Description of Chord Progressions by Minimal Transport Graphs Using the System & Contrast Model

LOUBOUTIN Corentin, BIMBOT Frédéric

ICMC 2016

UNIVERSITÉ DE RENNES 1
UMR IRISA

Outline of the work

1. Introduction to the S&C model
2. Computational approach
   - Chords relation description
   - S&C Description estimation
3. Experiments
   - Algorithm design
   - Evaluation using perplexity measure
4. Conclusion

Understand musical structure

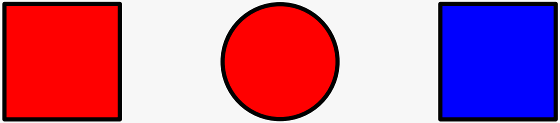
Various points of view:

- Structure music as a **succession of events** ?
  (for instance Tymoczko 2008)
- Structure music using **formal language theory** ?
  (for instance De Haas 2011)
- Structure music considering the simplest explanation using **minimum description length** principle ?
  (for instance Meredith 2013)

Our view ? $\Rightarrow$ Music structure also depends on an **expectation process.** (Narmour 2000)

Let's guess

1 2 3 ?

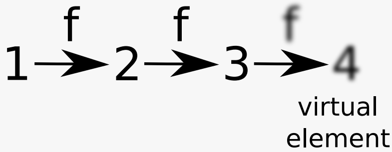


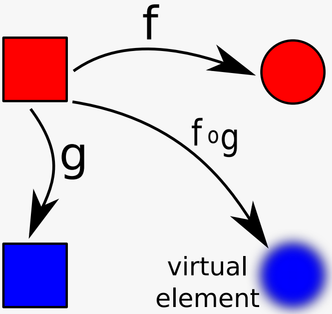
?

Relations $\Rightarrow$ Expectation

System as an extentsion of progressions

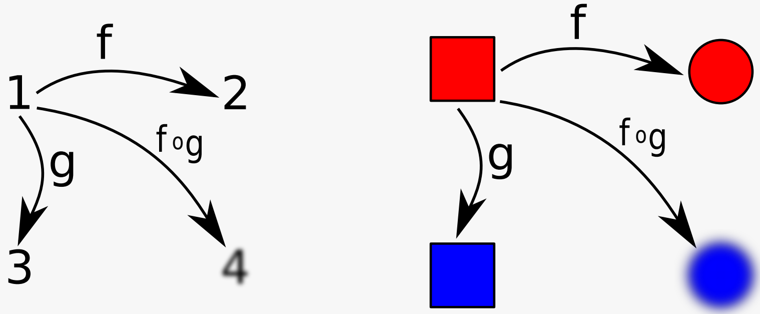
The expectation is induced by the *system* formed by the first three elements.





System as an extension of progressions

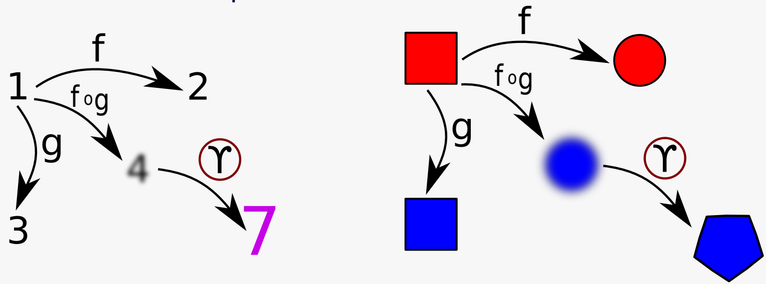
The expectation is induced by the *system* formed by the first three elements.



Progressions also form square systems.

The contrast

Modeling the difference between
the expectation and the observation.



