



CARMINE-EMANUELE CELLA

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# INTRODUCTION AND STRUCTURE OF THE COURSE

MUSIC 159

# INSTRUCTOR

## Carmine-Emanuele Cella

Assistant professor, CNMAT/Music  
1750 Arch street

PhD musical composition  
PhD applied mathematics

[carmine.cell@berkeley.edu](mailto:carmine.cell@berkeley.edu)  
[www.carminecella.com](http://www.carminecella.com)

Office hour:  
Monday, 3pm-4pm

Call me Carmine!

Sound

Mathematics

Music



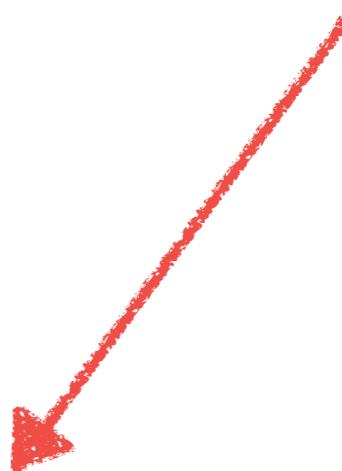
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# COURSE

## **Music 159**

### **Computer programming for music applications**

*Wow! So cool!!*



**Schedule: M 12:00P-2:59P | McEnerney (CNMAT)**

**(...in sequence with Music 158b)**

# REQUIREMENTS



Prerequisite:  
**158a/b or permission  
(programming practice,  
linear algebra)**



Textbook:  
**No full books but  
notes, papers, etc.**



All course  
materials online:  
**bcourses.berkeley.edu**



Computer access:  
**Personal laptop**



Software:  
**Max/MSP and  
Python (with packages),  
audio editor**

# SUGGESTIONS

## SUCCESS



Attend  
class



Participate  
constantly



Invest  
time



Focus on concepts



Seek help  
when needed

# POLICIES

## COURSE ENVIRONMENT



### Names/Pronouns

You deserve to be addressed in the manner you prefer. To guarantee that I address you properly, you are welcome to tell me your pronoun(s) and/or preferred name at any time, either in person or via email.



### Accessibility

I want you to succeed in this course. Contact me if you have special circumstances. I will find resources for you.



### Diversity

We embrace diversity of age, background, beliefs, ethnicity, gender, gender identity, gender expression, national origin, religious affiliation, sexual orientation, and other visible and non-visible categories. I do not tolerate discrimination.



### Title IX

You deserve a community free from discrimination, sexual harassment, a hostile environment, sexual assault, domestic violence, dating violence, and stalking. If you experience or know of a Title IX violation, you have many options for support and/or reporting.



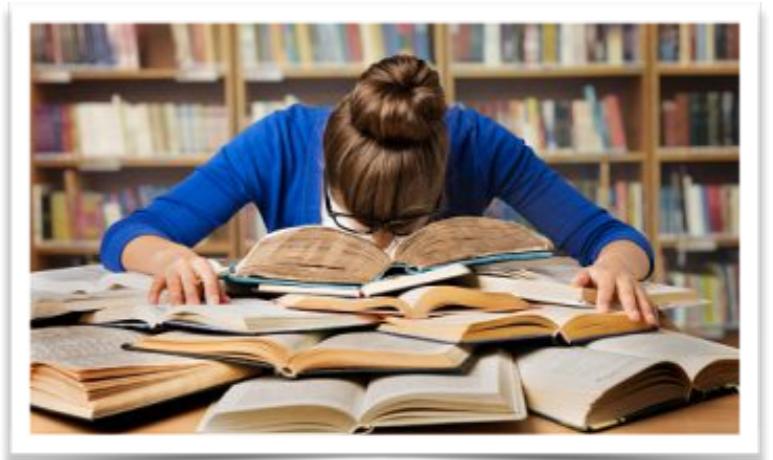
### Academic Integrity

The honor code is a cornerstone of our learning community and of this course. It is your responsibility to know and follow academic integrity policies. I will gladly answer any questions you have.

# GRADING



**30% attendance and participation**



**40% assignments**



**30% final exam**

*The grade distribution is: 100% -- 90% A; 89% -- 89% B; 79% -- 70% C; 69% -- 60% D; 59% -- 0% F*

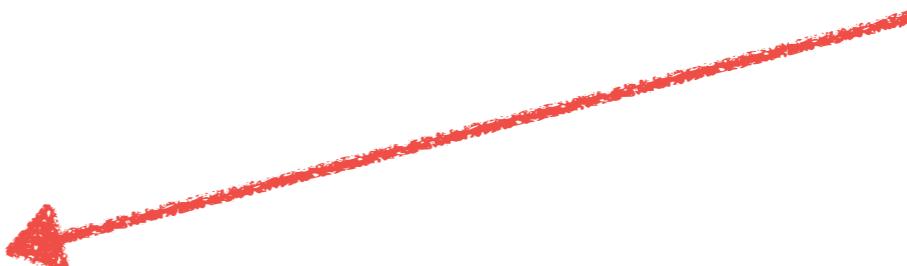
Plusses are awarded for the top three percent and minuses are reserved for the bottom three percent of each grade distribution above.

# REFERENCES (1)

Starred items are free!

