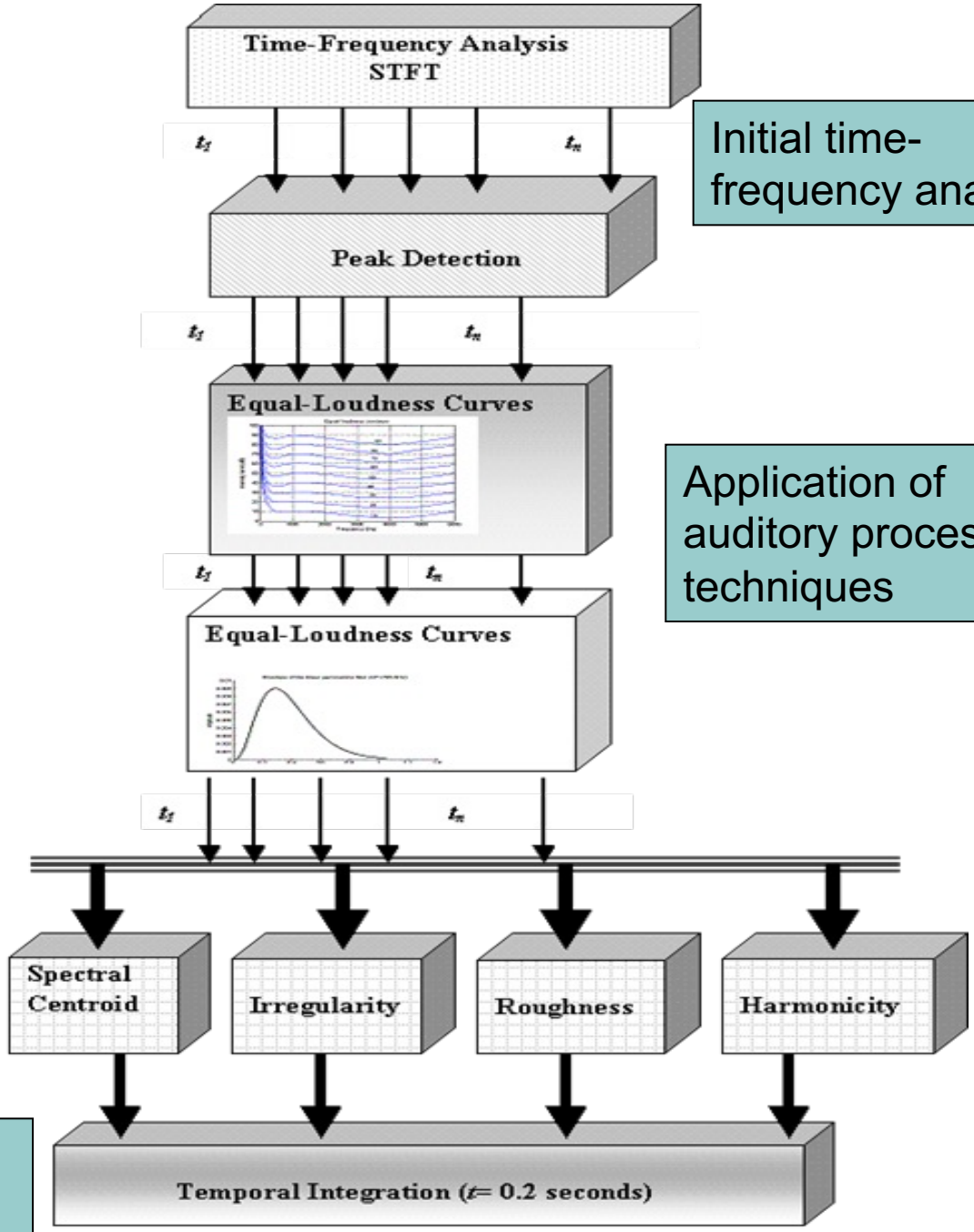
- To employ measures of timbre that have perceptual relevance.
- To take account of the multidimensional characteristic of timbre.
- To analyse the timbre evolution over time in the melody.
- To extract a relationship between characteristics of timbre in the melody and the melodic structure.
- To extract a melodic timbre structure that goes some way towards perceptually relevance.

