

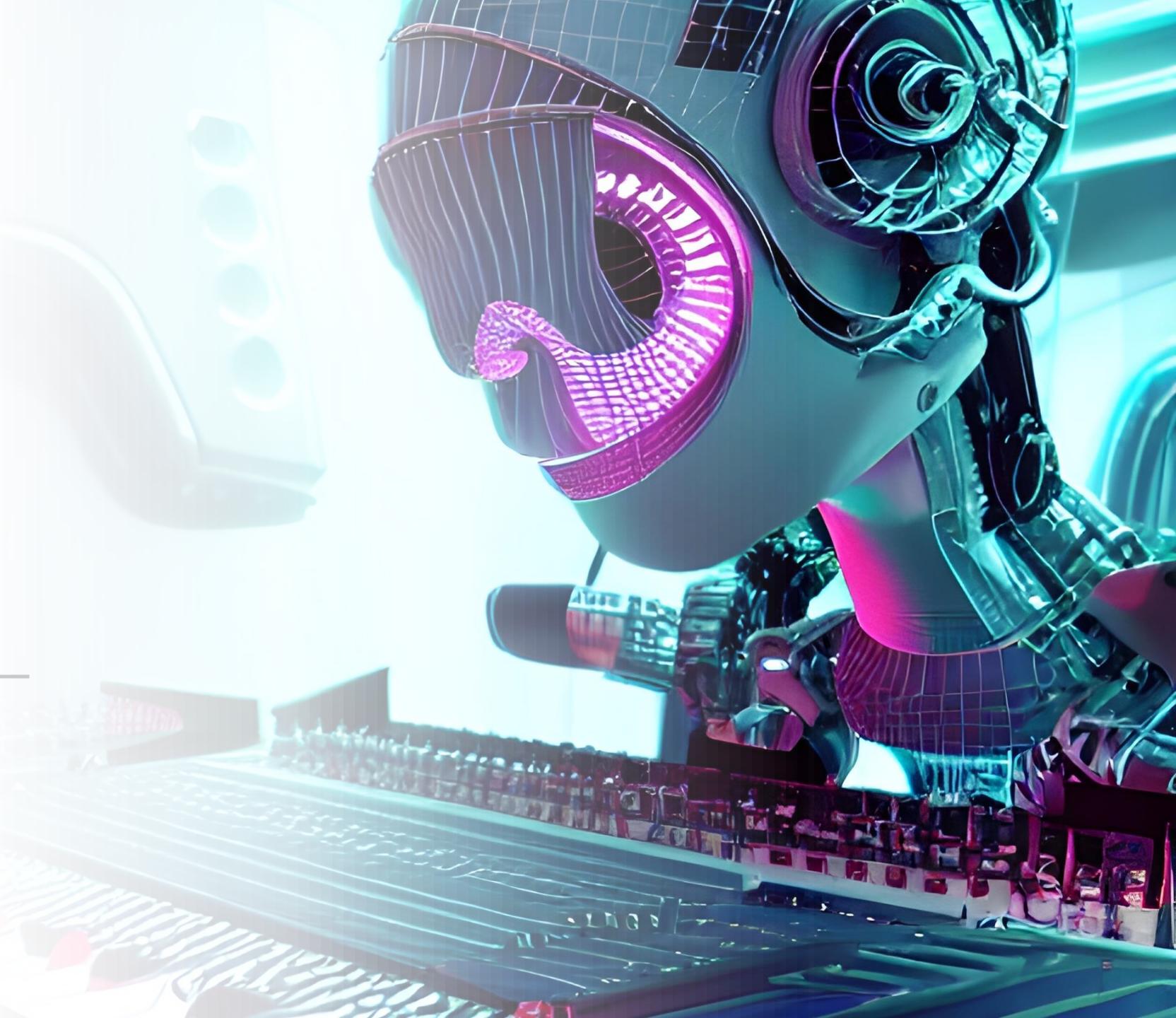


# **Selected Topics in Music and Acoustic Engineering: Build AI-enhanced Audio Applications in C++**

## **Lecture 6: AI improviser**

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**Dr Matthew Yee-King  
Spring 2023**

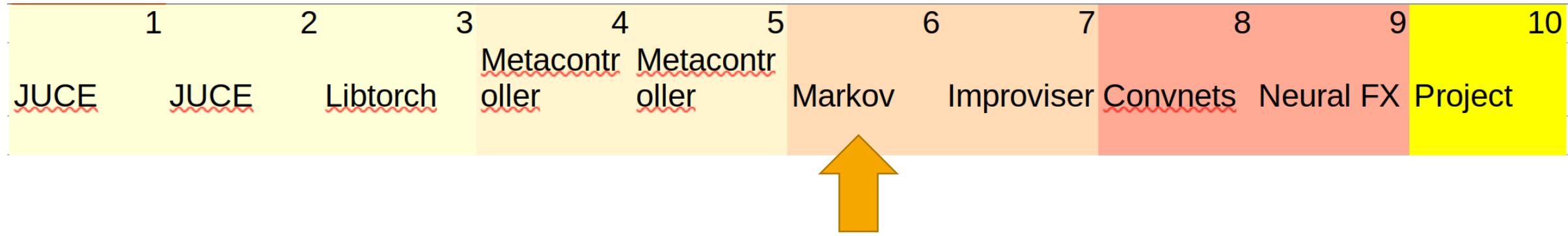


# Lecture summary

- Part 1: Meta-controller review
- Part 2: Beyond the sequencer
- Part 3: Hierarchical Markov models

# Recap of session 5

- Wekinator
- VST hosting
- Meta-controller



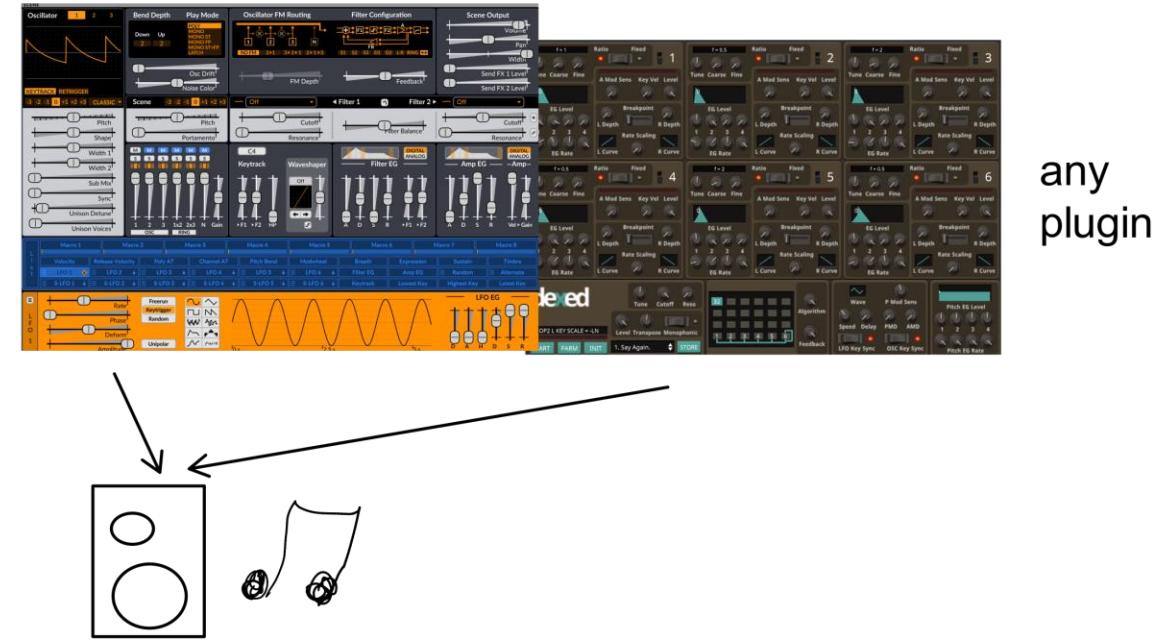
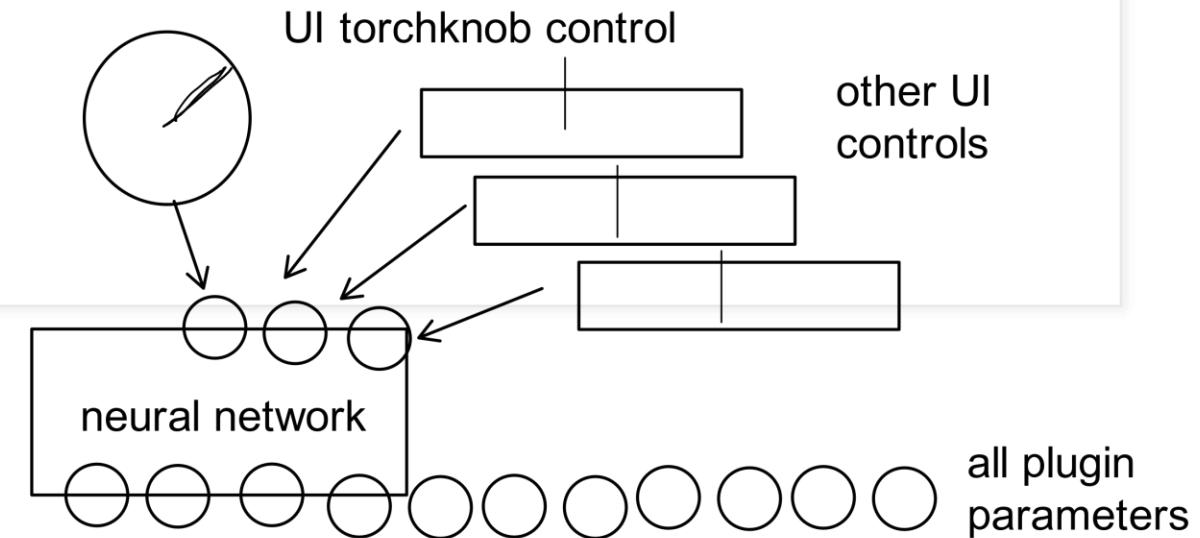
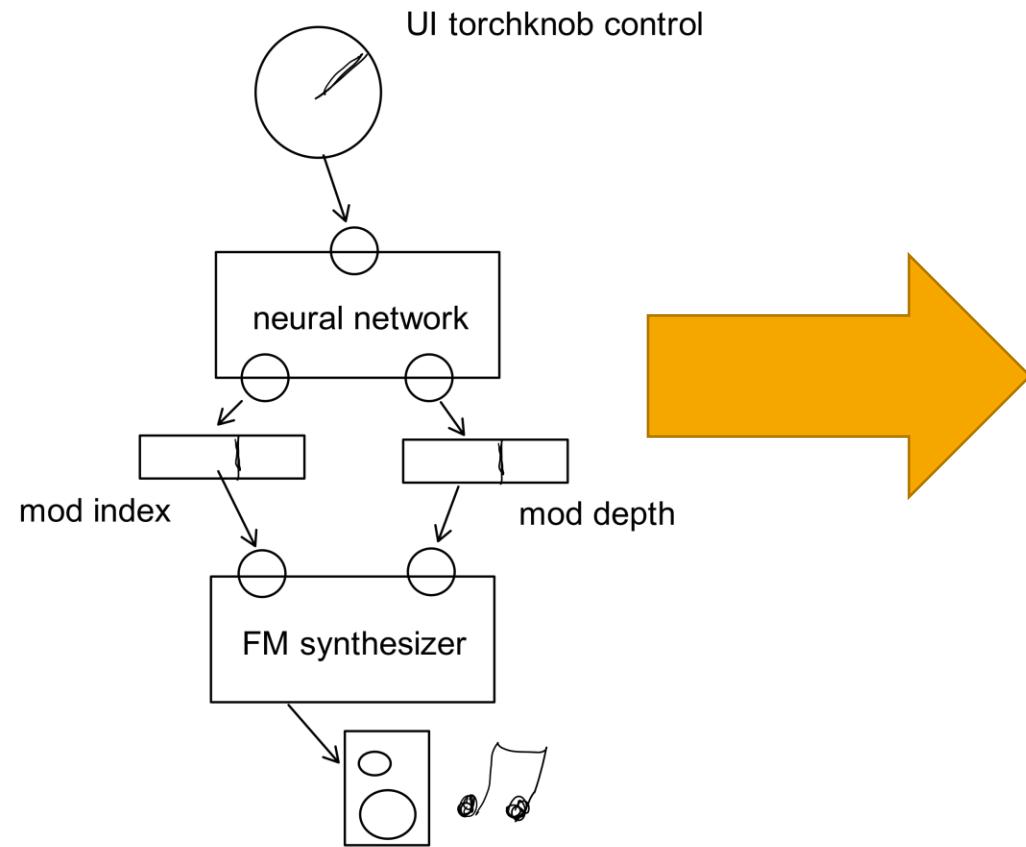
Where are we?



