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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:

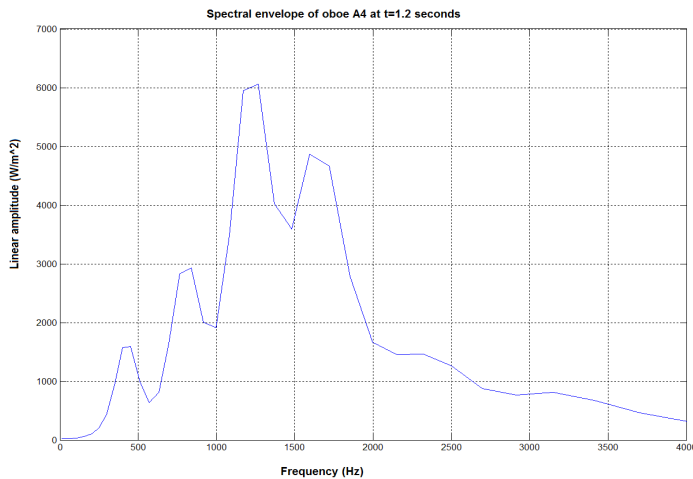
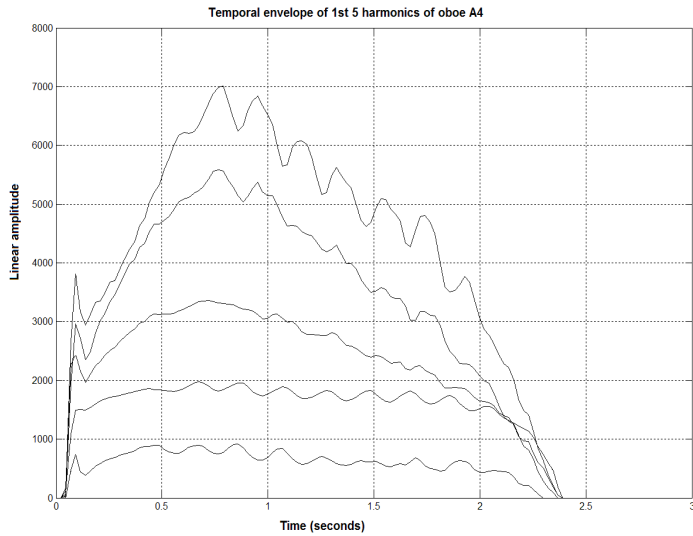
Pitch → frequency.

Rhythm → duration/time.

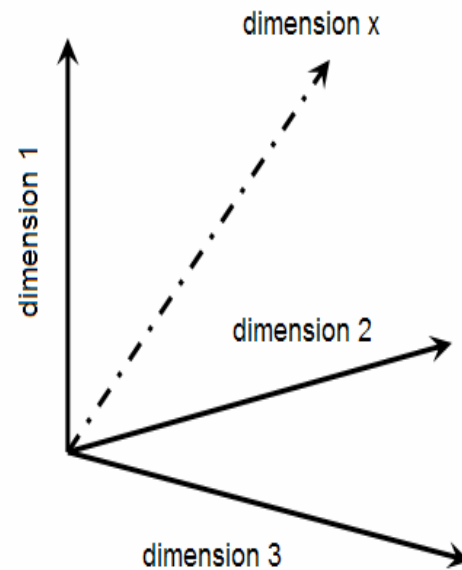
Thus...