Denial ⇒ Contrast (creates some closure to the system)

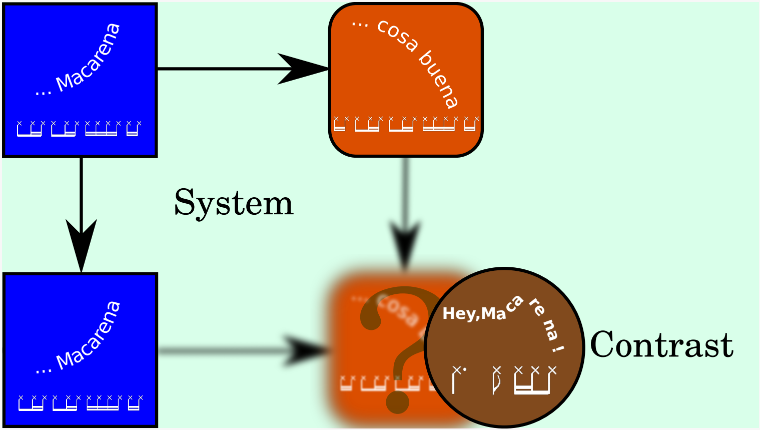
S&C in music

Recent formalization and exploration of the model

- The S&C model has been formalized to analyse structures from 3 to 6 motifs. (Bimbot ISMIR 2012)
- It generalizes the Narmour's Implication Realization model. (Bimbot Music Perception 2016)
- It is found in music from different types. (Bimbot ISMIR 2012, Deruty Master Thesis 2013)

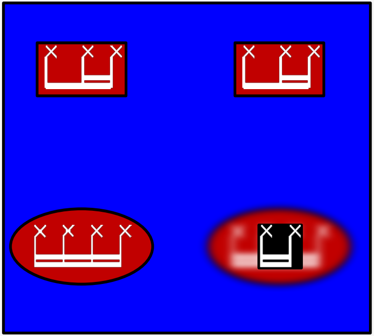
A very “popular” music example

Have you ever analyzed the Macarena ?



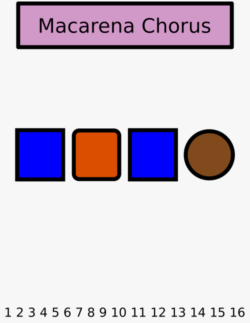
Multi-scale principle

The first element of the chorus of the Macarena can also be modelized as an S&C.

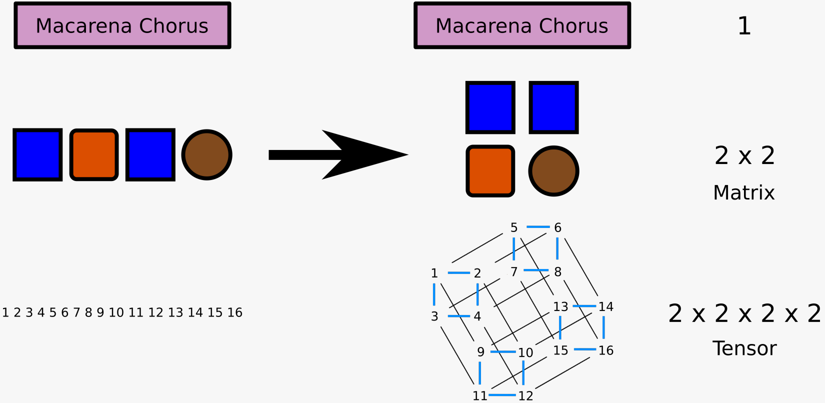


The S&C model works at multiple scales.

Multi-scale description



Multi-scale description



Just another way of organizing information.

From theory to application

Two more steps to go

1. A need to explicitely describe the relations between elements.
2. A need to design and evaluate an algorithmic implementation of the model.

Computational approach

Formalisation of the S&C model

Notations

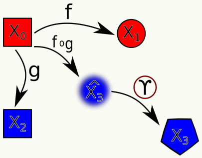
The System and Contrast model in its square form defines the organisation of a sequence of four elements as:

$$X = \begin{bmatrix} x_0 & x_1 \\ x_2 & x_3 \end{bmatrix}$$

with

- x_0 the primer of the system
- $x_1 = f(x_0)$ and $x_2 = g(x_0)$
- $x_3 = \gamma(\hat{x_3})$

where $\hat{x_3} = f(g(x_0))$ is the virtual element



Objective : modeling f, g, and γ.