# Part 1: Meta- controller review

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# Meta-controller system architecture



# Plugin hosting a plugin concept

- Can now query the plugin for its parameters

Meta-controller host



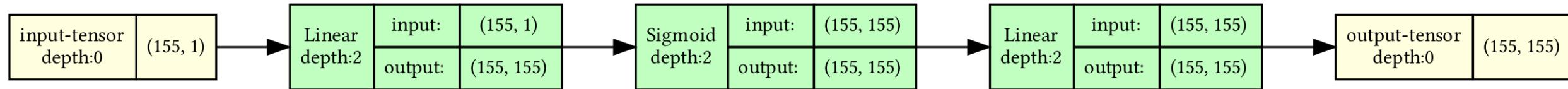
DAW host: Reaper, logic etc.

Param Output  
Param MASTER TUNE ADJ  
Param ALGORITHM  
Param FEEDBACK  
Param OSC KEY SYNC  
Param LFO SPEED  
Param LFO DELAY  
Param LFO PM DEPTH  
Param LFO AM DEPTH  
Param LFO KEY SYNC  
Param LFO WAVE  
Param TRANPOSE  
Param P MODE SENS.  
Param PITCH EG RATE 1  
Param PITCH EG RATE 2  
Param PITCH EG RATE 3  
Param PITCH EG RATE 4  
Param PITCH EG LEVEL 1  
Param PITCH EG LEVEL 2  
Param PITCH EG LEVEL 3  
Param PITCH EG LEVEL 4  
Param OP1 EG RATE 1  
Param OP1 EG RATE 2



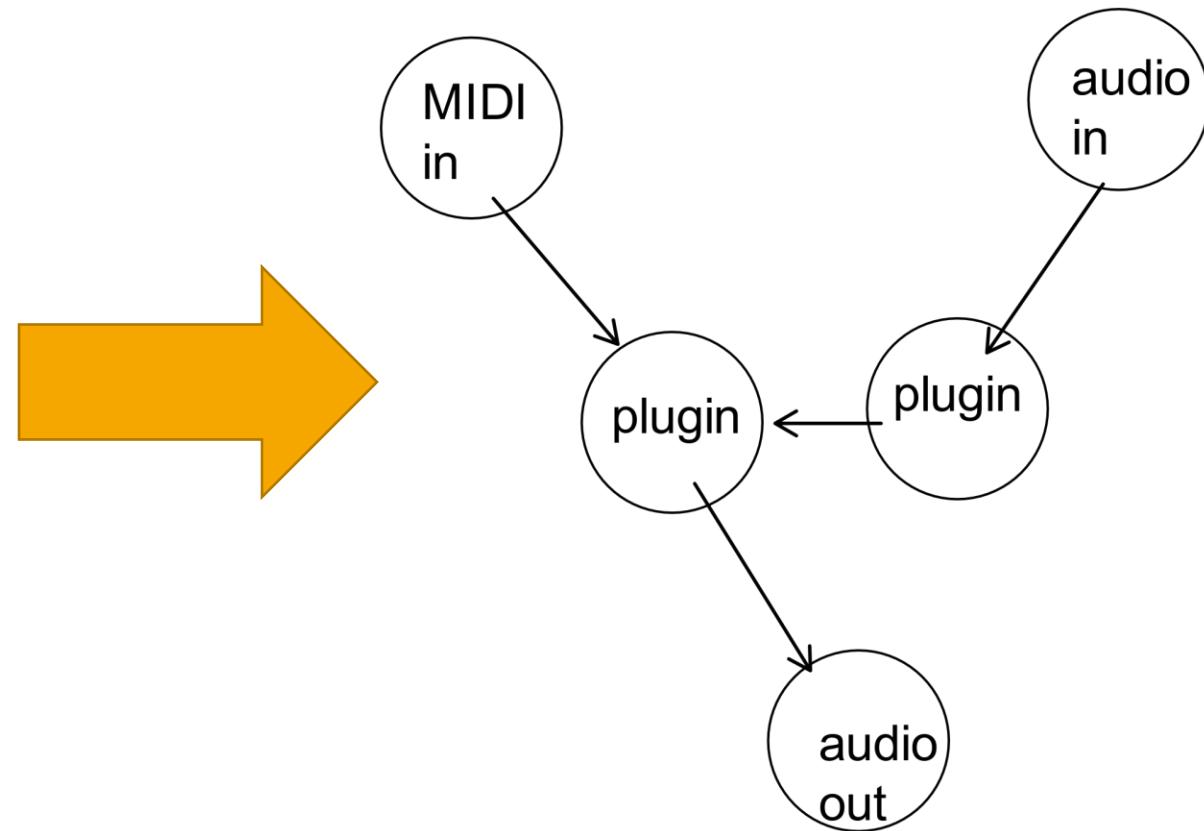
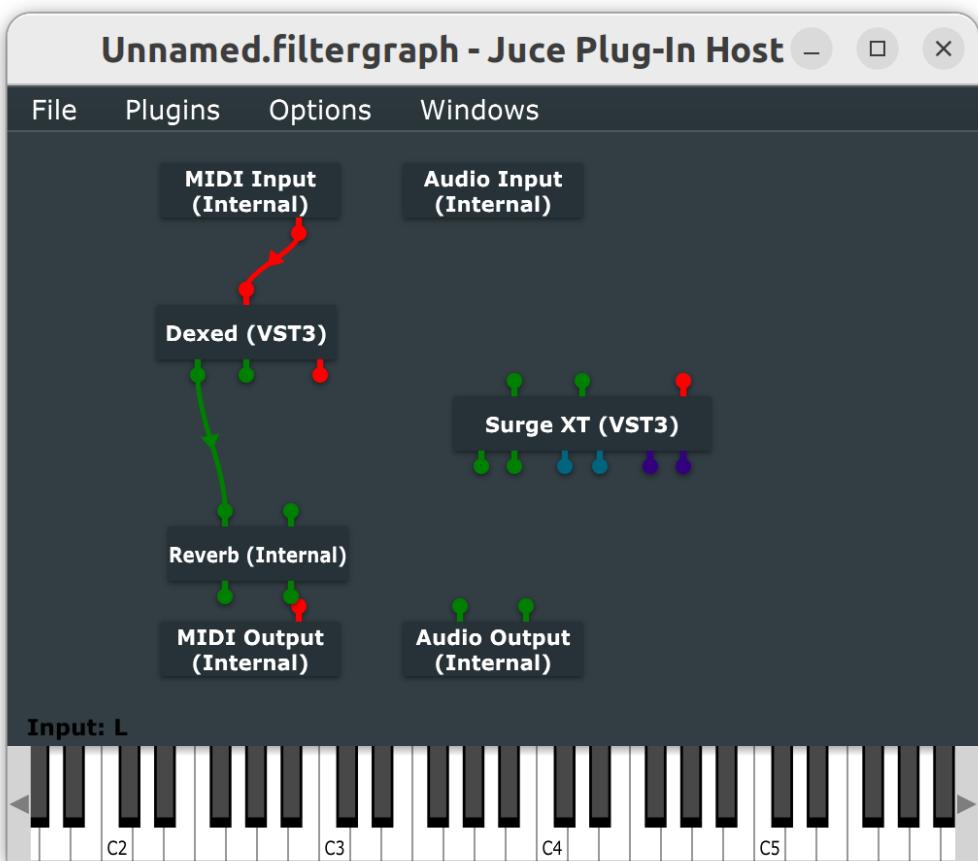
# How many parameters?

- Dexed: 155
- SurgeXT: **775**



# Neural network for Dexed control: 155 hidden nodes

# Audio Processor Graph

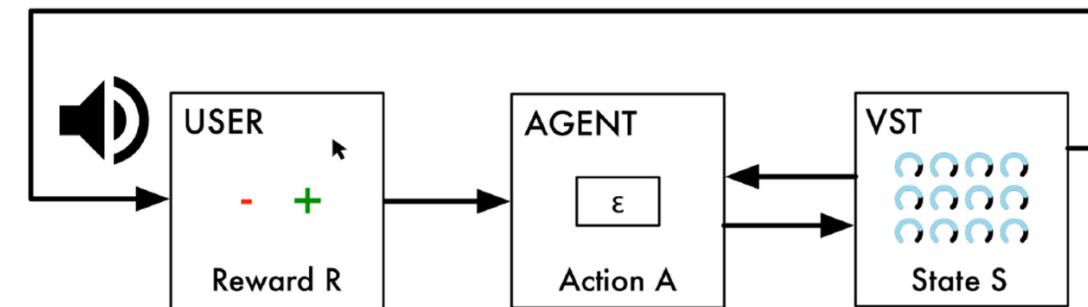


# Recent work with 'meta-controllers'

H. Scurto, B. V. Kerrebroeck, B. Caramiaux, and F. Bevilacqua, 'Designing Deep Reinforcement Learning for Human Parameter Exploration', *ACM Trans. Comput.-Hum. Interact.*, vol. 28, no. 1, p. 1:1-1:35, Jan. 2021, doi: [10.1145/3414472](https://doi.org/10.1145/3414472).