## Books

- [Dodge] R. Dodge, Computer music, 2nd edition, 1997, Schirmer books, NY.
- [Benson]\* D. Benson, Music: a mathematical offering, freely available on author's web page.
- [Rocchesso]\* D. Rocchesso, Introduction to sound processing, freely available on author's web page.
- [Smith]\* J. Smith, The mathematics of the DFT, chapter 5 (freely available on author's web page).
- [Burkov] A. Burkov, The Hundred-page machine learning book.



## Lecture notes

- [Cella2015a]\* C. E. Cell, A geometric interpretations of signals, 2015, available on [www.carminecella.com](http://www.carminecella.com)
- [Cella2017a]\* C. E. Cell, On room impulse response measurements with sine sweeps, 2017, available on [www.carminecella.com](http://www.carminecella.com)
- [Cella2016]\* C. E. Cell, On the multidimensional Haar transform, 2016, available on [www.carminecella.com](http://www.carminecella.com)
- [Cella2015b]\* C. E. Cell, Logistic regression and artificial neural networks, 2015, available on [www.carminecella.com](http://www.carminecella.com)
- [Cella2020]\*, C. E. Cell, Notes on the geometrical interpretation of neural networks, 2020, available on [www.carminecella.com](http://www.carminecella.com)

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# REFERENCES (2)

## Papers

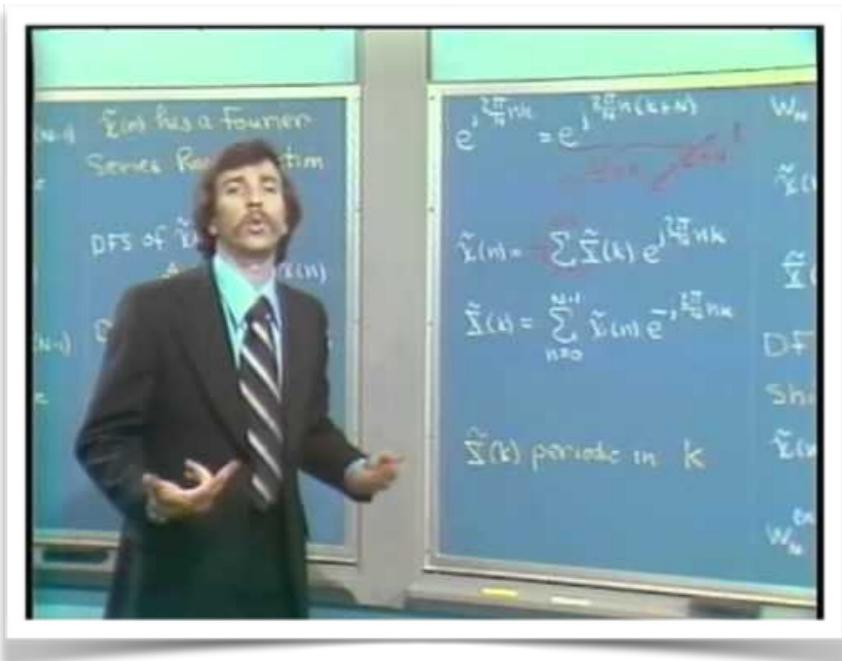
- [Caetano2020] Imitative Computer-Aided Musical Orchestration with Biologically Inspired Algorithms, HAIM, preprint.
- [Mor2019] Noam Mor, Lior Wolf, Adam Polyak, Yaniv Taigman, A universal music translation network, ICLR 2019.
- [Gillick2019]\* Jon Gillick C. E. Cella and David Bamman, Estimating unobserved audio features for targed-based orchestration, ISMIR 2019, Delft, The Netherlands.
- [Crayencour2019]\* H. C. Crayencour, C. E. Cella, Learning, probability and logic: towards a unified approach for content-based Music Information Retrieval, Frontiers in Digital Humanities, April 2019.
- [Gabrielli2018]\* L. Gabrielli, C. E. Cella, F. Vespertini, D. Droghini, E. Principi and S. Squartini, Deep Learning for Timbre Modification and Transfer: an Evaluation Study, AES 144th, 2018, Milan, Italy.
- [Cella2017b]\* C. E. Cella, Machine listening intelligence, International Workshop on Deep learning for music, 2017, Anchorage, ALASKA.
- [Lonstalen2016]\* V. Lonstalen, C. E. Cella, Deep convolutional networks on the pitch spiral for musical instrument recognition, ISMIR 2016, New York, USA.
- [Cella2013]\* C. E. Cella and J.J. Burred, Advanced sound hybridizations by means of the theory of sound-types, ICMC 2013, Perth, Australia.
- [Cella2011]\* C. E. Cella, Sound-types: a new framework for symbolic sound analysis and synthesis, ICMC 2011, Huddersfield, United Kingdom.

