

A black and white photograph of a couple kissing. The image is soft and slightly out of focus, with the couple's faces and hair filling the frame. The lighting is gentle, creating a romantic and intimate atmosphere. The text is overlaid on the right side of the image.

Algorithmic Thinking in Music

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Updated: January 2021

image (c) Mario Klingemann

“An **algorithm** can be defined as a predetermined set of instructions for solving a specific problem in a limited number of steps. Due to its **rule-based** nature, every algorithm can be expressed as a computer program, but the use of algorithms is not solely restricted to computers.”

Algorithmic Music Before the Computer

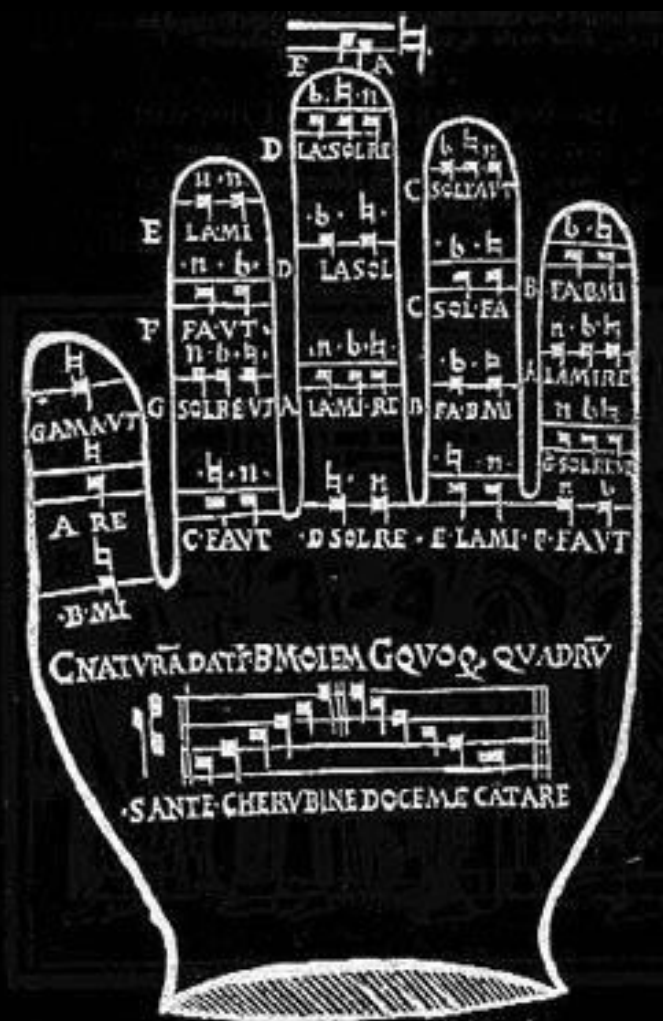
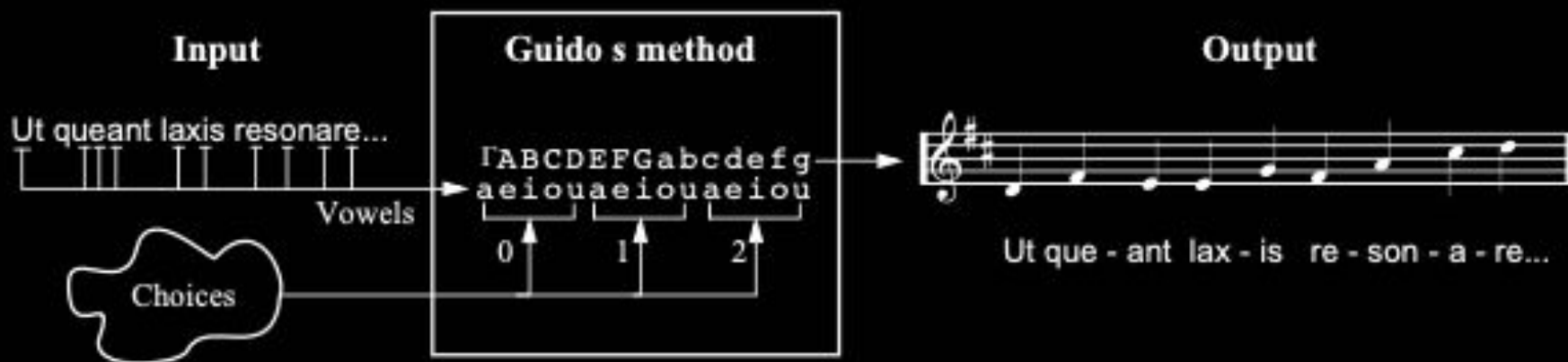