- 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



Multidimensional timbre space of x dimensions



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

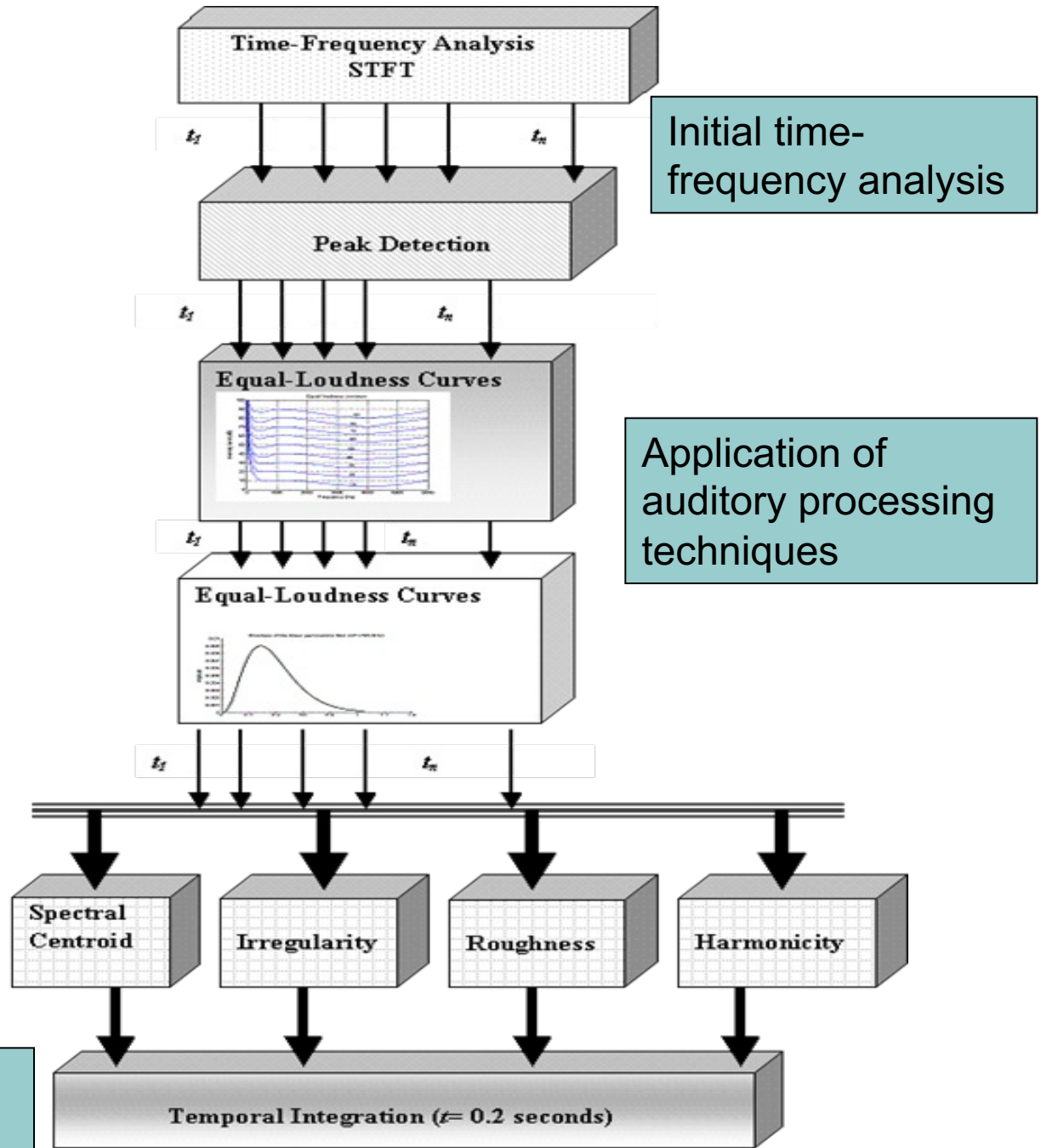
- Deriving perceptually relevant timbres.
- Absolute timbre values or relative timbre values?
- How to deal with multidimensional representation of timbre in...
 - Investigating timbre evolution over time.
 - Extracting and interpreting a timbre structure.
- Interpreting relation between timbre and melodic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