# CONTENT

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# STRUCTURE

**Part I: signals and transformations (DSP, spectral processing...)**



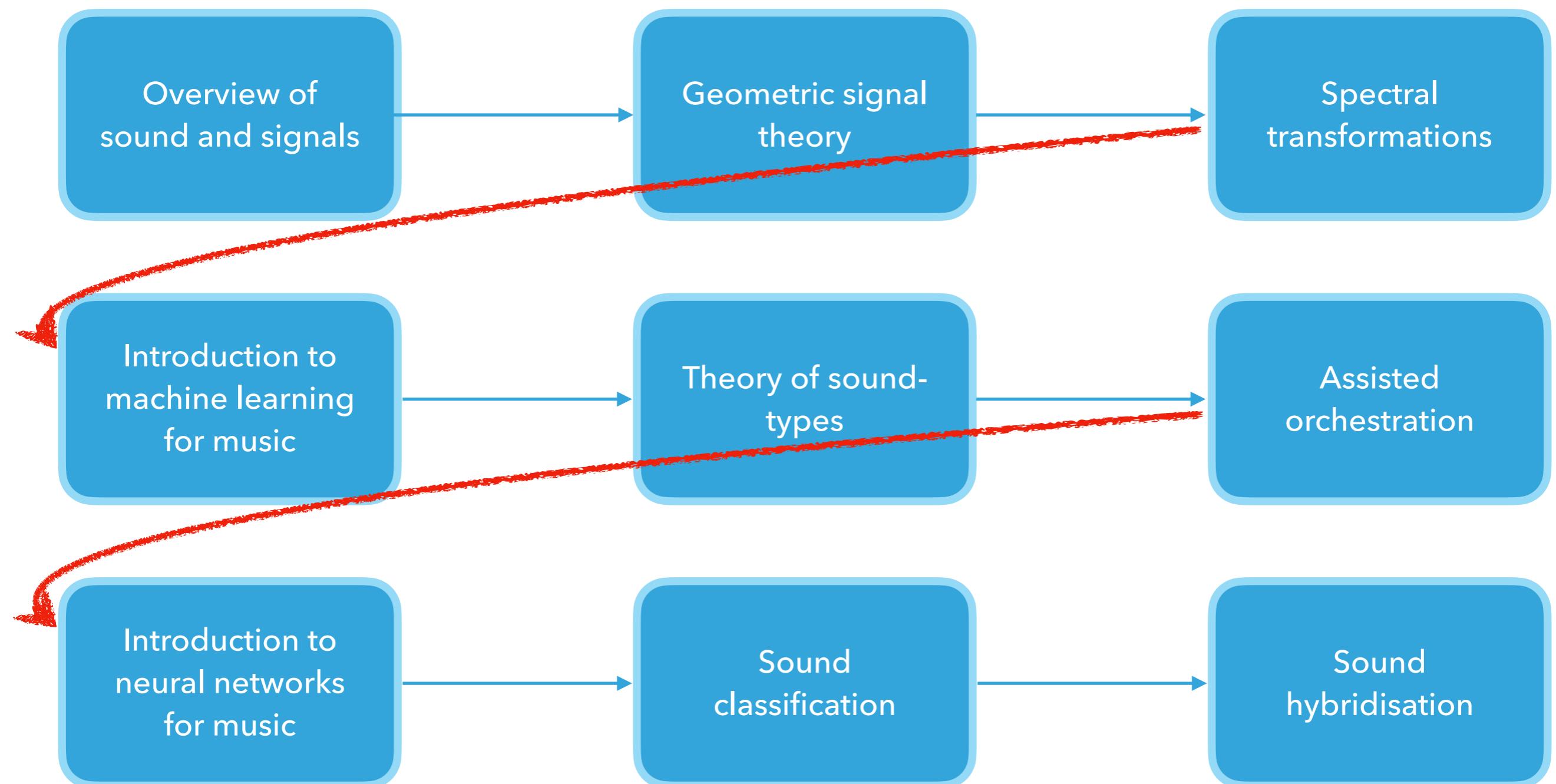
Do you know them??



**Part II: learning (models for music processing, neural networks..)**



# OVERVIEW



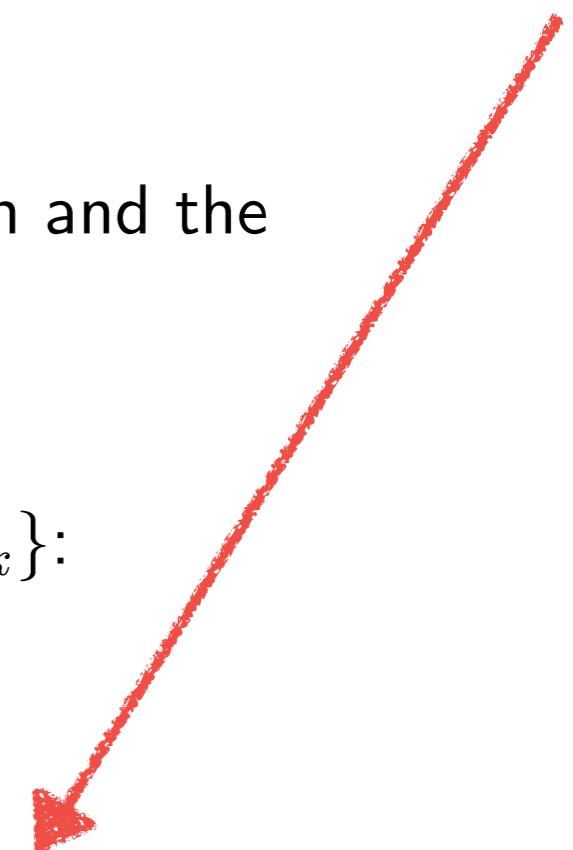
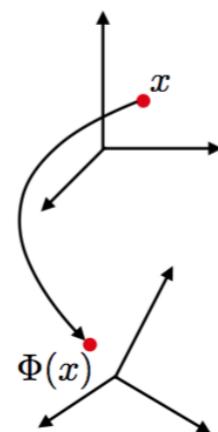
# ALL IN ONE SLIDE... OUCH

Yes, that's kinda Scary :(

Let  $\mathcal{H}$  be a Hilbert space, with  $\|\cdot\|$  and  $\langle \cdot, \cdot \rangle$  being the norm and the scalar product respectively.

