

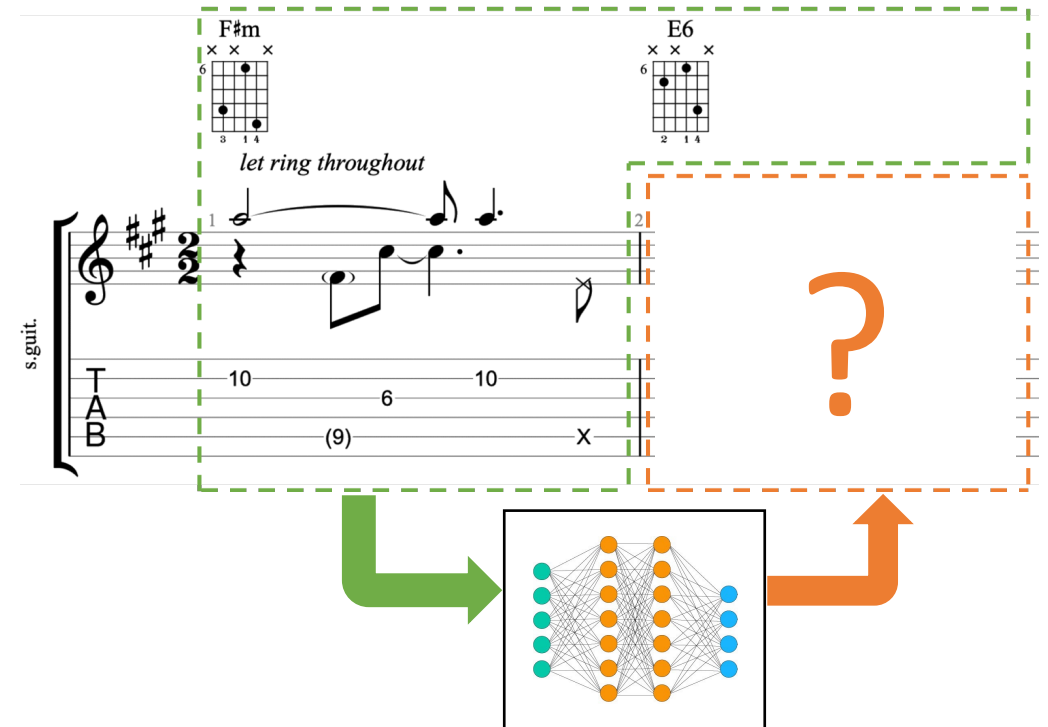
Modélisation de langages musicaux pour l'analyse de partitions et la composition

Louis Bigo

SCRIME

Université de Bordeaux, LaBRI

25 septembre 2023, Université d'Angers



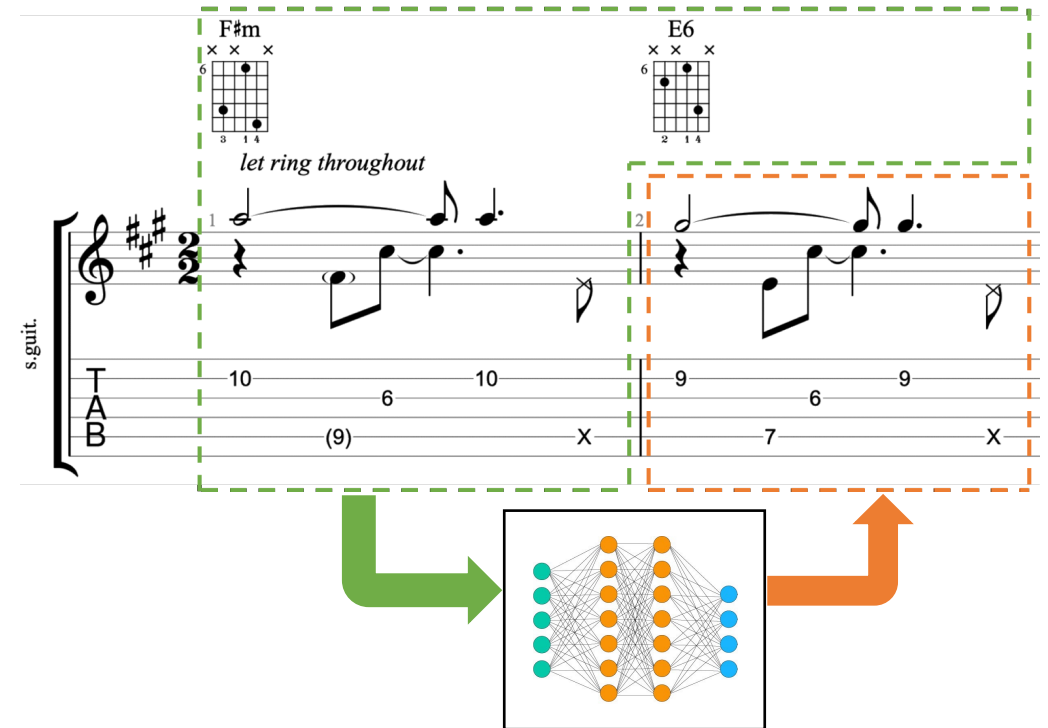
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Algomus

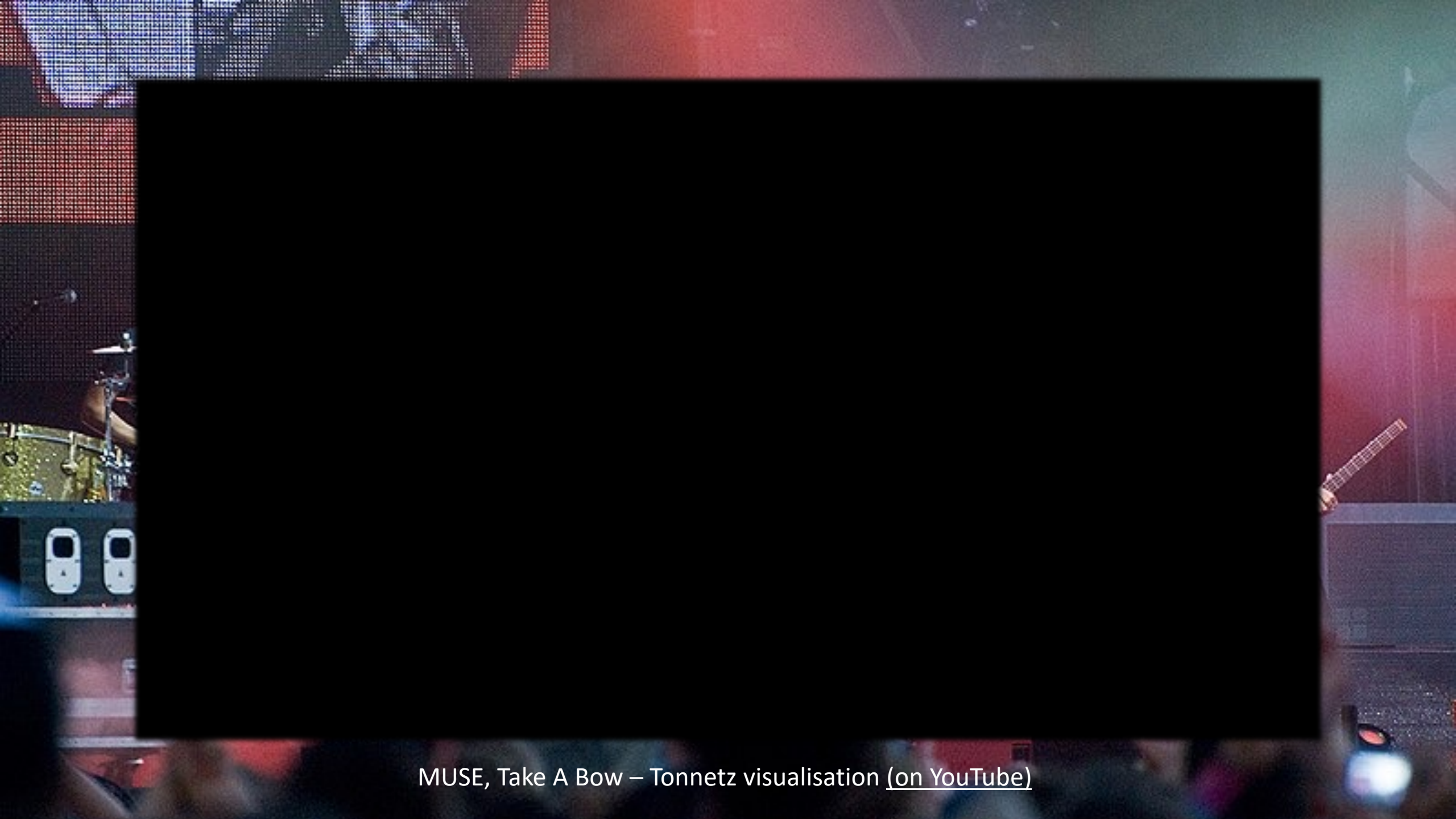
- Équipe d'informatique musicale **Algomus** (Lille, Amiens, Rouen)

Élaboration d'outils informatiques pour assister l'analyse et la composition de musique