Timbre analysis of melody: Difficulties

- Deriving perceptually relevant timbres.
- Absolute timbre values or relative timbre values?
- How to deal with multidimensional representation of timbre in…
  - Investigating timbre evolution over time.
  - Extracting and interpreting a timbre structure.
- Interpreting relation between timbre and melodic structure.

Perceptual Relevance

Timbre analysis: Stage I



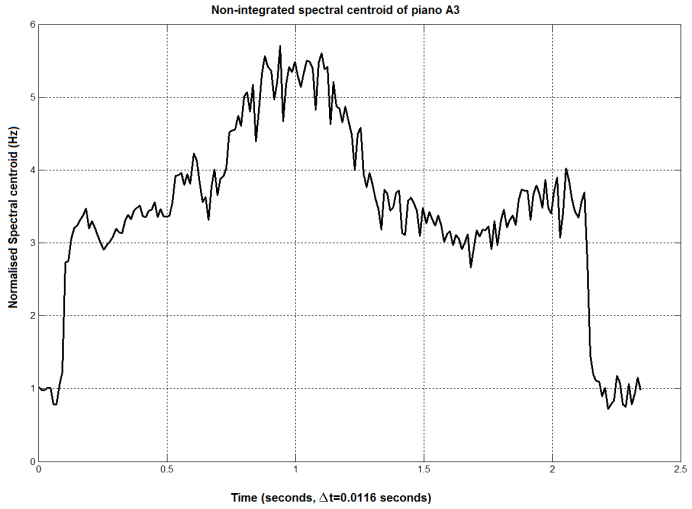
Initial time-frequency analysis

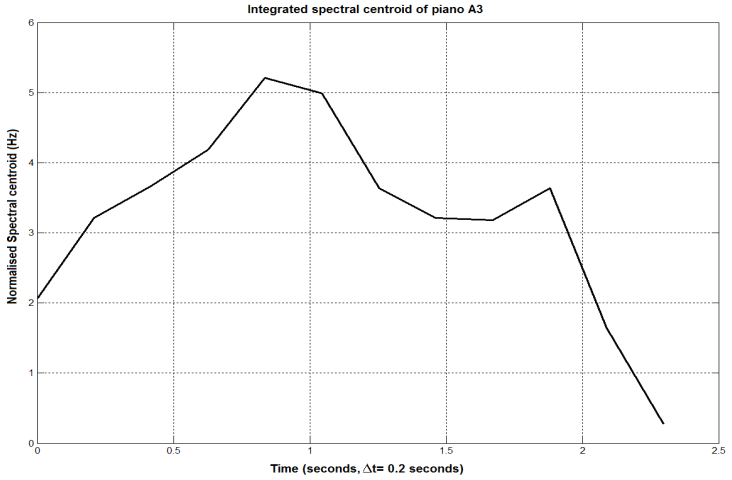
Application of auditory processing techniques