- A *projection* of  $y$  on  $x$  is defined as:  $P_x(y) = \frac{\langle y, x \rangle}{\|x\|^2} x$ ;
- a representation is the projection on a set of vectors  $\{b_k\}$ :  

$$\Phi(x) = \sum_k x \bar{b}_k = \langle x, b_k \rangle;$$



- example (DFT):  $X(k) = \sum_n x(n) e^{-j2\pi nk/N}$ ;
- class of **convolutional representations**:  $\Phi(x) = x \star \psi_\lambda$ , where  $\psi_\lambda$  are the projectors.

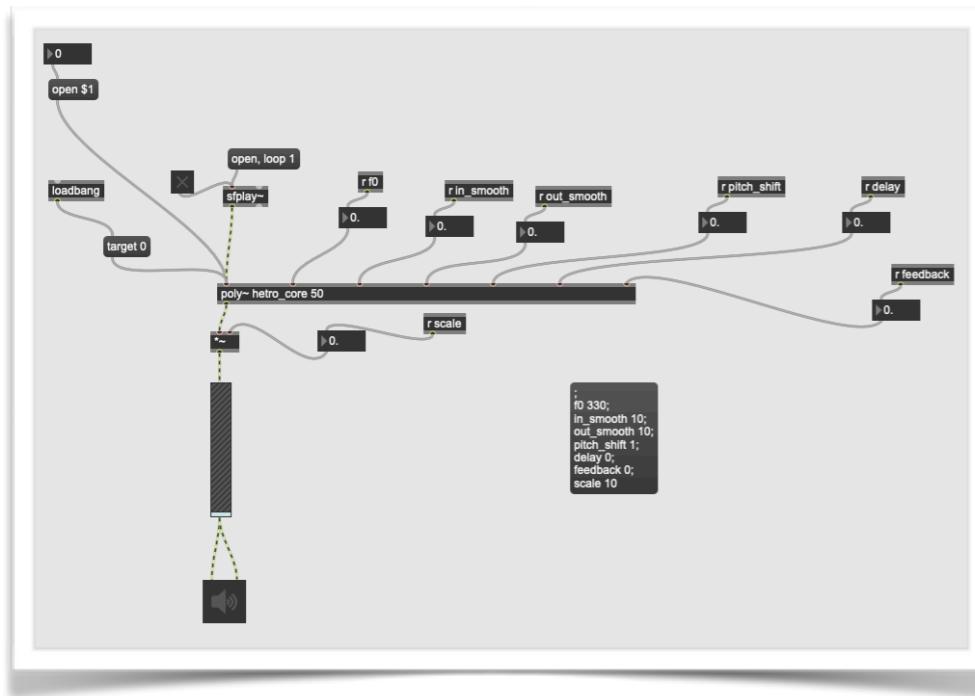
## YOUR FRIEND: SCALAR PRODUCT!

$$\sum_k x \bar{b_k} = \langle x, b_k \rangle$$



# SPECTRAL TRANSFORMATIONS

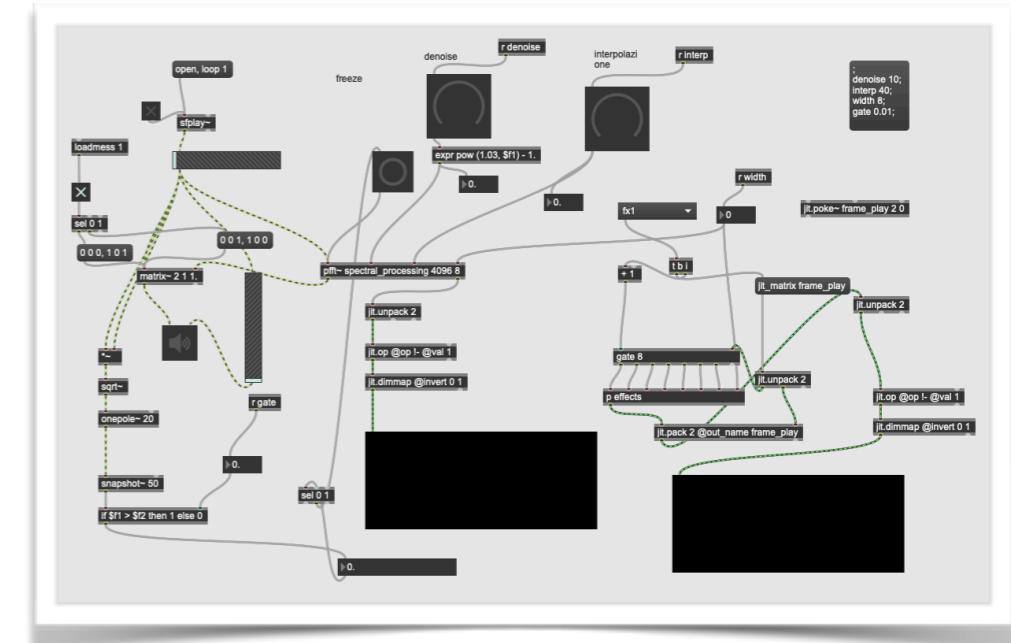
## DEMO!