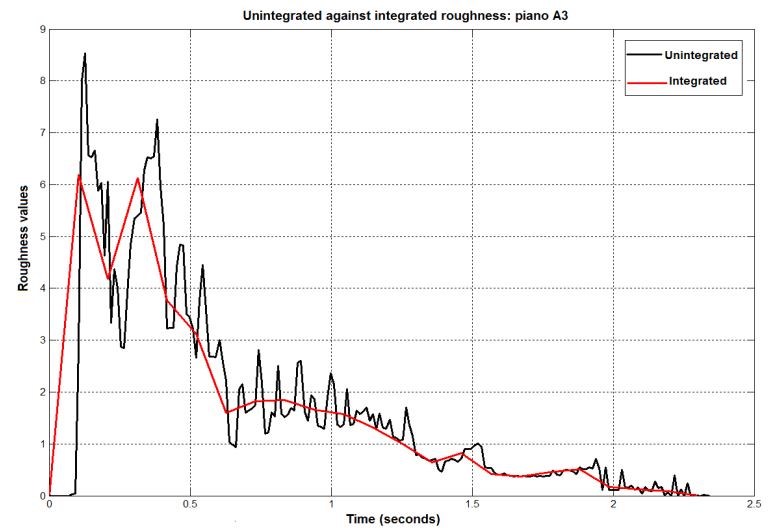
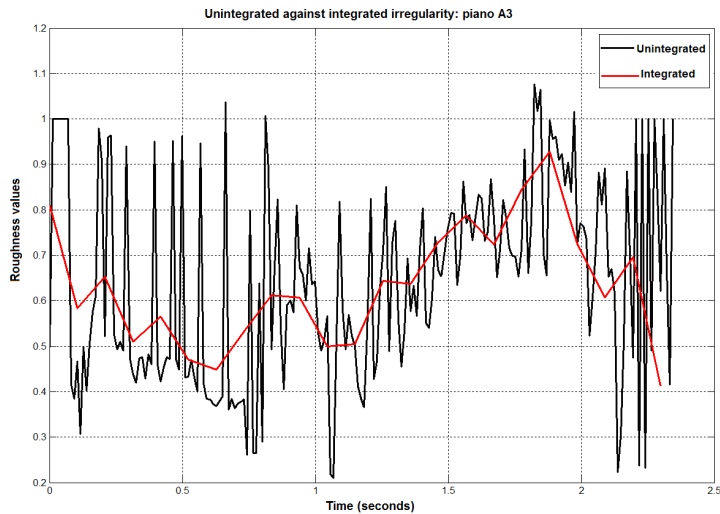
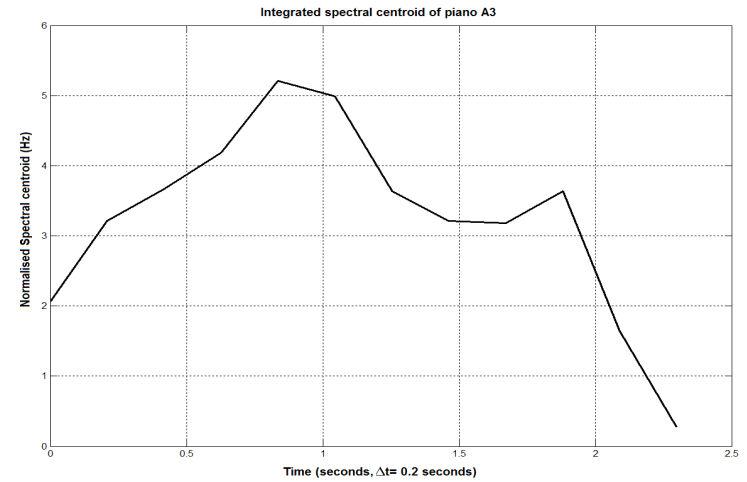
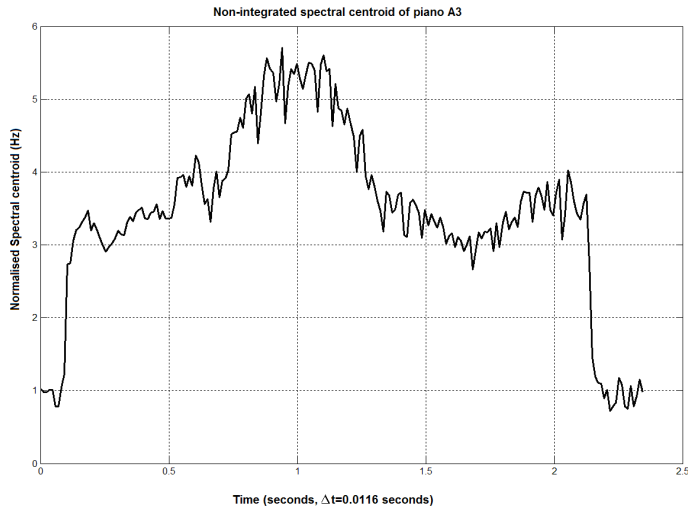
Perceptual Relevance



