(AI) and (Music)

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Outline

Technology and Music.

The Scope of AI and Music

Some Examples and Current Trends

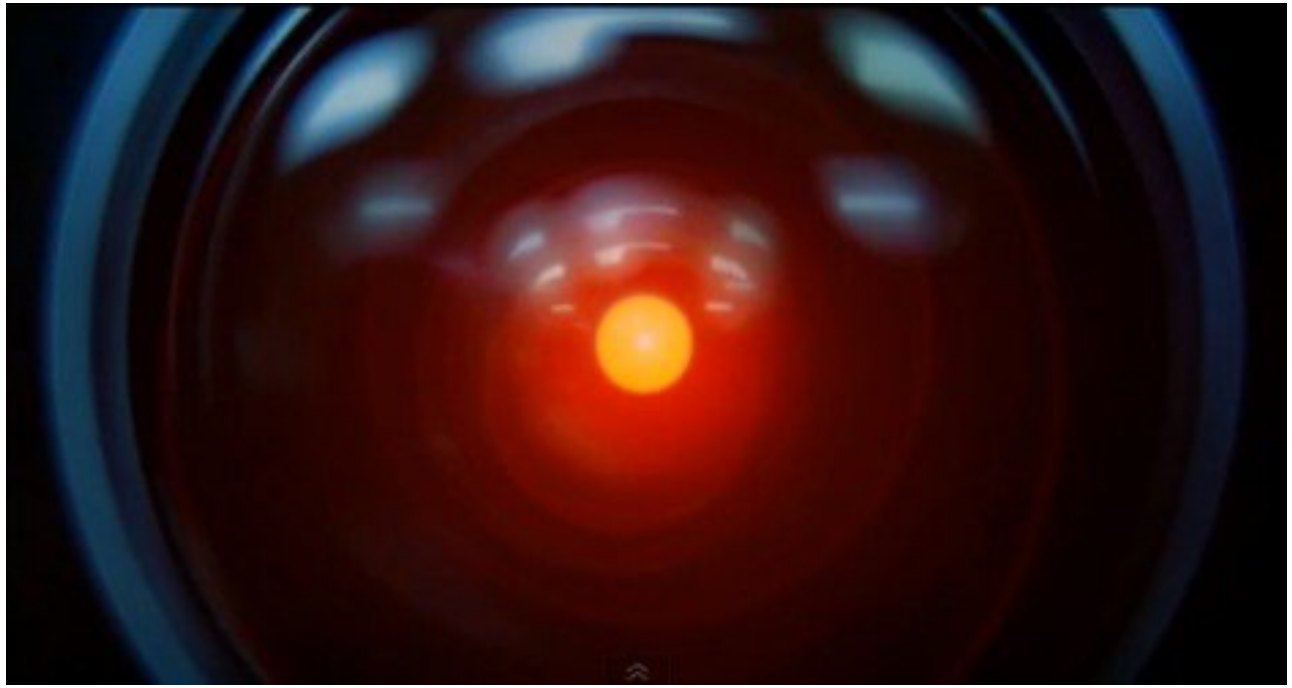
Our Research

Introduction to AI and Music

https://www.youtube.com/watch?v=jOzWN-PYh9s&t=1s

https://www.youtube.com/watch?v=SCm9O2KNEX4&t=2s

HAL9000, 2001: A Space Odissey

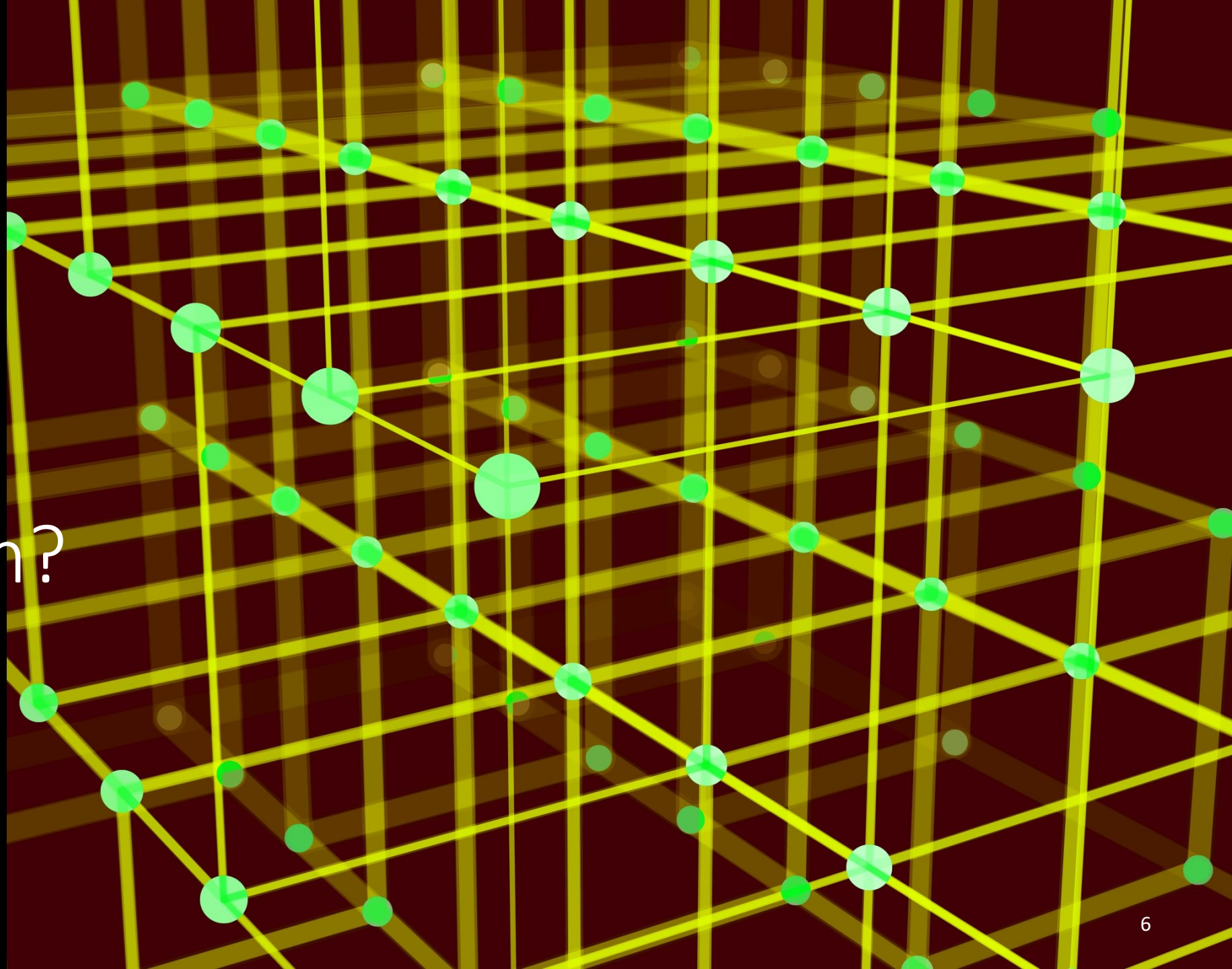


https://www.youtube.com/watch?v=E7WQ1tdxSqI

First Computer to Sing **(IBM7094, 1961)**

https://www.youtube.com/watch?v=41U78QP8nBk

Algorithmic Composition?



Mozart Musical Dice

“A popular early example is Mozart’s Musikalisches Würfelspiel (Musical Dice Game), whereby small fragments of music are randomly re-ordered by rolling a dice to create a musical piece.”

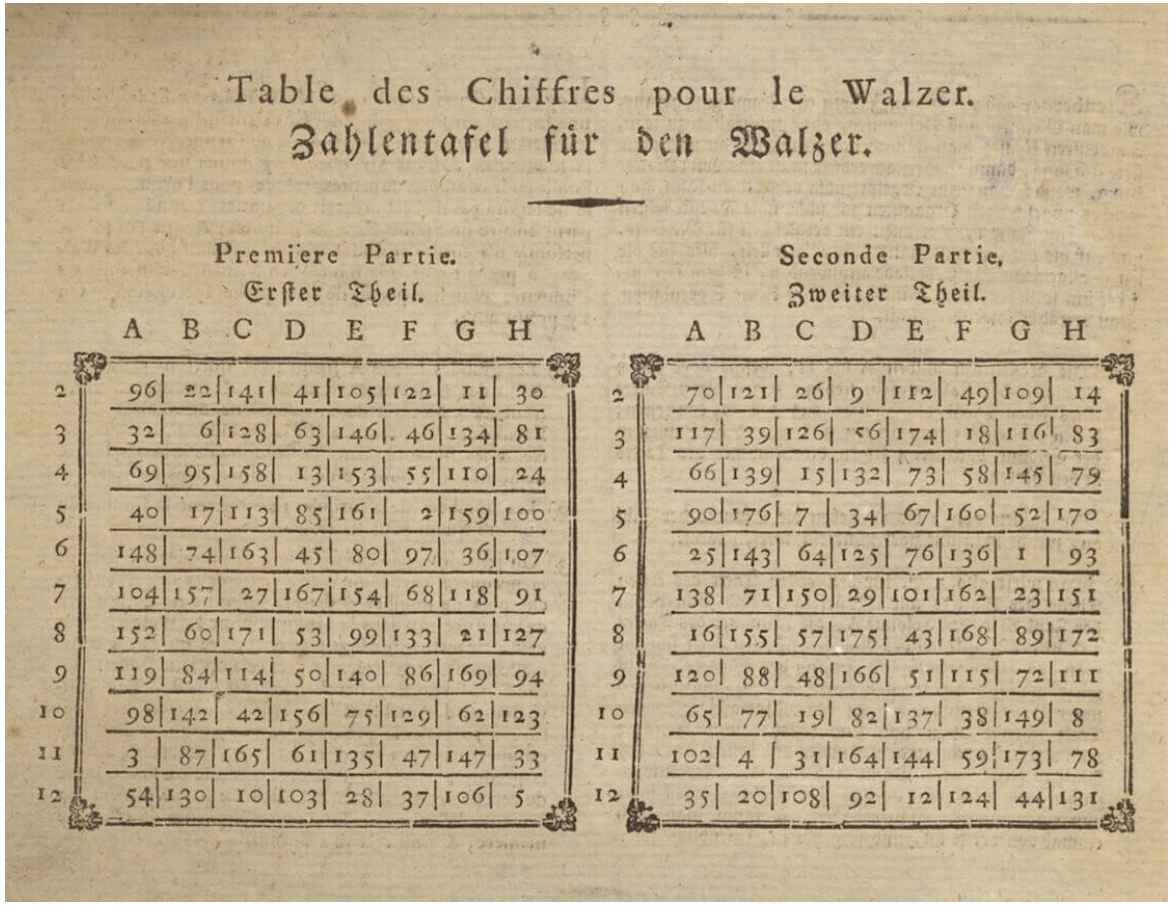


Table des Chiffres pour le Walzer.
Zahlentafel für den Walzer.

Premiere Partie.
Erſter Theil.

	A	B	C	D	E	F	G	H
2	96	22	141	41	105	122	11	30
3	32	6	128	63	146	46	134	81
4	69	95	158	13	153	55	110	24
5	40	17	113	85	161	2	159	100
6	148	74	163	45	80	97	36	107
7	104	157	27	167	154	68	118	91
8	152	60	171	53	99	133	21	127
9	119	84	114	50	140	86	169	94
10	98	142	42	156	75	129	62	123
11	3	87	165	61	135	47	147	33
12	54	130	10	103	28	37	106	5

Seconde Partie.
Zweiter Theil.

	A	B	C	D	E	F	G	H
2	70	121	26	9	112	49	109	14
3	117	39	126	56	174	18	116	83
4	66	139	15	132	73	58	145	79
5	90	176	7	34	67	160	52	170
6	25	143	64	125	76	136	1	93
7	138	71	150	29	101	162	23	151
8	16	155	57	175	43	168	89	172
9	120	88	48	166	51	115	72	111
10	65	77	19	82	137	38	149	8
11	102	4	31	164	144	59	173	78
12	35	20	108	92	12	124	44	131

David Cope

The composer David Cope began his “Experiments in Musical Intelligence” in 1981 as the result of a composer’s block;”

EMI, David Cope (1987)

https://www.youtube.com/watch?v=8PI--_a4LY4

Extract of: Opus Cope: An Algorithmic Opera (2021)

https://www.youtube.com/watch?v=PczDLl92vlc

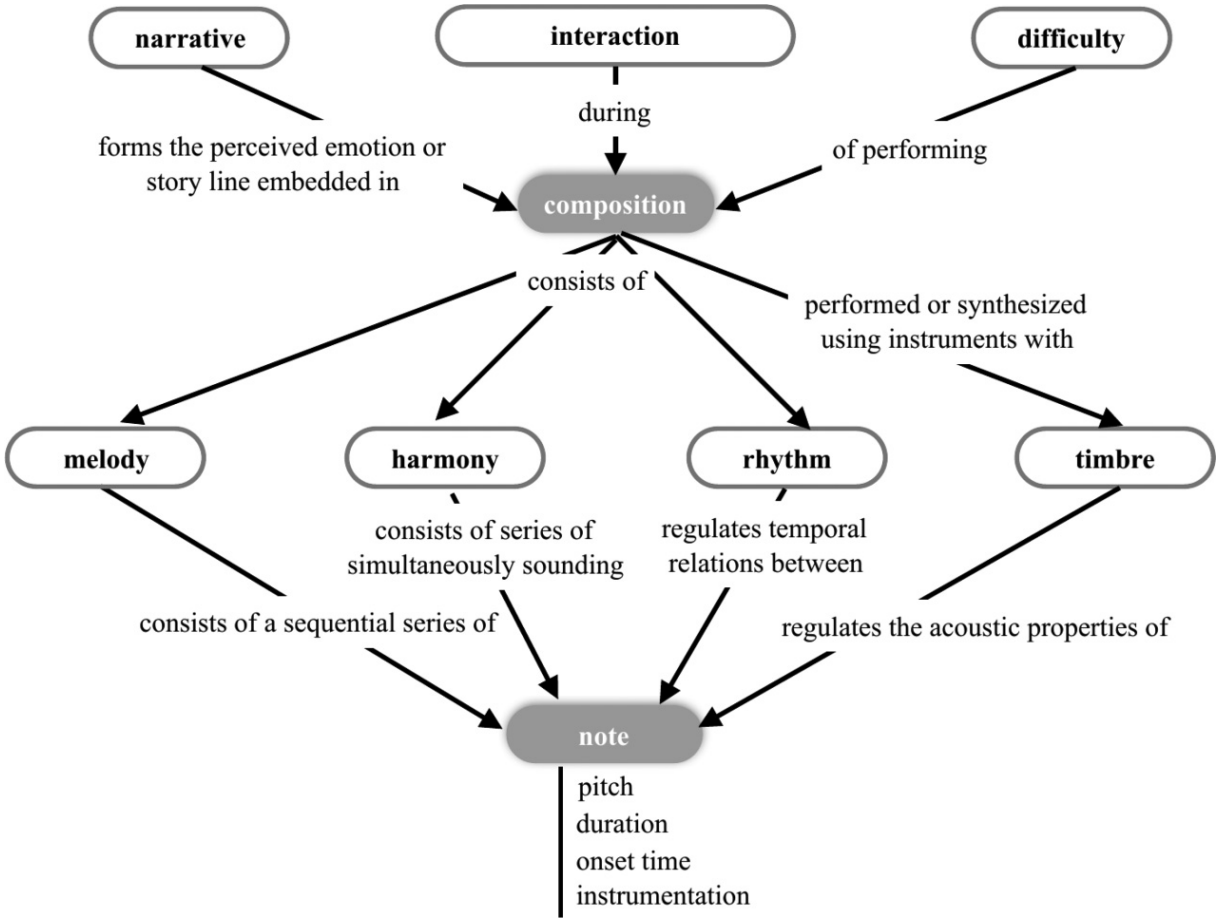
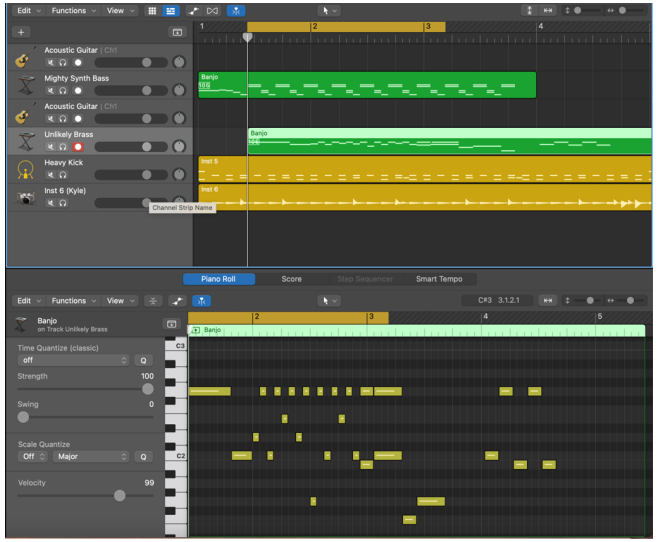


Fig. 1. Concept map for automatic music generation systems.

A Functional Taxonomy of Music Generation Systems

How can we turn music into data?