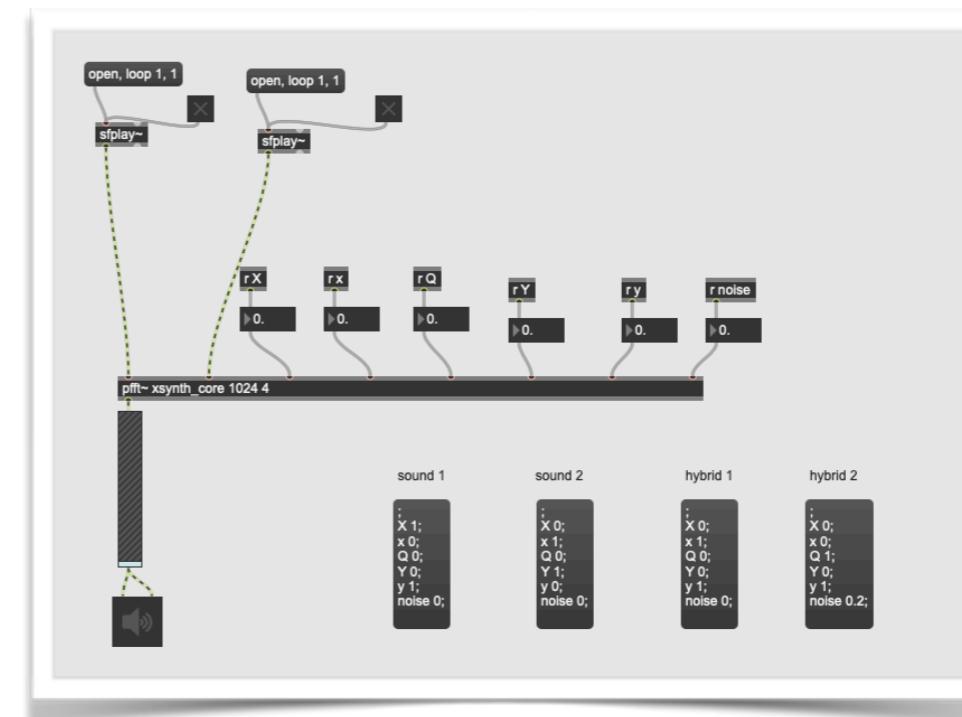
### Spectral delay

```
scale = 0.1
direct = 0.7
y = np.ndarray ((x.shape[0] + h.shape[0],))
print ("computing reverb")
for t in range(x.shape[0]):
    for m in range(h.shape[0]):
        y[t + m] = y[t + m] + x[t] * h[m] * scale
    y[t] = y[t] + x[t] * direct
    if (t % 100 == 0):
        print (t)
print ("saving data")
sf.write ("outverb.wav", y, sr)
print ("end")
```