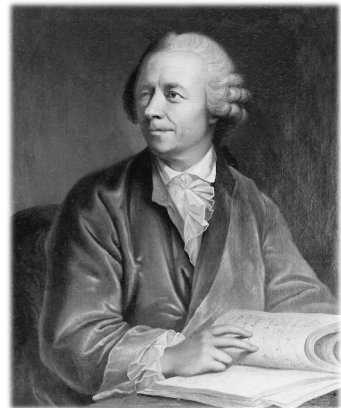
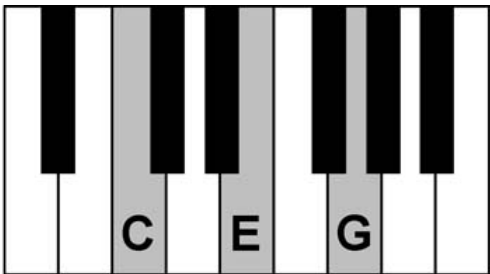
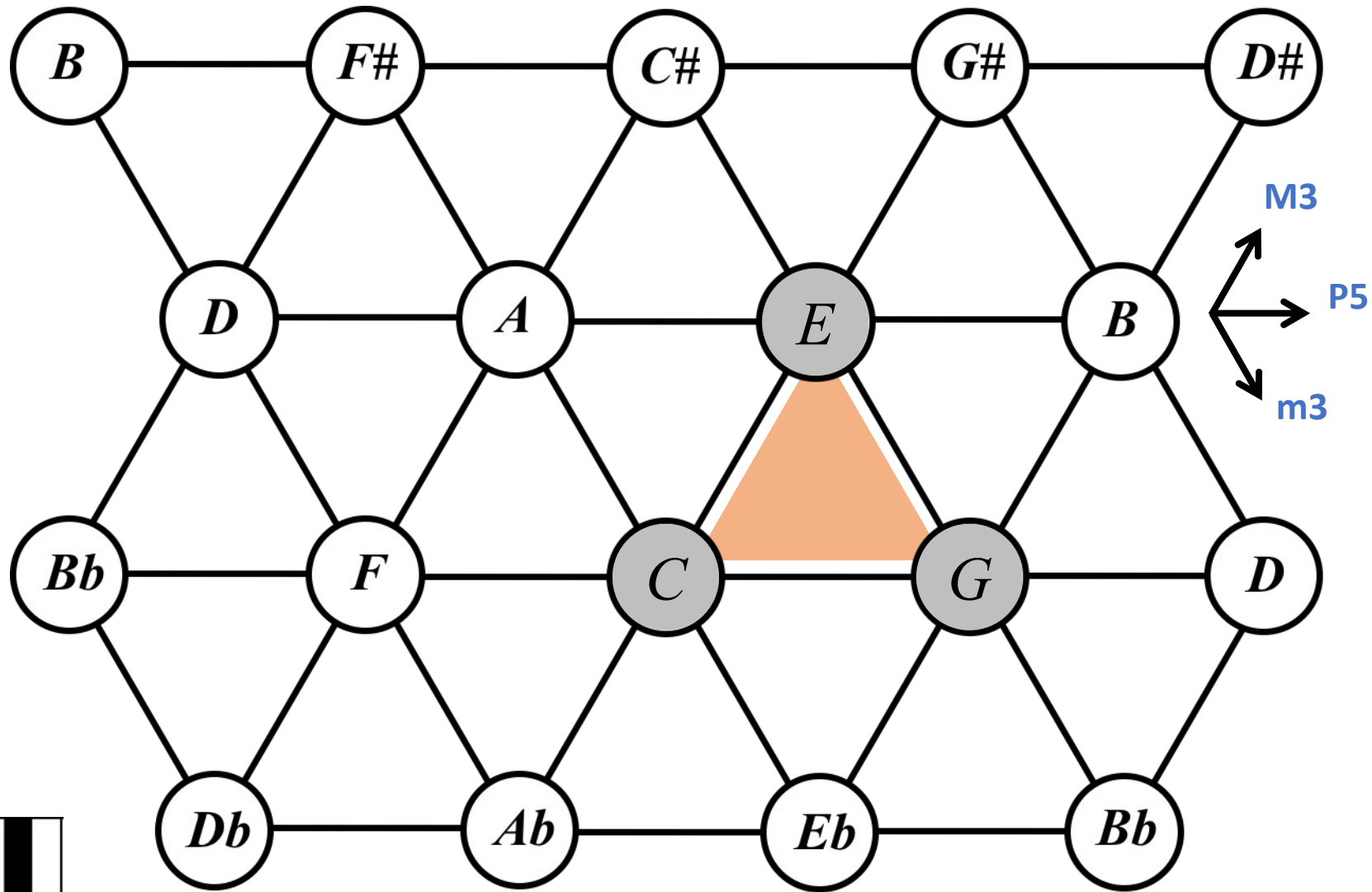
- Représentations informatiques *symboliques* de la musique
- Algorithmes (ML et/ou règles) pour le traitement et l'analyse de ces représentations





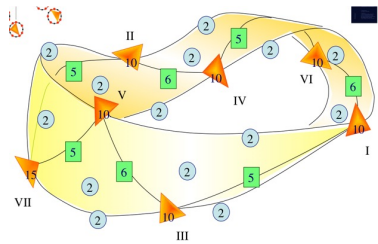


MUSE, Take A Bow – Tonnetz visualisation ([on YouTube](#))

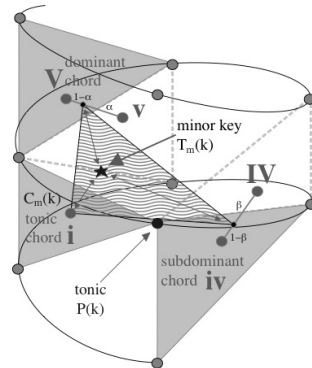


Le *Tonnetz*, Leonhard Euler, 1739

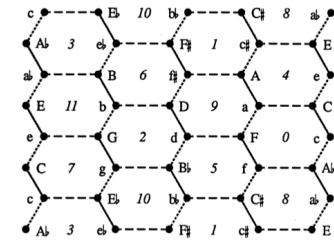
Espaces de représentation en musique



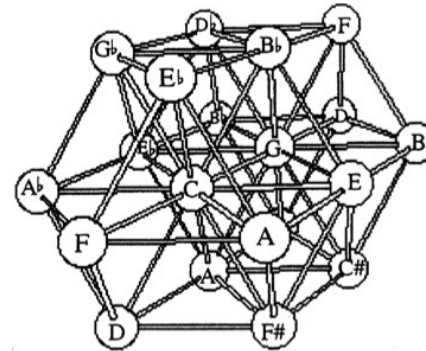
Tonality strip
[Mazzola, 2002]



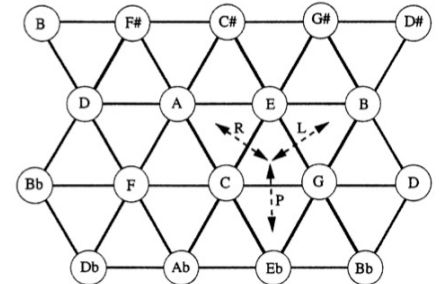
Spiral Array [Chew, 2000]



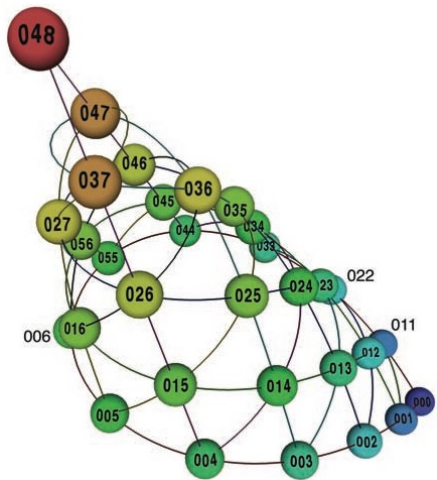
Chicken Wire Torus [Douthett and Steinbach, 1998]



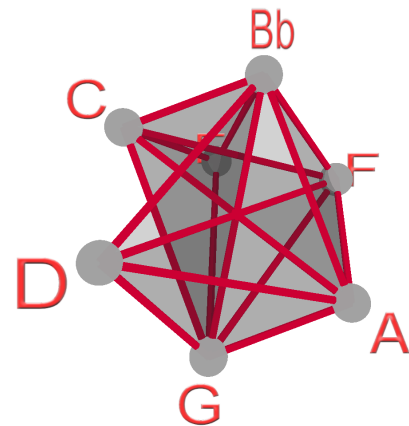
3D Tonnetz [Gollin, 1998]



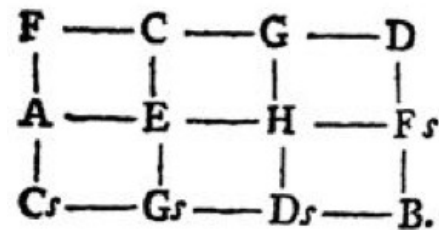
Tonnetz [Oettingen, 1866, Riemann, 1914]



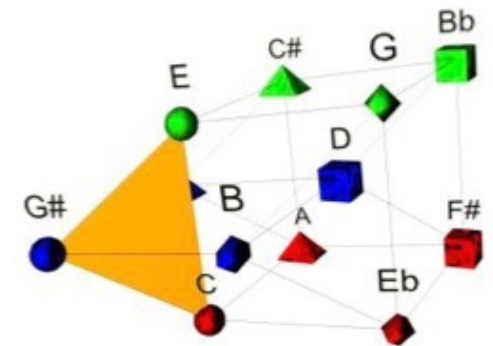
Voice-leading spaces
[Tymoczko, 2008]



Filtered PC-set complexes
[Bigo, 2019]



Speculum Musicum [Euler, 1739]



Model Planet [Barouin, 2011]

Langage musical ?





Langage musical ?

Boléro (M. Ravel)
youtube.com/gerubach

TALN et partitions

- **Traitement Automatique du Langage Naturel (TALN)**

Analyse de contenus/sentiments, résumés, traduction, génération, ...