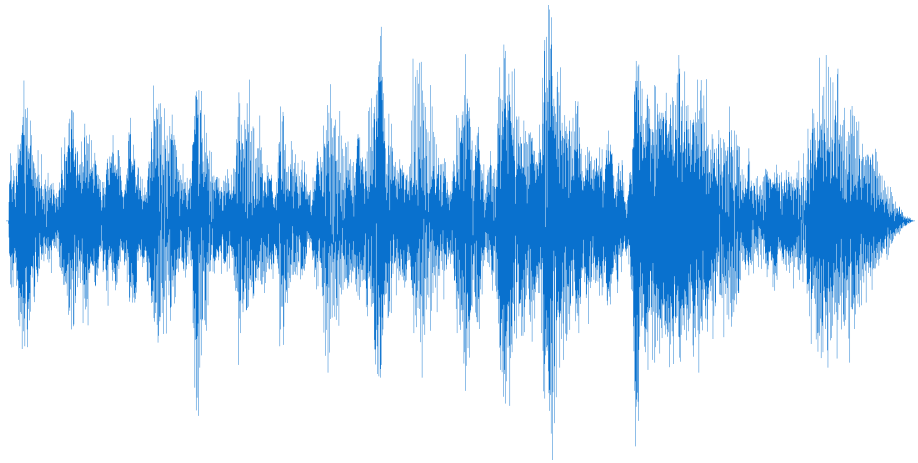


Table 1. Continued

Evolutionary/Population-based optimization algorithms	
Melody	(Horner and Goldberg 1991; Towsey et al. 2001; WASCHKA II 2007; Herremans and Sörensen 2012)
Harmony	(McIntyre 1994; Polito et al. 1997; Phon-Amnuaisuk and Wiggins 1999; Geis and Middendorf 2007; WASCHKA II 2007; Herremans and Sörensen 2012)
Rhythm	(Tokui and Iba 2000; Pearce and Wiggins 2001; Ariza 2002)
Interaction	(Biles 1998, 2001)
Difficulty	(Tuohy and Potter 2005; De Prisco et al. 2012)
Timbre	(Carpentier et al. 2010)
Local search-based optimization	
Melody	(Herremans and Sörensen 2012)
Harmony	(Herremans and Sörensen 2012; Herremans et al. 2015a)
Narrative	(Browne and Fox 2009; Herremans and Chew 2016a, 2017)
Timbre	(Carpentier et al. 2010)
Integer Programming	
Melody	(Cunha et al. 2016)
Other optimization methods	
Melody	(Davismoon and Eccles 2010)
Harmony	(Tsang and Aitken 1999; Farbood and Schoner 2001; Bemman and Meredith 2016)
Timbre	(Hummel 2005; Collins 2012)
Difficulty	(Radisavljevic and Driessen 2004)
Markov models	
Melody	(Pinkerton 1956; Brooks et al. 1957; Moorer 1972; Conklin and Witten 1995; Pachet and Roy 2001; Davismoon and Eccles 2010; Pearce et al. 2010; Gillick et al. 2010; McVicar et al. 2014; Papadopoulos et al. 2014)
Harmony	(Hiller Jr and Isaacson 1957; Xenakis 1992; Farbood and Schoner 2001; Allan and Williams 2005; Lee and Jang 2004; Yi and Goldsmith 2007; Simon et al. 2008; Eigenfeldt and Pasquier 2009; De Prisco et al. 2010; Chuan and Chew 2011; Bigo and Conklin 2015)
Rhythm	(Tidemann and Demiris 2008; Marchini and Purwins 2010; Hawryshkewich et al. 2011)
Interaction	(Thom 2000)
Narrative	(Prechtl et al. 2014a, 2014b)
Difficulty	(McVicar et al. 2014)
Factor oracles	
Interaction	(Assayag et al. 2006; Weinberg and Driscoll 2006; François et al. 2007; Assayag et al. 2010; Dubnov and Assayag 2012; François et al. 2013; Nika et al. 2015)
Rhythm	(Weinberg and Driscoll 2006)
Incremental parsing	
Interaction	(Pachet 2003)
Reinforcement learning	
Interaction	(Franklin 2001)
Rule/Constraint satisfaction/Grammar-based	
Melody	(Keller and Morrison 2007; Gillick et al. 2010; Herremans and Sörensen 2012)
Harmony	(Hiller Jr and Isaacson 1957; Steedman 1984; Ebcioğlu 1988; Cope 1996; Assayag et al. 1999b; Cope 2004; Huang and Chew 2005; Anders 2007; Anders and Miranda 2009; Aguilera et al. 2010; Herremans and Sörensen 2012, 2013; Tanaka et al. 2016)
Narrative	(Rutherford and Wiggins 2002)
Difficulty	(Lin and Liu 2006)
Interaction	(Lewis 2000; Chemillier 2001; Morales-Manzanares et al. 2001; Marsden 2004)
Narrative	(Casella and Paiva 2001; Farbood et al. 2007; Brown 2012; Nakamura et al. 1994)
Neural networks/Restricted Boltzmann machines/ LSTM	
Harmony	(Lewis 1991; Hild et al. 1992; Eck and Schmidhuber 2002; Boulanger-Lewandowski et al. 2012; Herremans and Chuan 2017)
Melody	(Todd 1989; Duff 1989; Mozer 1991; Lewis 1991; Toiviainen 1995; Eck and Schmidhuber 2002; Franklin 2006; Agres et al. 2009; Boulanger-Lewandowski et al. 2012)
Interaction	(Franklin 2001)
Narrative	(Browne and Fox 2009)

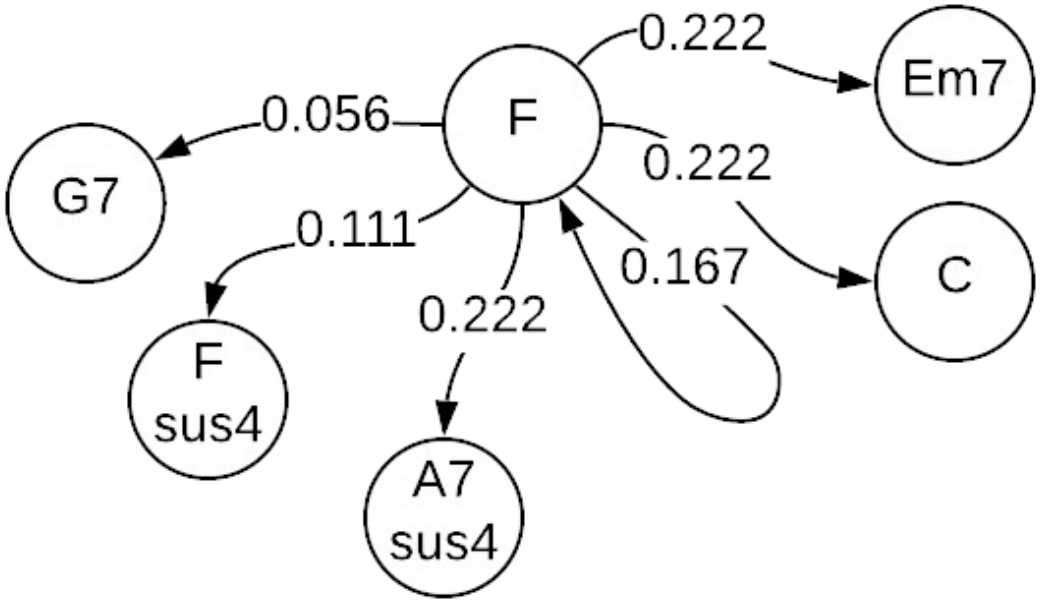
Measuring Success

Measuring Success

Human listeners

Using music theoretic rules

Using machine-learned models



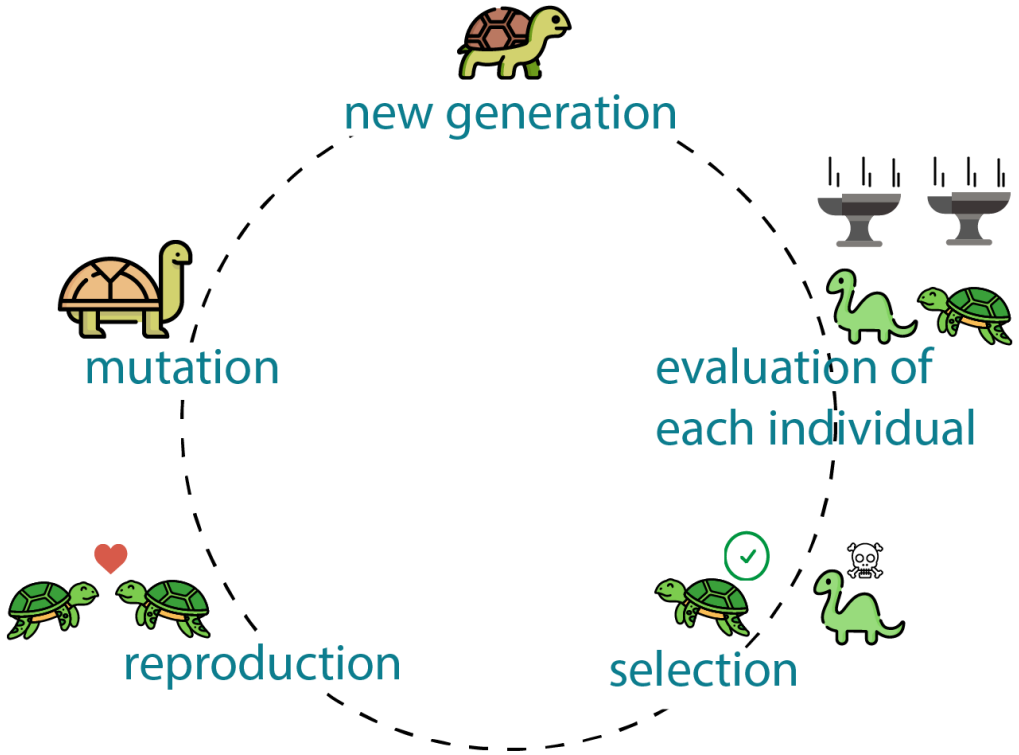
Markov Models

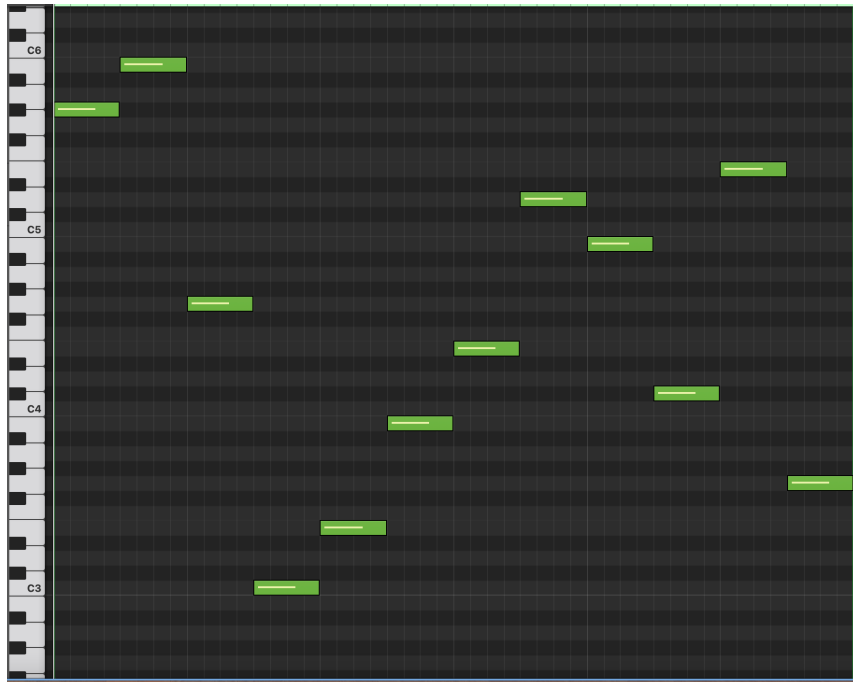
First-order, Higher Order, Variable Order…

Similarity… but how much?

- “Since similarity is central to metrics of success in music generation systems, an important challenge then becomes one of finding the right balance between similarity and novelty or creativity.”
- “It is interesting to speculate how much must be changed to create a new work.” (…)“in the case with high-order Markov models, run the risk of crossing the fine line between stylistic similarity and plagiarism” (Herremans et al., 2018, p. 695)

Genetic Algorithms





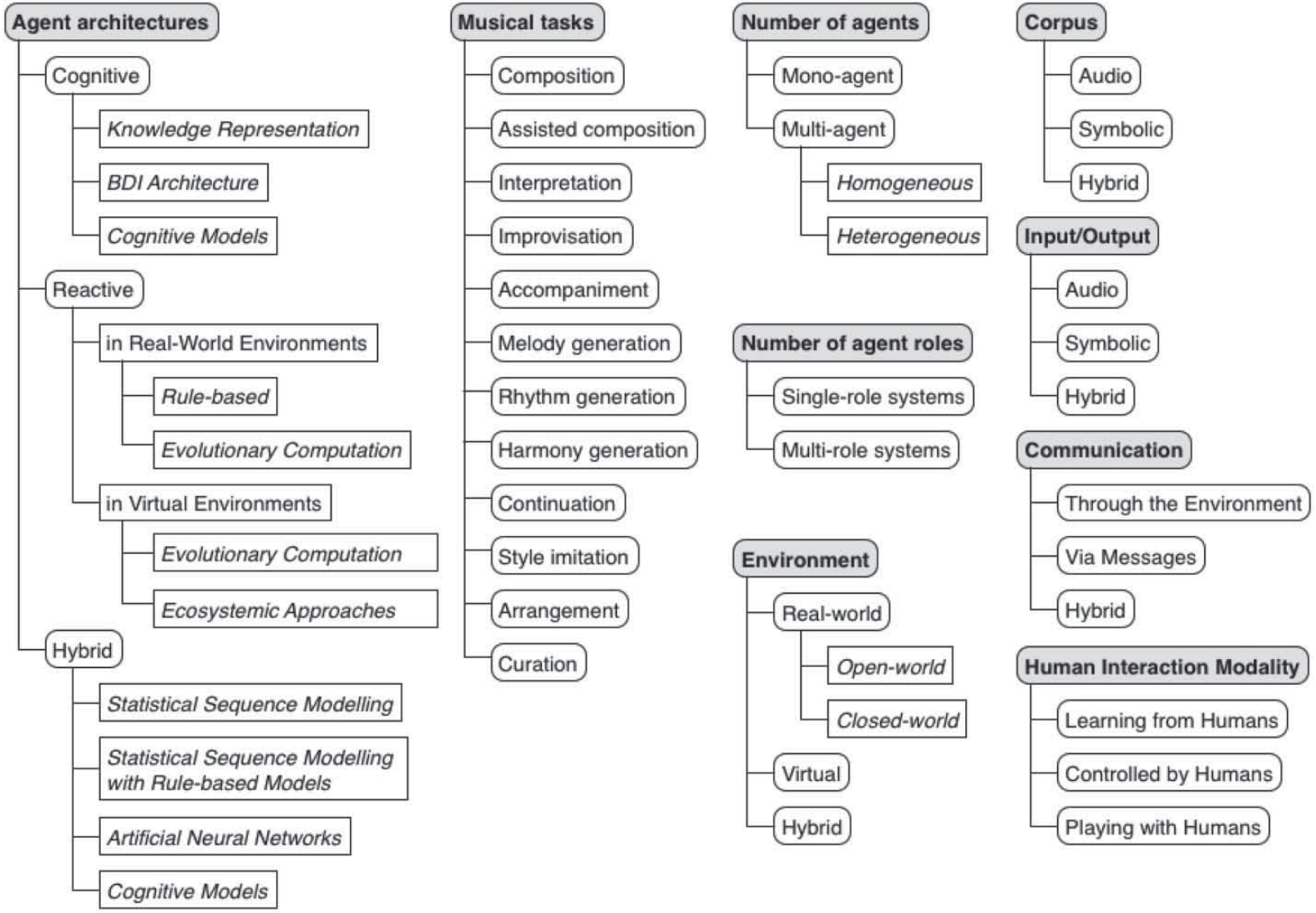
Flow Machines, Daddy's Car (Pachet, 2017)

https://www.youtube.com/watch?v=LSHZ_b05W7o

… and Continuator

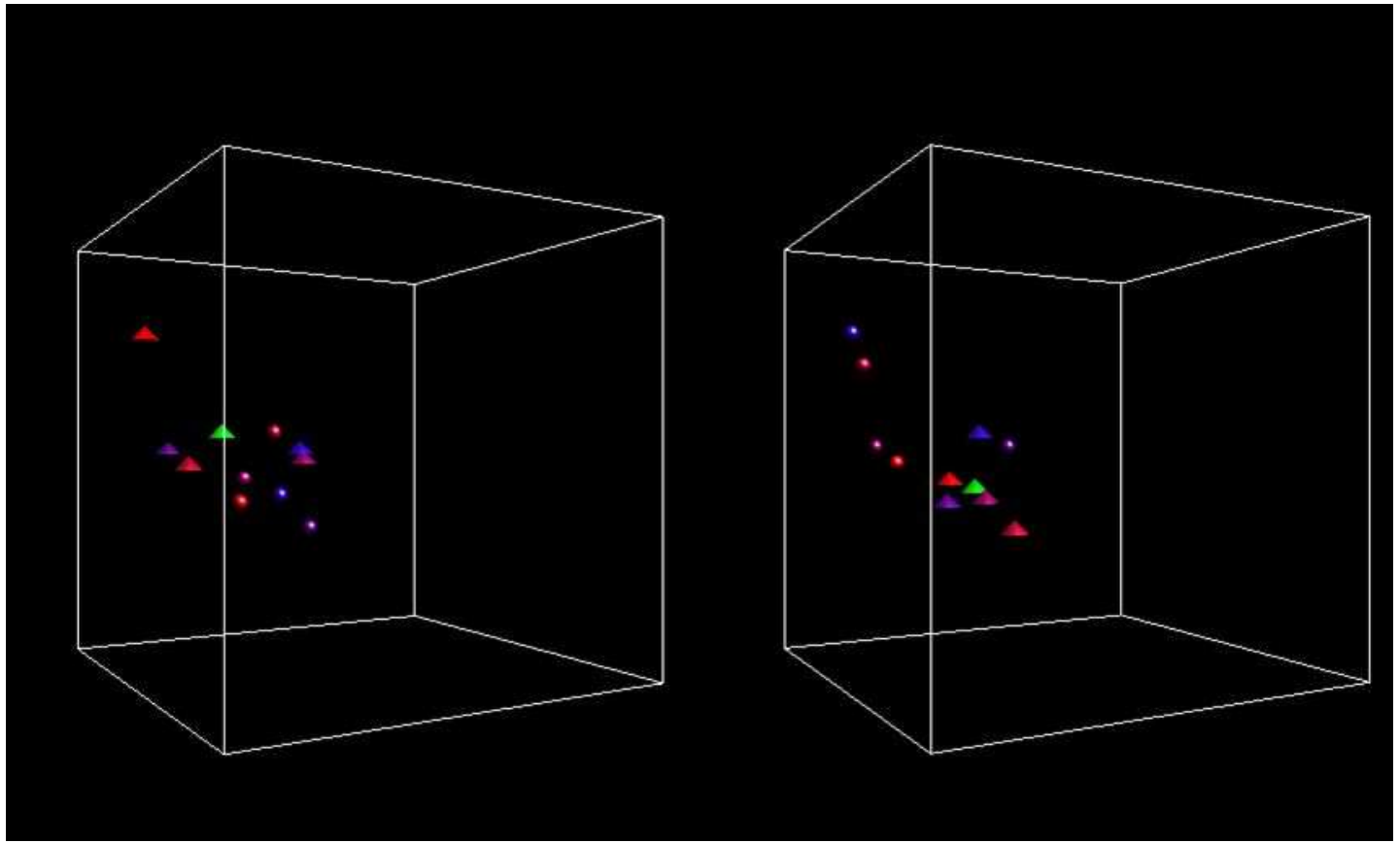
https://www.youtube.com/watch?v=ynPWOMzossI