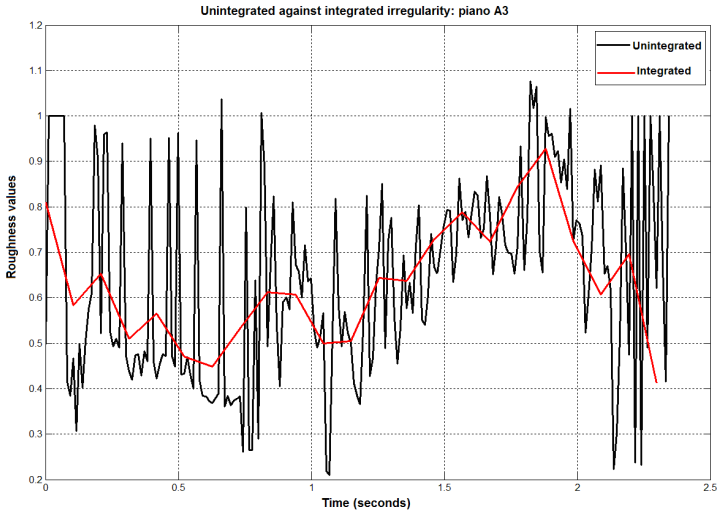
Calculation of timbre descriptors

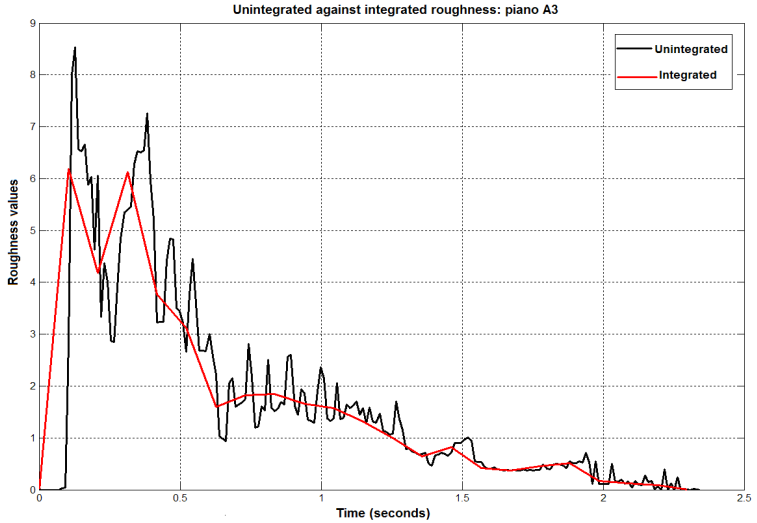
Time integration of timbre contours

Time integration of timbre contours









Multidimensional timbre analysis stage II: Absolute or relative timbre values?

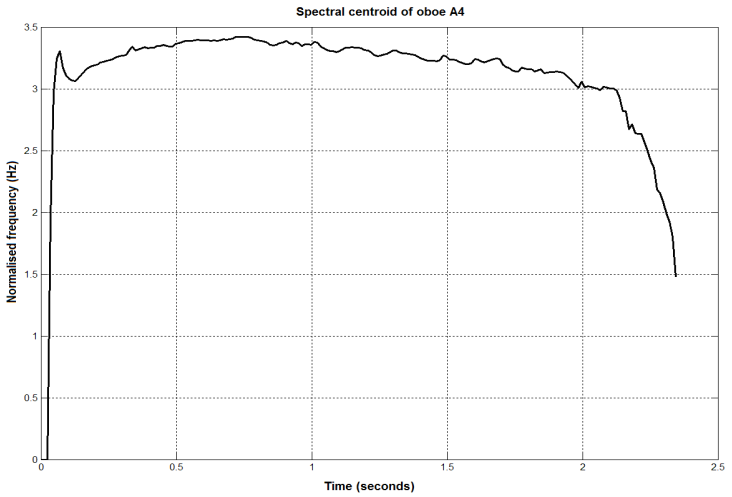
In an analysis of timbre in melody, the timbre is presented over time.

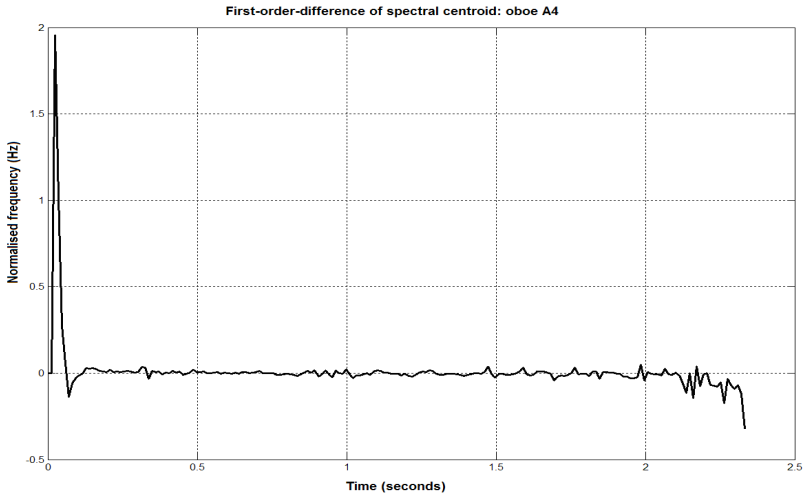
Therefore, the analysis can focus on either:

- Absolute timbre values (left)

  or..