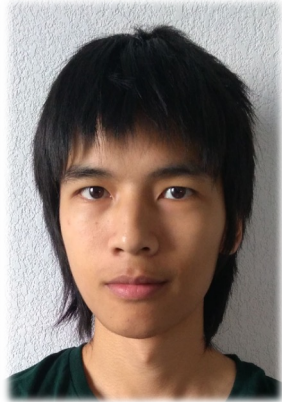
- Algorithmes de TALN sur des représentations musicales symboliques

```
NOTE_ON<60> TIME_SHIFT<500> NOTE_OFF<60> TIME_SHIFT<500> NOTE_ON<67>
```

- Étudier l'adaptabilité, la performance, les limites des algorithmes de TALN sur des données musicales
→ *Représentations, volume/disponibilité des données, évaluations, polysémie, sémantique, ... ?*

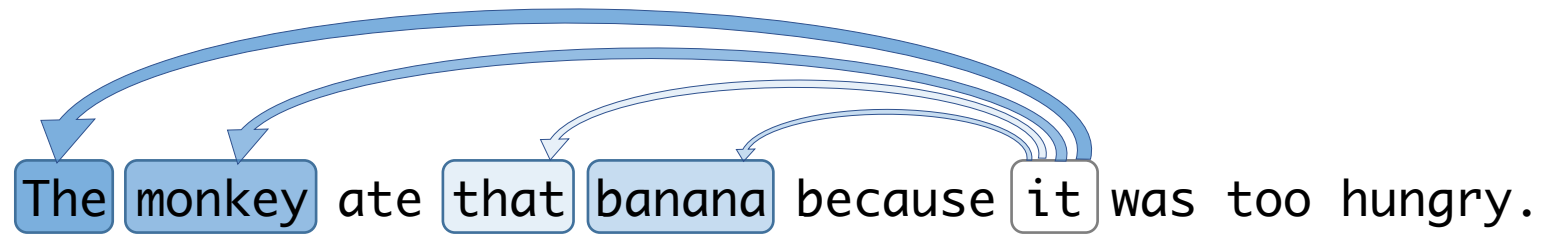


Mikaela Keller



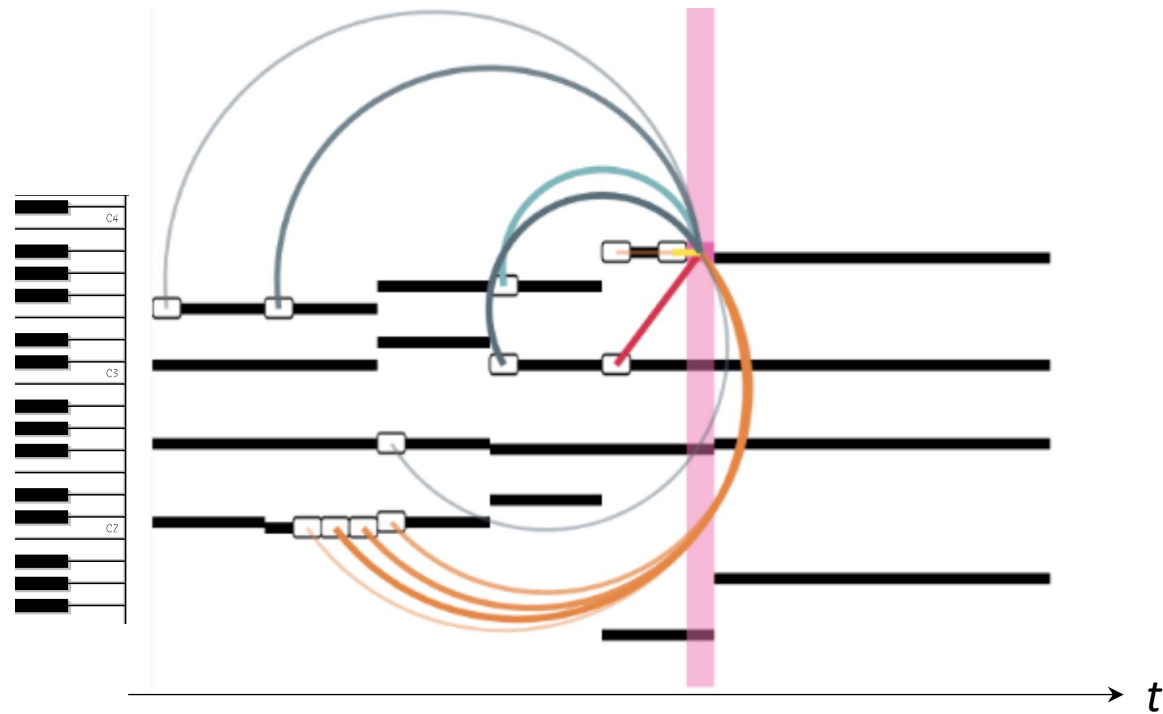
Viet-Toan Le

Auto-attention dans les partitions



➤ A. Vaswani et al. (2017) Attention Is All You Need

Auto-attention dans les partitions

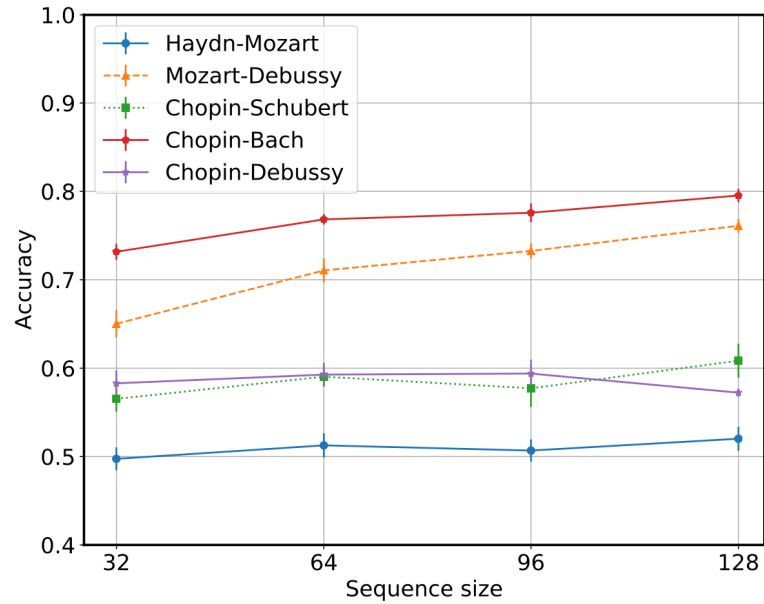
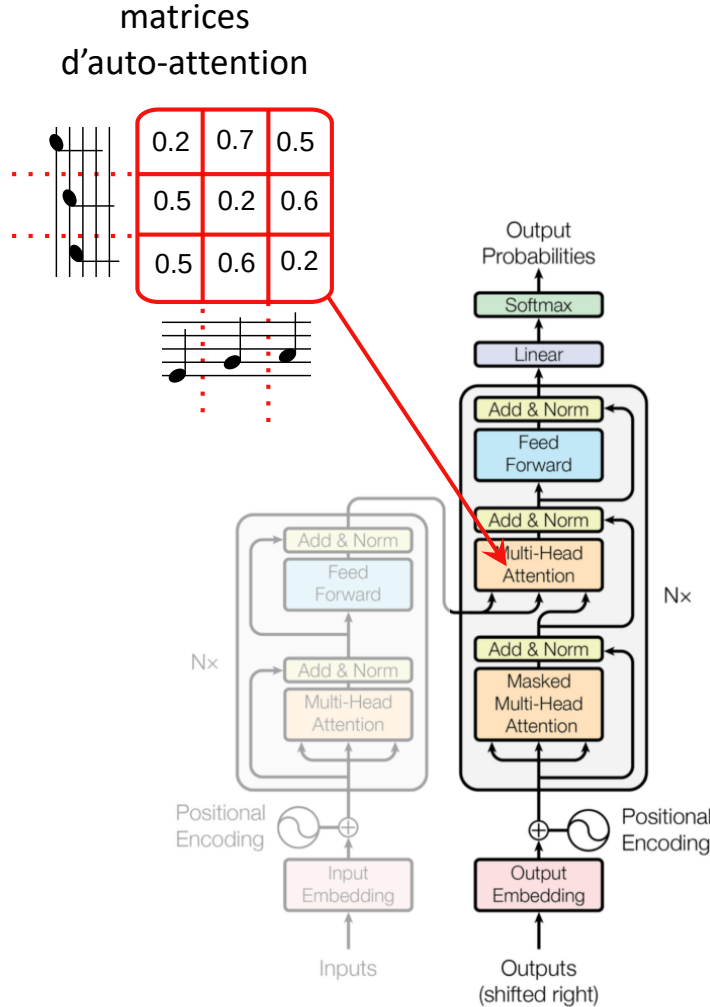


- A. Huang et al. (2018) Music Transformer: Generating Music with Long-Term Structure
- A. Huang et al. (2018) Visualizing Music Self-Attention