Musical Agents



Swarm Music

Swarm Music

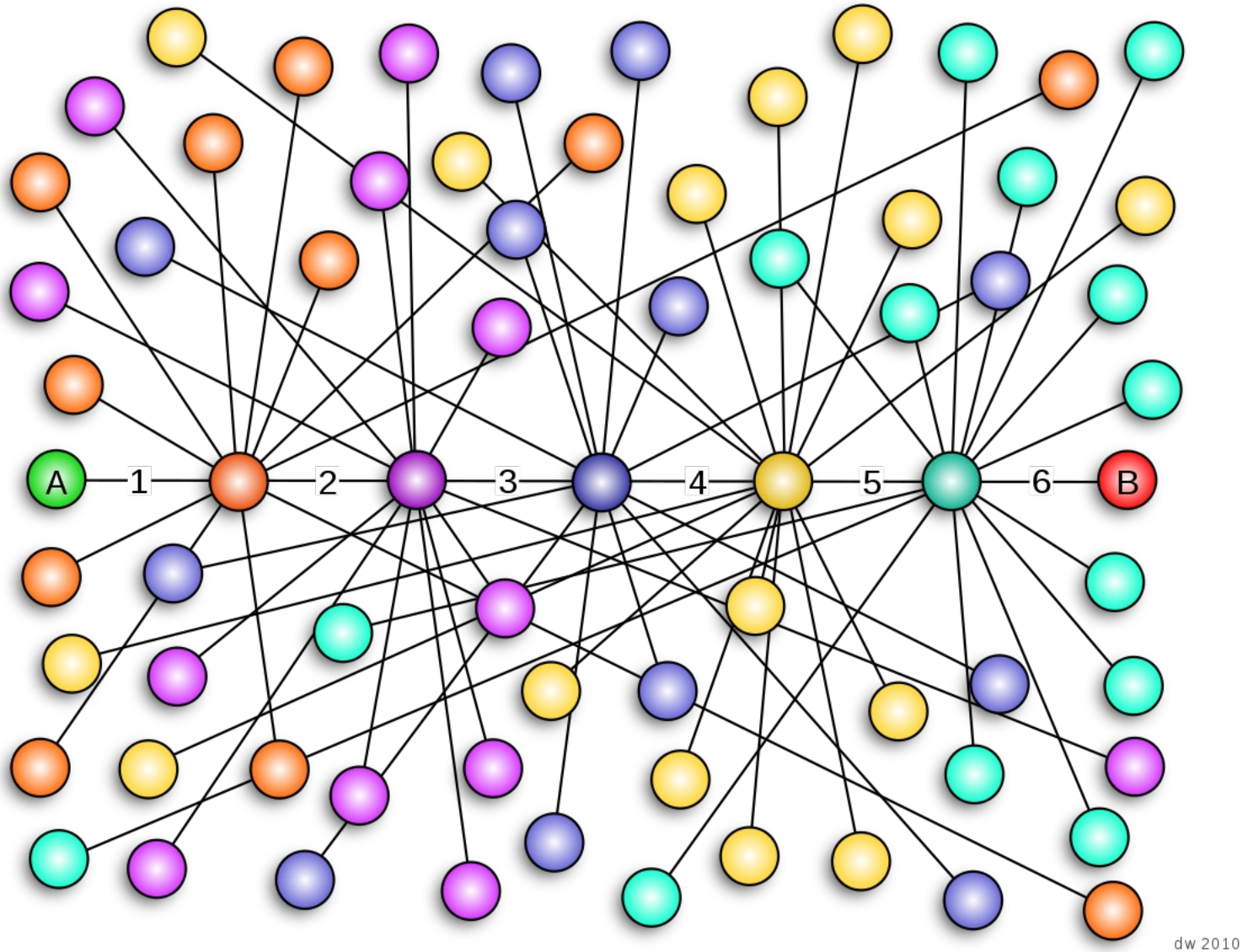


Google LM

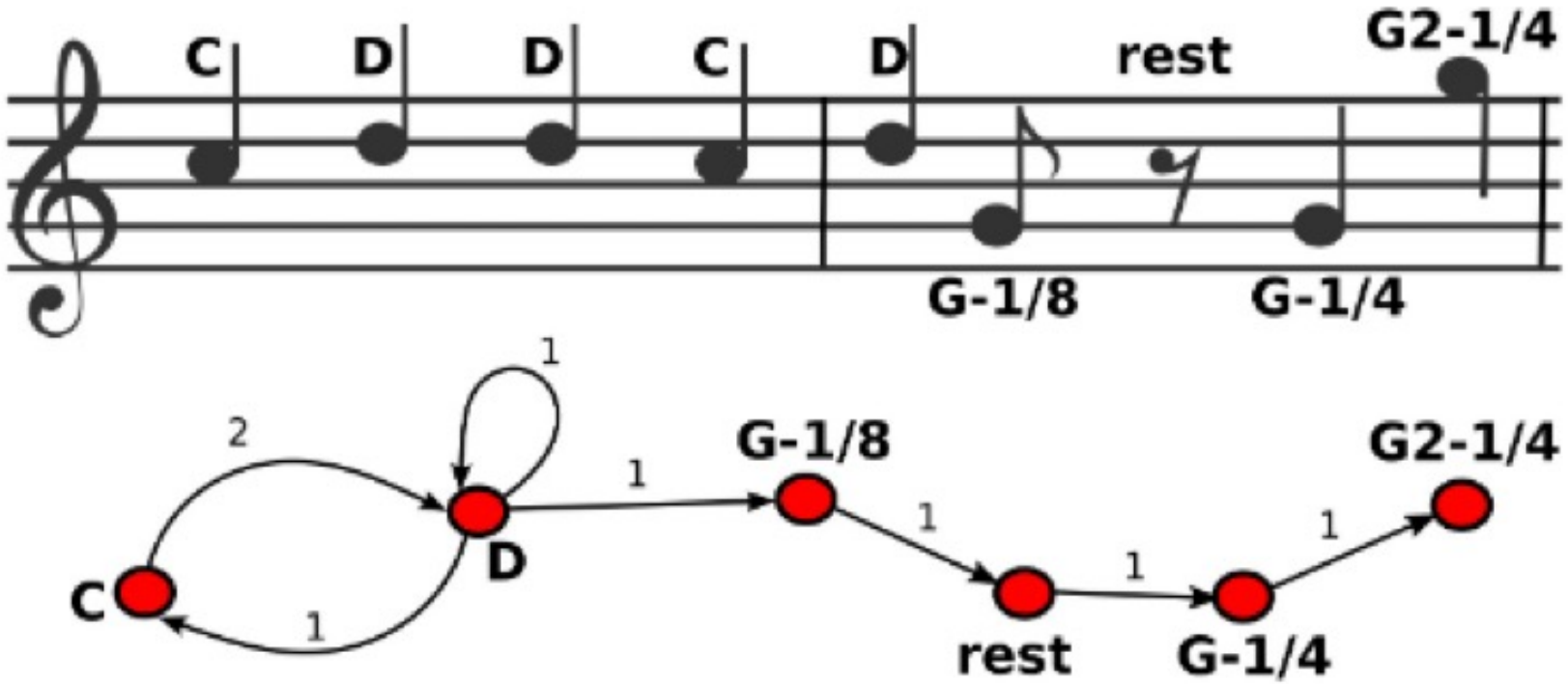
- https://google-research.github.io/seanet/musiclm/examples/

Our research

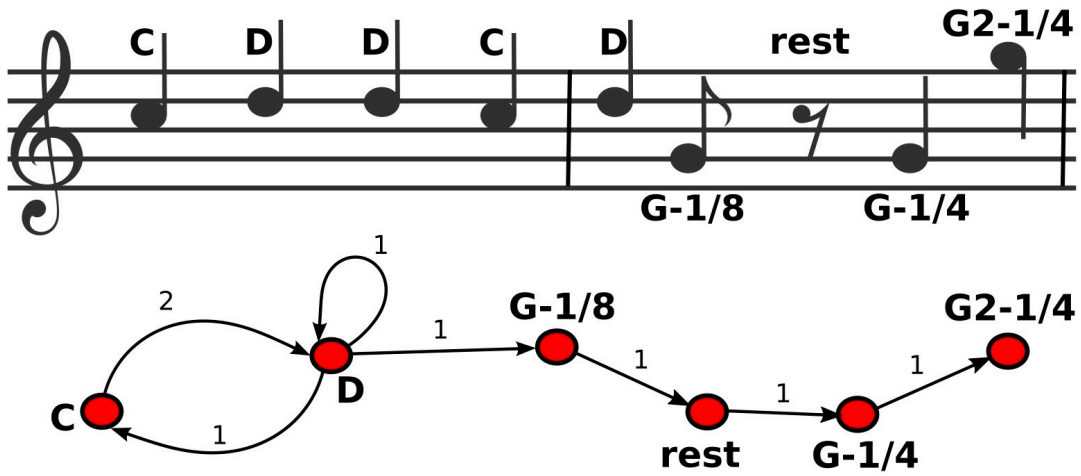
Complex Networks


A
1
2
3
4
5
6
B
dw 2010

From music to networks



Ferretti 2017



Modelling Sequences into Networks

- Each Musical element is mapped into a node.
- A Directed Edge is created between two consecutive elements.

What should be considered as a musical element?

What happens when multiple elements appear simultaneously?

State of the Art:

What should be considered as a musical element?

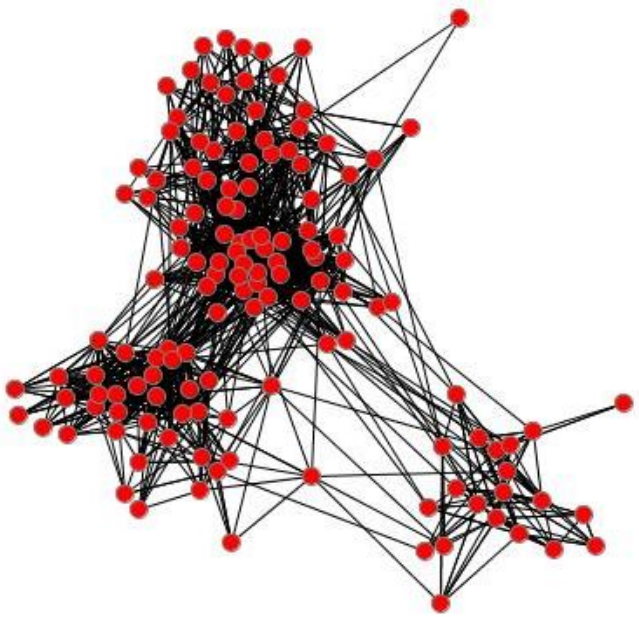


Fig. 3. Network from Bach's violin solos

Liu et al. (2009) investigate the creation of complex networks through the analysis of different pieces of classical and contemporary music, considering notes consecutively in the score to create nodes**.The authors ignore possible notes occurring simultaneously, thus focusing on the melodic dimension of the music.**

State of the Art:

What should be considered as a musical element?

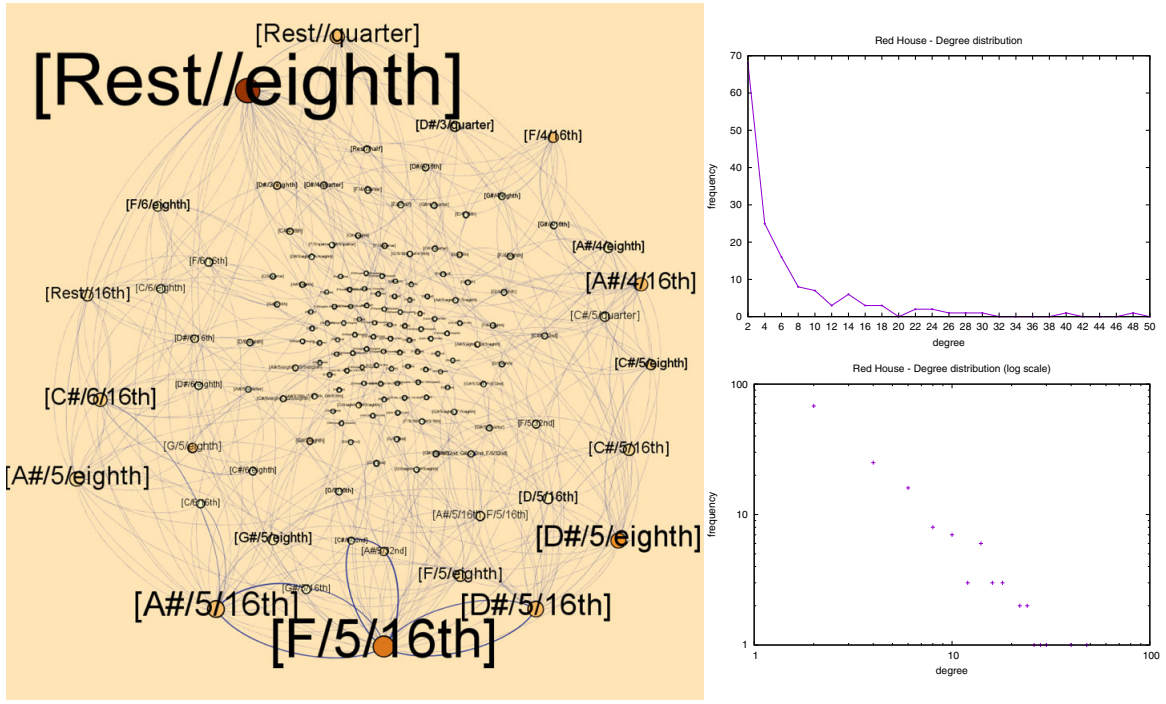
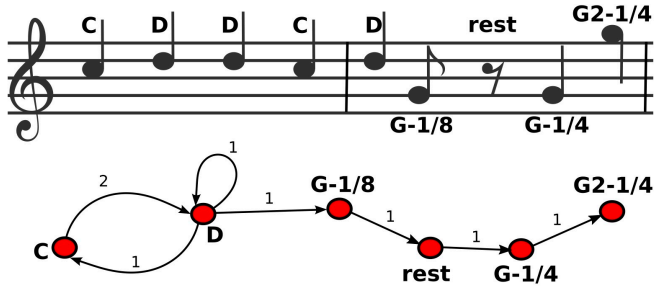


Fig. 3 Jimi Hendrix – Red House



Ferretti (2017) focuses on the creation of these networks from complex melodies existing in solos and justifies the existence of properties related to the concepts of small world.