- Relative timbre values, i.e. measures of timbre change (right).





Multidimensional timbre analysis II: Dealing with a multidimensional timbre space

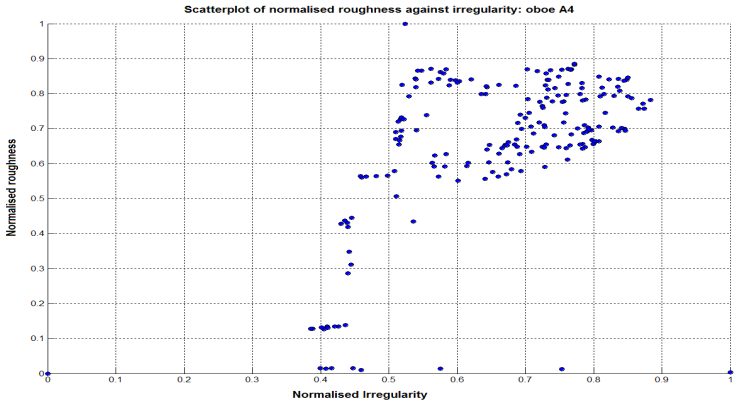
Problem: I wish to represent timbre evolution over time but still use a multidimensional timbre space.

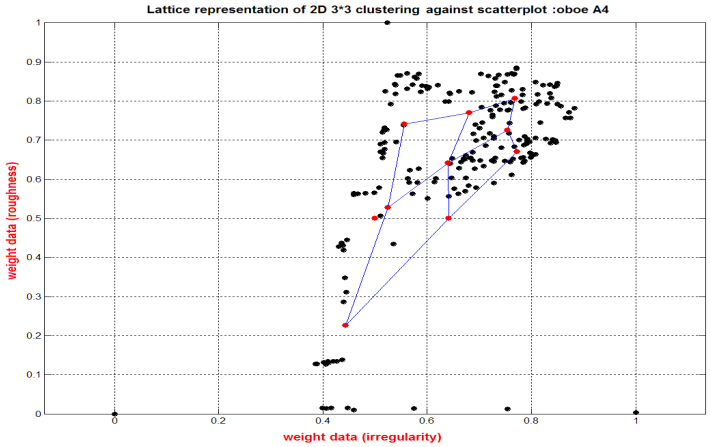
Required: Means of projecting multidimensional timbre space onto a 2D timbre against timbre space.

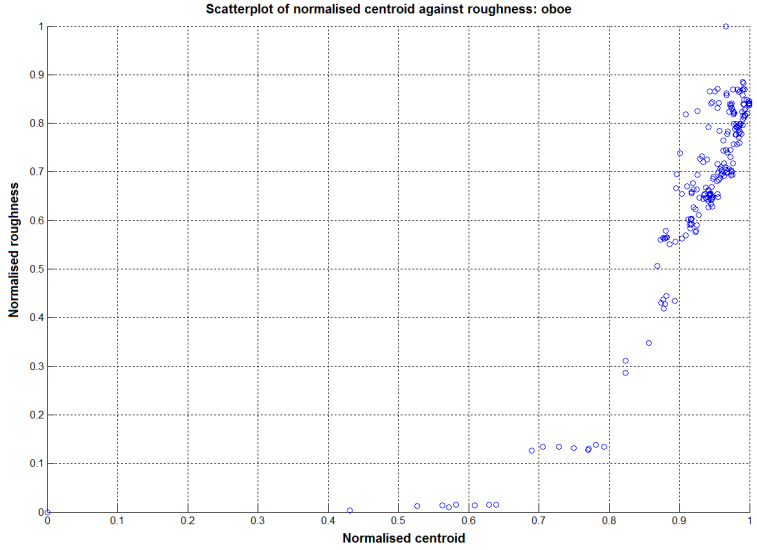
Current solution: Use of an unsupervised neural network, a **Kohonen Self-Organising Feature Map** (SOFM) (Kohonen, 1984)