Auto-attention dans les partitions

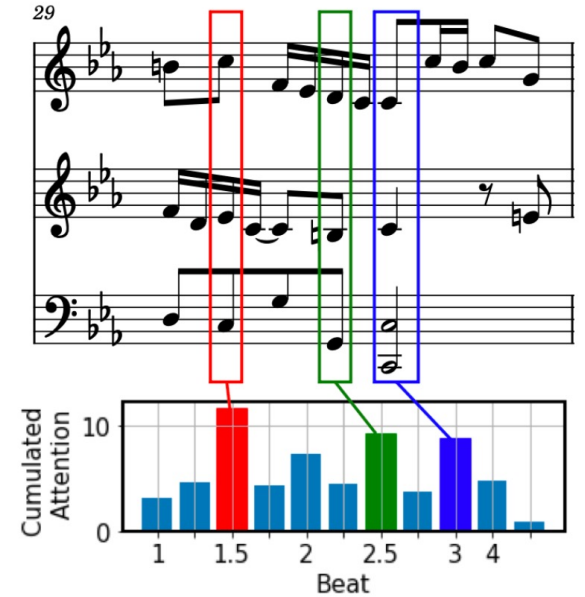


Gabriel Loiseau



identification de compositeur

J.-S. Bach, BWV 847
Fugue n°2 en do mineur



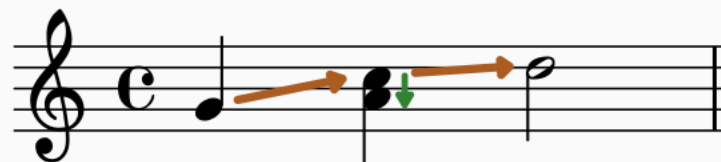
détection de fin de phrase

Expressivité musicale des tokens

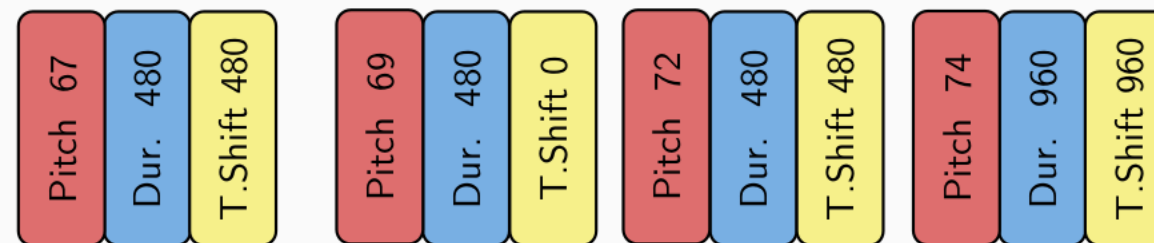
Objectif : des représentations *expressives*
pour alléger l'apprentissage



Viet-Toan Le



Structured

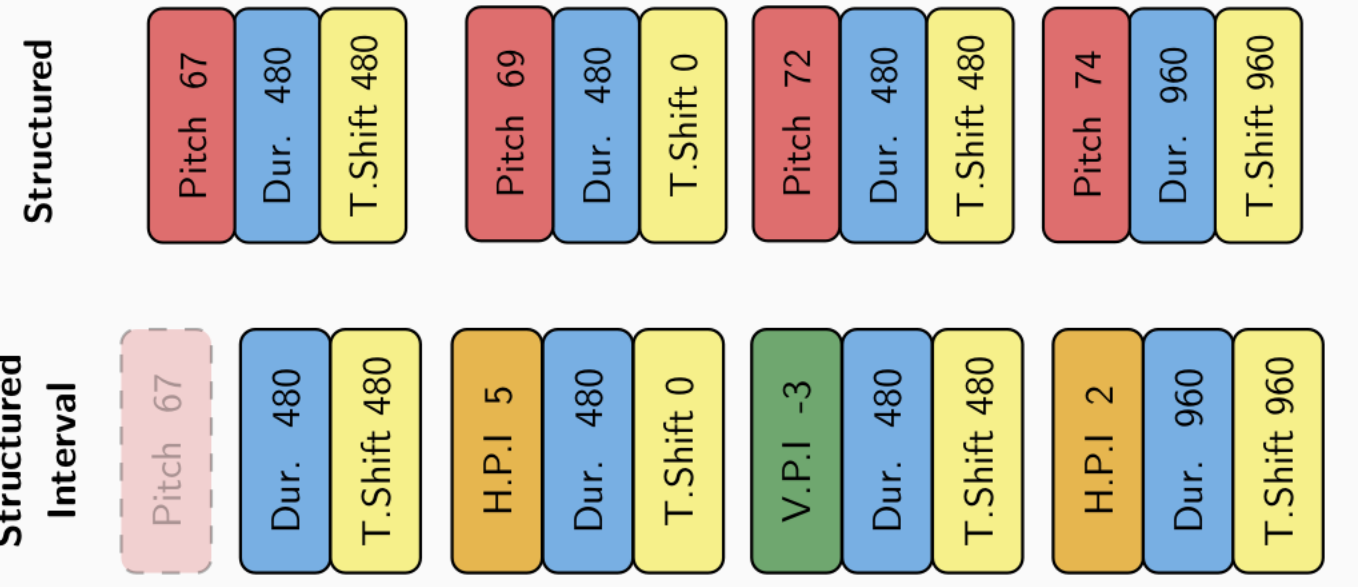
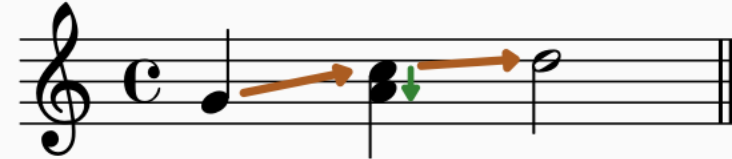


Expressivité musicale des tokens



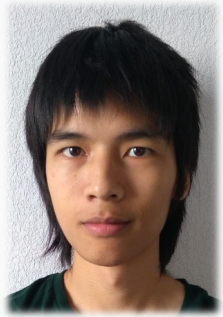
Viet-Toan Le

Objectif : des représentations *expressives*
pour alléger l'apprentissage



- Encodage des **intervalles** musicaux
→ hypothèse « cognitive »

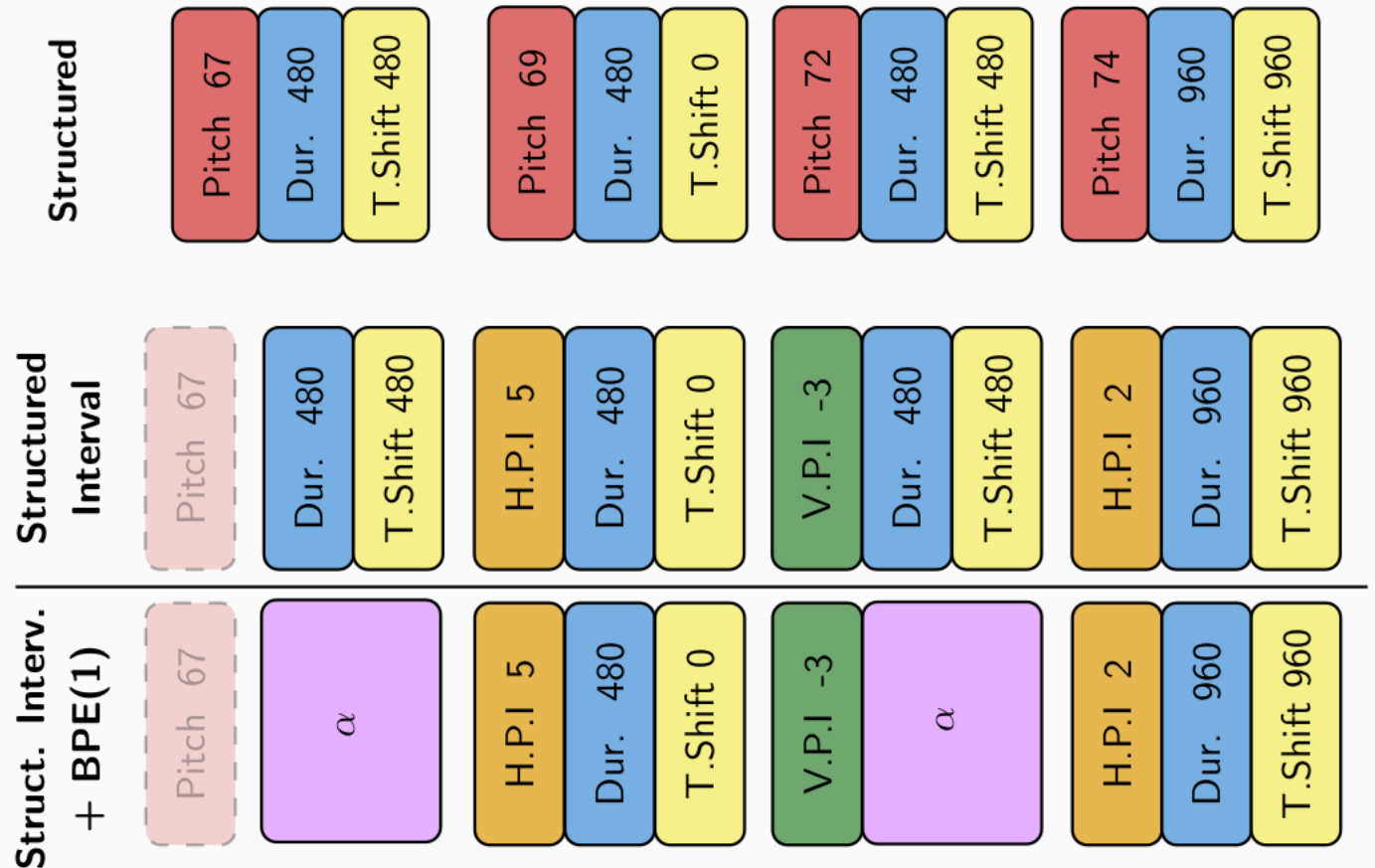
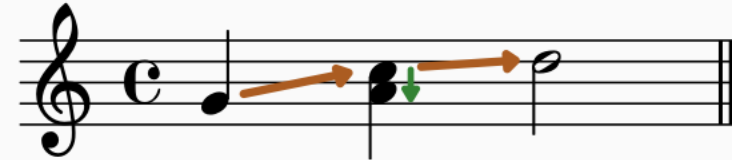
Expressivité musicale des tokens