Figure 9.2
Vowel/note correspondence.



Guido d'Arezzo's composition method
Plainchant, ~1026

+



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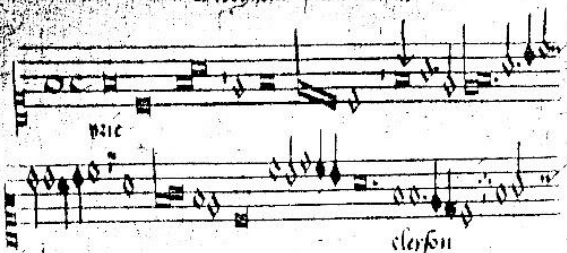
Guillaume de Machaut: De bon espoir - Puis que la douce
(isorythmisk motett, tenor- stemmen)

The image displays a musical score for Guillaume de Machaut's 'De bon espoir' motet, specifically the tenor part. It consists of six staves, each labeled 'Talea' (I to VI). The notation is in mensural style, with notes on a four-line staff. The rhythm is indicated by the number of stems (vertical lines) and flags (horizontal lines) on the notes. The score is divided into six sections, each with a 'Color' marking (Color 1 to Color 6) indicated by a dashed line. The notes are organized into groups of four, with the first group of four notes in each section being the same (Color 1), and the subsequent groups being different (Color 2 to Color 6). A red vertical bar is present on the third staff, Talea III, marking the beginning of the third section.

Guillaume de Machaut, De bon Espoir
Isorhythmic Motet ~ 1350

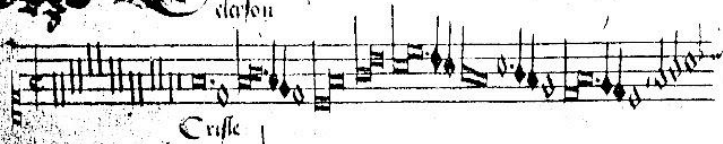
[Pd example](#)

Seleghem prolationum.



Pausant akendit per vatum

clayson



clayson



clayson

prie

clayson

clayson.

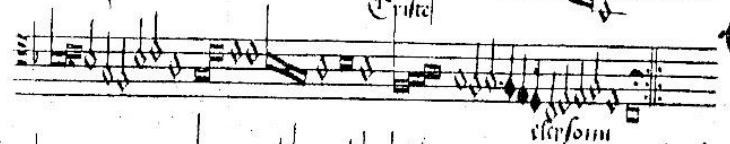


Pausant akendit

per vatum

Crise

clayson



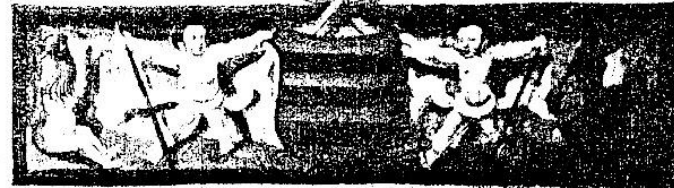
Crise



prie

clayson

clayson



A musical score for Johannes Ockeghem's Kyrie, featuring mensuration canons. The score is written for four staves: two vocal staves (Soprano and Alto) and two lute staves (Treble and Bass). The vocal staves contain the Latin text: "ste e - lei - son. Chri - ste e - lei - son." The lute staves contain the same text, but the notes are arranged in a way that creates a mensuration canon. The score is in G major (one sharp) and 3/4 time. The tempo is marked "Allegro". The score is divided into three measures. The first measure contains the text "ste e - lei - son." The second measure contains the text "Chri - ste e - lei - son." The third measure contains the text "ste e - lei - son." The notes are arranged in a way that creates a mensuration canon, meaning that the same melody can be played in different time signatures.