Describing relations between chords

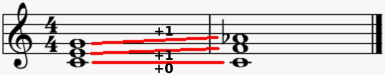
The relations between chords are described in terms of

minimal transport.

Definition

A *transport* between two chords $P = (p_i)_{0 \leq i \leq m_p}$ and $Q = (q_j)_{0 \leq j \leq m_q}$ is a set :

$$T = \{(p_k, q_k) | p, q \in [\![0; 11]\!], k \in [\![0; n]\!]\}$$

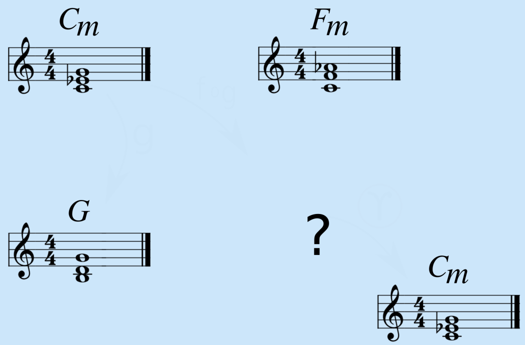


The cost of a transport is determined by the **taxicab norm** (L_1).

Minimal transport with S&C model

Minimal transport is used to describe relations in the S&C representation.

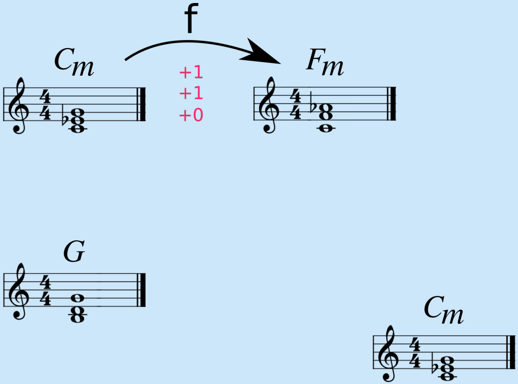
Example: *Cm* – *Fm* – *G* – *Cm* chord progression



Minimal transport with S&C model

Minimal transport is used to describe relations in the S&C representation.

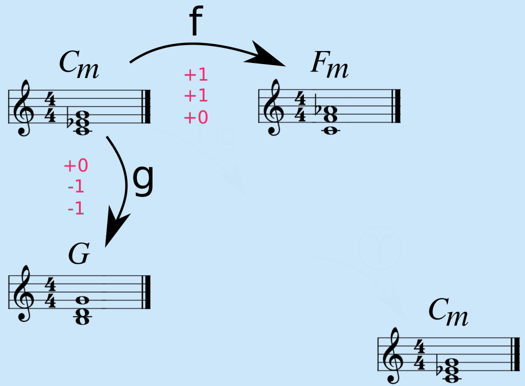
Example: *Cm* – *Fm* – *G* – *Cm* chord progression



Minimal transport with S&C model

Minimal transport is used to describe relations in the S&C representation.

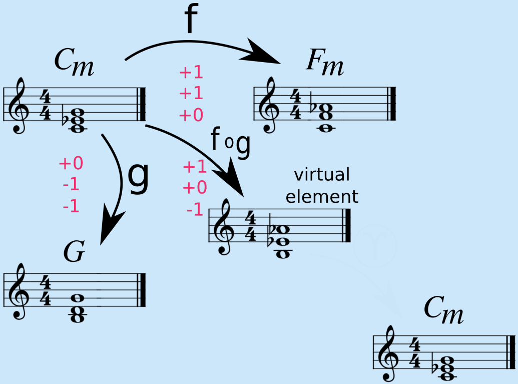
Example: *Cm* – *Fm* – *G* – *Cm* chord progression



Minimal transport with S&C model

Minimal transport is used to describe relations in the S&C representation.