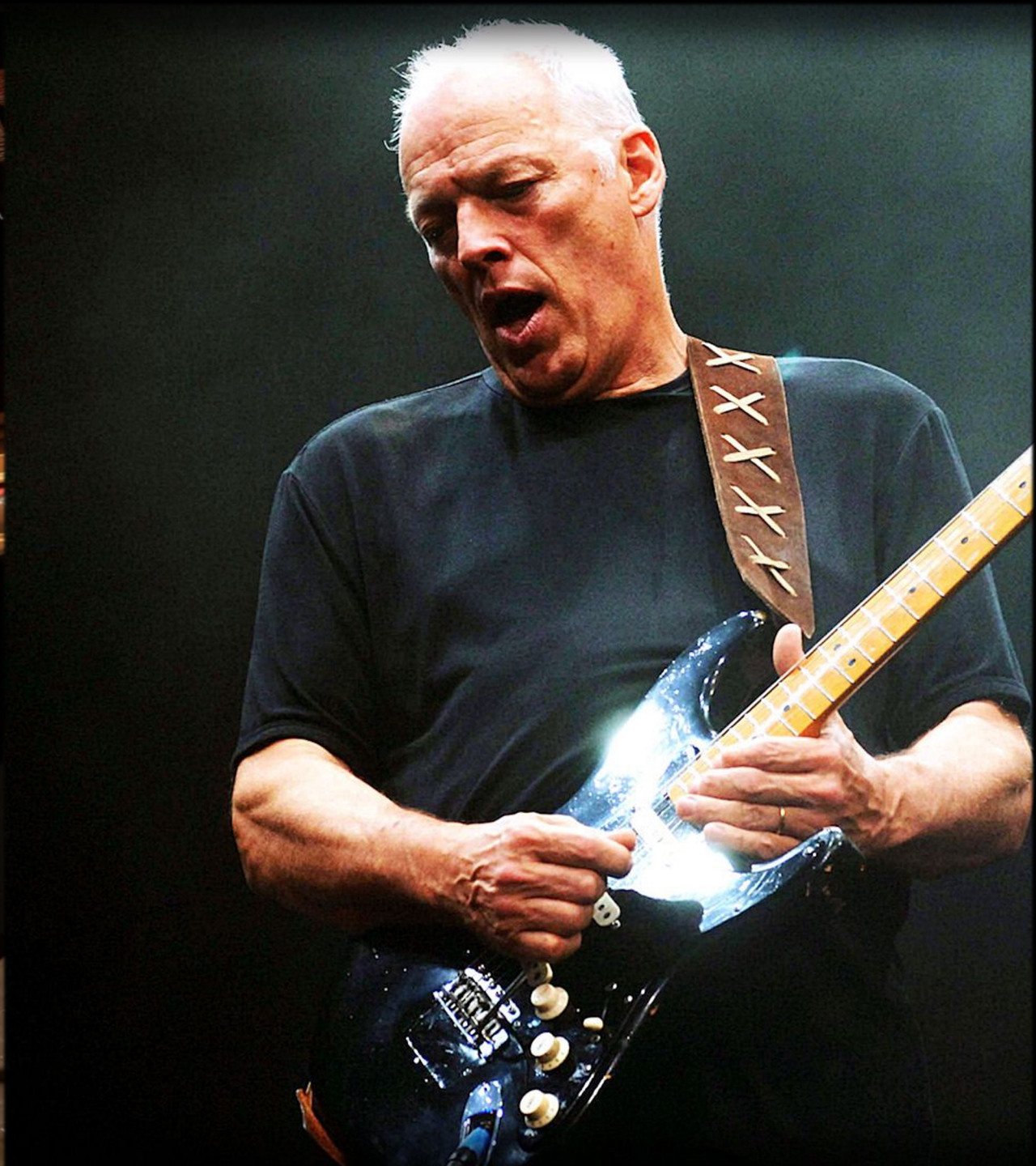


Viet-Toan Le

Objectif : des représentations *expressives*
pour alléger l'apprentissage

- Encodage des **intervalles** musicaux
→ hypothèse « cognitive »
- Encodage de **groupes fréquents** dans
un corpus donné
→ hypothèse « culturelle »







phrase 1

Half Cadence (HC)

phrase 2

Perfect Authentic Cadence (PAC)

Franz Schubert *Impromptu No.3 (Variations) in B-flat Major, D.935, Op.142*

phrase 1

demi-cadence (HC)

phrase 2

cadence parfaite (PAC)

Franz Schubert *Impromptu No.3 (Variations) in B-flat Major, D.935, Op.142*

phrase 1

demi-cadence (HC)

phrase 2

cadence parfaite (PAC)

V → I

Franz Schubert *Impromptu No.3 (Variations) in B-flat Major, D.935, Op.142*

- Conduite de voix

phrase 1

demi-cadence (HC)

phrase 2

cadence parfaite (PAC)

V → I

Franz Schubert *Impromptu No.3 (Variations) in B-flat Major, D.935, Op.142*

- Conduite de voix
- Rythme

phrase 1

demi-cadence (HC)

phrase 2

cadence parfaite (PAC)

V → I

Franz Schubert *Impromptu No.3 (Variations) in B-flat Major, D.935, Op.142*

- Conduite de voix
- Rythme
- Accord de préparation

phrase 1

demi-cadence (HC)

phrase 2

cadence parfaite (PAC)

V → I

Franz Schubert *Impromptu No.3 (Variations) in B-flat Major, D.935, Op.142*

- Conduite de voix
- Rythme
- Accord de préparation
- Gammes

Éléments de langage dans le répertoire classique : les *cadences*



L. Feisthauer

Quels éléments de la partition contribuent à identifier une cadence ?

- Conduite de voix
- Rythme
- Accord de préparation
- Gammes

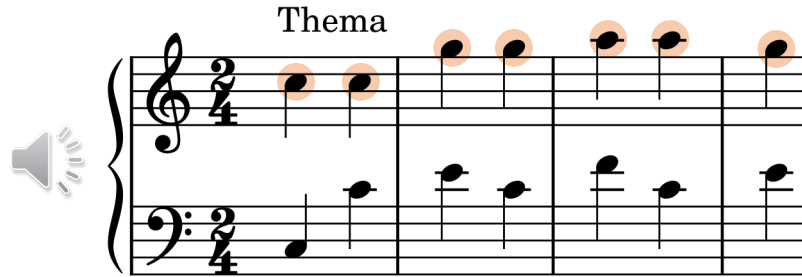
} codage de 44 descripteurs calculés à chaque *temps* de la partition

- Identification de cadences formulée comme un problème de classification binaire sur chaque temps
- Entraînement d'un classifieur SVM (*leave-one-piece-out validation*)

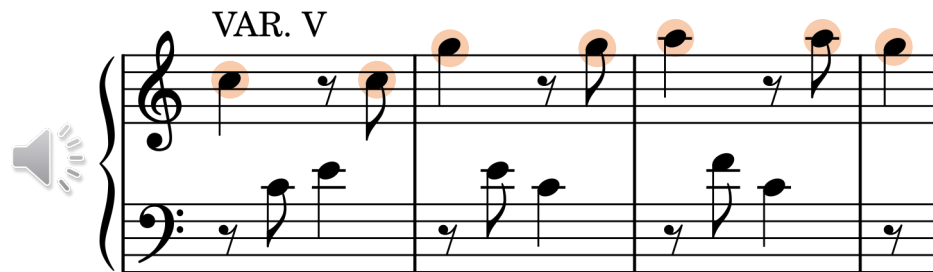
		beats	ref	TP	FP	FN	F_1
J. Haydn (21 quartets)	PAC	3583	51	42	28	9	0,69
	HC	3583	32	18	73	14	0,29
J.-S. Bach (12 fugues)	PAC	2357	36	26	3	10	0,80
	PAC+rIAC	2357	46	30	12	16	0.68