Fig. 9. Co-Explorer interface.



# Part 2: Sequencers

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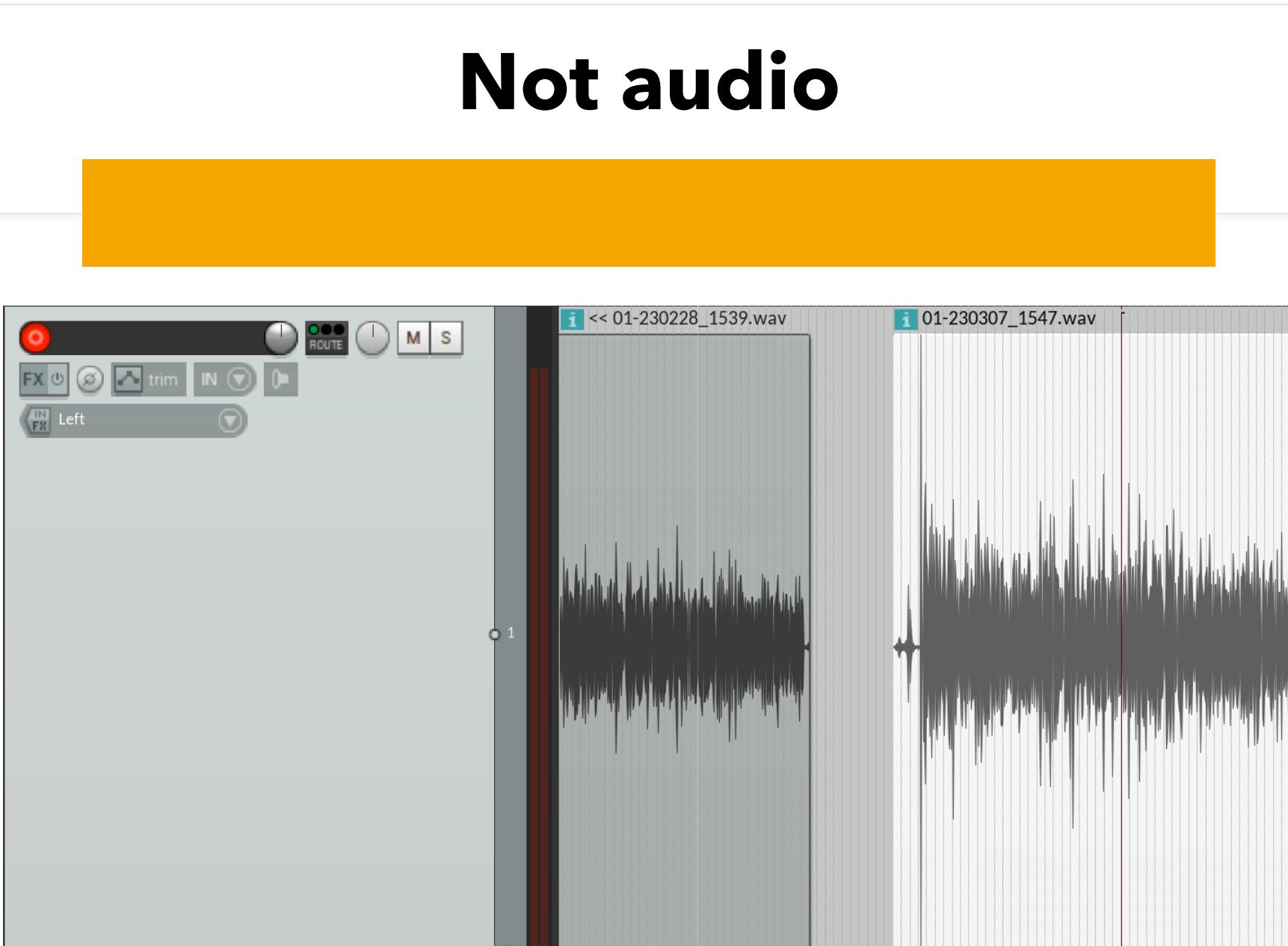


# What are we dealing with here? Symbolic representations

The screenshot shows a DAW interface with a MIDI track named "untitled MIDI item". The track displays several horizontal bars representing notes. Above the track, the time signature is set to 3.1.00 / 0:04.000. To the right of the track is a toolbar with various icons. Below the toolbar is a table that provides a symbolic representation of the MIDI data.

Index	Position	Length	Chan	Type	Parameter	Value	On
1 <<	2.4.00	0.0.38	1	Note	A2	96	0
2	2.4.25	0.0.75	1	Note	A#1	96	0
3	2.4.50	0.0.50	1	Note	F3	96	0
4	2.4.50	0.0.63	1	Note	C#0	96	0
5	2.4.88	0.0.38	1	Note	C#1	96	0
6	3.1.63	0.0.50	1	Note	G#2	96	0
7	4.1.00		1	(end)	All	0	0