Timbre analysis: Stage I



Time integration of timbre contours



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

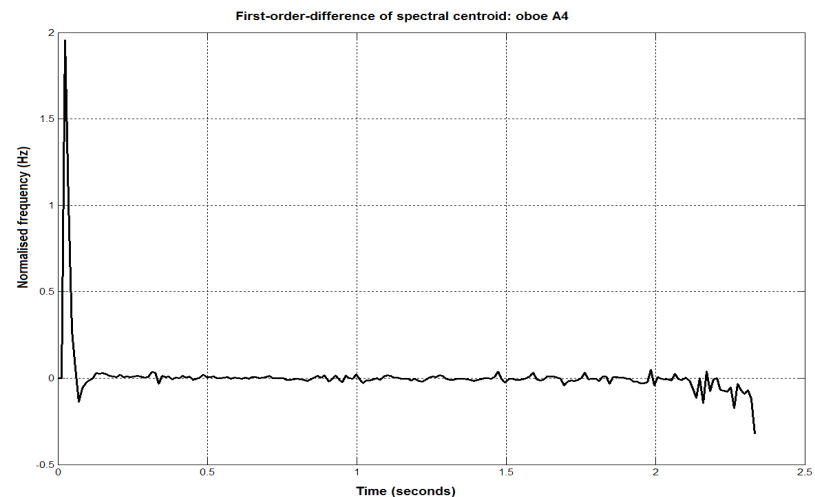
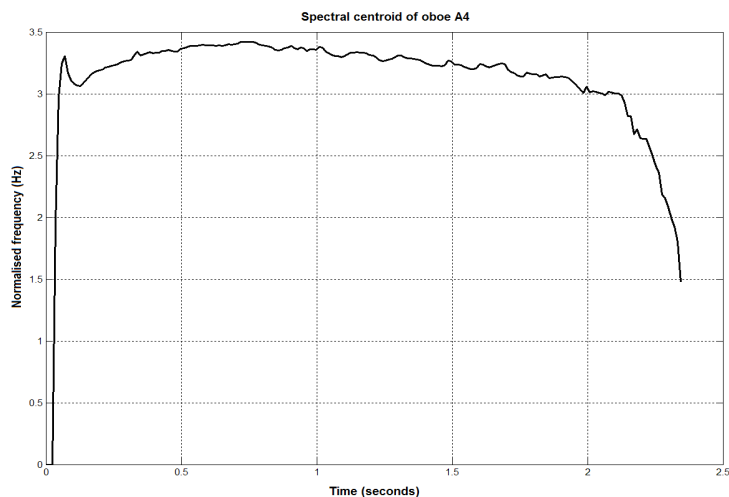
In an analysis of timbre in melody, the timbre is presented over time.