Éléments de langage dans le répertoire classique : la texture

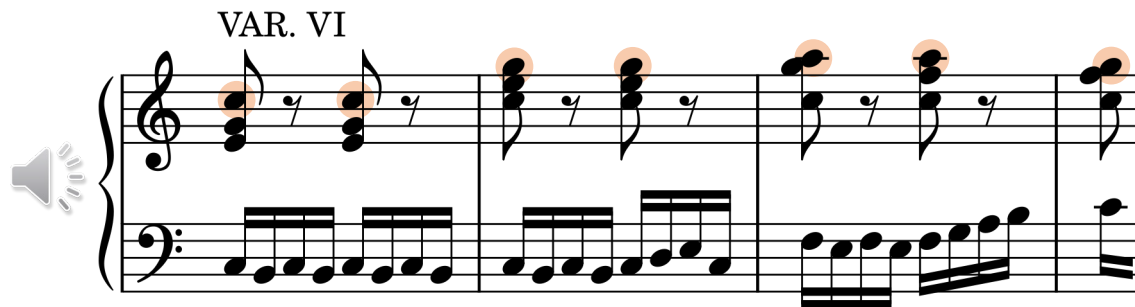
Thema



VAR. V



VAR. VI



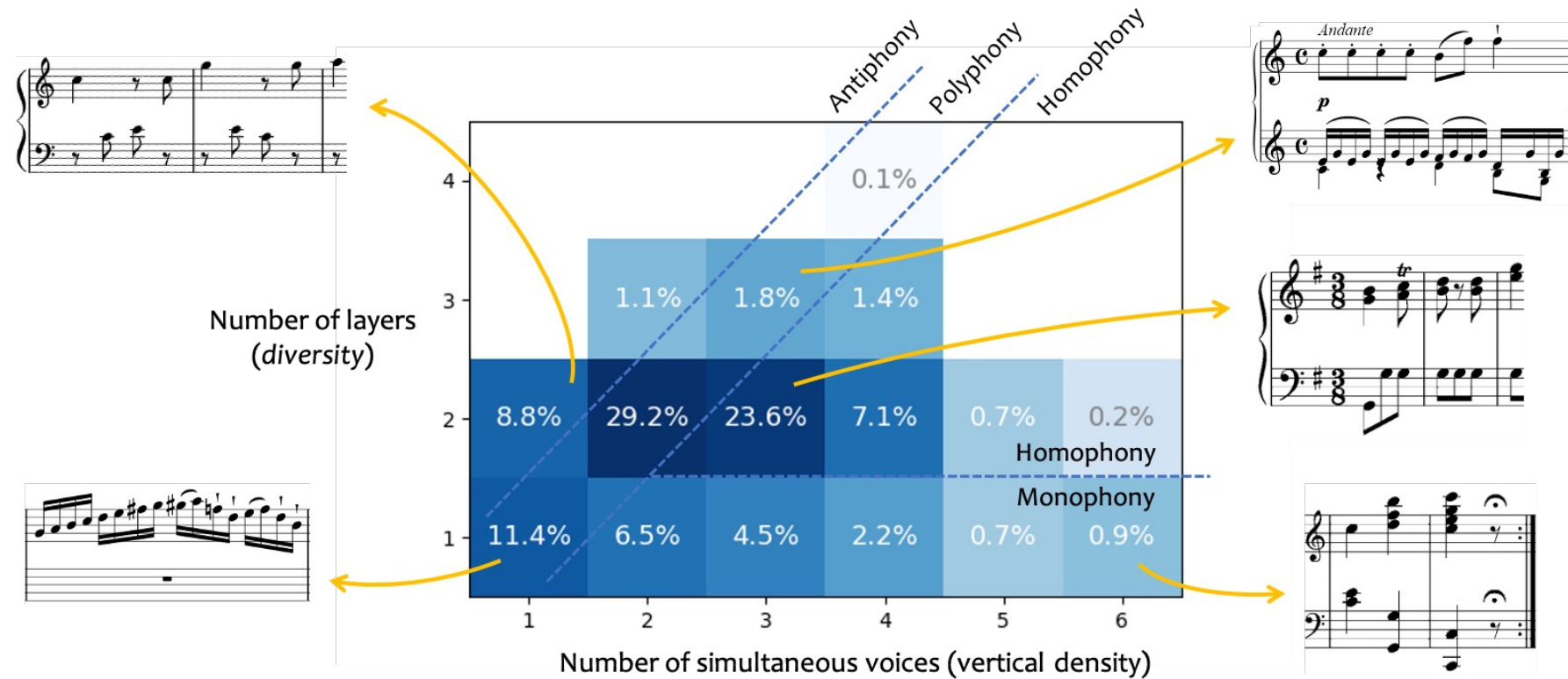
Variations sur "Ah vous dirai-je, Maman", W. A. Mozart

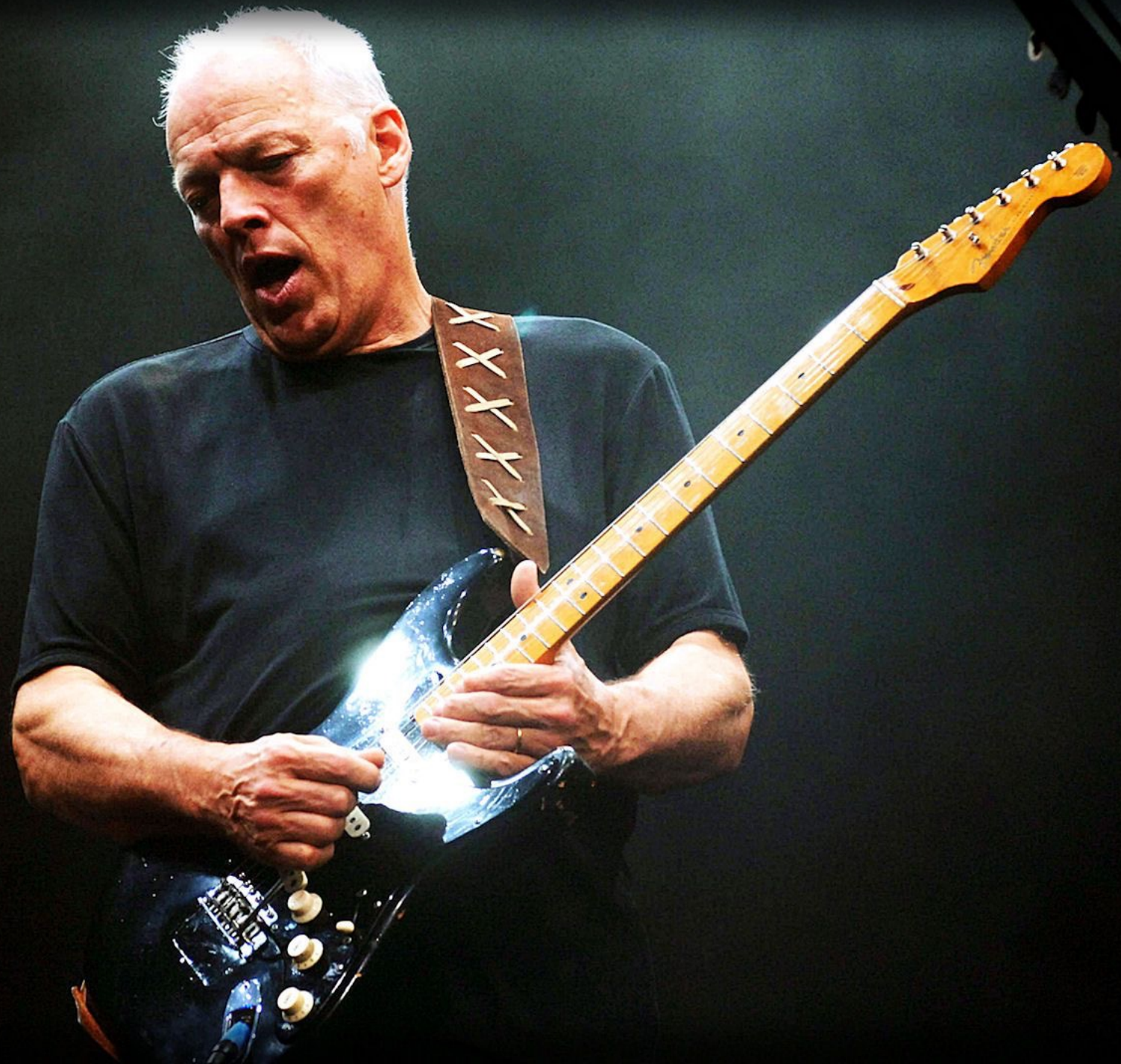


Annotation collaborative de texture



L. Couturier





1 2

full P sl. P H

TAB 12 x 10 9 12 9 10 12 12 12 x 10 10 10 12

Another Brick In The Wall (Pink Floyd) – guitar solo

Outils algorithmiques pour assister la composition de tablatures

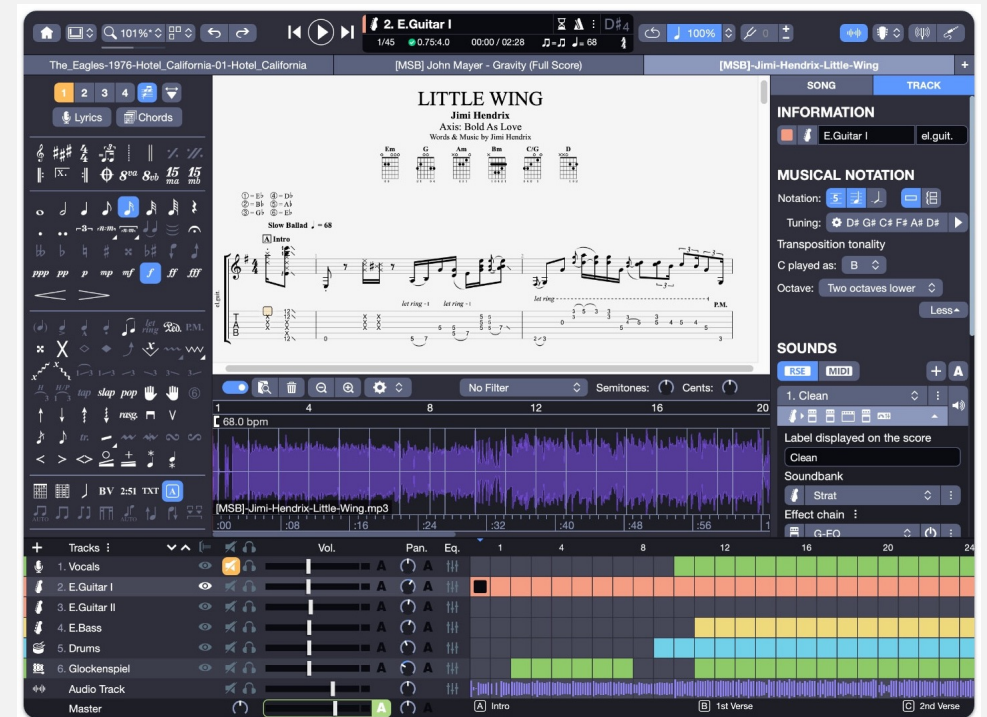
- Faciliter l'accès à la composition aux **guitaristes débutants**
- Stimuler la créativité des **guitaristes confirmés**



Benoît Navarret
Iremus

- M. McVicar (2015) AutoGuitarTab: Computer-Aided Composition of Rhythm and Lead Guitar Parts in the Tablature Space
- P. Sarmiento (2021) DadaGP: A Dataset of Tokenized GuitarPro Songs for Sequence Models

Collaboration industrielle



Guitar Pro (300 000 utilisateurs)
mySongBook (25 000 tablatures .xml)

Texture et *fonctions musicales* dans les tablatures de guitare

The image displays a musical score for guitar, consisting of a standard staff with notes and a six-line guitar tablature below it. The score is divided into two measures, 8 and 9, with measure 10 continuing the pattern. Measure 8 is marked with a 'C' (C major) chord, and measure 9 is marked with an 'Em' (E minor) chord. The tablature uses numbers 0-3 to indicate fret positions. A square box with an 'X' is placed over the first fret of the low E string in measure 8, and a square box with an 'X' is placed over the first fret of the low E string in measure 9. The notation includes various rhythmic values and articulation marks such as accents and slurs.