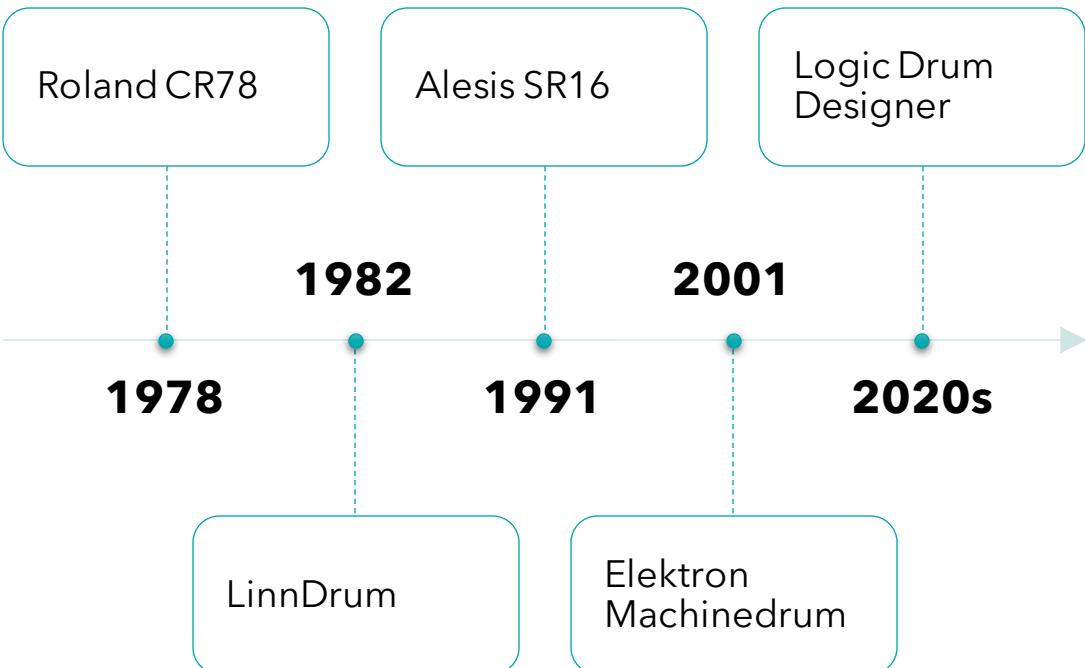
# Not audio





**Sequencing of symbolic musical data is not  
new**

# Drum machines





# Sequencers

Raymond Scott  
Electronium

Korg SQ10

DAWs

1964

1989

2014

1950s

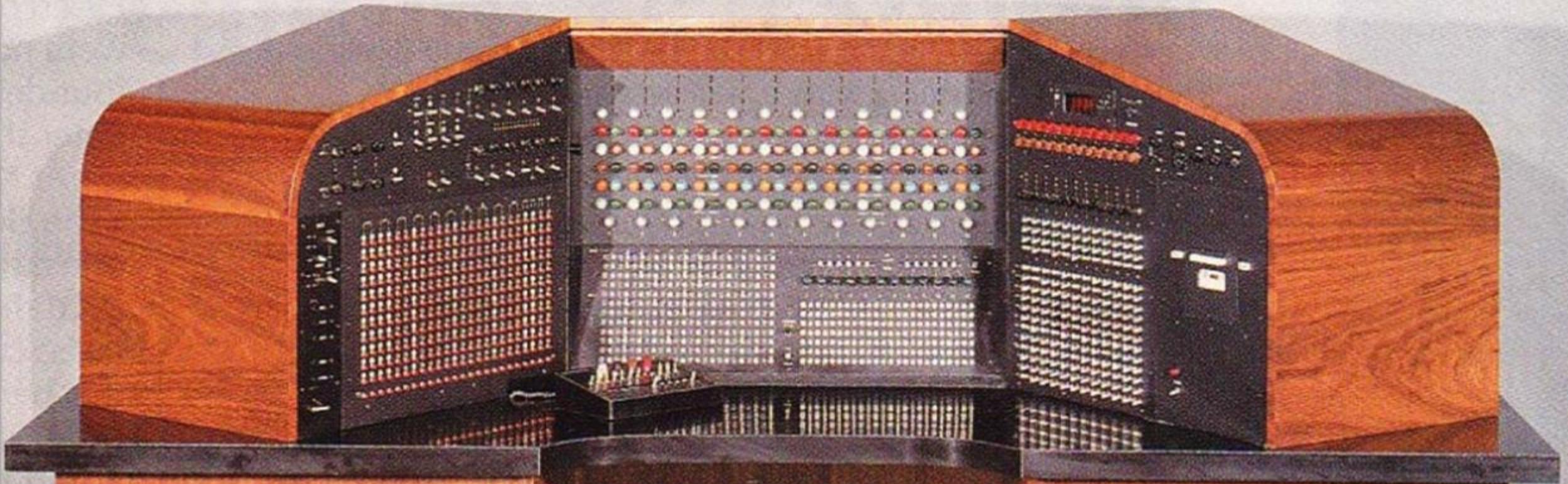
1978

1990s

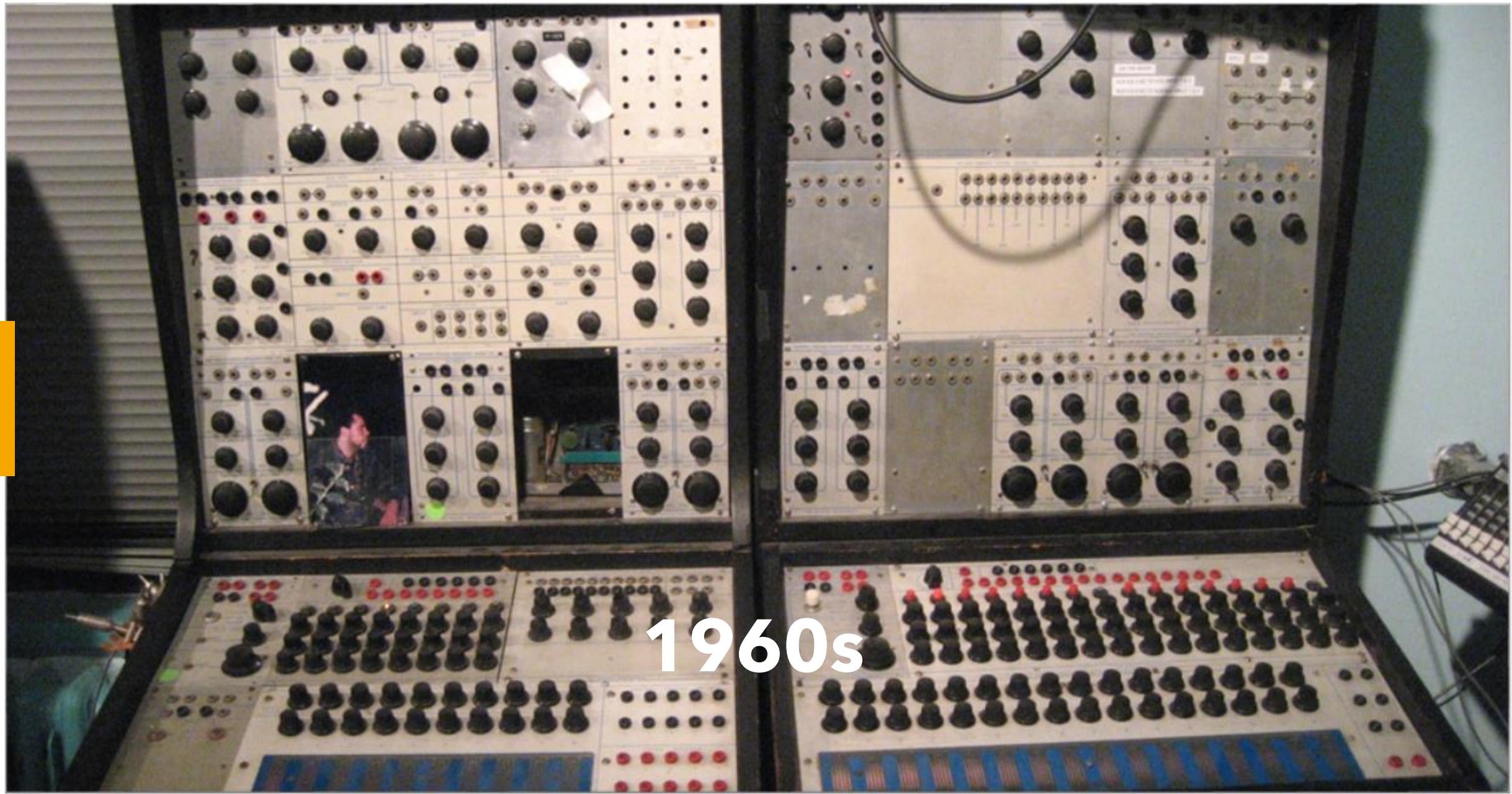
Buchla 100

Cubase, Trackers

Bitwig



1950s



1960s

# 1970s





1980s



0006 / 0023 001 / 016 12 E SP CHRD [redacted] 01 JPBrass2.u20 4 5 01 / 01

	0	1	2	3	4	5	6	7								
8																
000	A-2	5000	C-3	8000	D-2	3000	---	0000	D-1	2000	---	0000	D-3	4000	---	0000
001	---	0000	C-3	8000	D-3	3000	---	0000	---	0000	---	0000	---	0000	---	0000
002	A-2	5000	C-3	8000	D-2	3000	---	0000	D-1	2000	---	0000	D-3	4000	---	0000
003	A-2	5000	C-3	8000	D-2	3000	---	0000	---	0000	---	0000	---	0000	---	0000
004	A-2	6000	C-3	8000	D-3	3000	D-3	1000	D-2	2000	A-2	1000	D-3	4000	---	0000
005	---	0000	C-3	8000	D-2	3000	---	0000	---	0000	---	0000	---	0000	---	0000
006	A-2	5000	C-3	8000	D-2	3000	---	0000	---	0FFF	D-3	4000	---	0000	---	0000
007	---	0000	C-3	8000	A-2	3000	---	0000	---	0000	---	0000	---	0000	---	0000
008	A-2	5000	C-3	8000	C-3	3000	C-3	1000	D-1	2000	A-2	1000	D-3	4000	---	0000
009	A-2	5000	C-3	8000	C-3	3000	C-3	1000	D-1	2000	A-2	1000	D-3	4000	---	0000

1980s-90s



# 1990s- 2000s



## New Tune 4

Structure Edit Functions View Options

72.0000 4 4 /16

6 selected  
Qua 1/16-Note  
Loop ON  
Transpose \*  
Velocity \*  
Dynamics  
Gate Time  
Delay

SuggStak  
MX13  
Yamaha  
1 Drag  
1 Drag  
Pro 71\*recorded  
M-YS1  
M-YS1  
Dragon Hall\*recorded  
Fireflut\*recorded