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

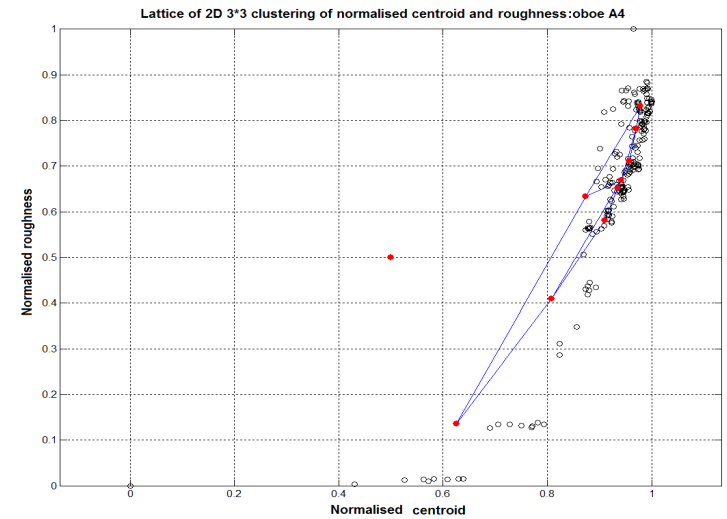
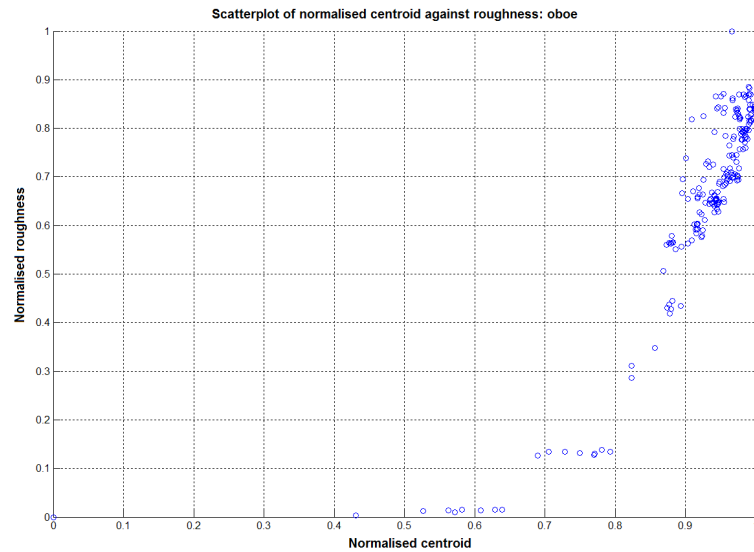
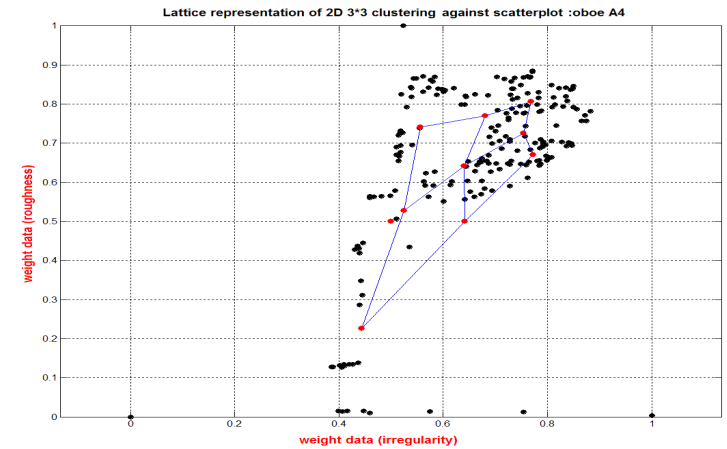
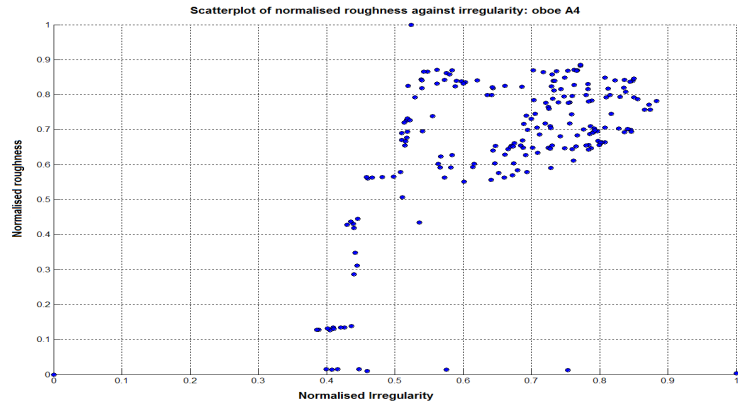
Problem: I wish to represent timbre evolution over time but still use a multidimensional timbre space.

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 .