Space Oddity (David Bowie)

Guitare *rythmique*

Texture et *fonctions musicales* dans les tablatures de guitare

The image displays a musical score for a guitar solo, consisting of a standard musical staff and a guitar tablature (TAB) staff. The score is for measures 69 through 72. Measure 69 begins with a treble clef, a key signature of one flat (B-flat), and a common time signature. The melody in measure 69 is marked with a 'full' dynamic and includes a circled '12' in the TAB. Measure 70 features a 'full' dynamic and a '1/4' dynamic marking. Measure 71 includes a 'P.M.' (palm mute) instruction. Measure 72 concludes with a double bar line and a circled 'X' in the TAB. The TAB staff uses numbers 10, 12, 13, and 8 to indicate fret positions, with various slurs and ties connecting notes across measures. The notation includes stems, beams, and accents to indicate rhythm and articulation.

Another Brick In The Wall (Pink Floyd)

Guitare solo

Texture et *fonctions musicales* dans les tablatures de guitare

The image displays a musical score for the guitar part of "Sultans of Swing" by Dire Straits. It consists of two staves: a standard musical staff with a treble clef and a guitar tablature staff. The score is divided into four measures, numbered 51 through 54. Measure 51 contains a whole rest. Measure 52 features a guitar trill (gamma) over a chord. Measure 53 shows a power chord (P) with a vibrato (v) and a guitar trill. Measure 54 features a harmonic (H) and a wavy line indicating a tremolo effect. The tablature staff shows the corresponding fret numbers and techniques for each measure.

Measure	Tablature
51	[]
52	6 5 3 7 5 3 7 5 3
53	(3) (3) (3) 6 5 X 5 7 5 7
54	/7 5 7 5 (5)

Sultans of Swing (Dire Straits)

Identification de parties de *guitare rythmique*

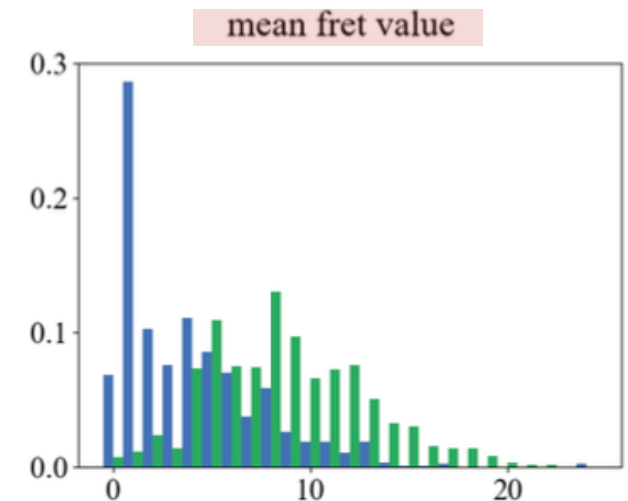
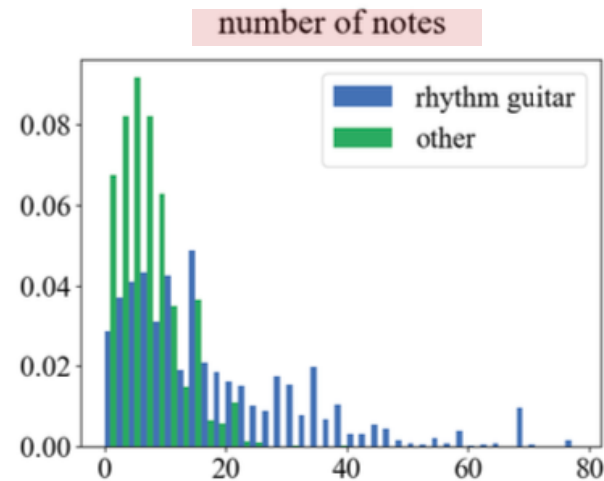


D. Régnier

- Analyser les codes de l'accompagnement à la guitare dans le style populaire moderne
- Séparer automatiquement des sous-corpus pour l'entraînement de modèles génératifs

note features		chord features		tab features	
# notes	(7e+2)	chords*	(2e+3)	min fret	(2e+3)
single notes*	(1e+3)	# 2-chords	(1e+1)	max fret	(2e+3)
min pitch	(3e+3)	# 3-chords	(3e+2)	mean fret	(2e+3)
max pitch	(8e+2)	# 4-chords	(5e+2)	min string	(3e+3)
mean pitch	(2e+3)	# 5-chords	(2e+2)	max string	(4e0)
pitch ambitus	(1e+3)	# 6-chords	(9e+1)	mean string	(7e+2)
pitch variety	(2e+3)	chord variety	(9e+2)	<i>l-r(s)*</i>	(1e+2)
min interval	(3e+1)	m/M triad*	(5e+2)	<i>l-r (100%)*</i>	(1e+2)
max interval	(1e-1)	fifth interval*	(1e+2)	<i>w.b(s)*</i>	(6e0)
interval var	(2e+2)			<i>bend(s)*</i>	(2e+3)
duration var	(1e+2)			<i>l-h vibr(s)*</i>	(8e+2)

31 descripteurs à chaque *barre de mesure*



- Classification (LSTM) : $F_1 = 0.95$ - référence : 7000 mesures annotées manuellement (~100 pièces)

Continuation de *guitare rythmique* par imitation de texture

- Uniformité de la texture dans les parties de guitare rythmique
→ Rythme, ambitus, densité, positions (cordes + frettes)

The image displays two guitar rhythm parts side-by-side, each enclosed in a blue rounded rectangle. The left part is for a C major chord and the right part is for an E minor chord. Both parts feature a consistent rhythmic pattern of eighth notes and chords, with a focus on uniformity in texture, rhythm, and fret positions.