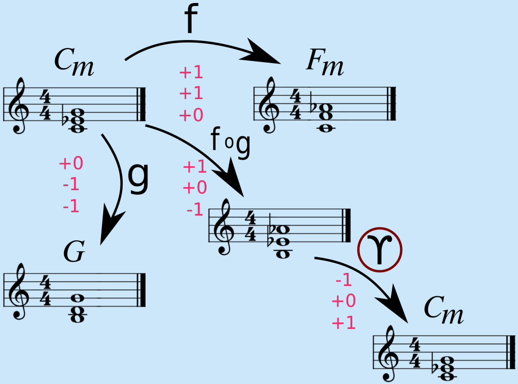
Example: *Cm* – *Fm* – *G* – *Cm* chord progression



Minimal transport with S&C model

Minimal transport is used to describe relations in the S&C representation.

Example: *Cm* – *Fm* – *G* – *Cm* chord progression



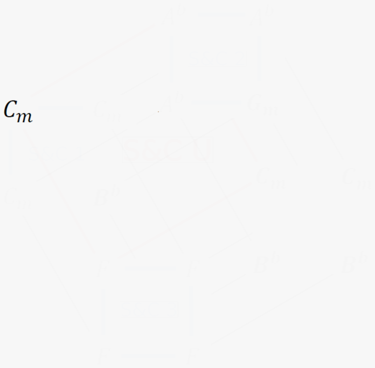
Biscale description for chord sequences

A sequence of 16 chords can be described as 4 square S&Cs linked by an upper-scale S&C, resulting in a tensor structure.

Cm Cm Cm Bb Ab Ab Ab G F F F F Cm Cm Bb Bb

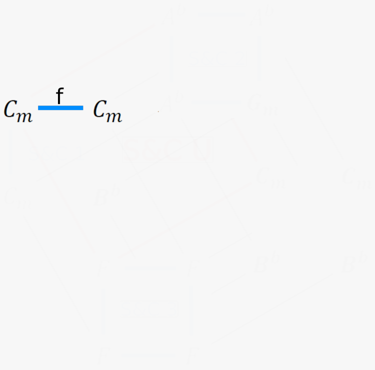
Biscale description for chord sequences

A sequence of 16 chords can be described as 4 square S&Cs linked by an upper-scale S&C, resulting in a tensor structure.



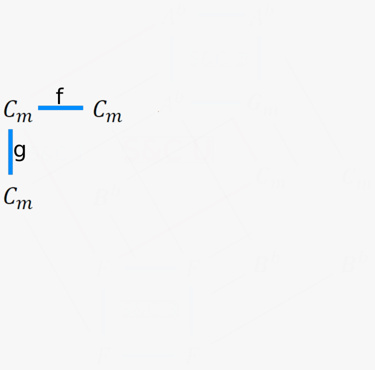
Biscale description for chord sequences

A sequence of 16 chords can be described as 4 square S&Cs linked by an upper-scale S&C, resulting in a tensor structure.



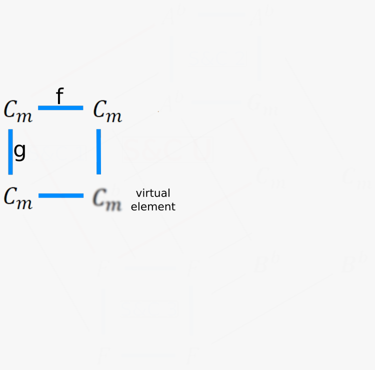
Biscale description for chord sequences

A sequence of 16 chords can be described as 4 square S&Cs linked by an upper-scale S&C, resulting in a tensor structure.



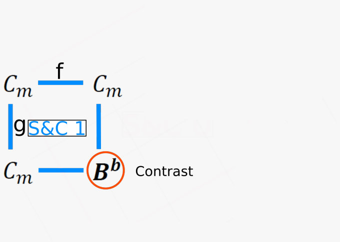
Biscale description for chord sequences

A sequence of 16 chords can be described as 4 square S&Cs linked by an upper-scale S&C, resulting in a tensor structure.