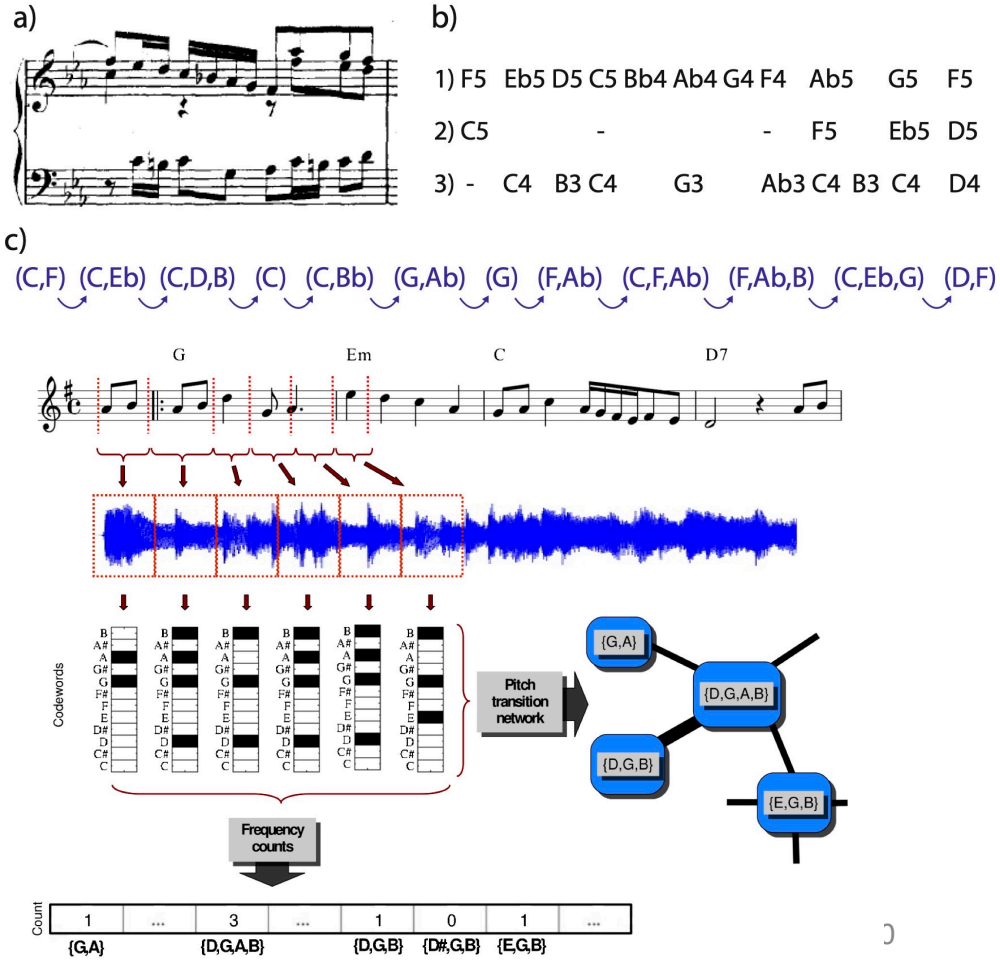
State of the Art:

What happens when multiple elements appear simultaneously?

Gomez chooses to focus on the harmony of the piece, and defines each node of the network according to the notes that occur simultaneously at each instant.

Serrà et al. try to explain the evolutionary direction of contemporary music through the properties of the networks created.

What should be considered as a musical element?



State of the Art:

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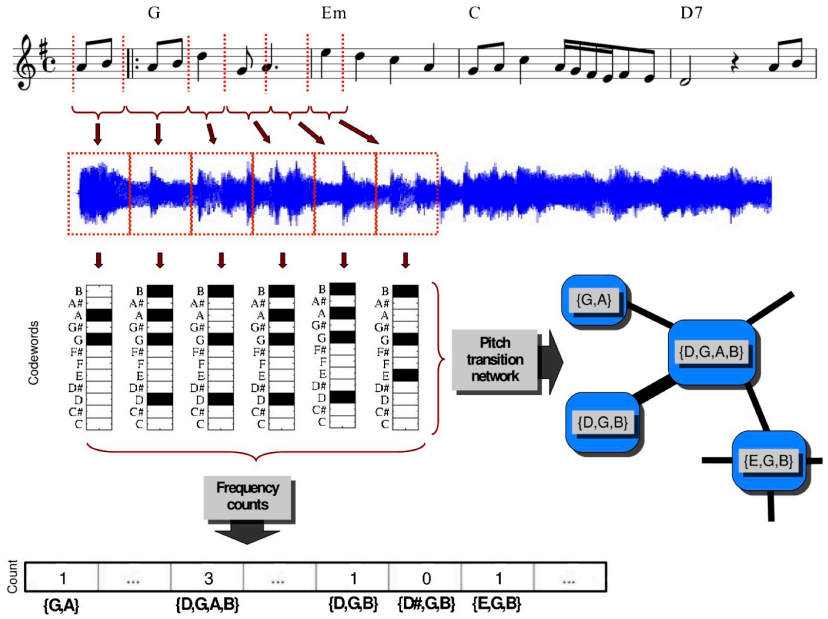
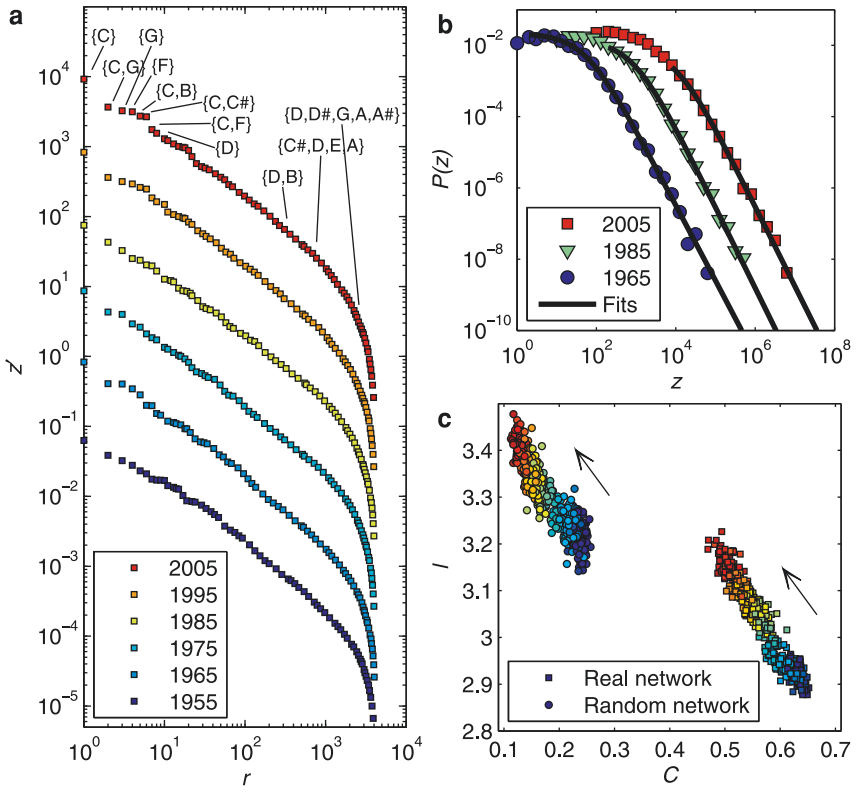
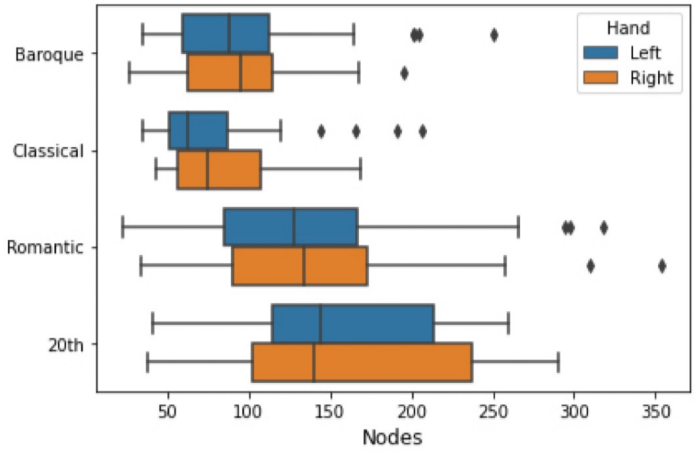
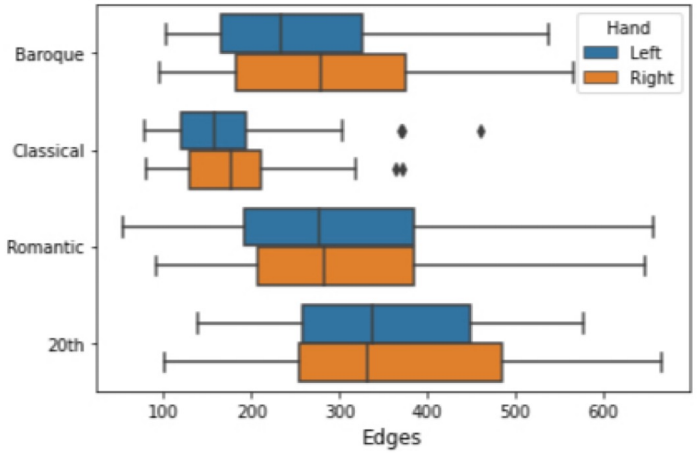
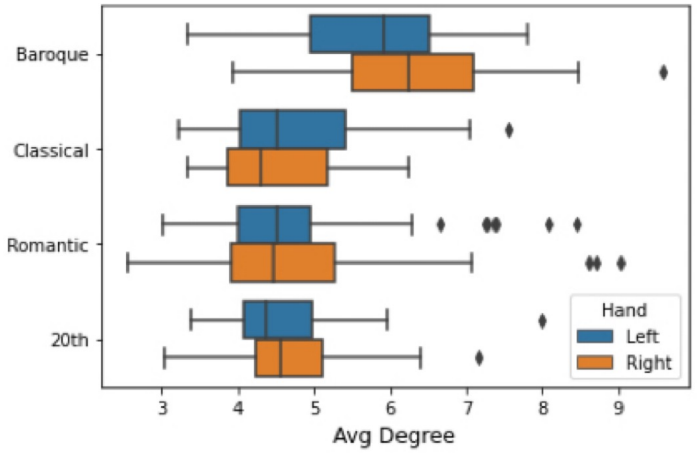


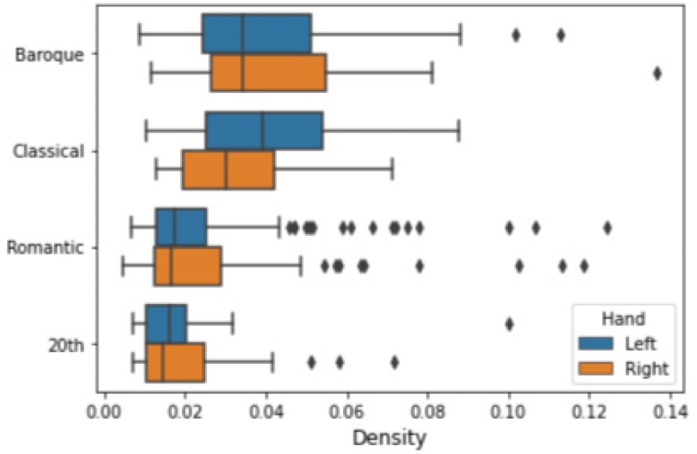


Results on Piano Works









Introduction to AI and Music

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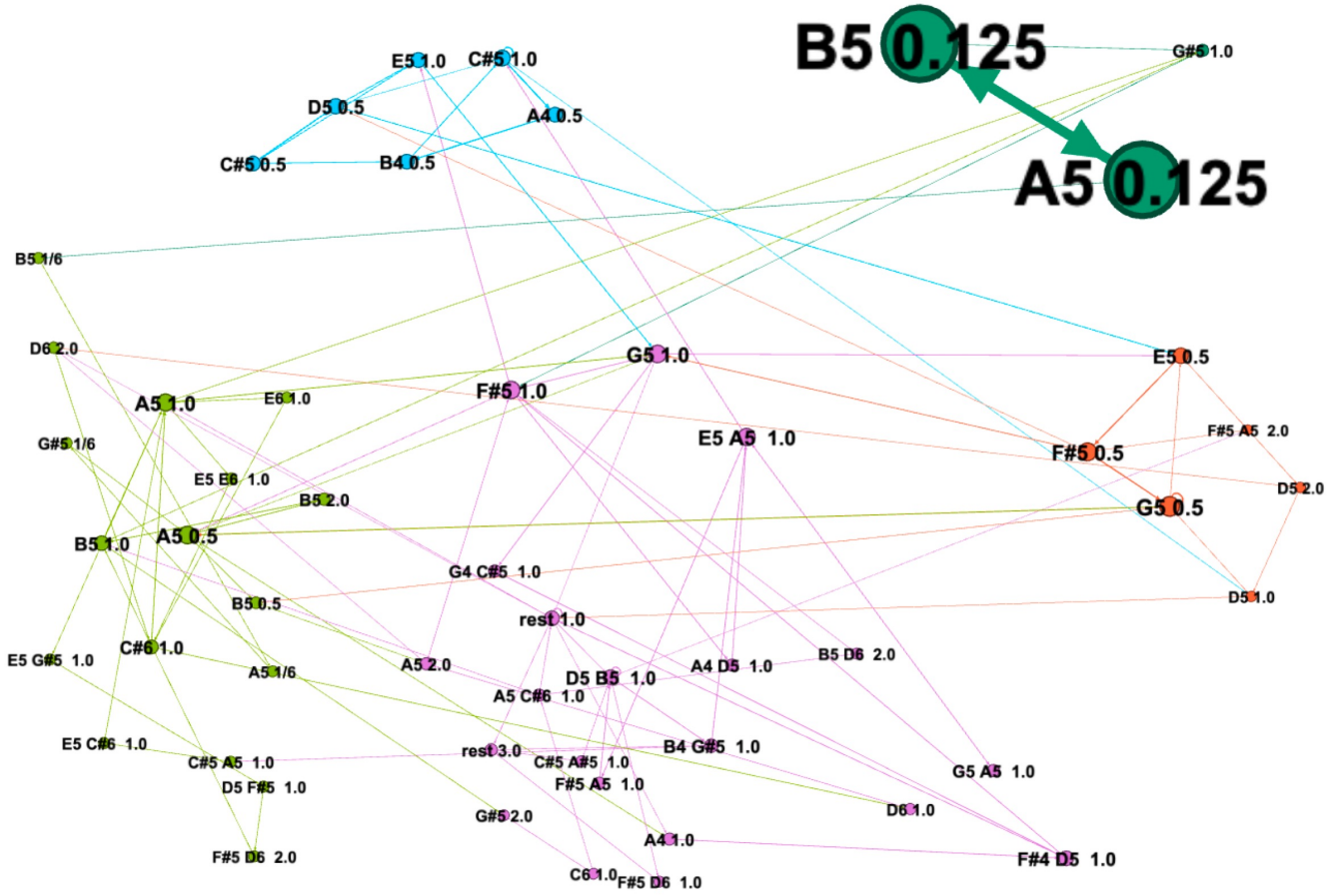
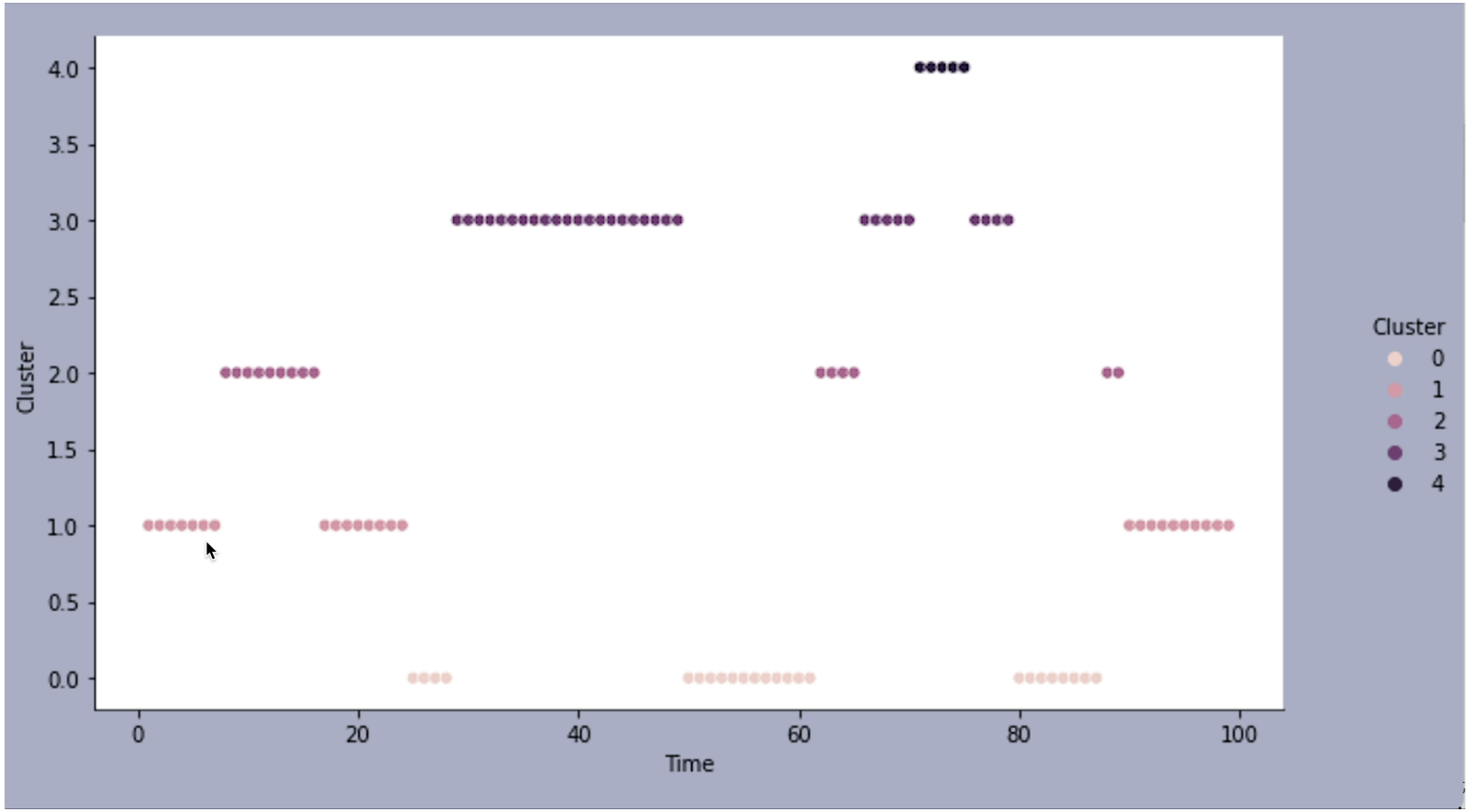
https://www.youtube.com/watch?v=SCm9O2KNEX4&t=2s