Johannes Ockeghem, *Missa Prolationum*, Kyrie
Mensuration Canons ~ 1450



Contrapunctus VI

"a 4, in Stile francese"



J. S. Bach, *Art of Fugue, Contrapunctus XVI*
Baroque Counterpoint ~ 1740



3	1	9	5	4	6	8	7	12	10	11	2
5	3	11	7	6	8	10	9	2	12	1	4
9	7	3	11	10	12	2	1	6	4	5	8
1	11	7	3	2	4	6	5	10	8	9	12
2	12	8	4	3	5	7	6	11	9	10	1
12	10	6	2	1	3	5	4	9	7	8	11
10	8	4	12	11	1	3	2	7	5	6	9
11	9	5	1	12	2	4	3	8	6	7	10
6	4	12	8	7	9	11	10	3	1	2	5
8	6	2	10	9	11	1	12	5	3	4	7
7	5	1	9	8	10	12	11	4	2	3	6
4	2	10	6	5	7	9	8	1	11	12	3

41 42 43 *rit.*

S. *frü - he - ren Na - men* *al - le ver - klun - geo,*

Chor *die frü - he - ren Na - men* *al - le ver - klun - gen.*

A. *die frü - he - ren Na - men* *al - le ver - klun - gen.*

41 42 43

Anton Webern, *Kantata I*, Op. 29

Twelve-Tone Music, 1939

Ce morceau utilise un mode de hauteurs (36 sons), de valeurs (24 durées), d'attaques (12 attaques), et d'intensités (7 nuances). Il est entièrement écrit dans le mode.

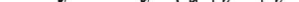
Attaques: \triangleright \uparrow \cdot $-$ \frown \triangleright \triangleright \geq \cdots $\overset{sf}{\triangleright}$ $\overset{sf}{\triangleright}$ no sign


(avec l'attaque normale, sans signe, cela fait 12.)

Intensités: *ppp pp p mf f ff fff*
 1 2 3 4 5 6 7

Sons: Le mode se partage en 3 Divisions ou ensembles mélodiques de 12 sons, s'étendant chacun sur plusieurs octaves, et croisés entre eux. Tous les sons de même nom sont différents comme hauteur, comme valeur, et comme intensité.

f Valeurs: λ_{max} chromatique of (from)

Division I: durées chromatiques de 1 à 12  etc.)

Division II: durées chromatiques de 1 à 12  etc.)

Division III: durées chromatiques de 1 à 12 ♩ ($\text{♩} \mid \text{♩} \mid \text{♩}\cdot \mid \text{♩} \mid \text{♩} \overline{\hspace{0.5em}} \mid$ etc.)

Au total 24 durées: 

Musical notation for measures 13-24. The notation continues from the previous system, showing various rhythmic patterns and rests. Measure 13 starts with a quarter note, followed by a half note in measure 14. Measures 15-18 show a sequence of quarter and half notes. Measures 19-24 include a variety of note values, including quarter, half, and whole notes, with some measures containing rests. The system concludes with a double bar line.

Voici le mode:

I  Musical score for the first staff of 'The Rose Tree'. It begins with a treble clef and a key signature of one flat (B-flat). The melody consists of eighth and sixteenth notes, with some beamed sixteenth notes. Dynamics include ppp, ppp, ff, f, mf, ff, f, mf, ff, pp, ff, and p. There are also slurs and accents.