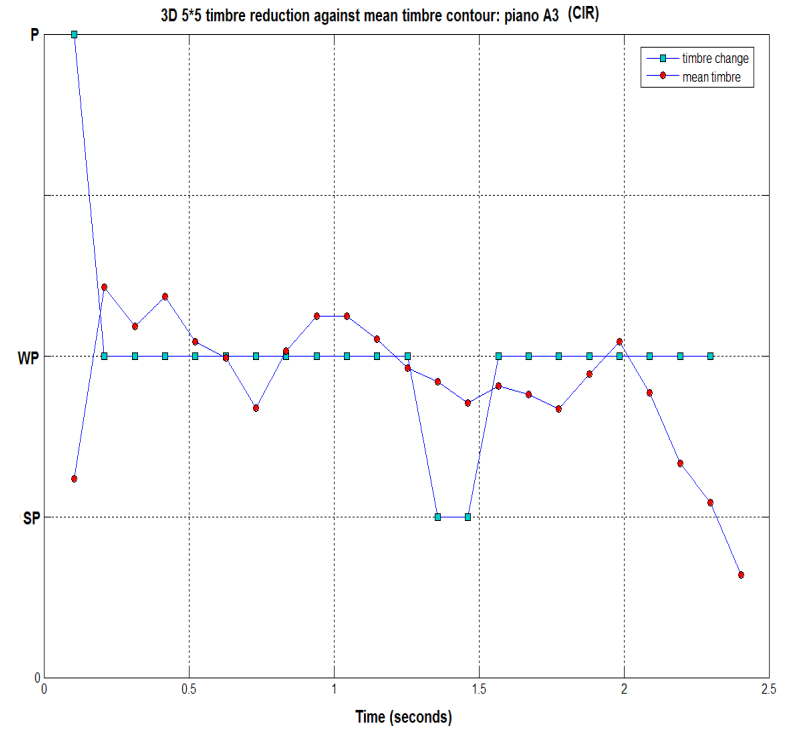
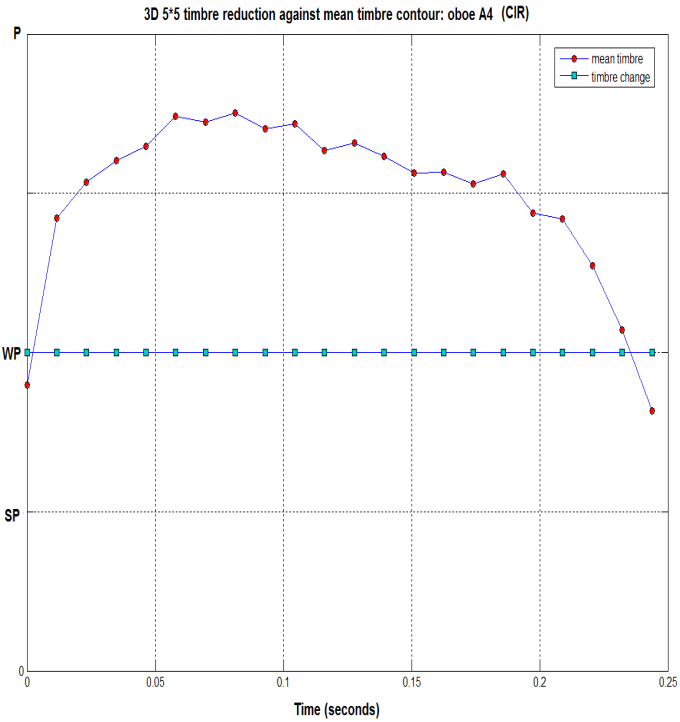
We still have absolute values!!