1 9 17 25 33 41 49 57



# NERDSEQ

HYBRID TRACKER SEQUENCER



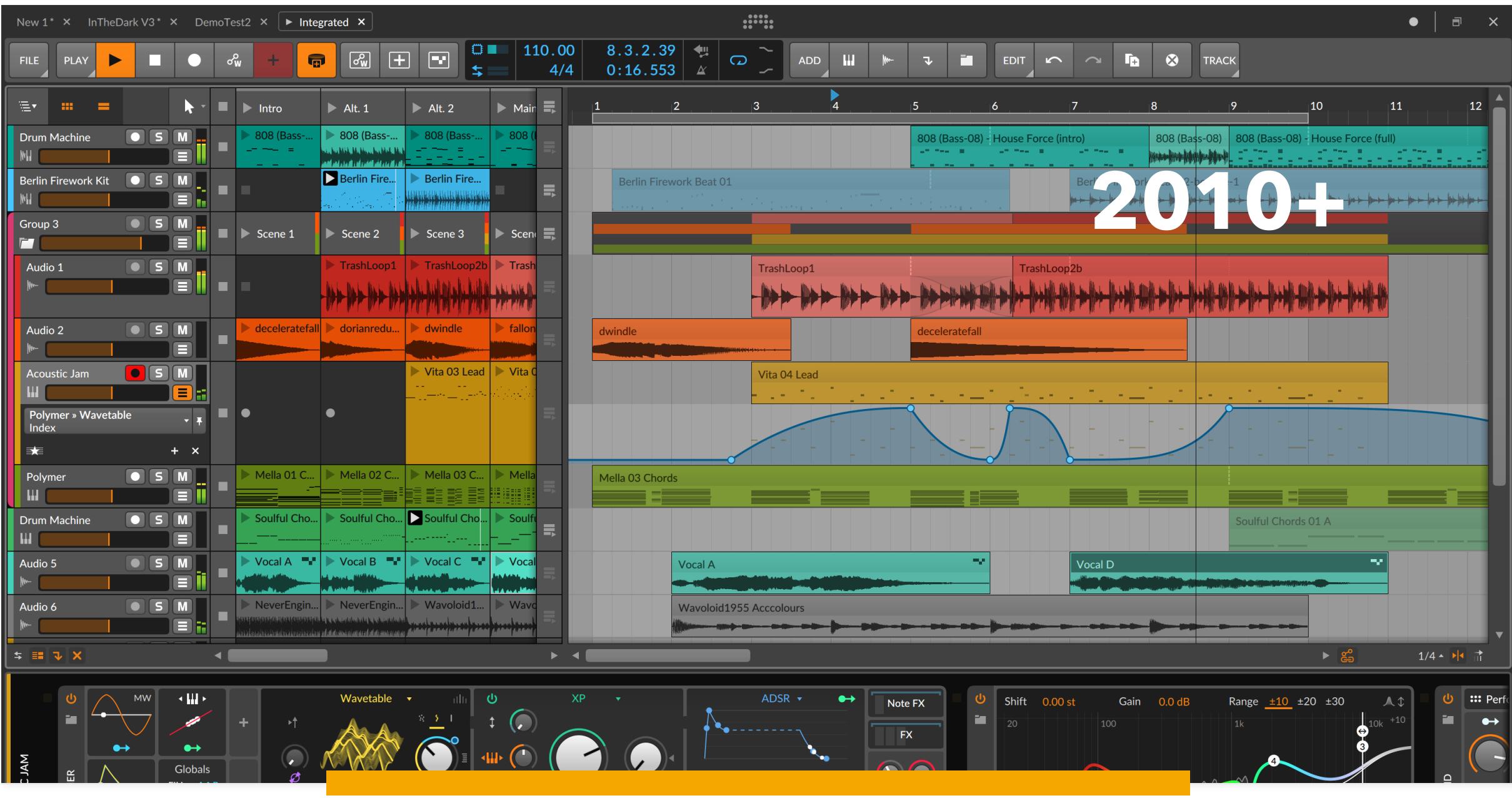
2010+

SHIFT

OK

DOWN





# Sequencing sound objects

B. Truax, 'The POD system of interactive composition programs', Computer Music Journal, pp. 30-39

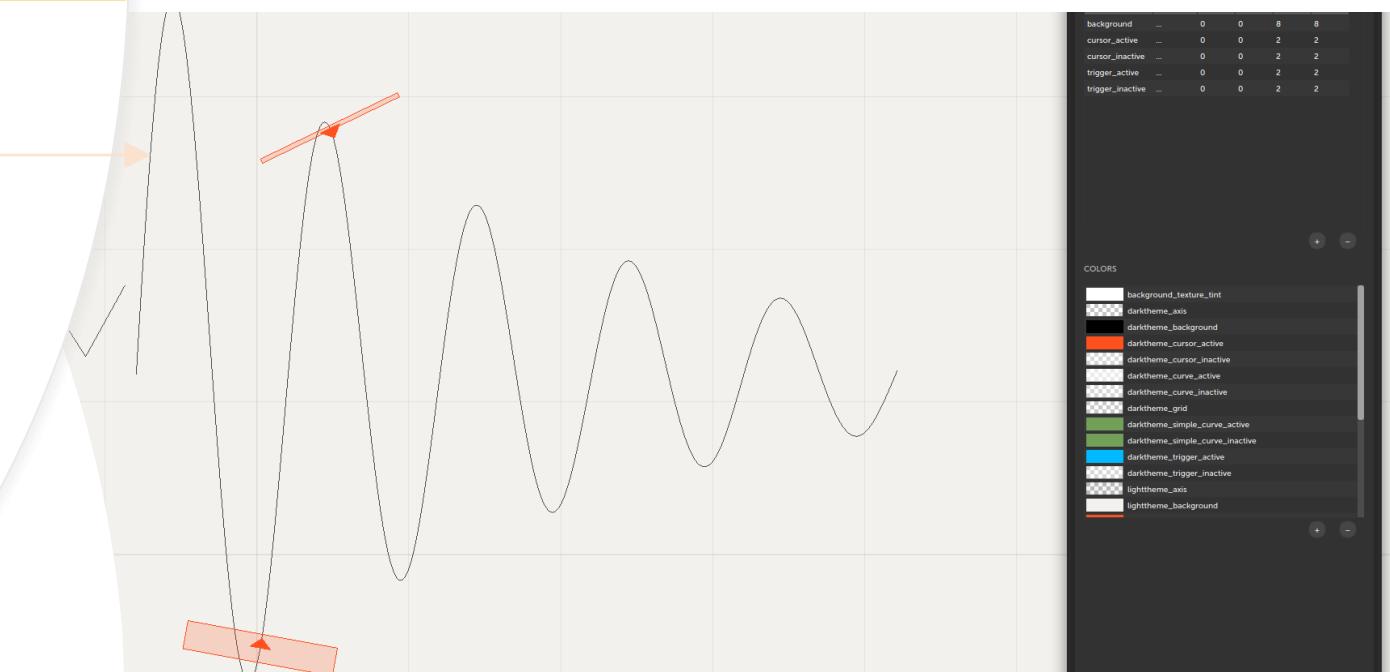
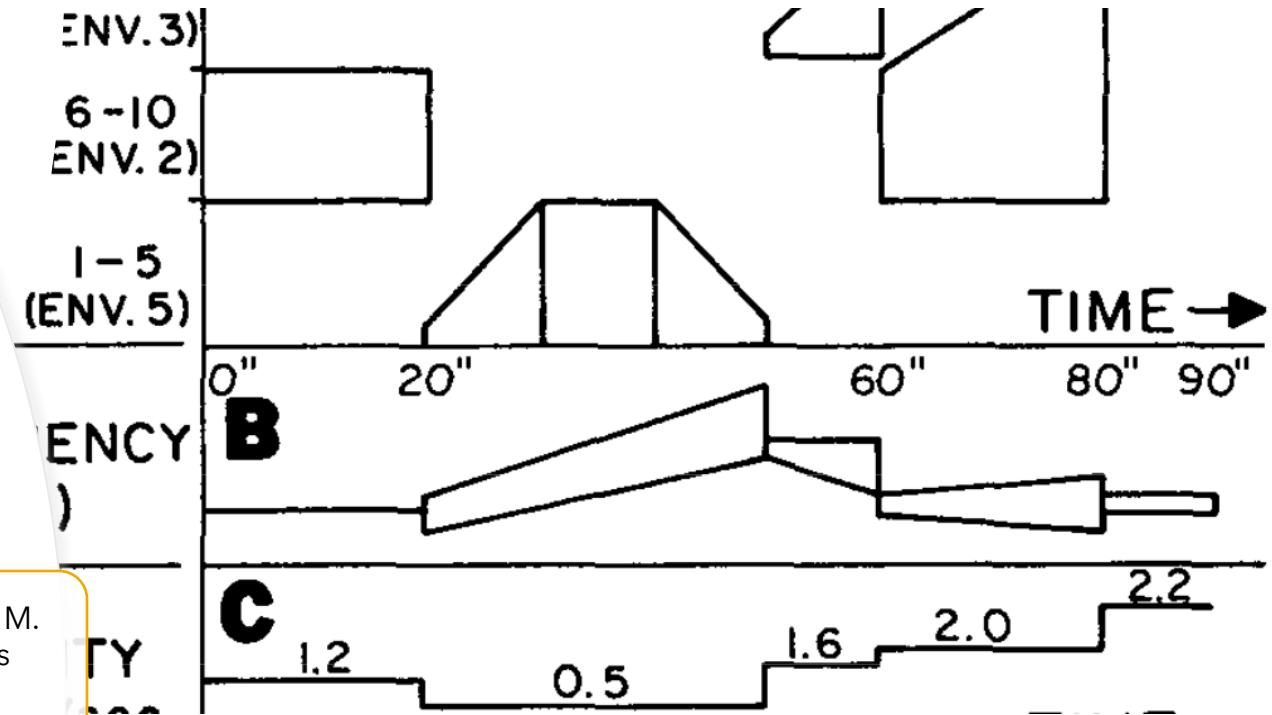
G. Jacquemin, T. Coduys, and M. Ranc, 'IANNIX 0.8', in Journées d'Informatique Musicale

1977

1990s

2004-2012

M. Puckette, 'Pure Data: another integrated computer music environment', *Proceedings of the second intercollege computer music concerts*, pp. 37-41, 1996.



# Limited research work here!

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I found limited work examining music sequencers .

M. Duignan, J. Noble, and R. Biddle, 'A taxonomy of sequencer user-interfaces', in *ICMC*, 2005.

Characteristic		
Medium	Textual	Graphical
Abstraction Level	Predetermined	Custom
Linearisation Stage	Eager	Delayed
Event Ordering	Control	Data
Applicability	Special	General



## **Part 3: A brief overview of algorithmic composition**

# **Algorithmic composition represents a huge body of work**

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**"Since [the 1960s], researches on algorithmic composition has emerged in an endless stream"**

S. Ji, J. Luo, and X. Yang, 'A comprehensive survey on deep music generation: Multi-level representations, algorithms, evaluations, and future directions', *arXiv preprint arXiv:2011.06801*, 2020.

# Music generation is a popular subject for surveys

. Papadopoulos and G. Wiggins, 'AI methods for algorithmic composition: A survey, a critical view and future prospects', in AISB symposium on musical creativity, 1999, vol. 124, pp. 110-117 203

D. Herremans, C.-H. Chuan, and E. Chew, 'A functional taxonomy of music generation systems', ACM Computing Surveys (CSUR), vol. 50, no. 5, pp. 1-30, 2017..

C. Hernandez-Olivan and J. R. Beltran, 'Music composition with deep learning: A review', Advances in Speech and Music Technology: Computational Aspects and Applications, pp. 25-50, 2022.

1999

2013

2017

2020

2022

J. D. Fernández and F. Vico, 'AI methods in algorithmic composition: A comprehensive survey', Journal of Artificial Intelligence Research, vol. 48, pp. 513-582, 2013.

S. Ji, J. Luo, and X. Yang, 'A comprehensive survey on deep music generation: Multi-level representations, algorithms, evaluations, and future directions', arXiv preprint arXiv:2011.06801, 2020.

## Techniques [2017]

D. Herremans, C.-H. Chuan, and E. Chew, 'A functional taxonomy of music generation systems', ACM Computing Surveys (CSUR), vol. 50, no. 5, pp. 1-30, 2017..

- Markov models
- Factor oracles
- Incremental parsing
- Reinforcement learning
- Rule/Constraint satisfaction/Grammar-based
- Neural networks/Restricted Boltzmann machines/ LSTM
- Evolutionary/Population-based optimization algorithms
- Local search-based optimization
- Integer Programming
- Other optimization methods

• [1]

"Since [2015], researches on algorithmic composition with deep learning has emerged in an endless stream" (paraphrased)

S. Ji, J. Luo, and X. Yang, 'A comprehensive survey on deep music generation: Multi-level representations, algorithms, evaluations, and future directions', *arXiv preprint arXiv:2011.06801*, 2020.

Since 2017...  
deep learning

# Developments in melody generation with deep networks

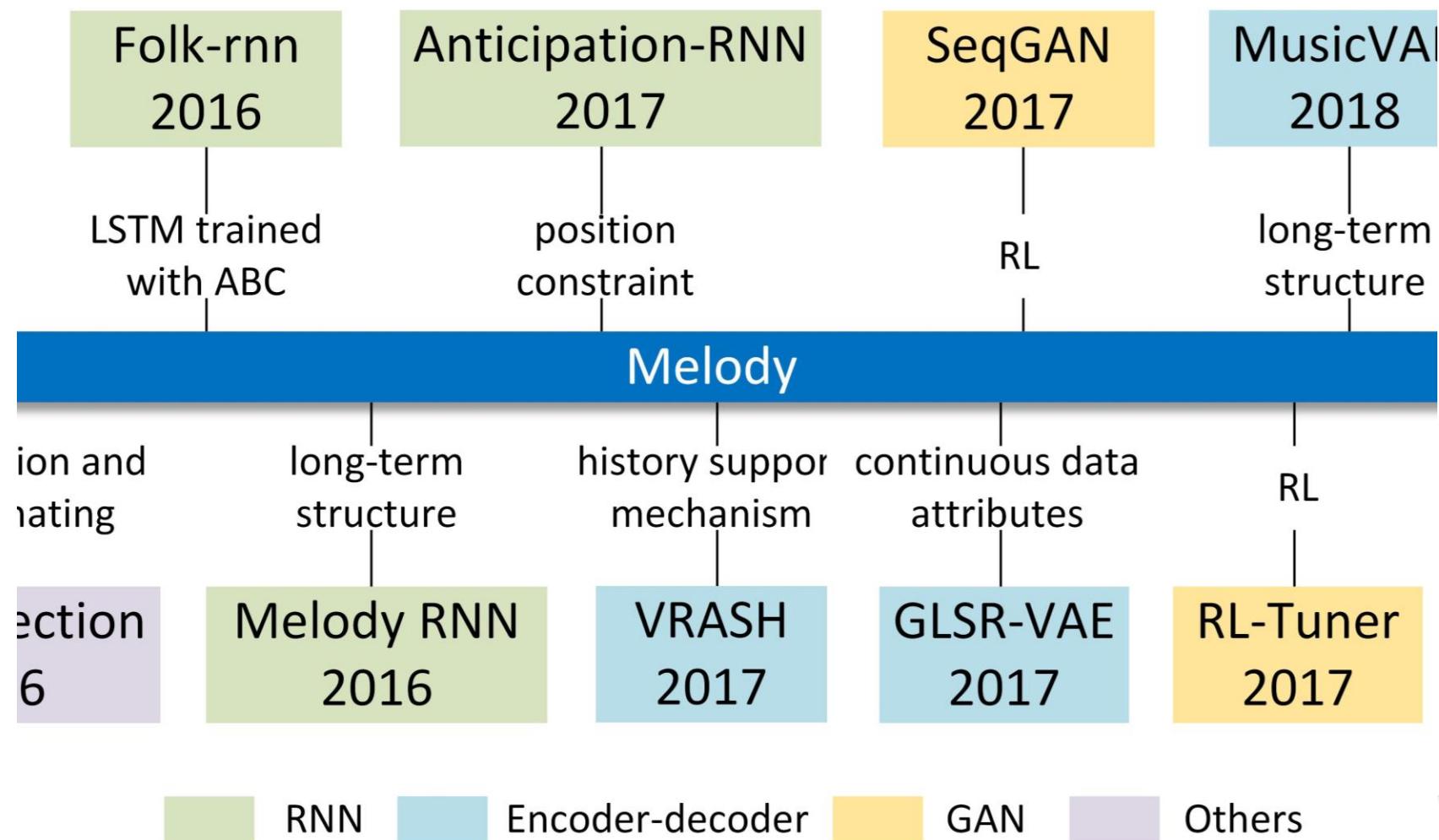


Fig 6 Chronology of melody generations from S. Ji, J. Luo, and X. Yang, 'A comprehensive survey on deep music generation: Multi-level representations, algorithms, evaluations, and future directions', *arXiv preprint arXiv:2011.06801*, 2020.