C

8

0 0 0 0 0 0 0 0

1 1 1 1 1 1 1 1

0 0 0 0 0 0 0 0

2 2 2 2 2 2 2 2

3 3 3 3 3 3 2 2

X

Em

10

0 0 0 0 0 0 0 0

0 0 0 0 0 0 0 0

2 2 2 2 2 2 2 2

2 2 2 2 2 2 2 2

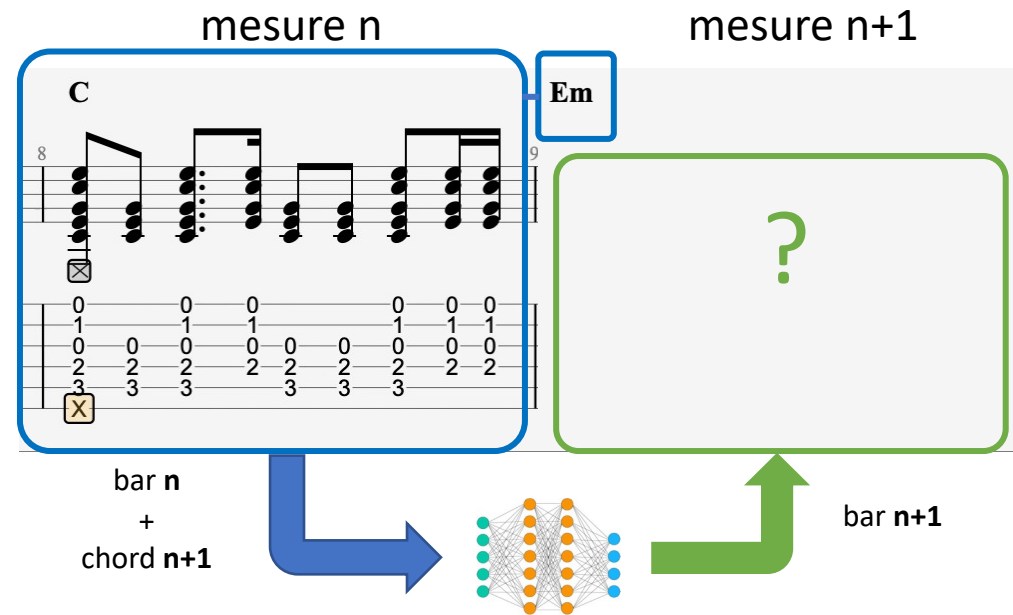
0 0 0 0 0 0 0 0



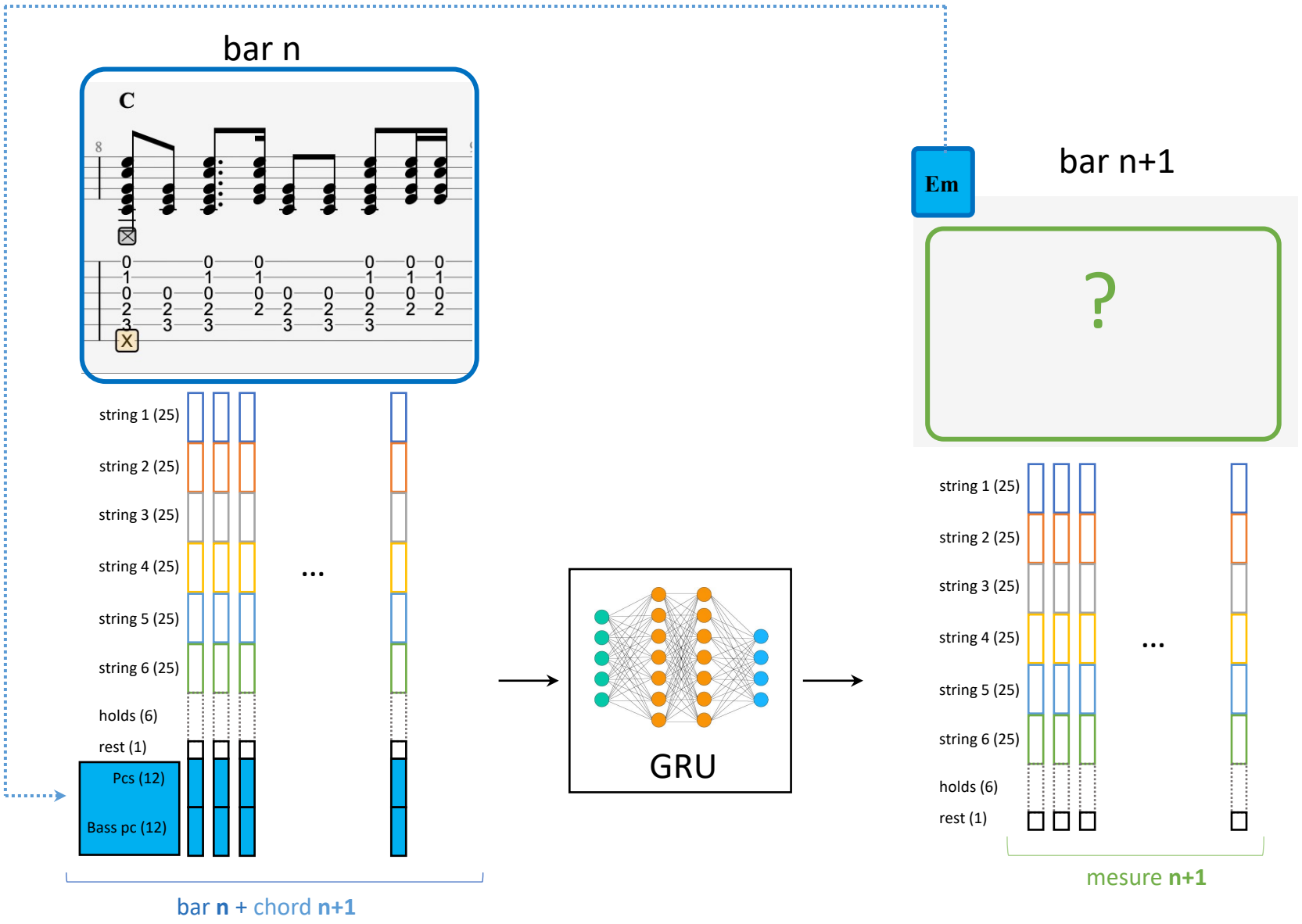
A. D'Hooge

Continuation de *guitare rythmique* par imitation de texture

- Uniformité de la texture dans les parties de guitare rythmique
→ Rythme, ambitus, densité, positions (cordes + frettes)



- Entraînement : \simeq 10 000 paires de mesures contigües de *guitare rythmique*



Continuation de *guitare rythmique* par imitation de texture

Guitar

A5 E5

1 2 3

TAB

2 0 2 0 4 0 2 0 2 0 2 0 4 0 2 0

2 0 2 0 4 0 2 0 2 0 2 0 2 0 4 0 2 0

A5 E5

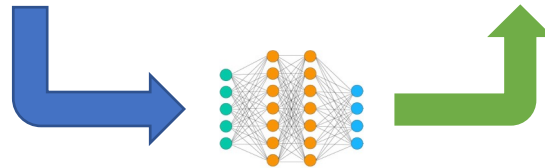
4 5

TAB

2 0 2 0 4 0 2 0 2 0 2 0 4 0 2 0

2 0 2 0 0 2 2 0 2 0 0 2

Twenty Flight Rock (Eddie Cochran)



Continuation de *guitare rythmique* par imitation de texture

The image displays musical notation for guitar, showing a continuation of a rhythmic texture. The notation is presented in two systems, each with a treble clef staff and a guitar tablature staff.

System 1 (Top):

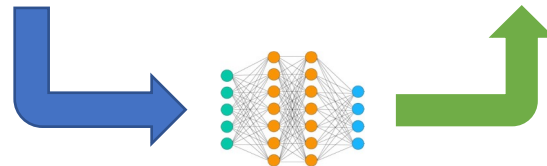
- Chord 1:** Dm7. Treble staff: quarter note D4, quarter note F4, quarter note A4, quarter note C5. Tablature: 5 5 5 5 (bottom string), 5 7 5 (middle strings), 5 (top string).
- Chord 2:** Am. Treble staff: quarter note A4, quarter note C5, quarter note E5, quarter note G5. Tablature: 5 5 5 5 (bottom string), 5 5 7 7 (middle strings), 0 (top string).

System 2 (Bottom):

- Chord 3:** Dm7. Treble staff: quarter note D4, quarter note F4, quarter note A4, quarter note C5. Tablature: 5 5 5 5 (bottom string), 5 7 5 (middle strings), 5 (top string).
- Chord 4:** Am. Treble staff: quarter note A4, quarter note C5, quarter note E5, quarter note G5. Tablature: 5 5 7 7 (bottom string), 5 7 7 (middle strings), 7 (top string).

The Dm7 section of the bottom system is highlighted with a blue rounded rectangle, and the Am section is highlighted with a green rounded rectangle. A blue arrow points from the Dm7 section to a neural network diagram, and a green arrow points from the neural network diagram to the Am section.

Miss You (The Rolling Stones)

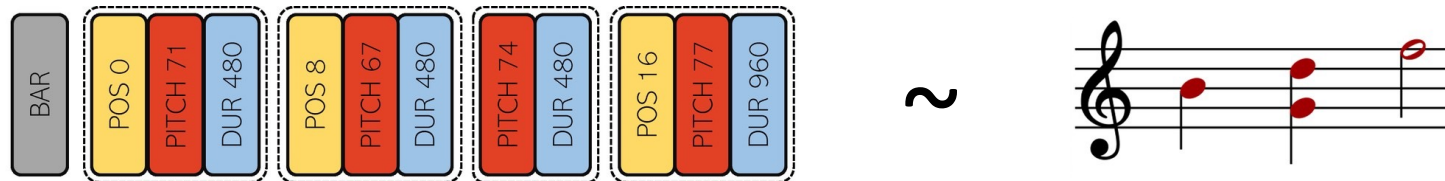


The background of the slide is a close-up, slightly blurred image of a musical score. The paper has a warm, aged, yellowish-brown tone. Several staves of music are visible, with black ink notation including notes, stems, and clefs. The perspective is from an angle, making the staves appear to recede into the distance.

Musique, langage naturel et intelligence artificielle

Représentations et algorithmes

- Adaptation/déformation de représentations



- Vers le développement d'architectures dédiées ?

Musique et langage

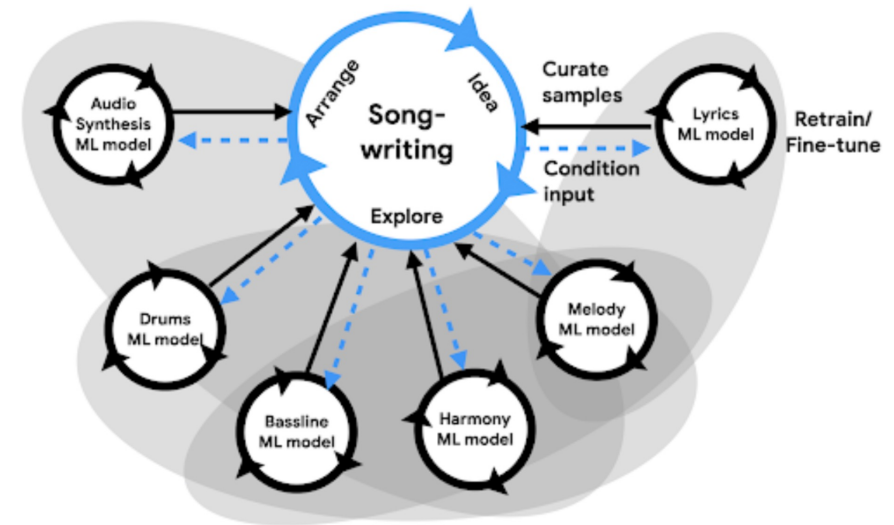
« A **cadence** is an effect of temporary or permanent conclusion marking the termination of a **phrase**. »

« A **phrase** is a unit of musical structure terminated by a **cadence**. »

➤ Bockman and Starr, *Perceiving Music: Problems in Sight and Sound*. 1962

Composition musicale et Intelligence Artificielle

- L'assistance *ponctuelle* dans le processus de composition
- L'enjeu du renouvellement des pratiques de composition



- Huang et al. "AI song contest: Human-AI co-creation in songwriting." 2020

A background image of a musical score on aged, yellowed paper. The score consists of several staves with handwritten musical notation, including notes, rests, and clefs. The paper has a warm, golden-brown tone. A white, rounded rectangular box is centered over the middle of the page.

Questions ?