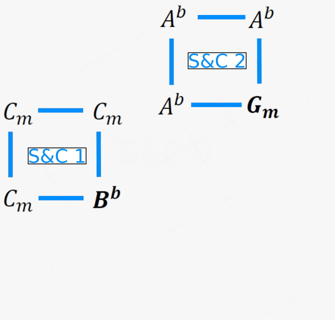
Biscale description for chord sequences

A sequence of 16 chords can be described as 4 square S&Cs linked by an upper-scale S&C, resulting in a tensor structure.



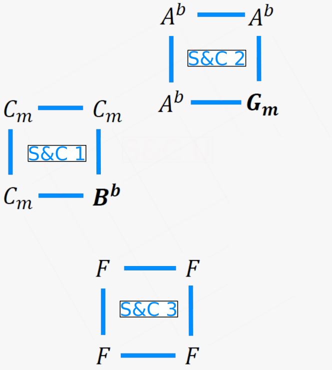
Biscale description for chord sequences

A sequence of 16 chords can be described as 4 square S&Cs linked by an upper-scale S&C, resulting in a tensor structure.



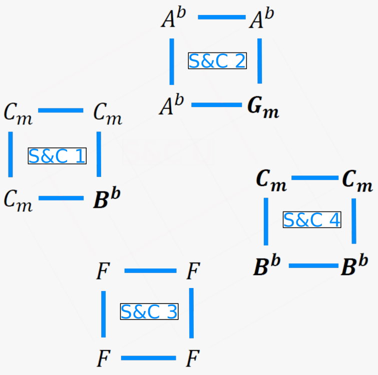
Biscale description for chord sequences

A sequence of 16 chords can be described as 4 square S&Cs linked by an upper-scale S&C, resulting in a tensor structure.



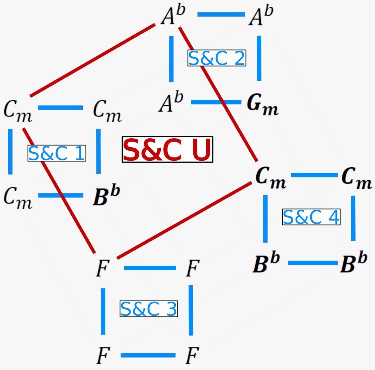
Biscale description for chord sequences

A sequence of 16 chords can be described as 4 square S&Cs linked by an upper-scale S&C, resulting in a tensor structure.



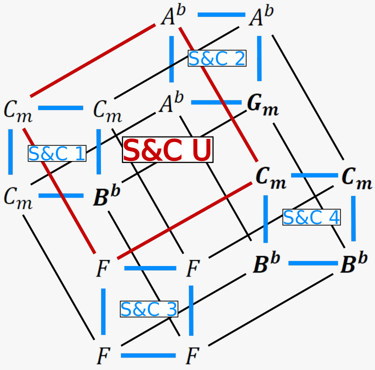
Biscale description for chord sequences

A sequence of 16 chords can be described as 4 square S&Cs linked by an upper-scale S&C, resulting in a tensor structure.



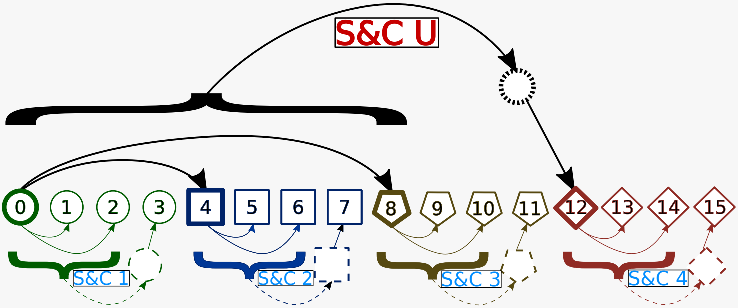
Biscale description for chord sequences

A sequence of 16 chords can be described as 4 square S&Cs linked by an upper-scale S&C, resulting in a tensor structure.