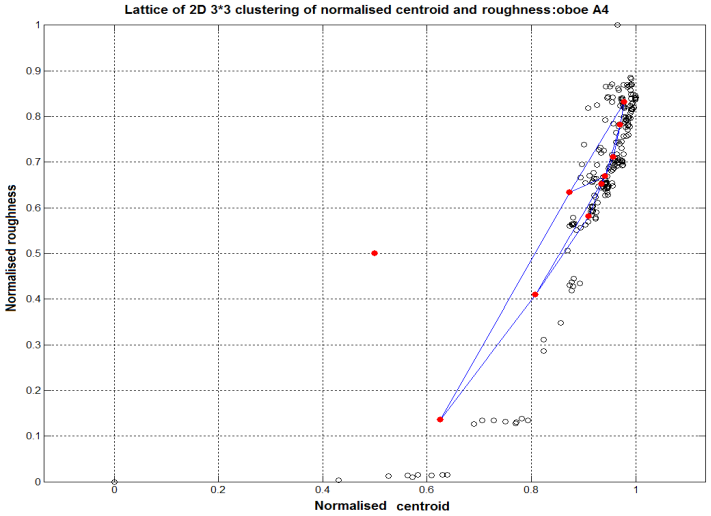
- To extract patterns of interrelations in the multidimensional space
- To project them onto a space of lower dimensionality.

SOFM Clustering: 2D example









SOFM Clustering: Considerations

- **Number of clusters**:
  - High number of clusters => higher resolution clustering =>difficult to extract general structure.
  - Lower number of clusters => lower resolution clustering =>less *noise* and easier to extract general structure.

- **Dimensionality of clustering (2D, 3D or 4D):**
  - Need to be aware of range of the timbre space of each descriptor.

Current implementation focuses on:

2D 3×3, **3D 5×5** and **4D 10×10** clustering.

Extracting timbre change information

Steps:

1. Time-dependent descriptors assigned to derived timbre clusters (expressed as weights, *w*) => finding *w* that minimises the Euclidean distance, *d*.

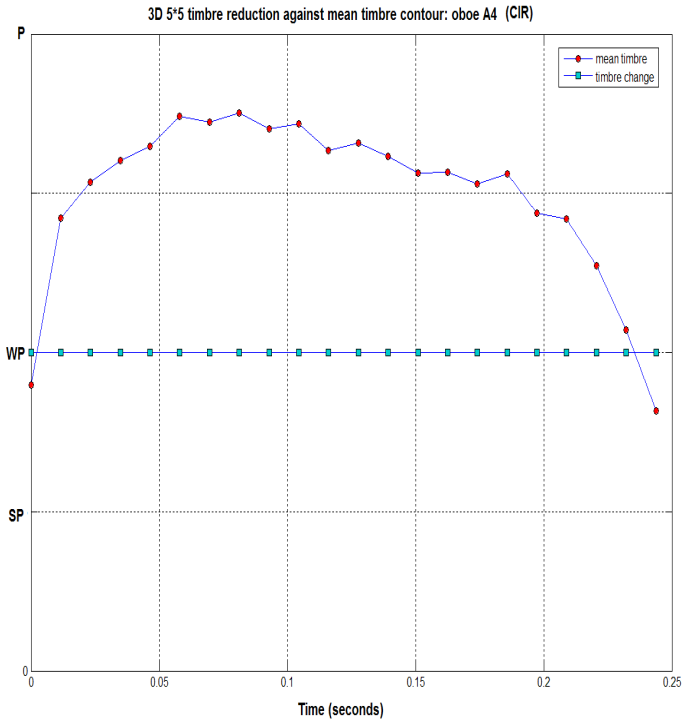
   We still have absolute values!!