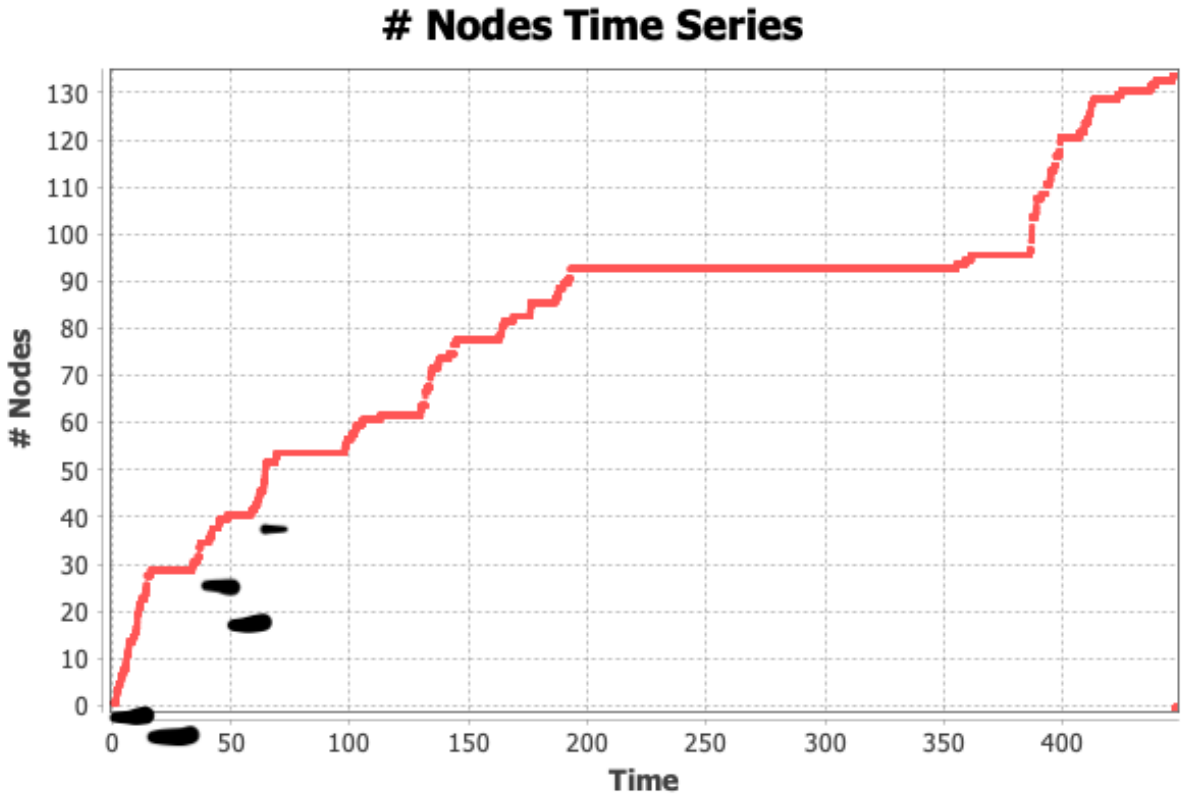
Clusterizing the network

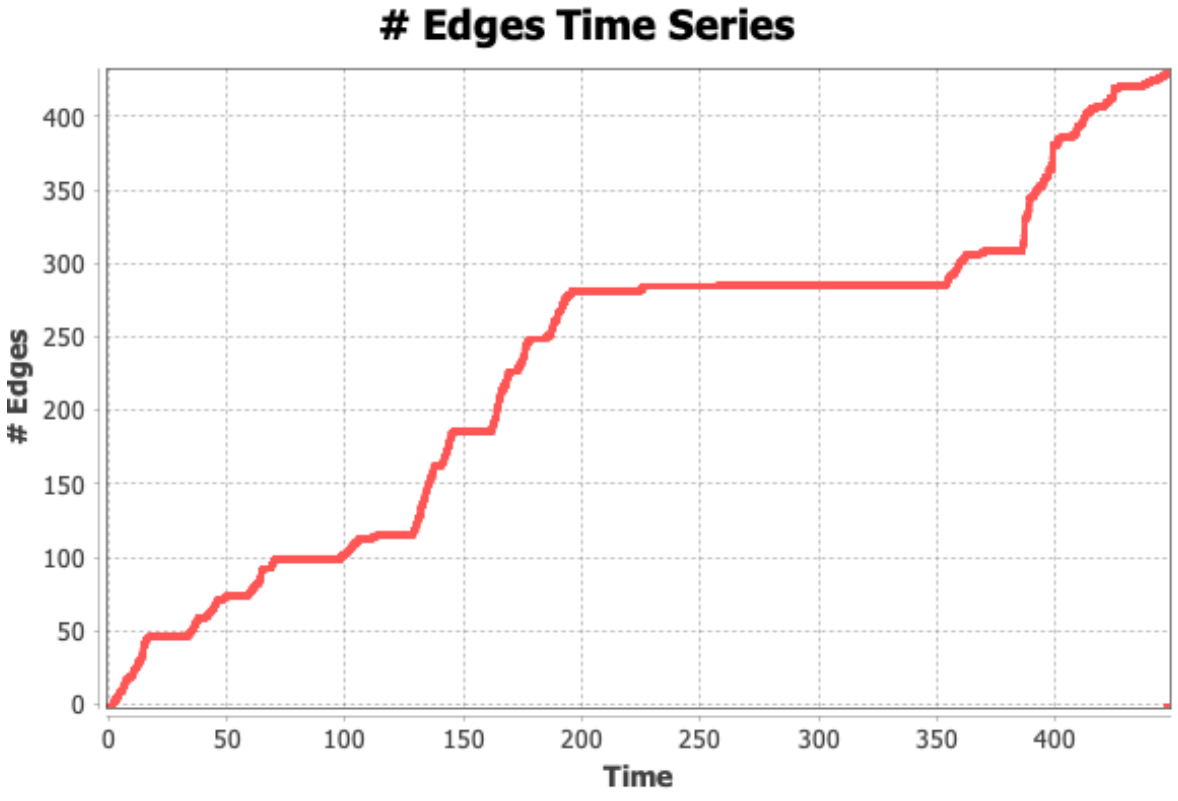


Demo on Clusterized Melodies

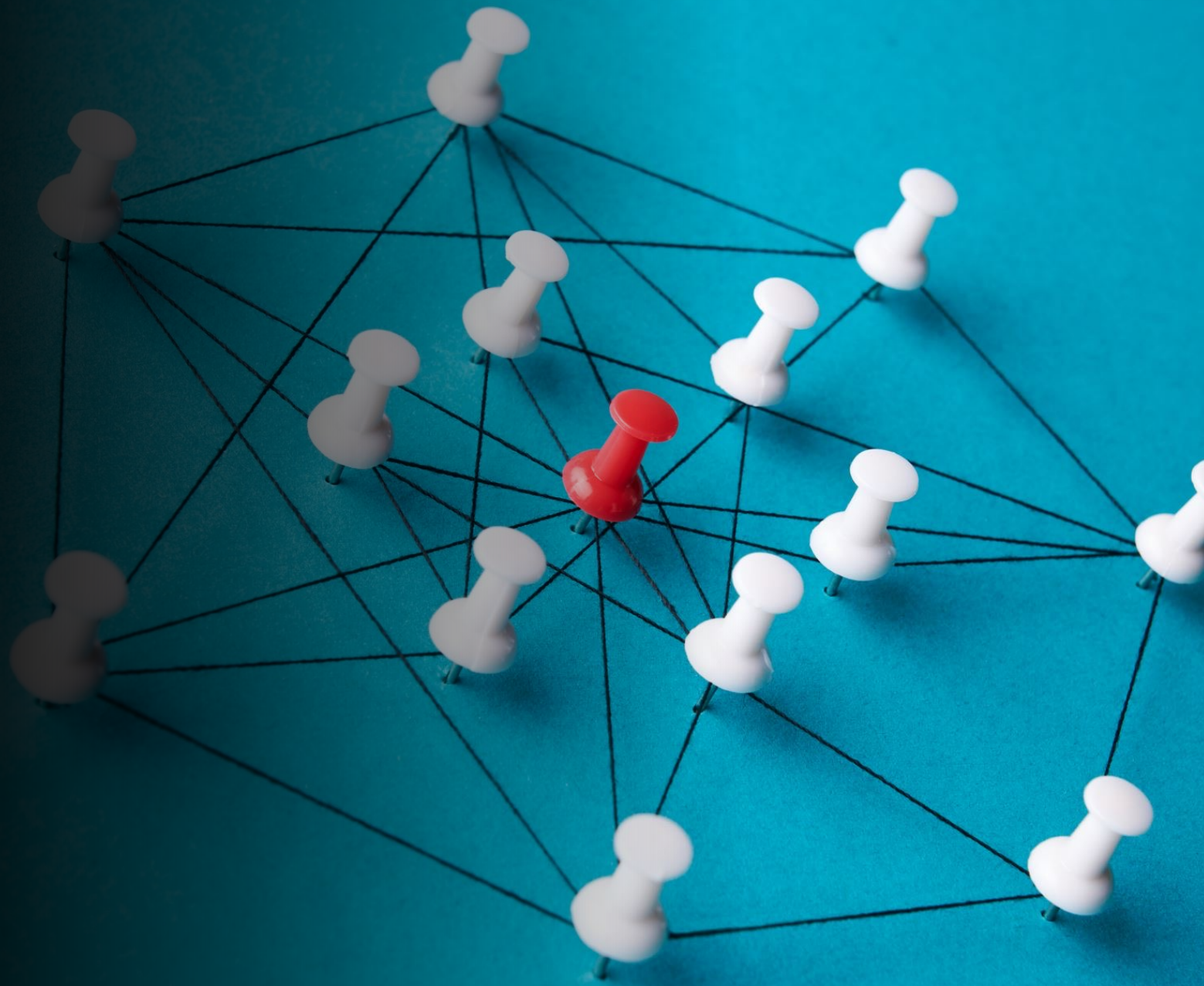
On Musical Form…

A – B – C – D – E – C – A – B – C - coda





Is there a better network representation?



Schoenberg on the dimensions of Music…

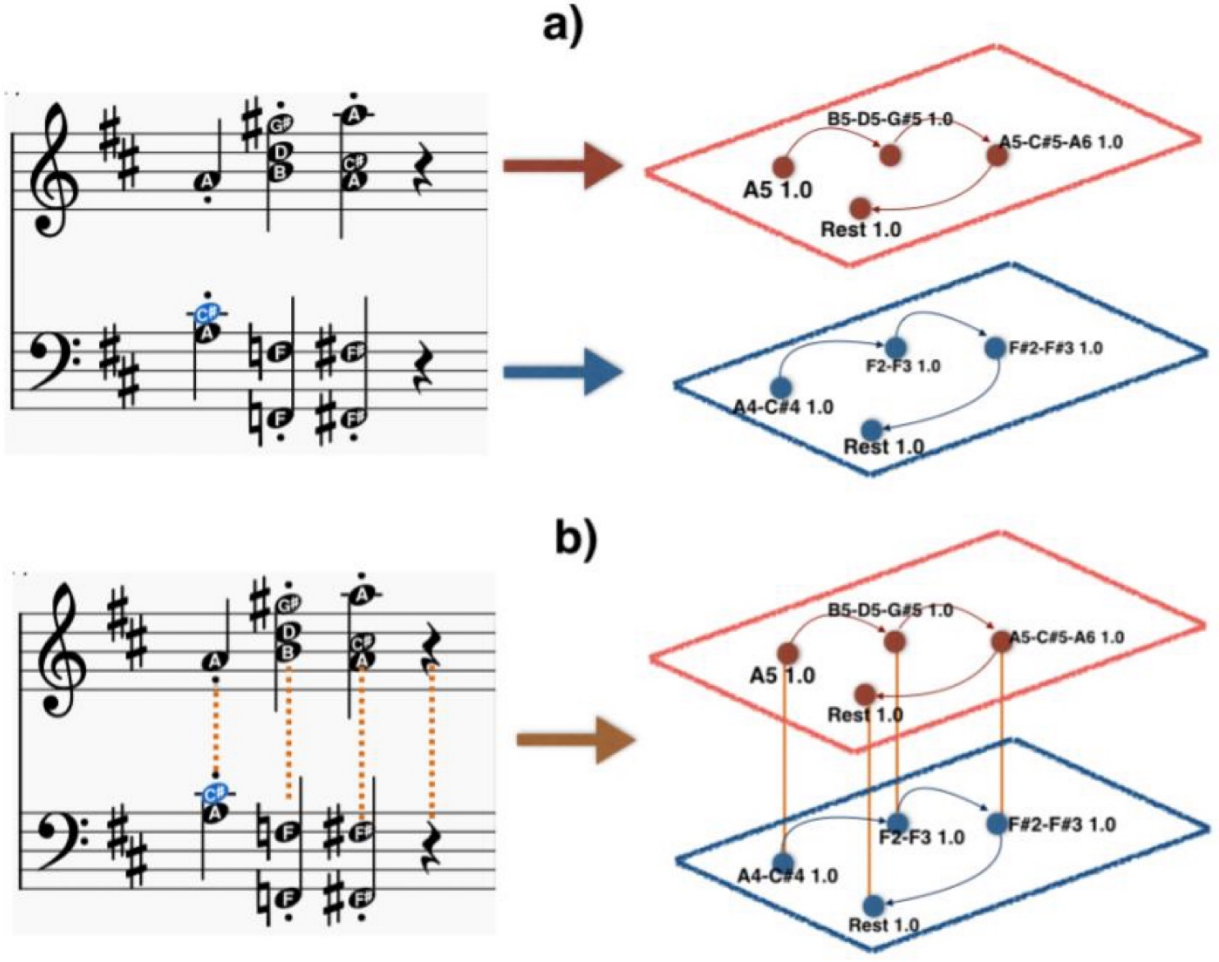
'The elements of a musical idea are partly incorporated in the horizontal plane as successive sounds and partly in the vertical plane as simultaneous sounds';*31 or: 'In accordance with this [law], harmony and melody, vertical and horizontal, form a musical unit, a space, in both of whose dimensions the musical substance is deposited.*

The conception of the dimensions of musical space is therefore connected with 'harmony and melody'—without 'vertical' and 'harmony', or 'horizontal' and 'melody', thereby being identical.

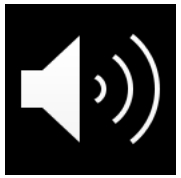
“(…) many real-world systems do not operate in isolation. On the contrary, they are interconnected and what happens at a single level of interaction affects the structure and function at another interconnected layer.”

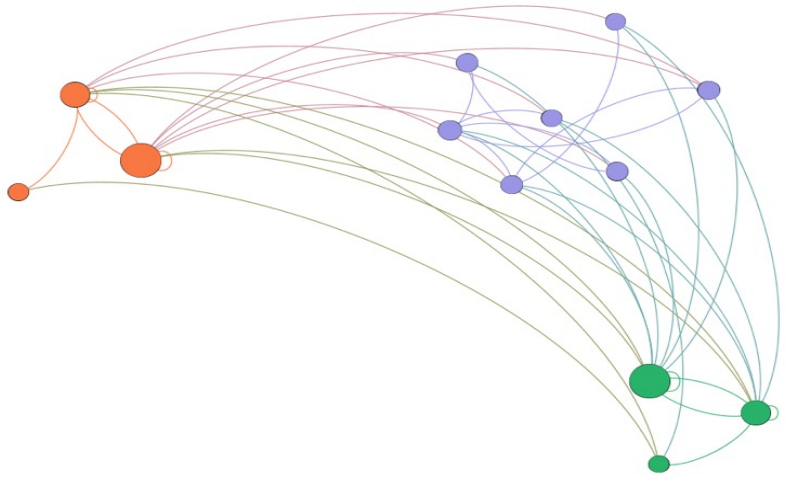
Cosnet (Complex Systems and Network Lab, University of Zaragoza)

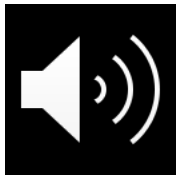
Multilayer Networks- Methodology

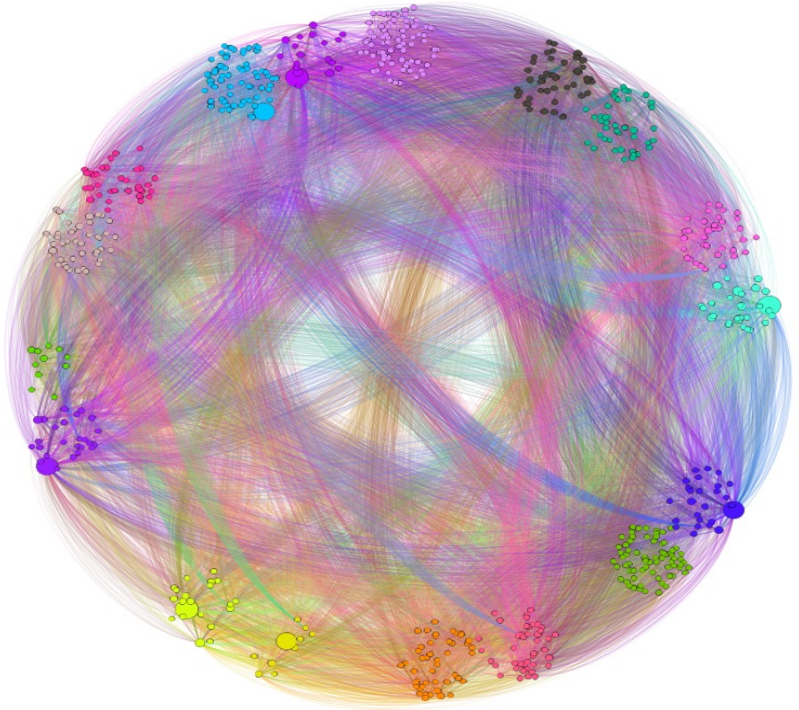


Bono Rosselló, 2021





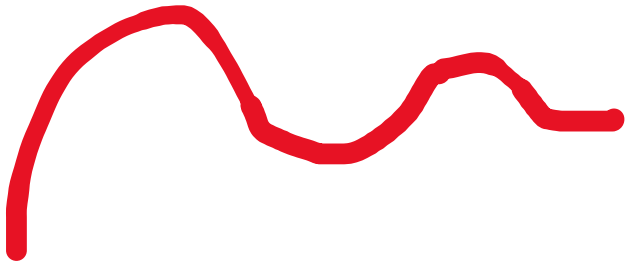




Dynamics of the Network and Texture

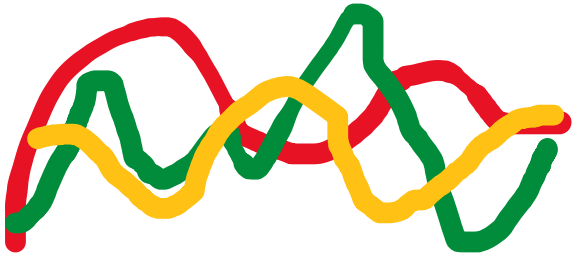
But… What is Texture?