### Convolution-based reverb

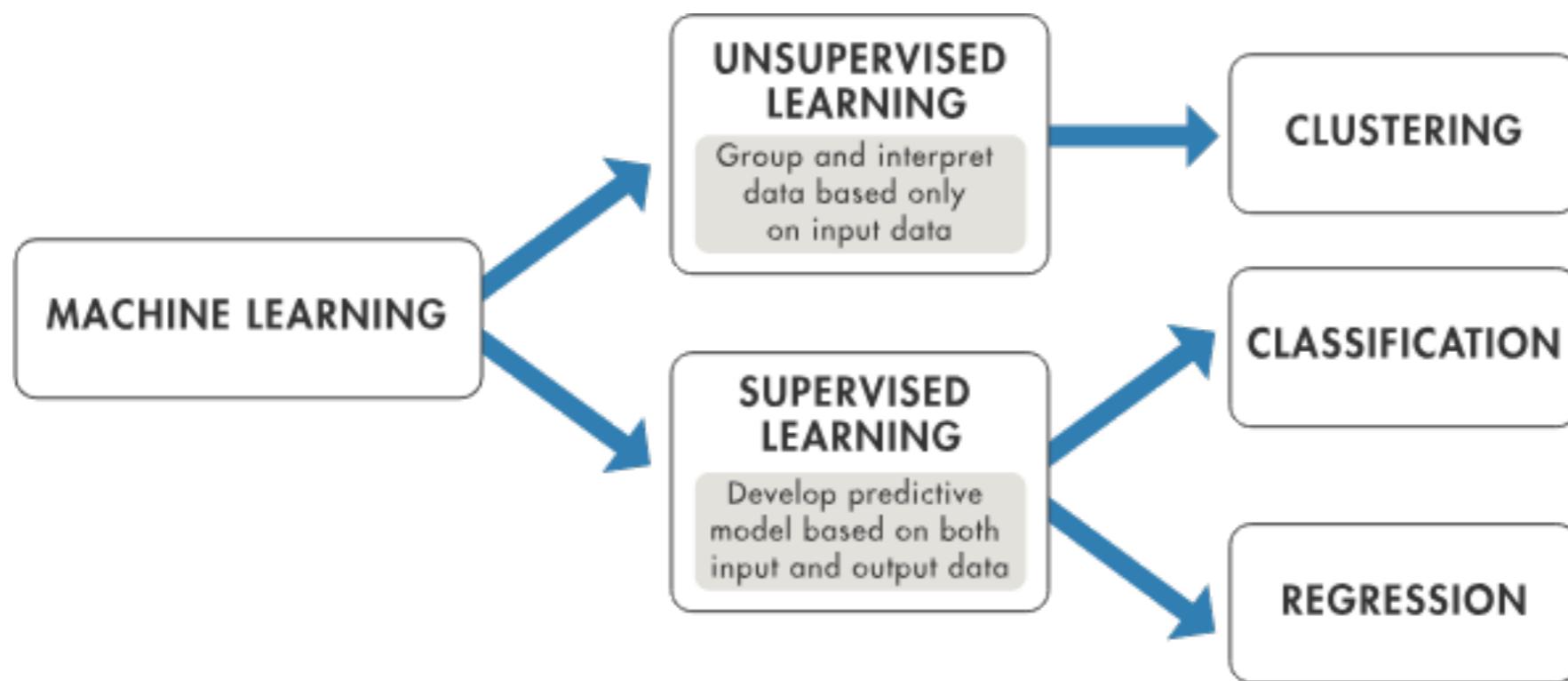


### Spectral freeze



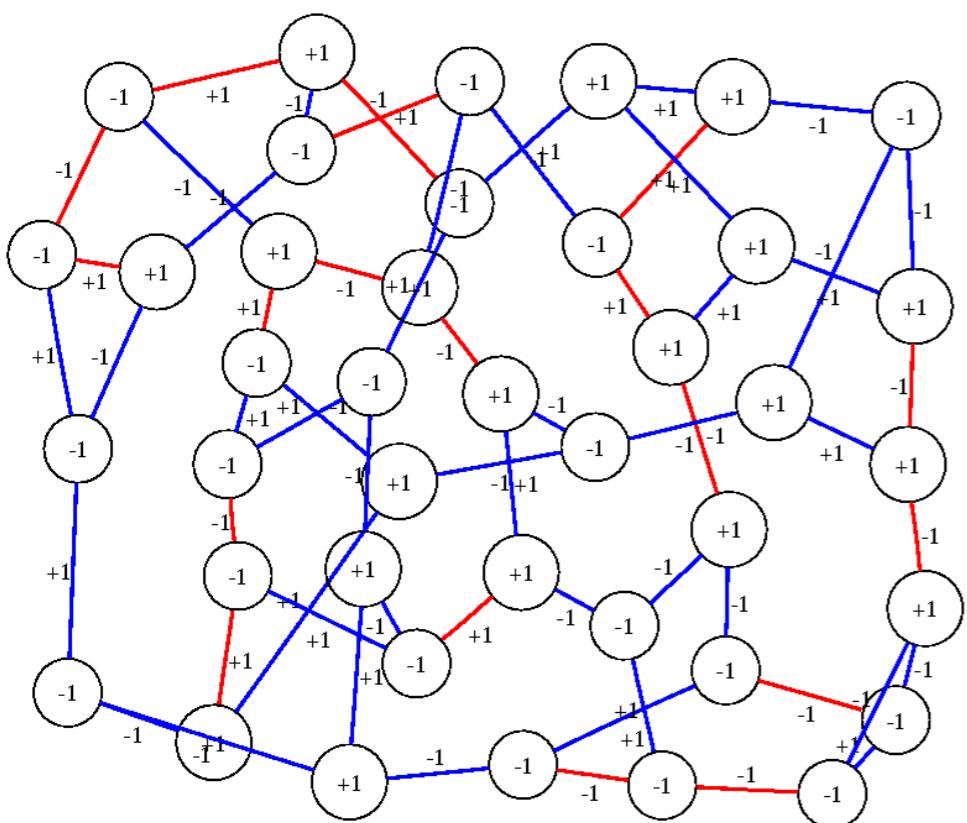
### Cross-synthesis

# MACHINE LEARNING (??)

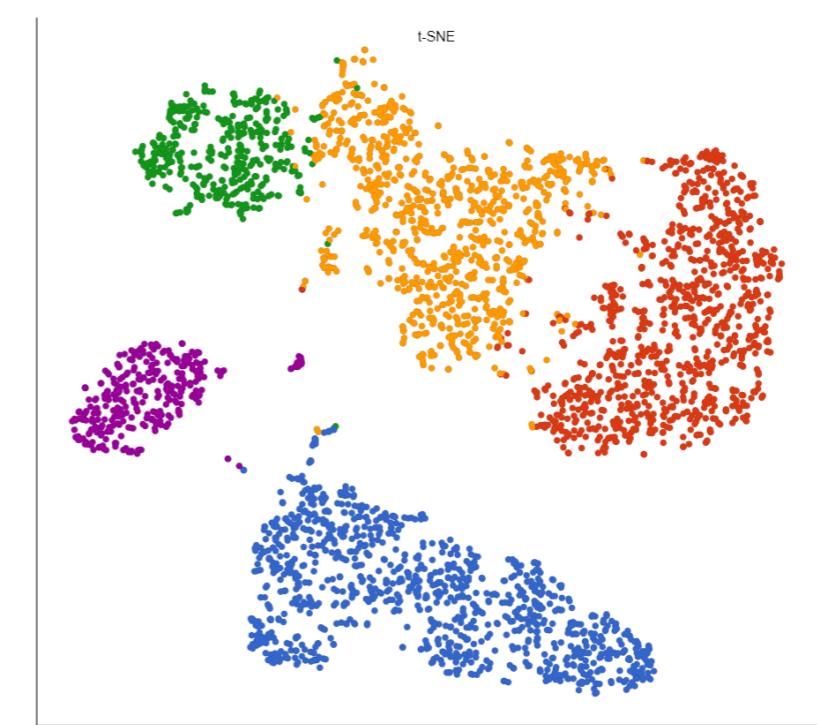


...and what about GENERATION !?

# TWO MAIN TOOLS



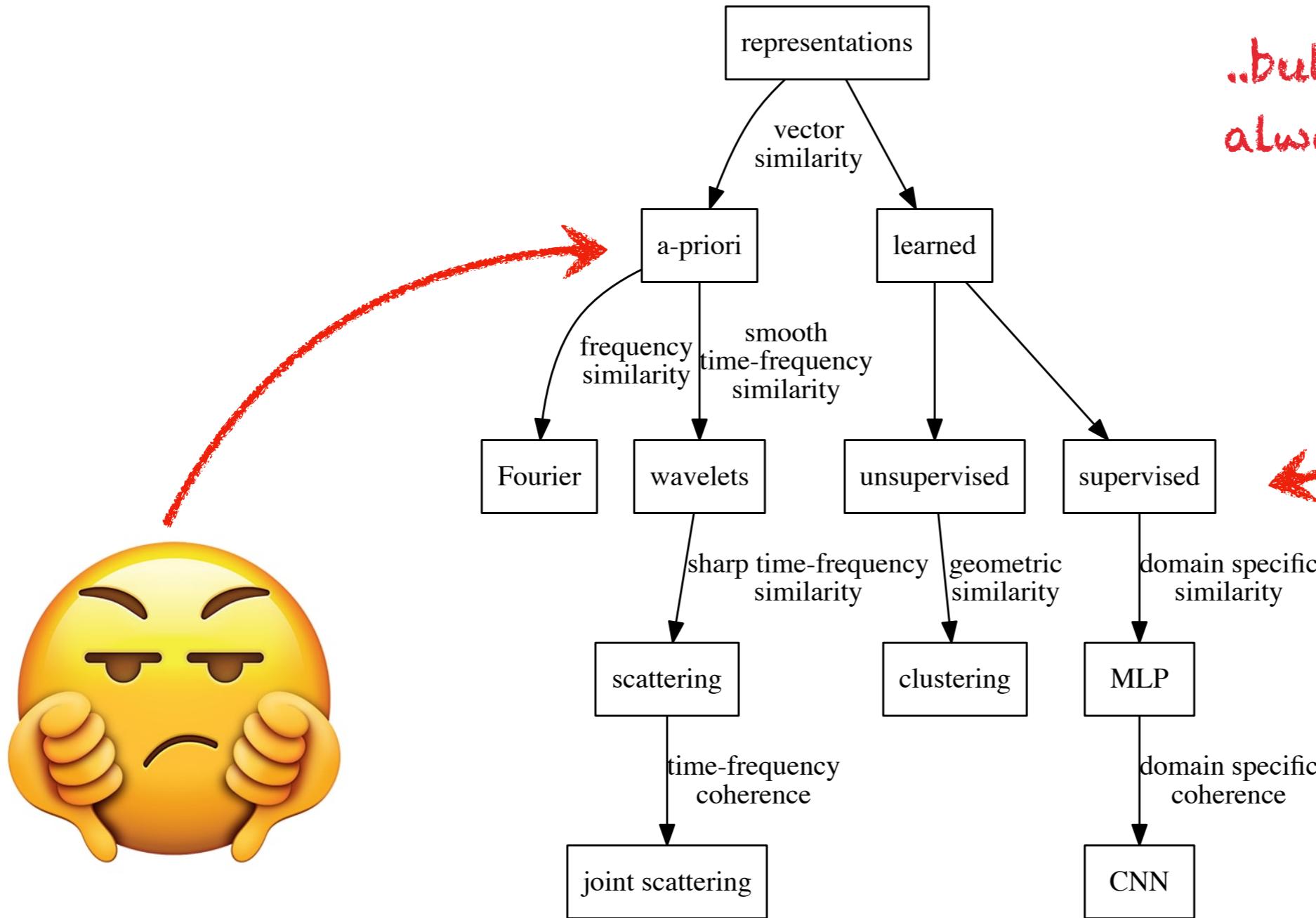
Probabilities (time)



Clustering (timbre)

...and a bit of linear regression, logistic regression, gradient descent, kNN, SVM, dimensionality reduction, etc...

# A UNIFIED VIEW ON LEARNING AND NEURAL NETWORKS



..but scalar product is  
always your friend!