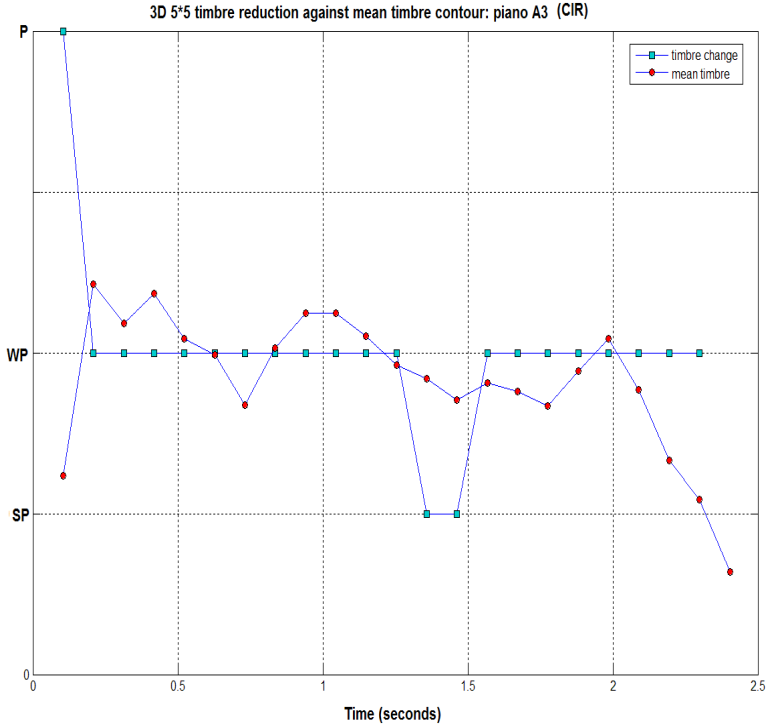
2. Compare values of *d* between derived clusters with maximum distance between clusters, d_{max} as follows:

$$x = \frac{d}{d_{\max}}$$

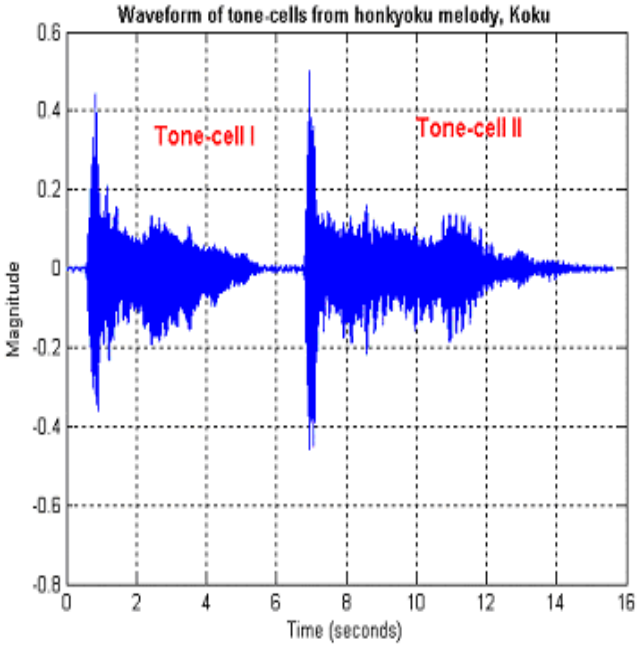
3. The change, *x*, is assigned to one of 3 types depending on value:
   1. If 0<=*x*<=1, *strong prolongation* (repeat)
   2. If 0.1<*x*<0.7, *weak prolongation* (intermediate change)
   3. If 0.7<=*x*<=1.0, *progression* (large change)

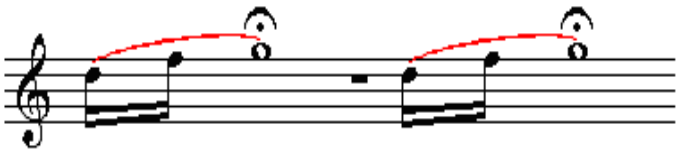
Timbral change plots





Timbral change analysis: shakuhachi melody “Kokû” motif A.