MONOPHONIC



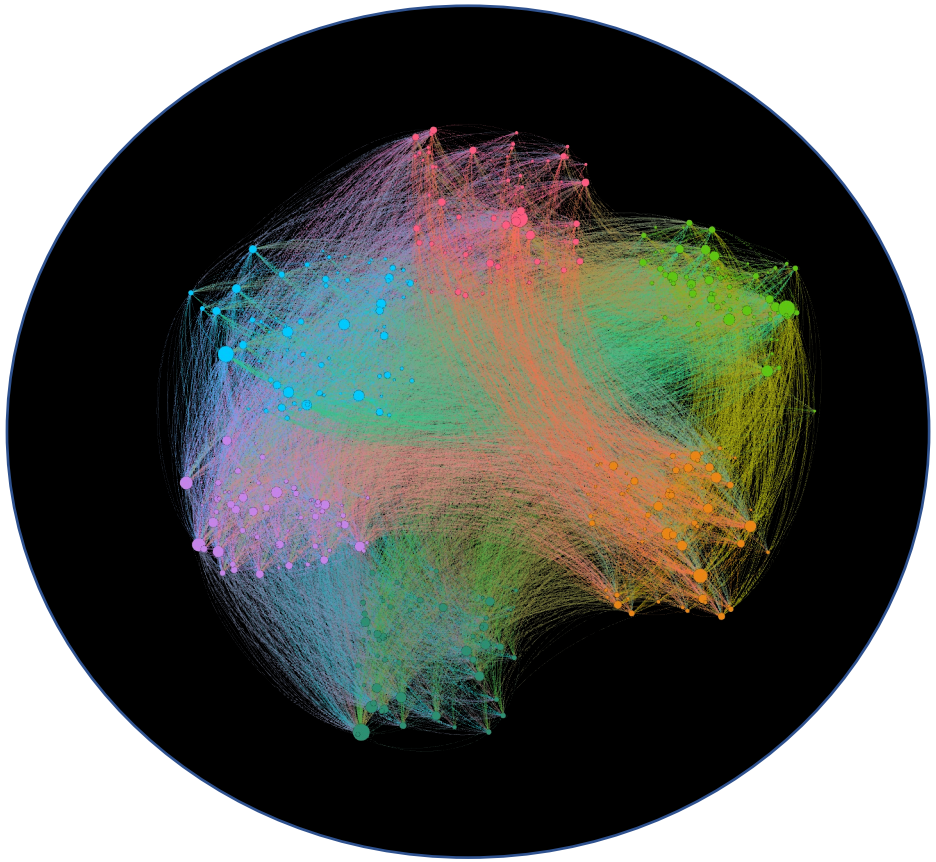
HOMOPHONIC

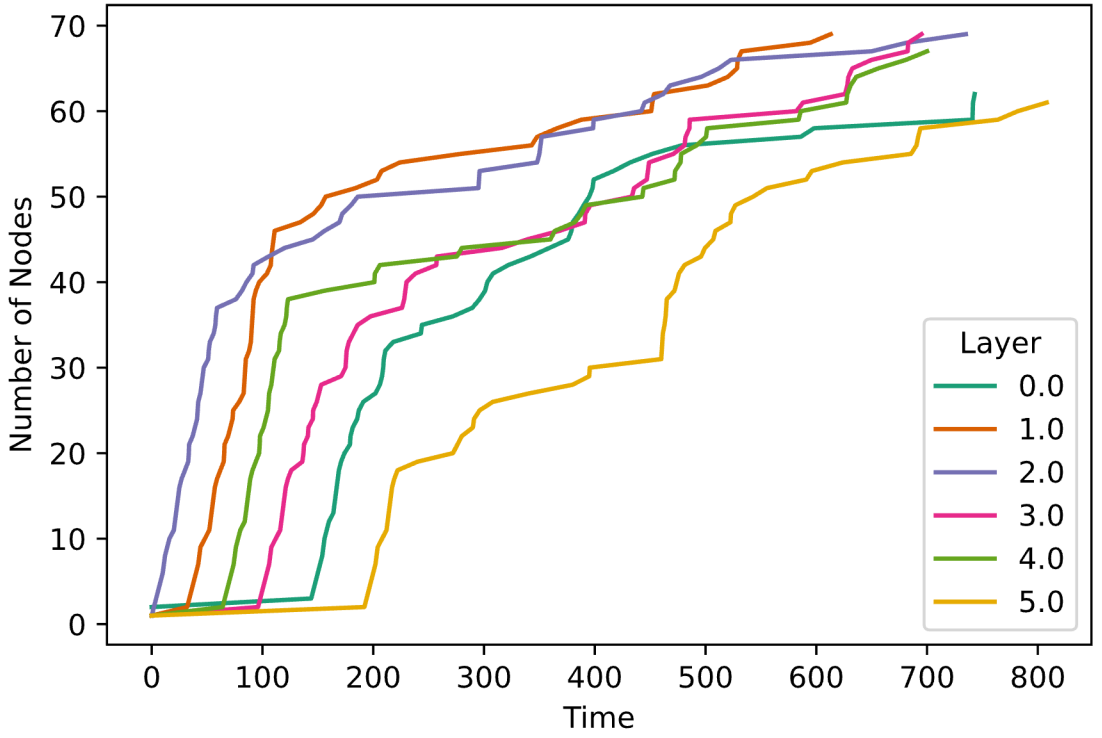
POLYPHONIC



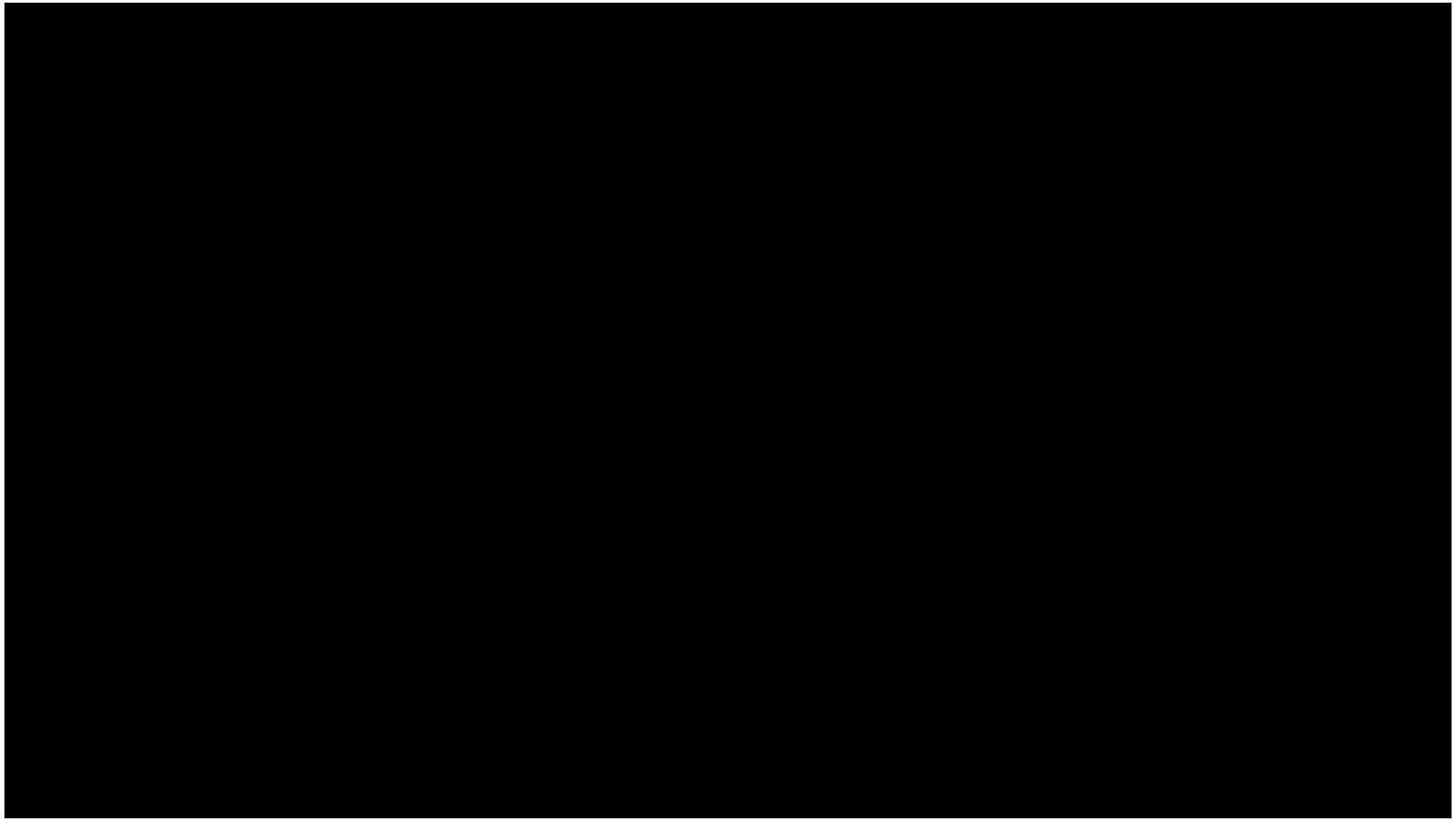
Polyphonic Texture: *'Ricercar a 6' J.S.Bach*

Polyphonic Texture: *'Ricercar a 6' J.S.Bach*

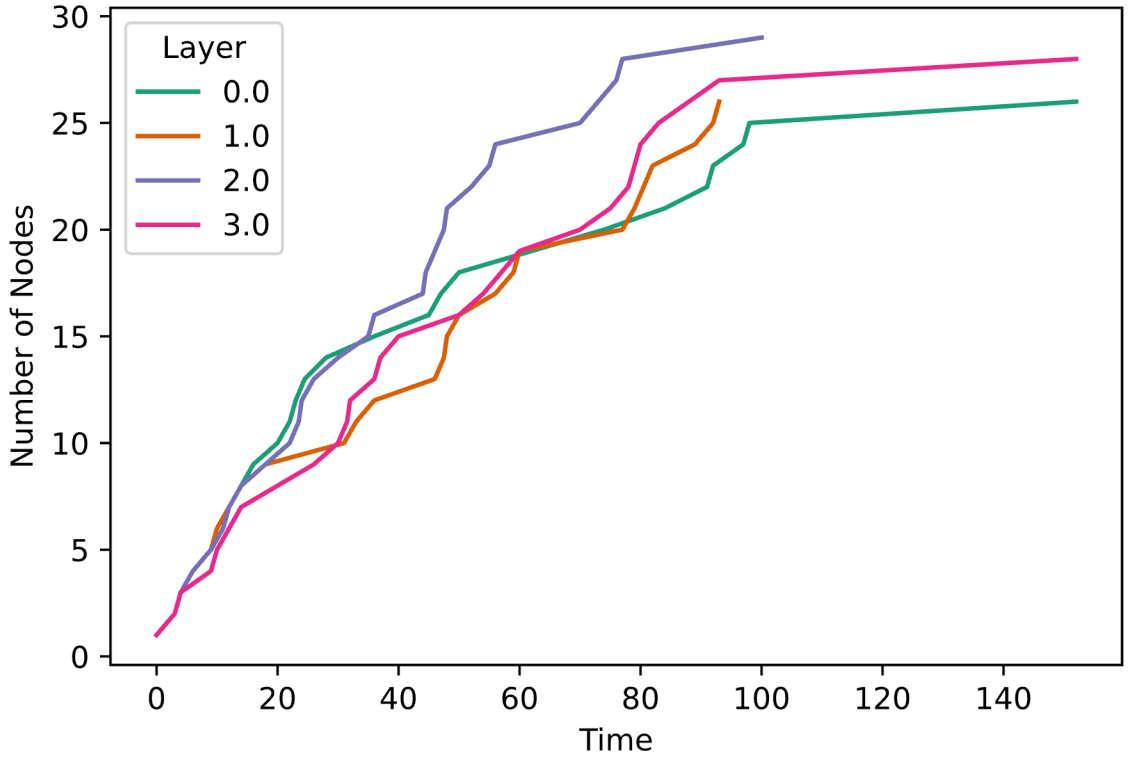




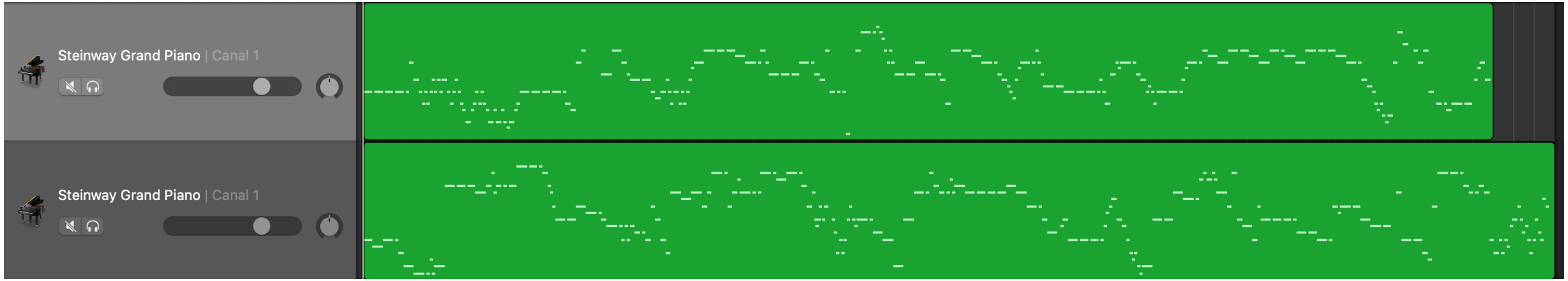
Homophonic Texture: *'If ye Love Me' Thomas Tallis*



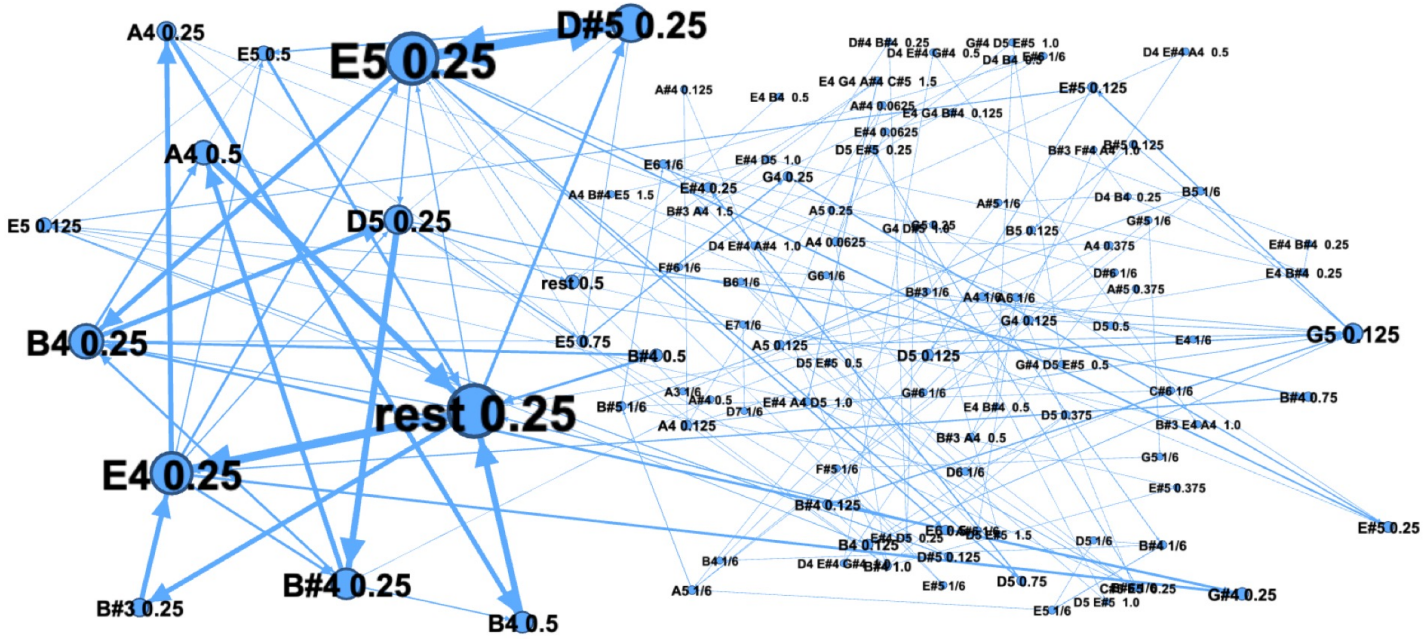
Homophonic Texture: *'If ye Love Me' Thomas Tallis*