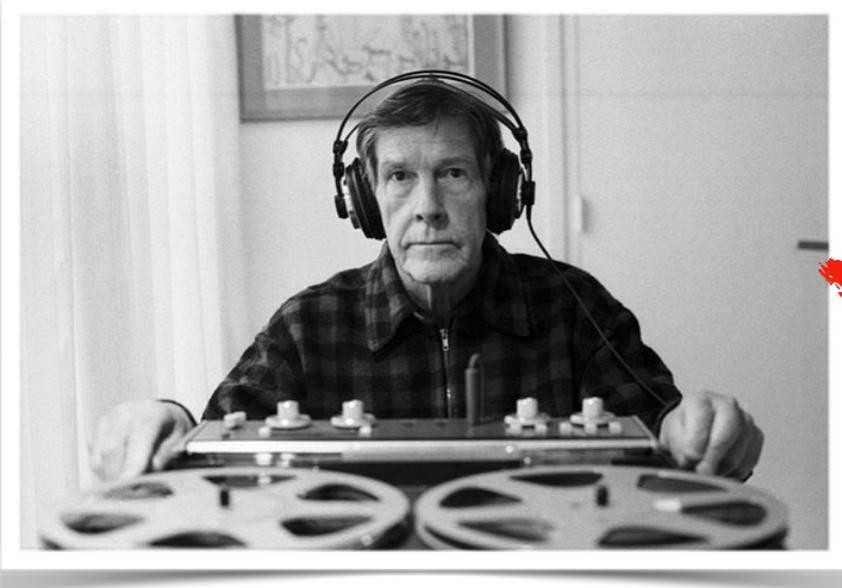


# Boring...

# EXAMPLES

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# ADVANCED HYBRIDISATIONS

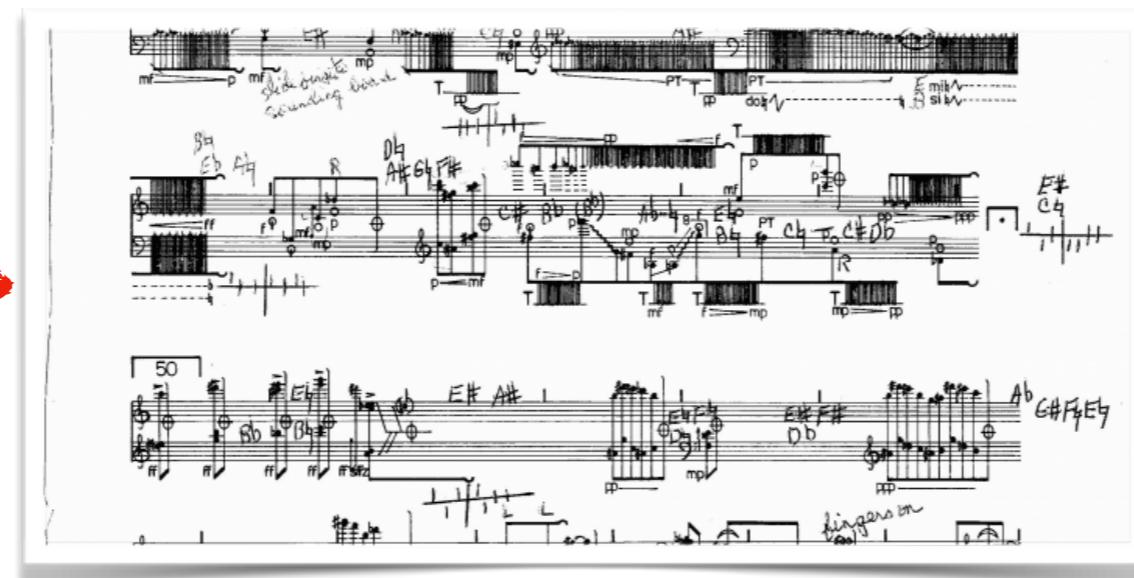


John Cage...



..and the Beach boys??

..and  
contemporary music?



A detailed musical score page featuring multiple staves of music. The top staff includes markings like 'mf', 'p', 'ff', 'scattering board sounding board', and 'T'. The middle staff has markings such as 'D4', 'A4', 'C#4', 'B3', 'P', 'PT', and 'pp'. The bottom staff includes markings like '50', 'E# A# 1', 'D# B#', 'Ab G# F# E#', and 'fingers in'. The score is filled with various note heads, rests, and dynamic markings.

# COMPUTER-ASSISTED ORCHESTRATION

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**Target: Cars**



Created by Yu luck  
from Noun Project

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# STYLE TRANSFER (?)

The following audio samples were transferred between:

- Symphony, Mozart
- String Quartet, Haydn
- Cantata (Chorus opera & Orchestra), Bach
- Organ, Bach
- Piano, Bach
- Harpsichord, Bach
- In training distribution
- ❖ Electric Guitar, Charlie Christian
- ❖ Electric Guitar, Metallica
- ❖ Classical Guitar & Orchestra , Jazz
- ❖ Trumpet & Orchestra, Jazz
- ❖ Midi samples of Piano & Trumpet, Elvis Presley, Rihanna
- ❖ Music of Africa
- ❖ Whistling (Human)
- ❖ Out of training distribution

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# THANK YOU!

**Suggested exercise: review some basic linear algebra!**