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## **Algorithmic composition in commercial software**

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- Logic Pro
  - Arpeggiator
  - MIDI FX
  - Drum Machine Designer
  - Chord Track
- Cubase
  - Arpeggiator
  - MIDI FX
  - Groove agent
  - Chord Track

# Summary

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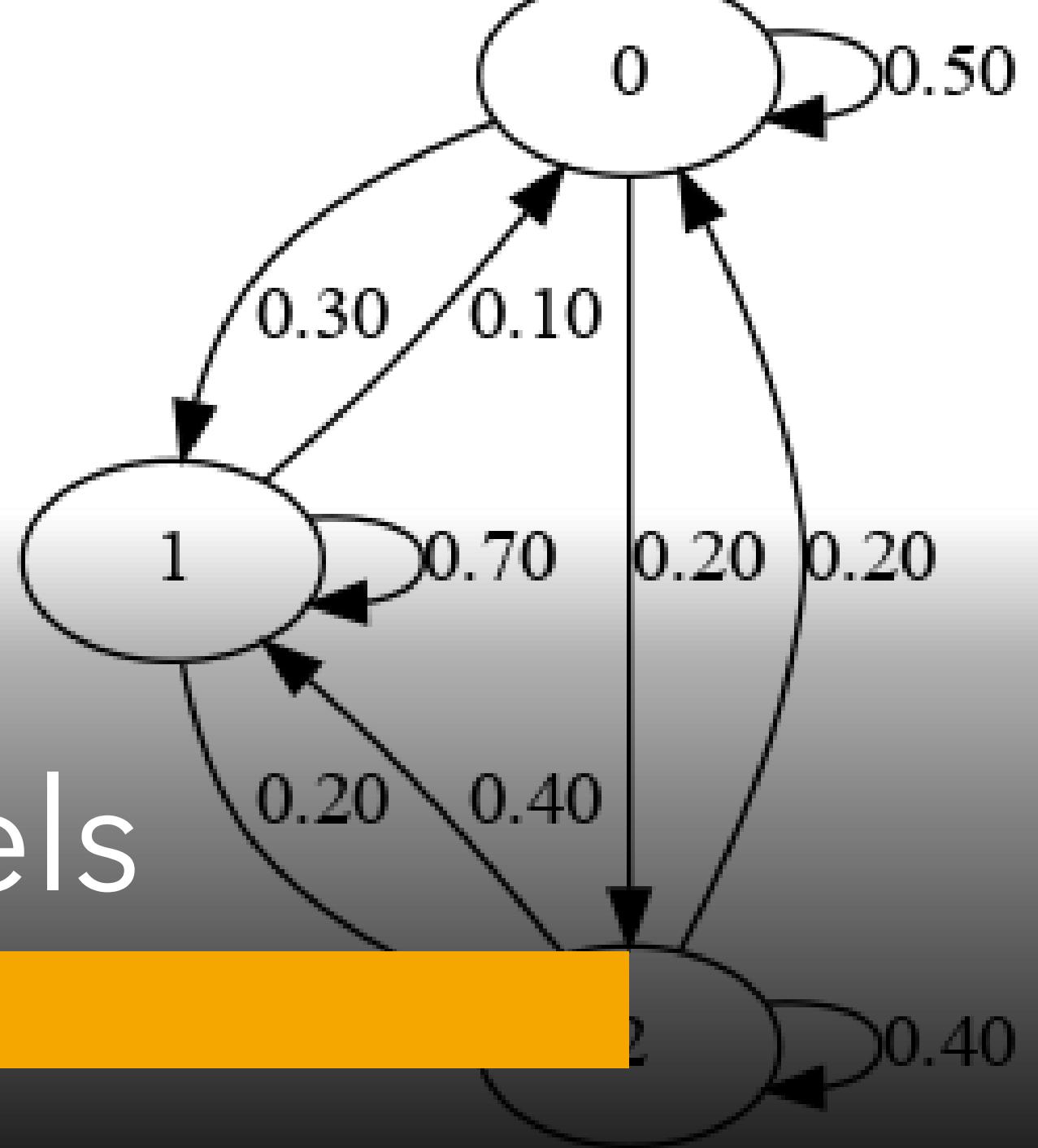
- **There is a long history of sequencer technology**
- **Algorithmic composition is a heavily studied topic**
- **Deep learning is a popular technique at the moment, but many other techniques exist and have musical value**



## PART 4: Variable Markov Models and LSTMs

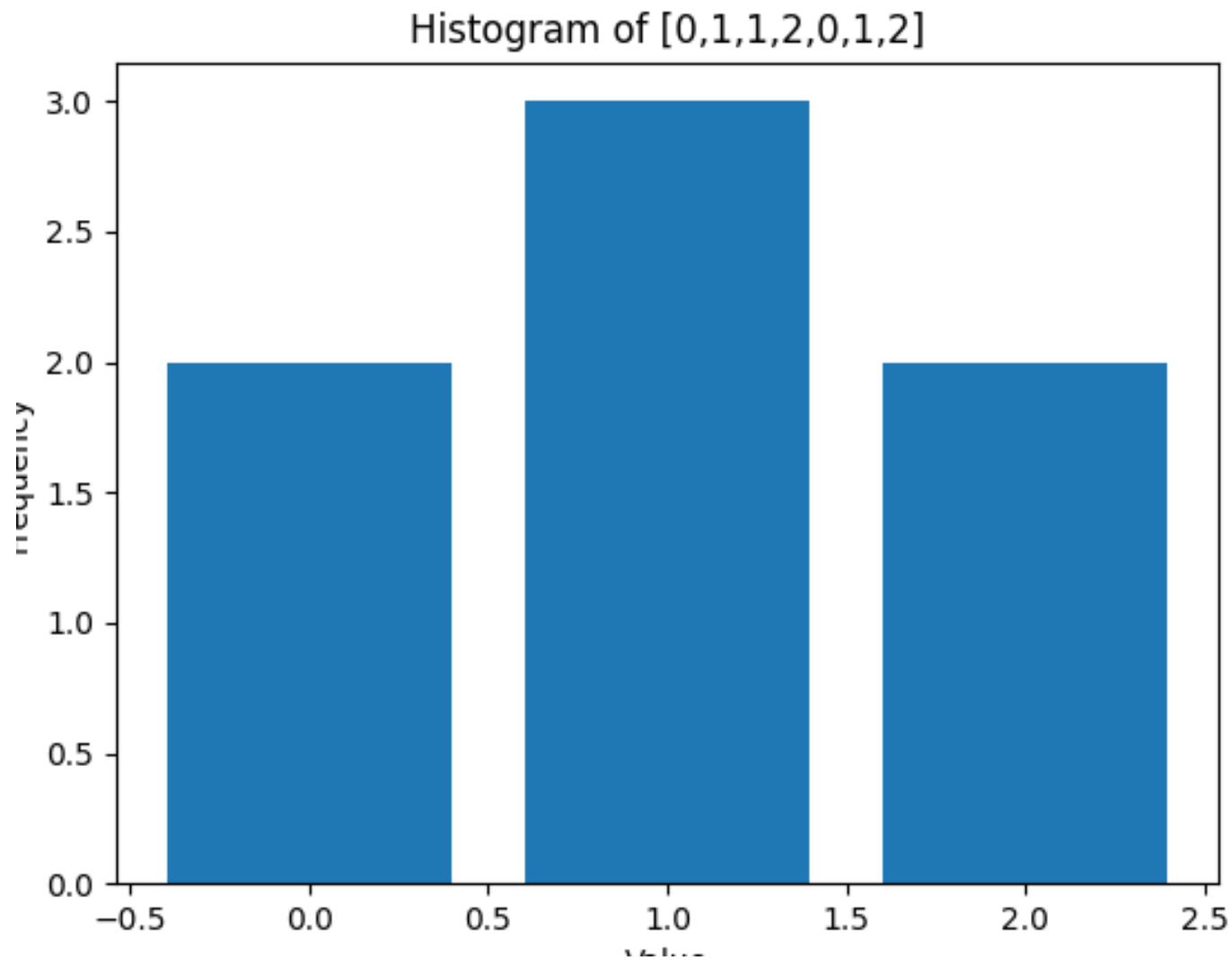
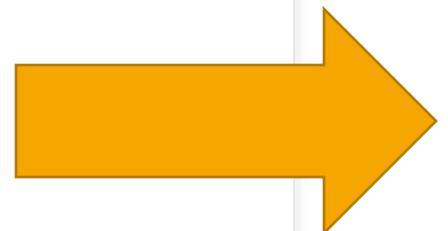
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# Markov models



# Zero order Markov model: just a distribution

Observed states:  
[0, 1, 1, 2, 0, 1, 2]