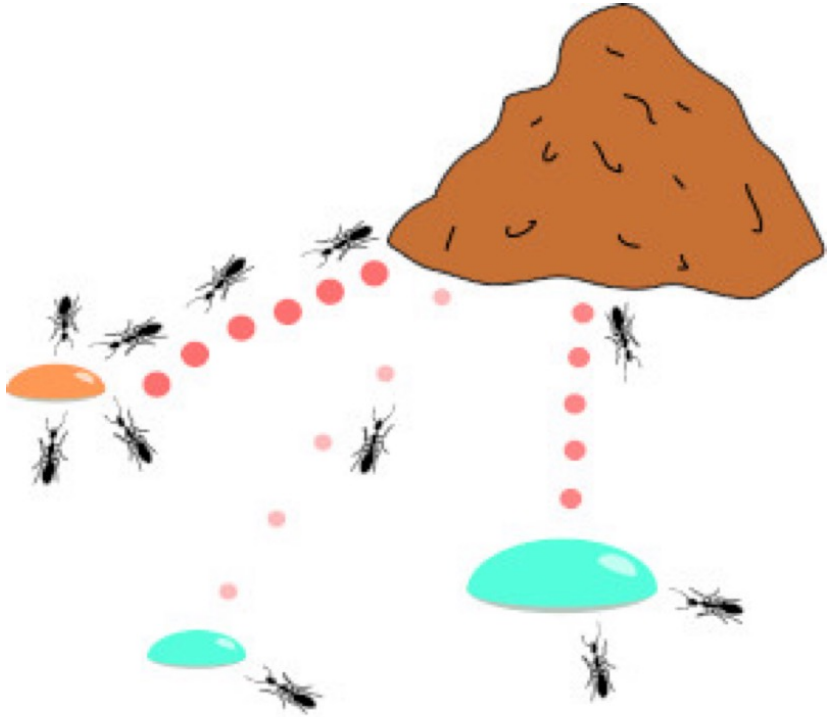
Random walks

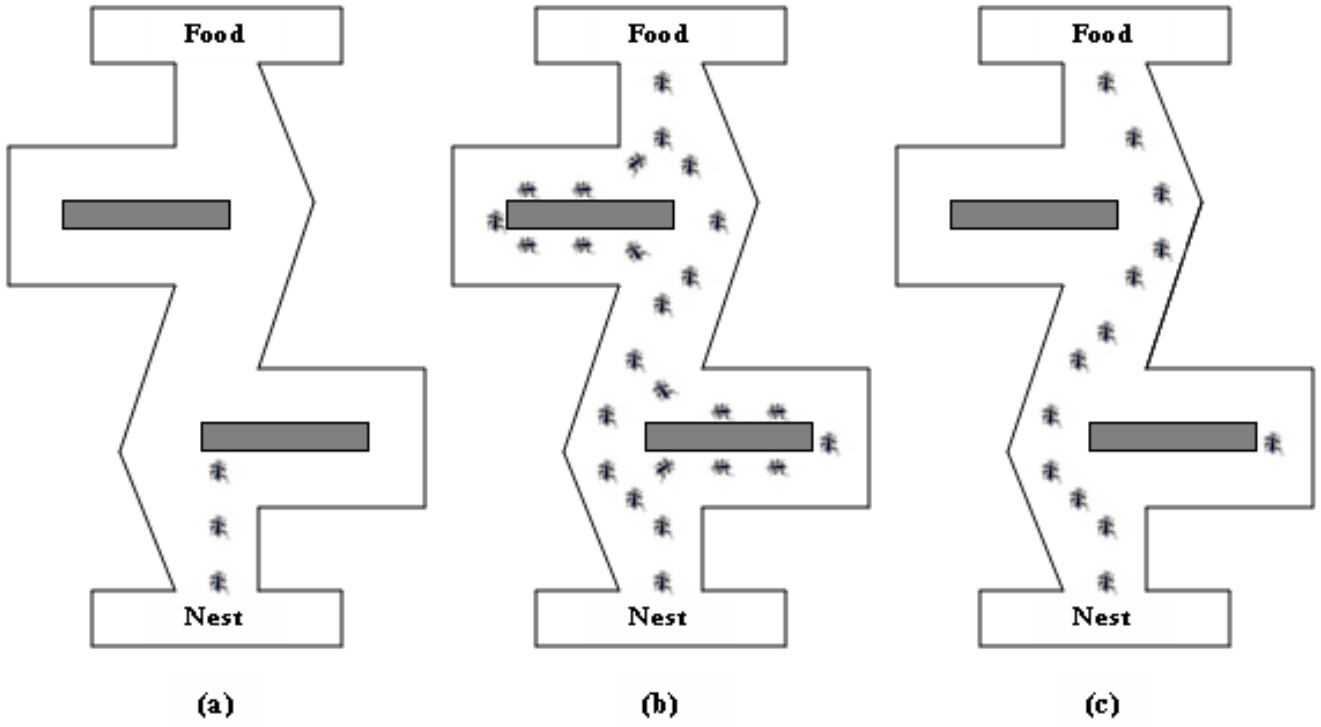


No Structure

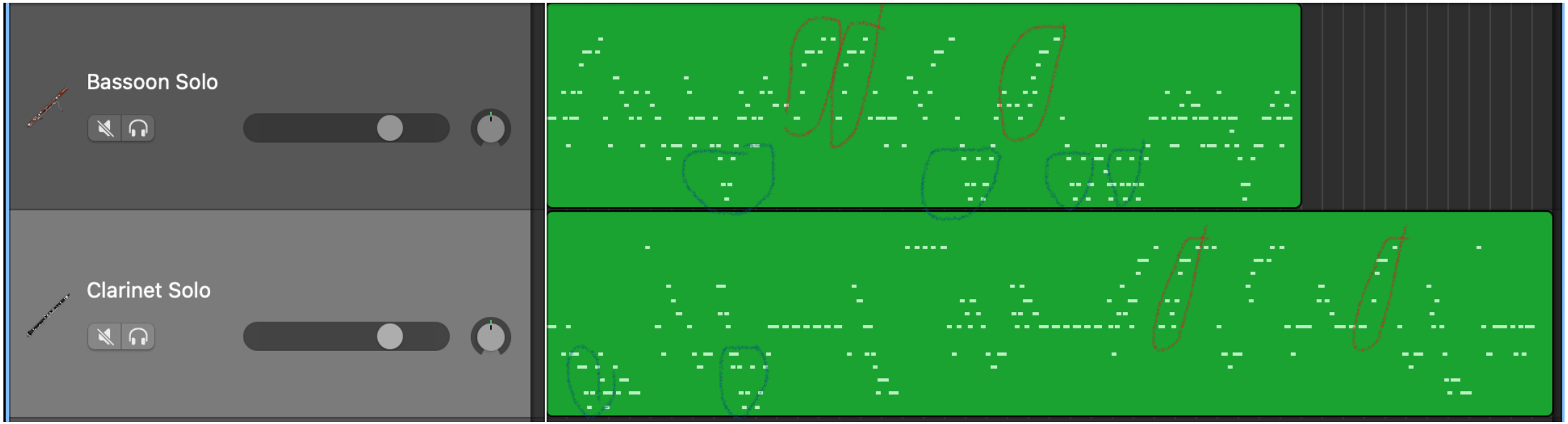


Ant Colony Optimization





Evaluating… music?

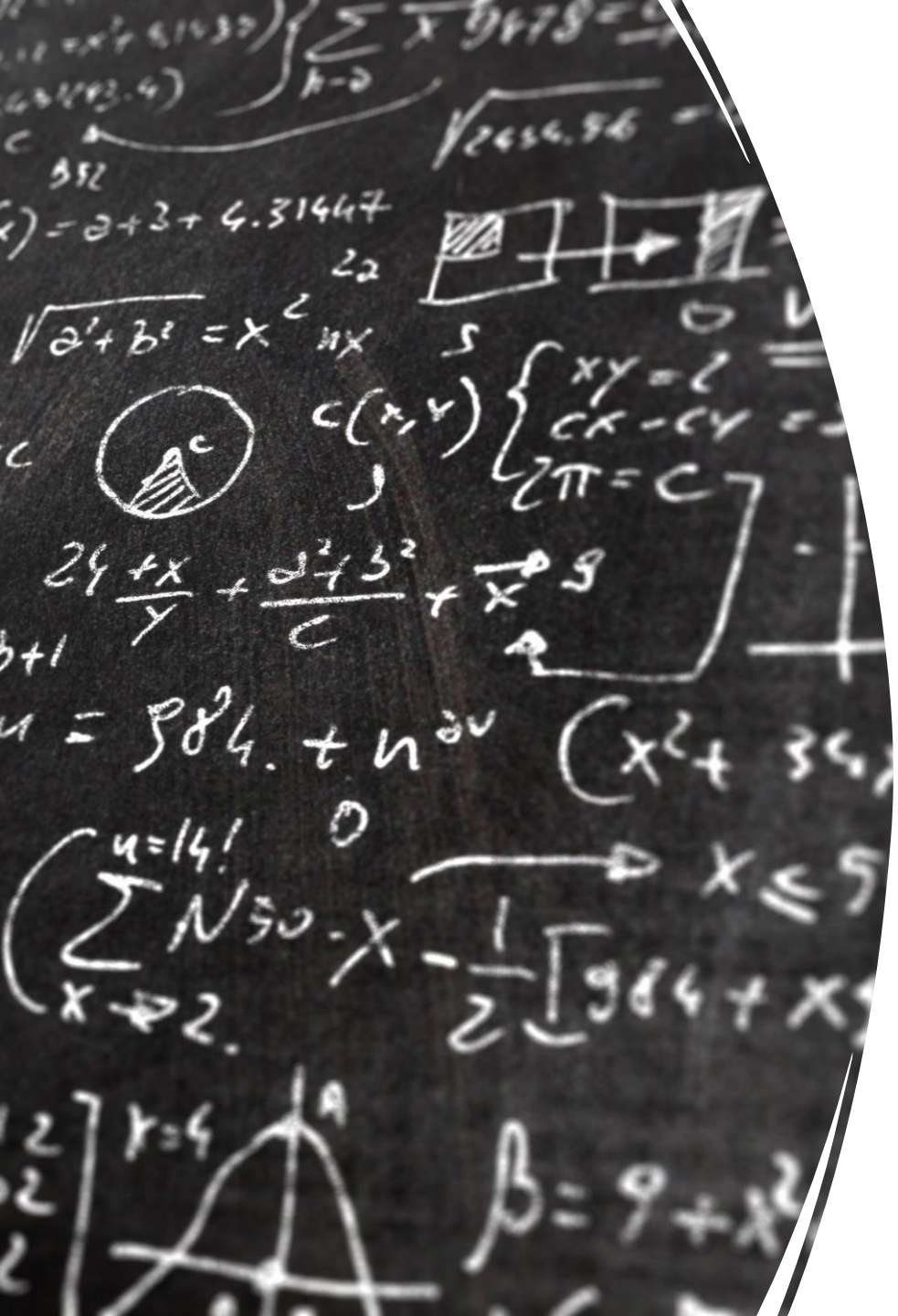


Interactions, roles, emergence?

$$ASDecisionRule \rightarrow p_{ij}^{k}(t) = \frac{[\tau_{ij}]^{\alpha}\,[\eta_{ij}]^{\beta}}{\sum_{l \in N_i^k} [\tau_{il}]^{\alpha} \cdot [\eta_{il}]^{\beta}}, \qquad \text{if} \quad j \in N_i^k$$

$$UpdatePheromones \rightarrow \tau_{ij}(t) = (1-\rho)\cdot\tau(t-1) + \sum_{k=1}^{m} \Delta\tau_{ij}^{k}$$

$$\Delta\tau_{ij}^{k} = \frac{1}{L_k}, \qquad \text{if } arc(i,j) \text{ is used by ant k on its tour}$$



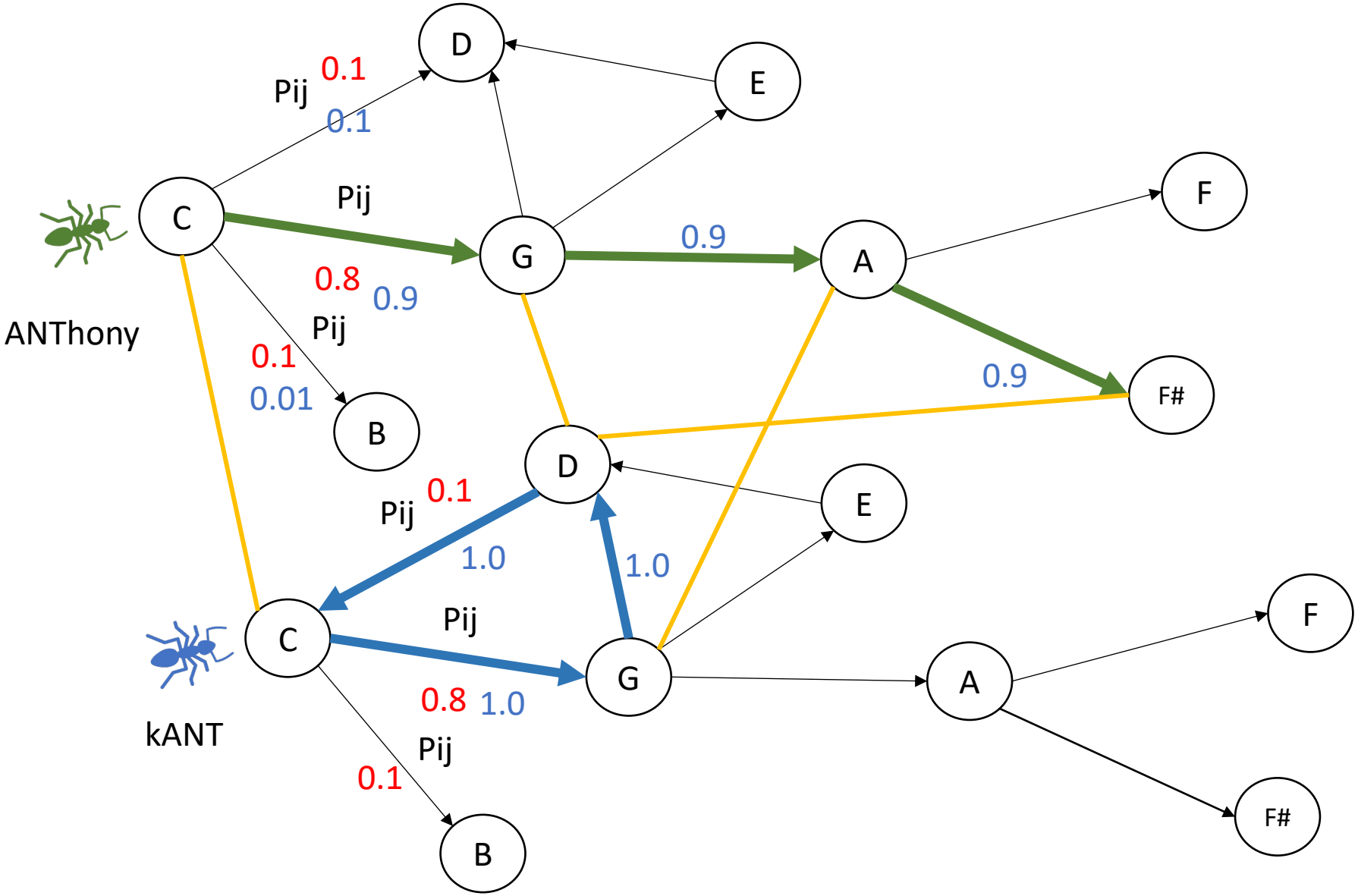
How should we modify the equations?