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

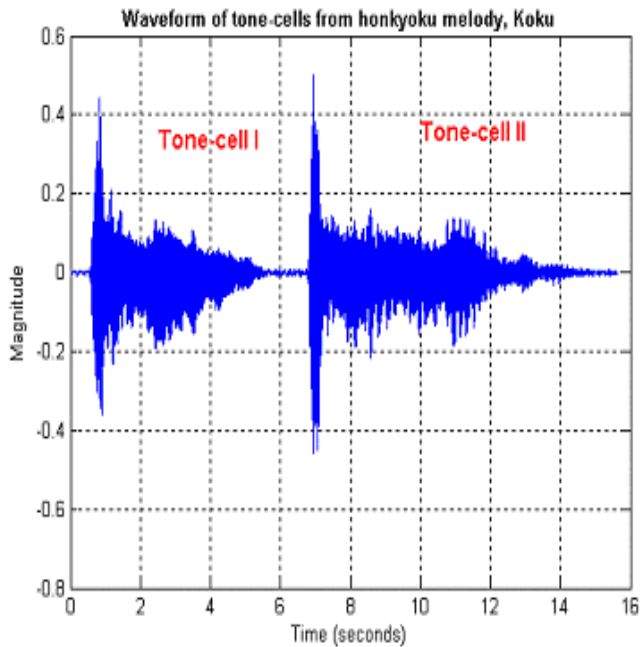
$$x = \frac{d}{d_{max}}$$

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

Timbral change plots



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

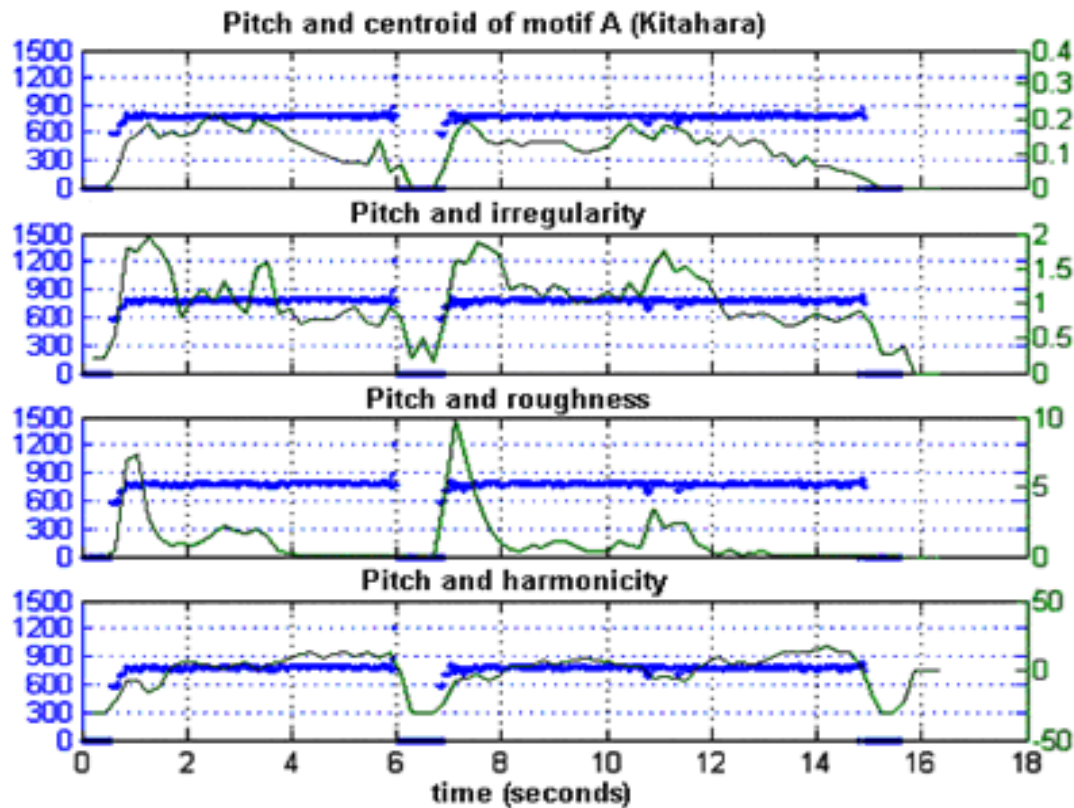


Section I: Kokû (Kitahara)