# First order Markov model: transitions

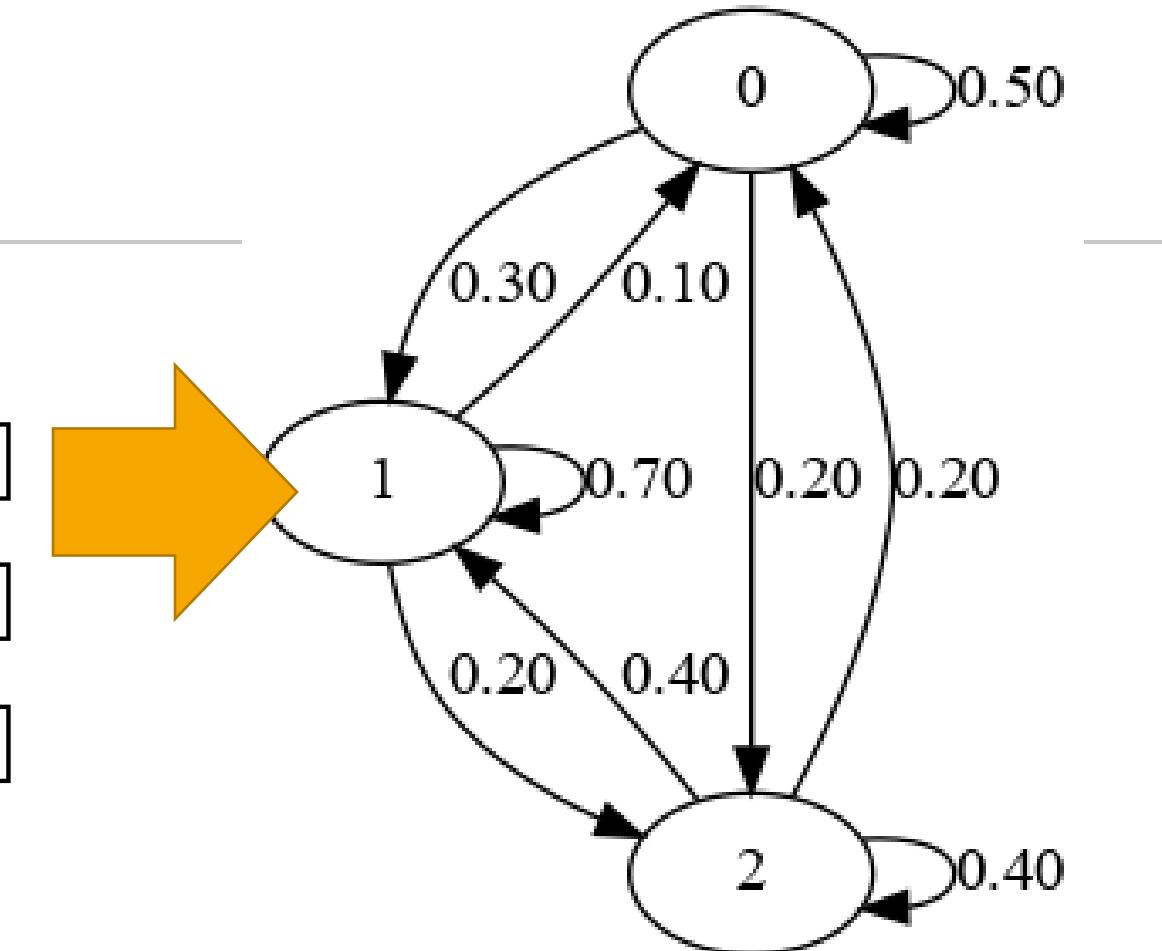
State transitions

	0	1	2
--	---	---	---

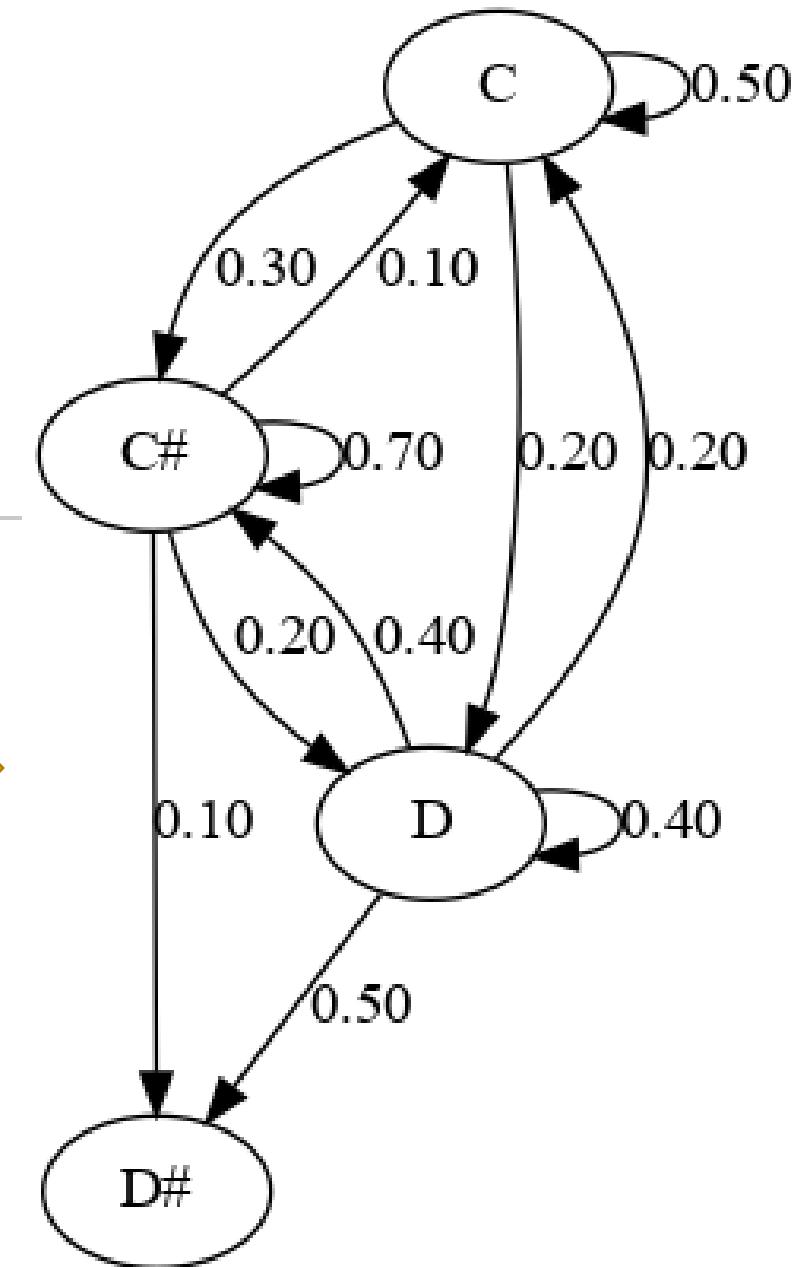
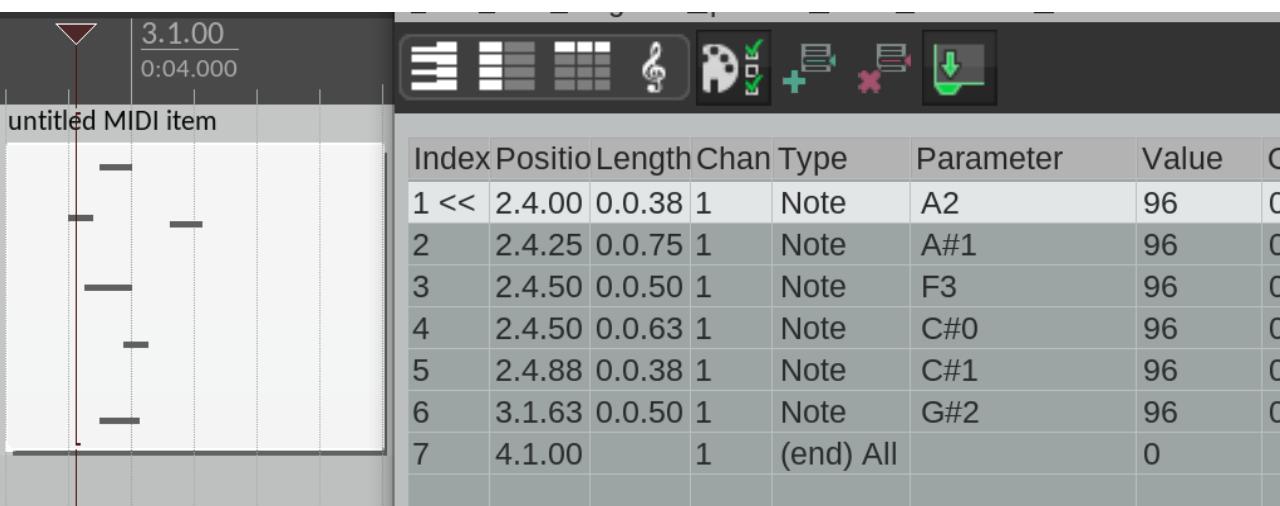
0	[0.5, 0.3, 0.2]		
---	-----------------	--	--