Equations

$$p_{ij}^{k}(t) = \frac{\left[\tau in_{ij}\right]^{\alpha_{in}} \cdot \left[\tau ex_{ij}\right]^{\alpha_{ex}} \cdot \left[\eta_{ij}\right]^{\beta}}{\sum_{l \in N_i^k} \left[\tau in_{il}\right]^{\alpha_{in}} \cdot \left[\tau ex_{il}\right]^{\alpha_{ex}} \cdot \left[\eta_{il}\right]^{\beta}}, \qquad \text{if} \quad j \in N_i^k$$

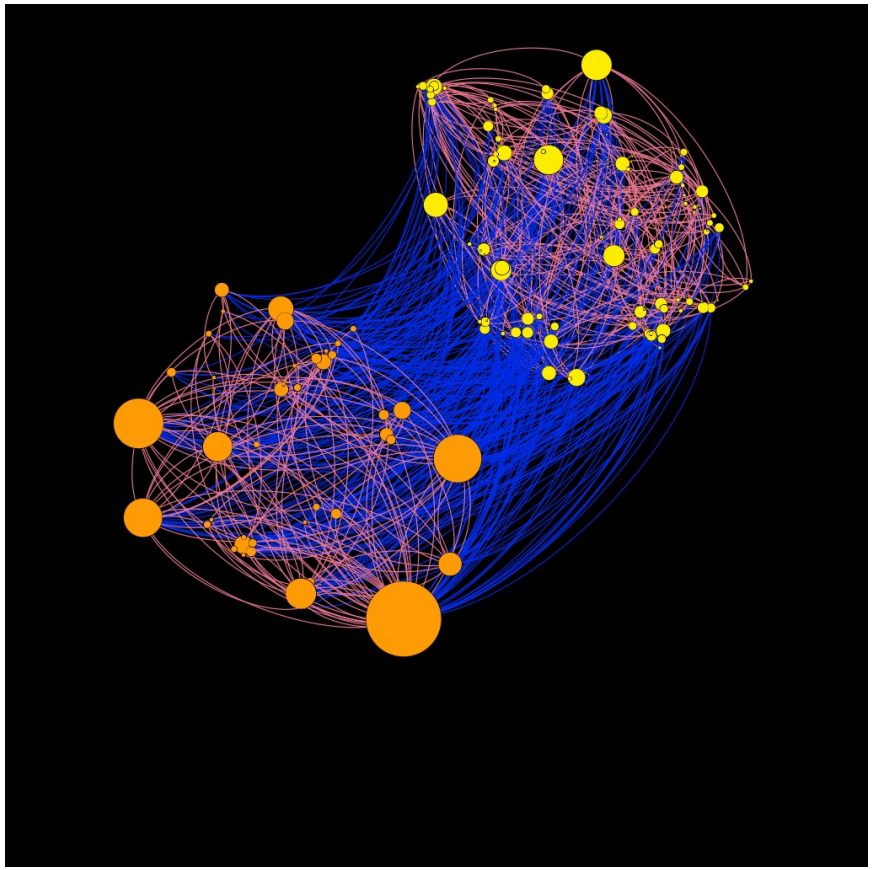
$$\tau in_{ij}(t) = \begin{cases} (1-\rho_{in}) \cdot \tau in_{ij}(t-1) + \triangle \tau in_{ij} & \text{if } ij \in path \\ (1-\rho_{in}) \cdot \tau in_{ij}(t-1) & \text{if } ij \notin path \end{cases}$$

$$\tau ex_{ij}(t) = \begin{cases} (1-\rho_{ex}) \cdot \tau ex_{ij}(t-1) + \sum_{l=1}^{L} \triangle \tau ex_{ij} & \text{if } \exists jk: \ k \in path_l \\ (1-\rho_{ex}) \cdot \tau ex_{ij}(t-1) & \text{else} \end{cases}$$

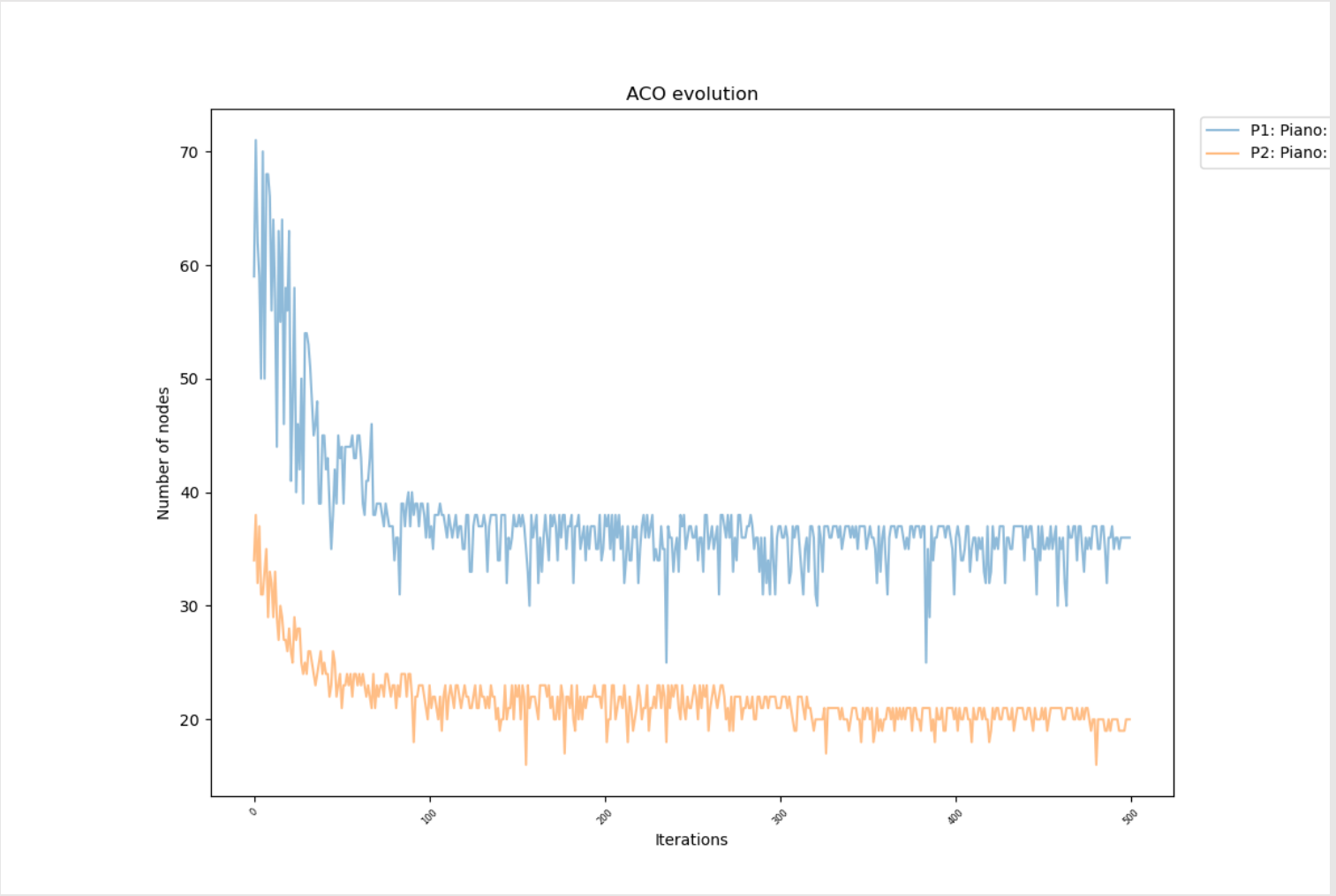

D
E
Pij
0.1
0.1
C
Pij
G
0.9
A
F
0.8
0.9
Pij
ANThony
0.1
0.01
B
0.9
F#
D
Pij
0.1
E
1.0
1.0
C
Pij
F
G
A
0.8
1.0
kANT
Pij
0.1
B
F#

Original

Random Walk ACO-Biased



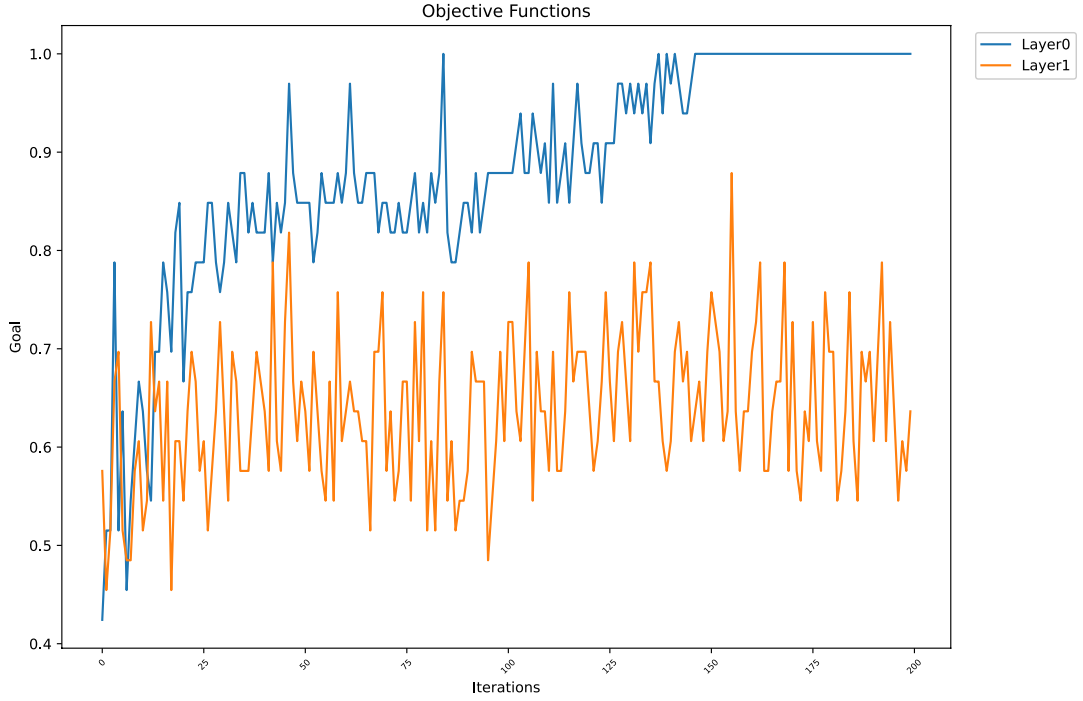
Evolution of the Random Walks



Experiment 1

Table 1: Parameter Configuration of Example 1

Parameter	Layer 0	Layer 1
Intra-pheromone factor (α_{in})	2	0
Extra-pheromone factor (α_{ex})	0	2
Heuristic information factor (β)	1	1
Target Length of Objective Function (F)	8	8



Experiment 2

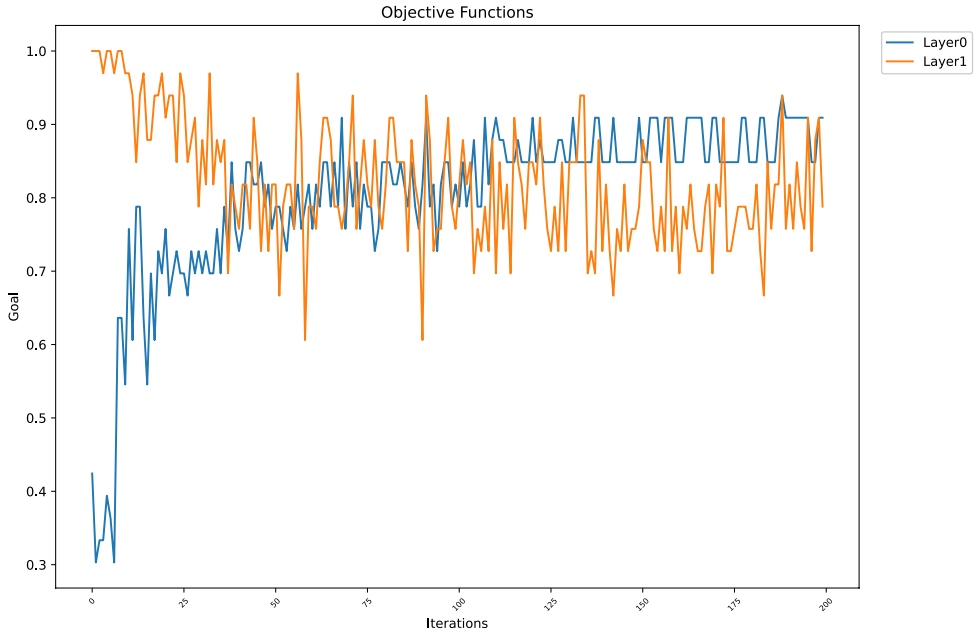
Table 2: Parameter Configuration of Example 2

Parameter	Layer 0	Layer 1
Intra-pheromone factor (α_{in})	1	1
Extra-pheromone factor (α_{ex})	2	2
Heuristic information factor (β)	1	1
Target Length of Objective Function (F)	4	32

Experiment 2

Table 2: Parameter Configuration of Example 2

Parameter	Layer 0	Layer 1
Intra-pheromone factor (α_{in})	1	1
Extra-pheromone factor (α_{ex})	2	2
Heuristic information factor (β)	1	1
Target Length of Objective Function (F)	4	32

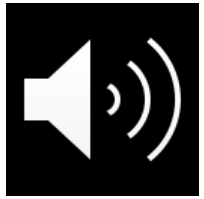


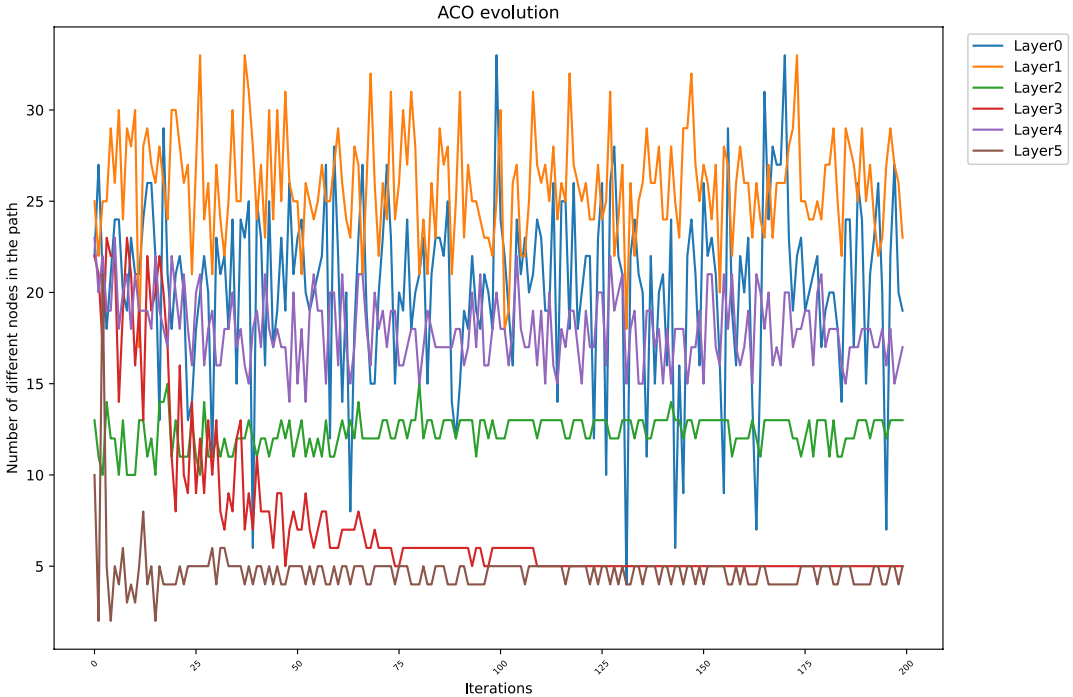
Experiment 3

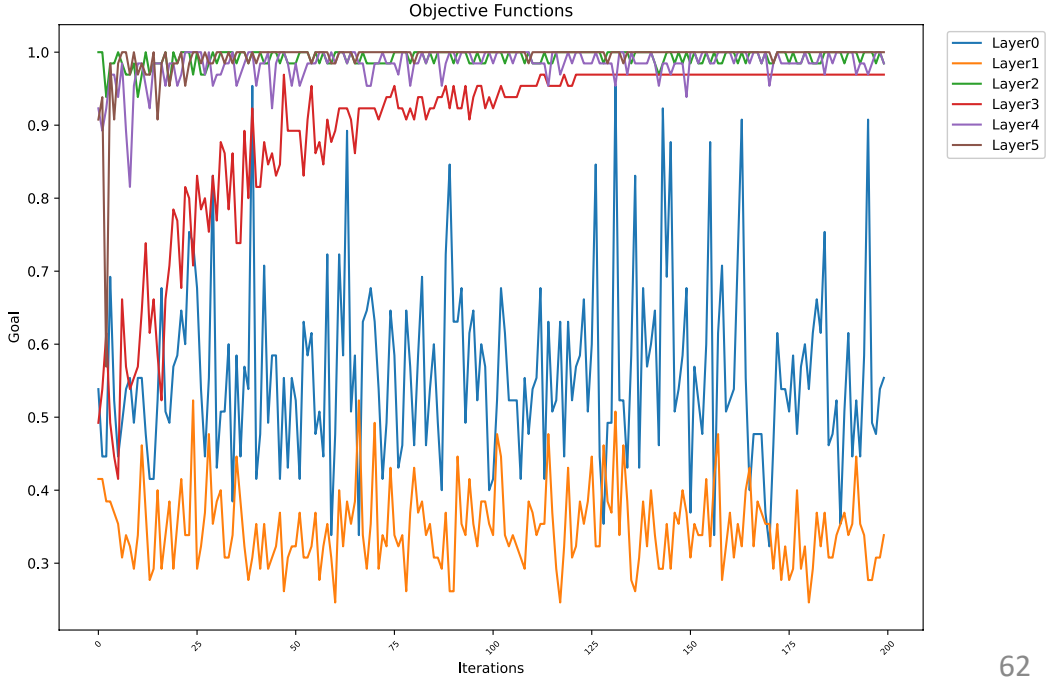
Table 3: Parameter Configuration of Example 3

Parameter	Layer 0	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5
Intra-pheromone factor (α_{in})	0	0	2	2	1	1
Extra-pheromone factor (α_{ex})	1	2	2	2	2	2
Heuristic information factor (β)	1	1	2	1	1	1
Target Length of Objective Function (F)	4	4	16	4	32	8

6-voices Experiments







Thanks

Contact: Lluc.Bono.Rosselló@ulb.be