Nested S&C description estimation

Optimization of an S&C: finding the set of transport $\{f, g, \gamma\}$ that minimizes the global transport cost S&C.

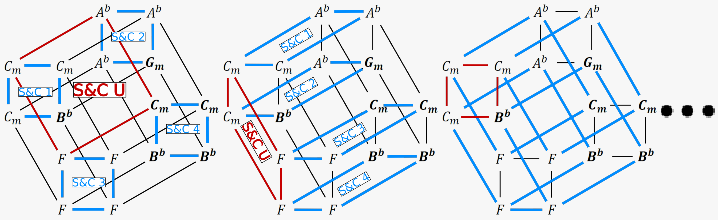


Optimization in two steps:

1. optimization of the S&C U
2. optimization of the four sub-S&C.

Multiple tensorial configurations

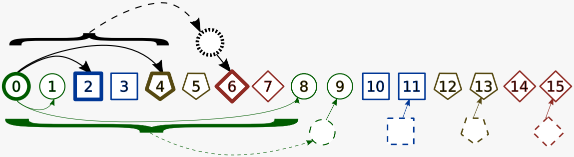
30 possible choices of combination of squares corresponding to the four sub-S&Cs in the tensor.



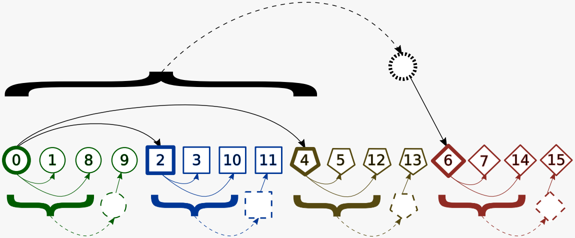
A choice of four sub-S&C is a permutation of the initial sequence.

Tensorial permutations

Using permutations, the four sub-S&C
and the upper-scale S&C are different.



equivalent to



Experiments

Experiments

Evaluating with perplexity

What is Perplexity ?

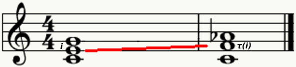
Model prediction ability

$$PPx = 2^{-log(P_{model}(data))} = 2^{Negative\ Log\ Likelihood\ (i.e.\ NLL)}$$

$$model_1 > model_2 \Leftrightarrow PPx_1 < PPx_2$$

Calculating $P(Y|X)$

$$\log P(Y|X) = \frac{1}{K}\sum_{i=1}^{K} \log p(y_{\tau(i)}|x_i)$$



Perplexity calculation process

Sequence : $X_0\ X_1\ \ldots\ X_n$

Bigram model

$$NLL_{bigram} = -\frac{1}{n}[\log p(X_0) + \log p(X_1|X_0) + \cdots + \log p(X_n|X_{n-1})]$$

Tensorial model

1. Estimate configuration ϕ that minimizes global minimal transport.
2. Compute perplexity given ϕ

$$NLL_{\phi} = -\frac{1}{n}[\log p(X_0) + \log p(X_1|X_{\phi(1)}) + \cdots + \log p(X_n|X_{\phi(n)})]$$

Both are first order models.

Experiment protocol

Data

- A corpus of 45 sections of recent pop songs represented as sequences of 16 chords.
- The probabilities are estimated using leave-one-out cross-validation strategy.

Results

	Perplexity
Bigram	3.84
Best piece-specific permutation	2.73
Best global permutation	3.17

Additional experiments show the benefit from the virtual element. (see paper)

Conclusions

These are only preliminary results
which indicate the potential following trends:

Outcomes

- In our experiments the S&C model outperforms the sequential model on chord sequence prediction.
- Using minimal transport with S&C model appears as an effective way to model chord progression.

Perspectives

Future work

- Improve optimization complexity using crossing free property (Tymokzco 2006)
- Constraint transports to comply with musicological rules
- Investigate the effectiveness of S&C model to other musical dimensions (melody, rhythm)

Thank you

Questions ?