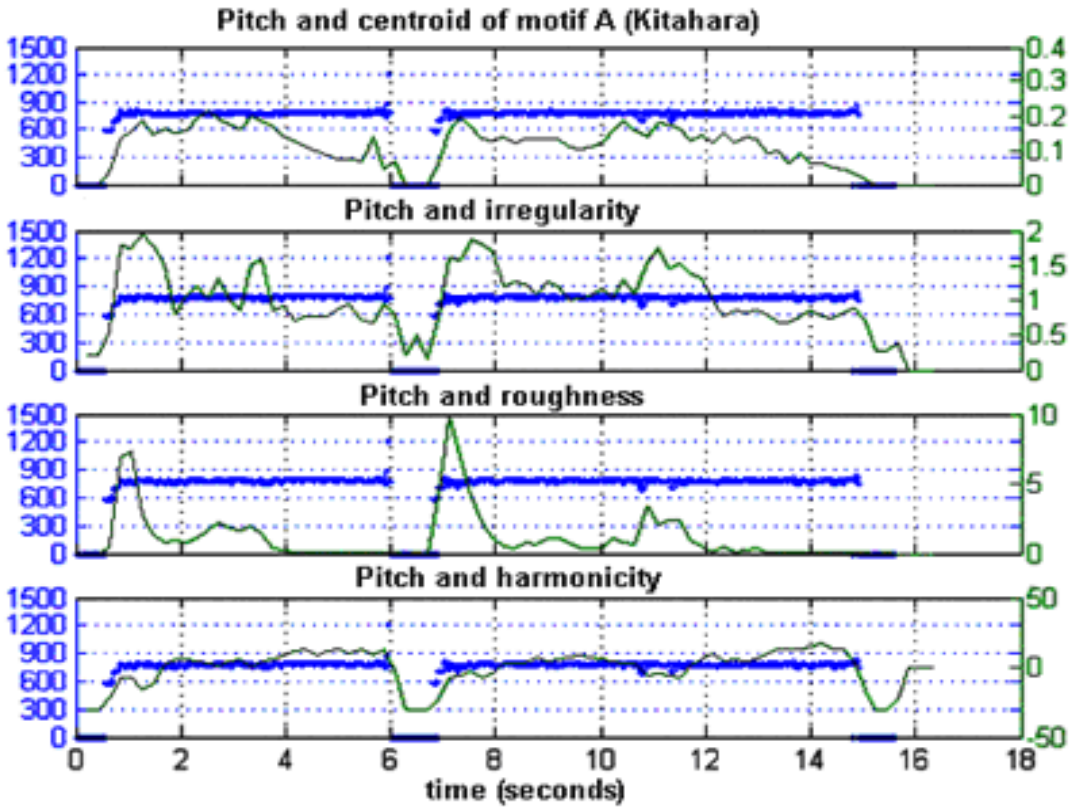




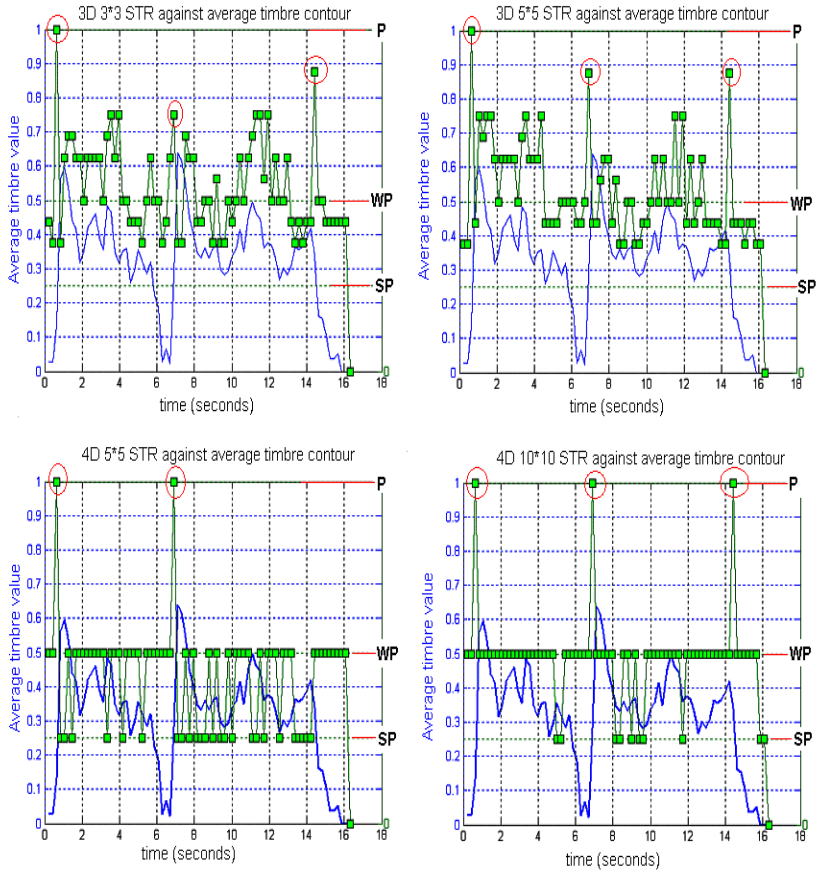
Section I: Kokû (Kitahara)

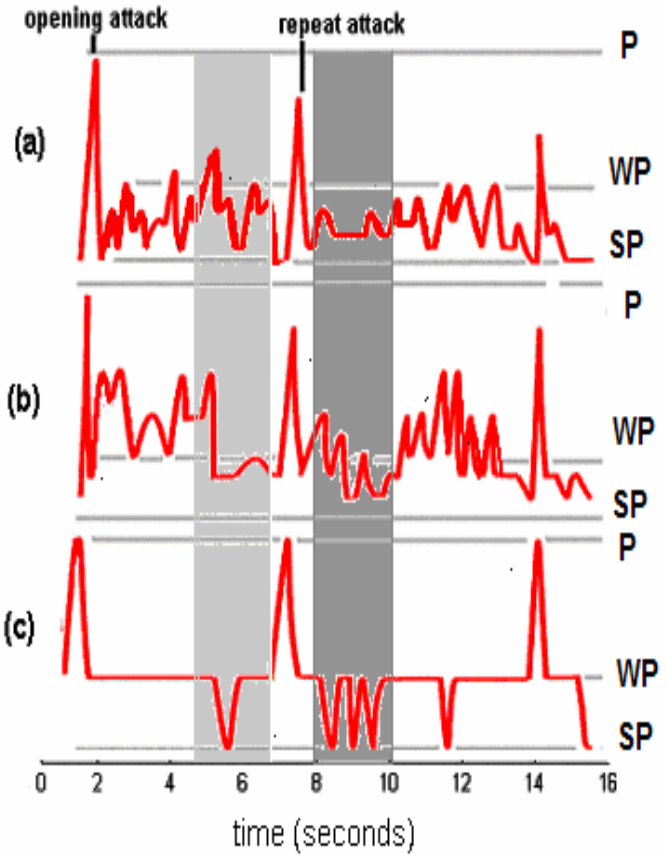
Tone cells: Kokû (Kitahara)

Timbral change analysis: shakuhachi melody “Kokû” motif A.



Summary timbral reductions: “Koku” motif A.





2D 3×3

3D 5×5

4D 10×10

Further work: main considerations

- Verify perceptual relevance of timbre change analysis.
- Apply analysis technique to several versions of the same melody → attempt to reveal general aspects of structure.
- Apply analysis to different melodies of the same tradition.
- Apply analysis to melodies of different traditions.
- Use different timbre descriptors →the analysis captures significant timbre characteristics.