1	[0.1, 0.7, 0.2]		
---	-----------------	--	--

1	[0.2, 0.4, 0.4]		
---	-----------------	--	--

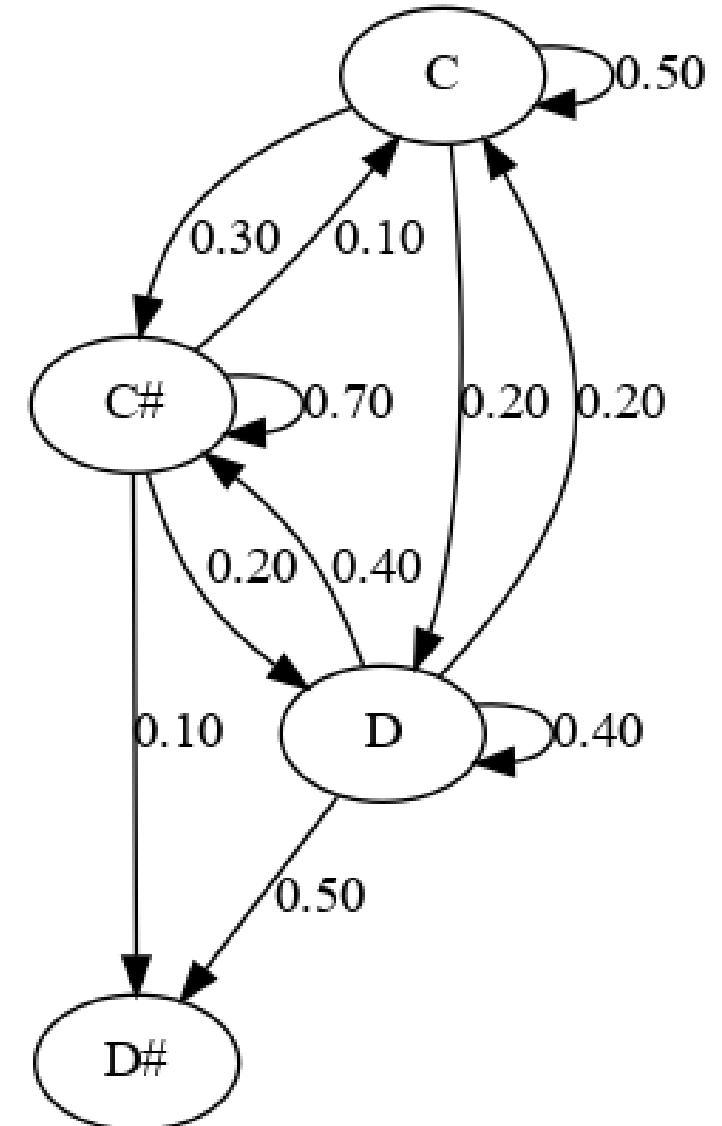


# Musical markov



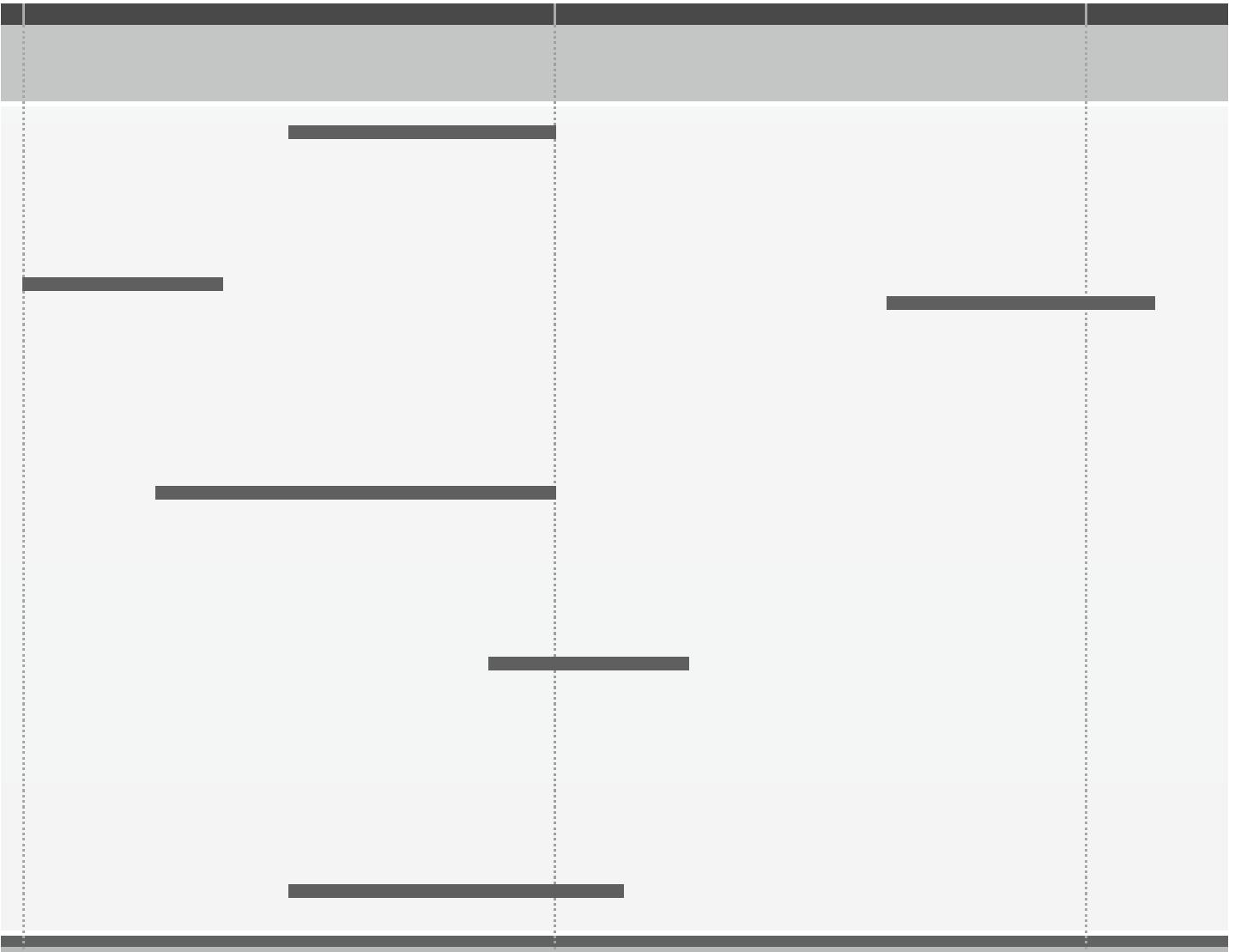
## Generating

- Select a starting state
- $\text{Rand}(0,1)$
- Select next state
- ...



# What are the states in music?

- Notes and rests: ["C", "D", "-", "-"]
  - Velocity: ["127", "65" .. ]
  - Note length ["0.5", "0.1"]

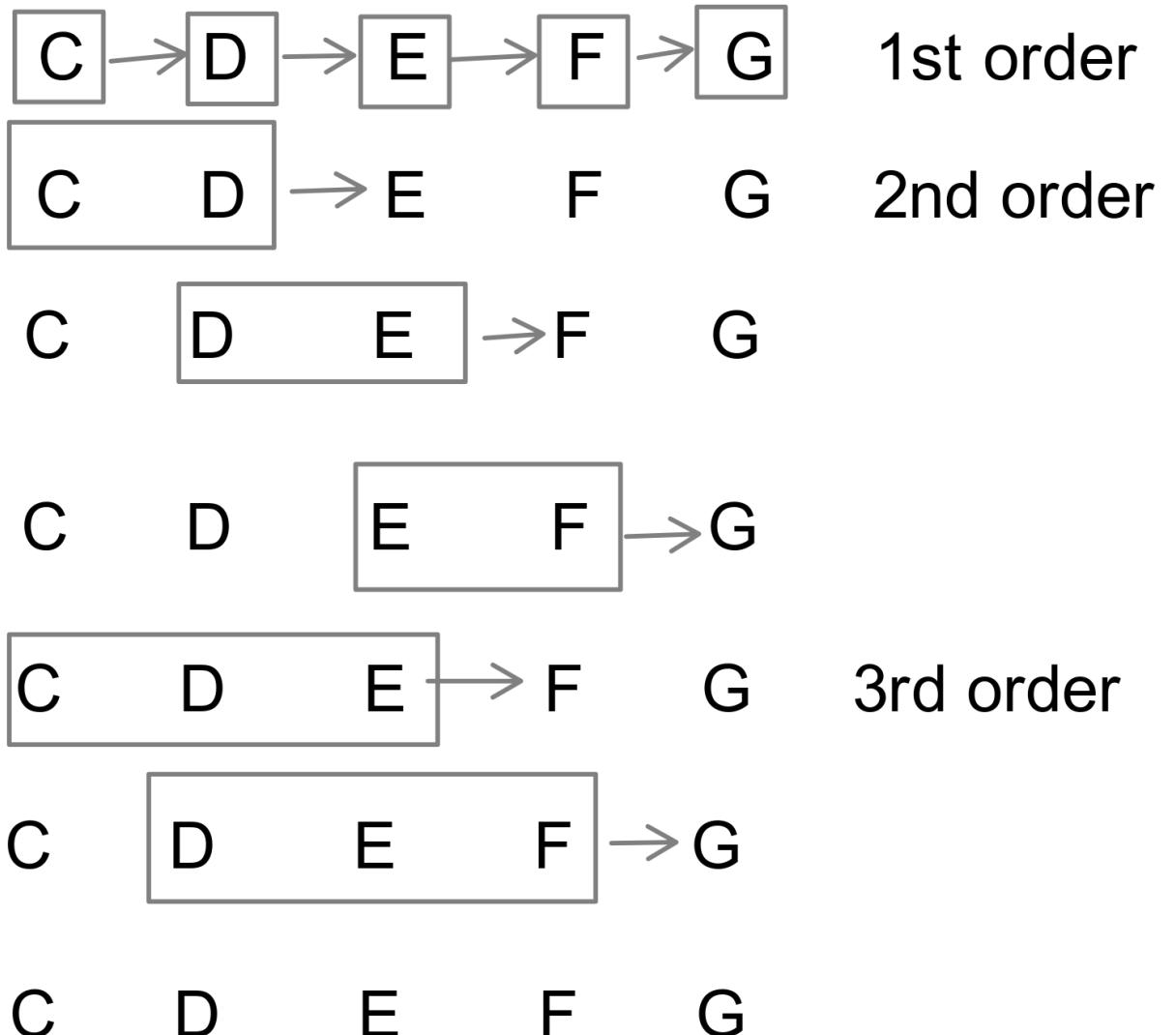


# Higher order

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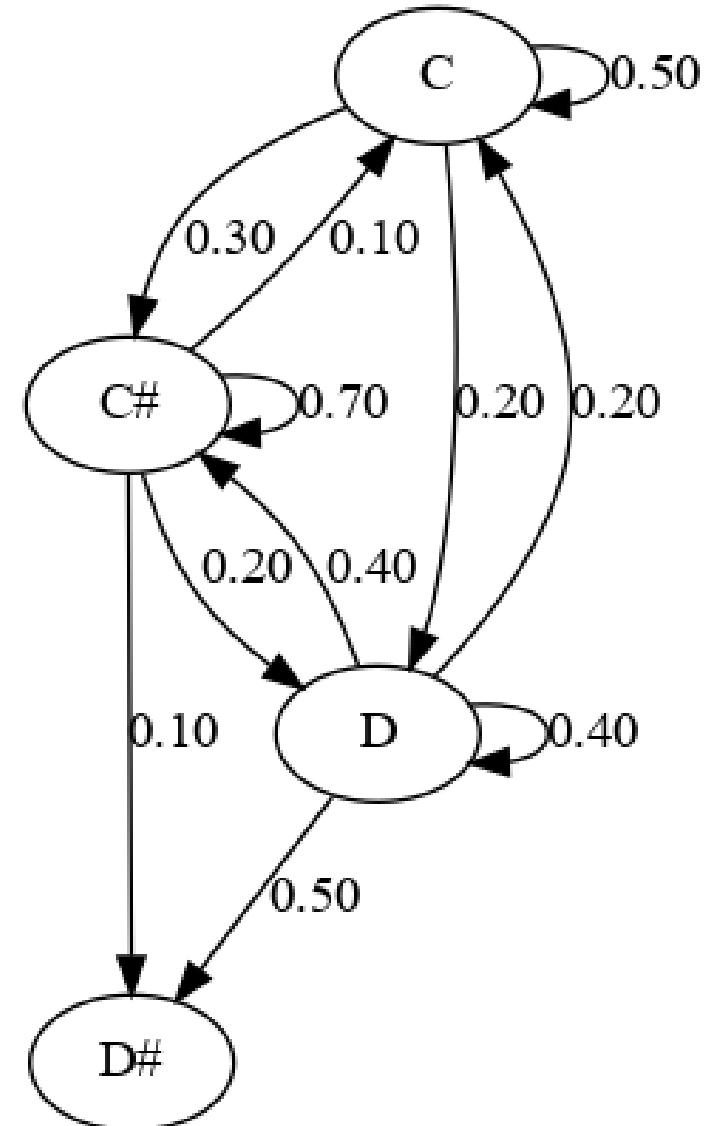
How many previous states?

Longer memory, less observations



## Generating with higher order

- Set memory = [C,D]
- Select a starting state
- Rand(0,1)
- Select next state
- ...



## Generating with variable order

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- Always choose the highest order with at least two options

# Markov models

- D. Herremans, C.-H. Chuan, and E. Chew, 'A functional taxonomy of music generation systems', *ACM Computing Surveys (CSUR)*, vol. 50, no. 5, pp. 1-30, 2017.

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## Markov models

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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)

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# About the lab

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- Build a plugin that hosts a plugin
- Query the plugin parameters
- Create a neural network
- Train the neural network



# Lecture summary

- Part 1: Torchknob review
- Part 2: Previous work: wekinator, learner.js
- Part 3: Meta-controller system design



# **Selected Topics in Music and Acoustic Engineering: Build AI-enhanced Audio Applications in C++**

## **Lecture 5: the meta-controller**

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**Dr Matthew Yee-King  
Spring 2023**