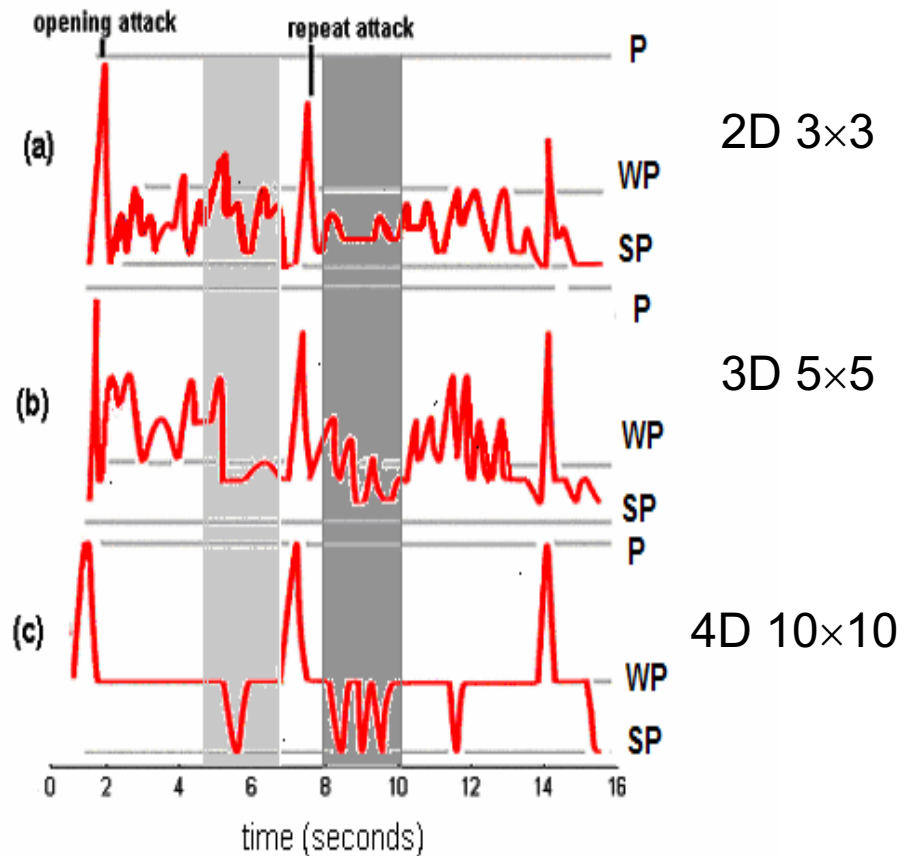
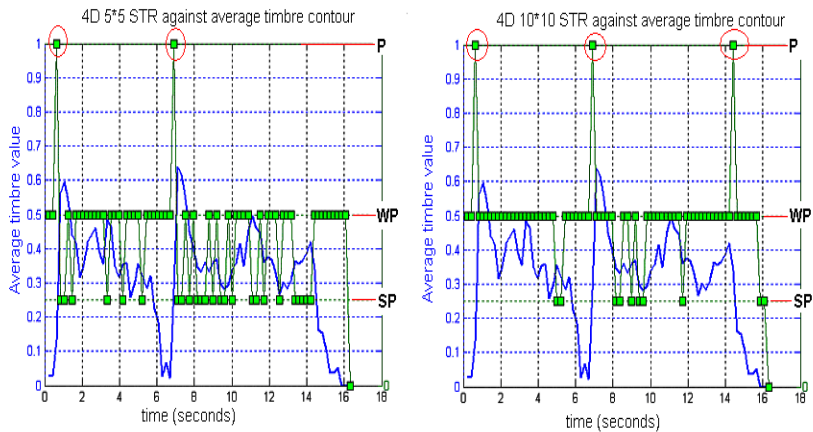
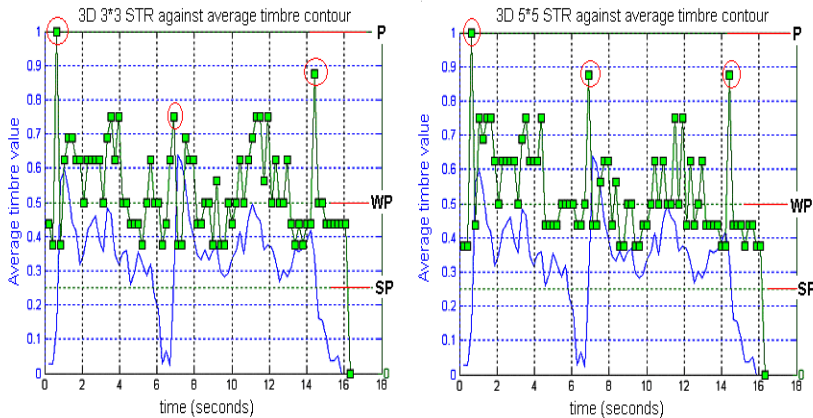


Tone cells: Kokû (Kitahara)

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



Summary timbral reductions: “Koku” motif A.





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.