(la Division I est utilisée dans la portée supérieure du Piano)

II *sf* The 1st Chorus uses the upper range of the piano. *ff mf mf p pp p v p f f f f*

(la Division II est utilisée dans la portée médiane du Piano)

III

(la Division III est utilisée dans la portée inférieure du Piano)

(la Division III est utilisée dans la portée inférieure du Piano)

Olivier Messiaen

Etudes de rythme - II. Mode de valeurs et d'intensités

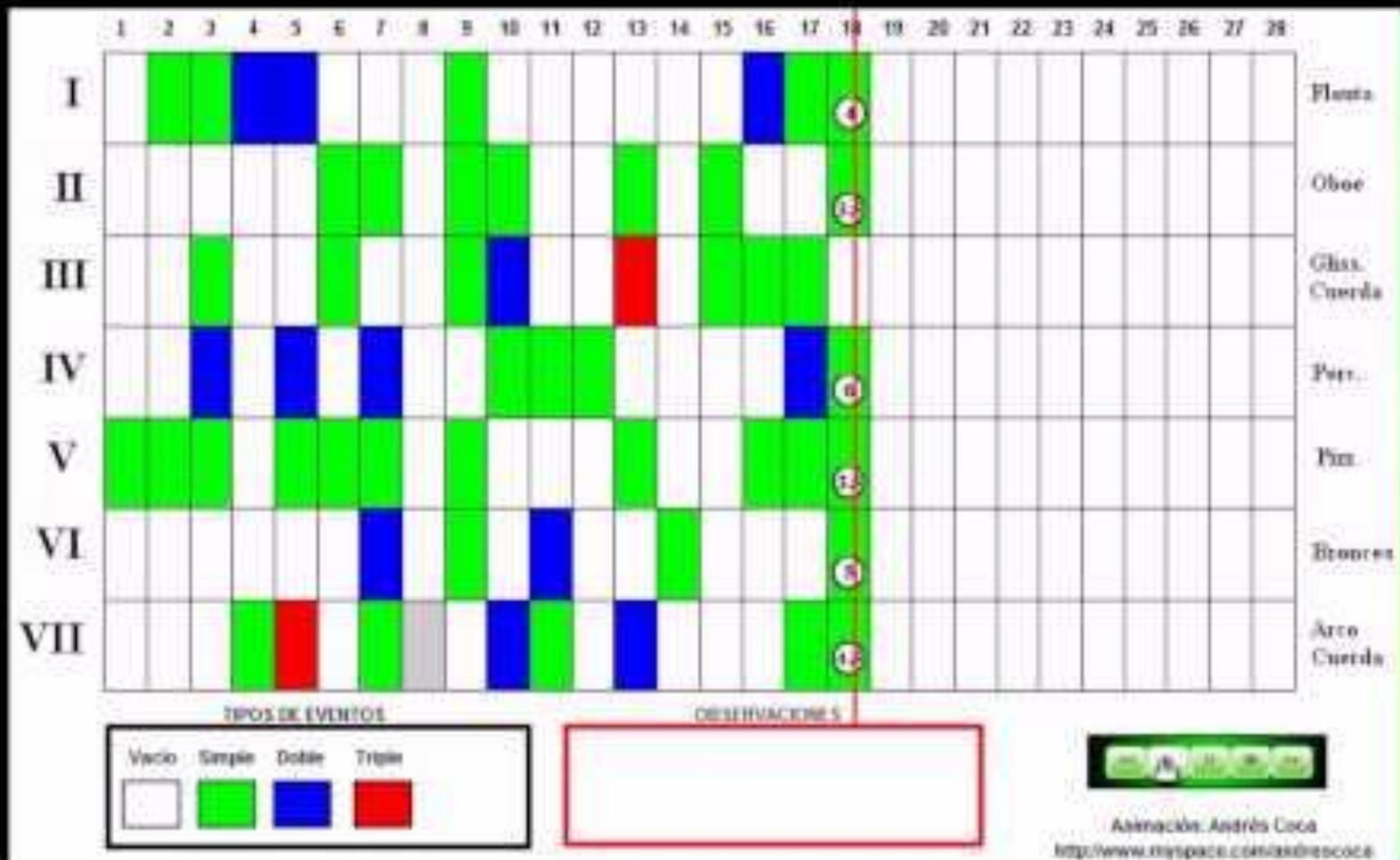
Ce morceau utilise un mode de hauteurs (36 sons), de valeurs (24 durées), d'attaques (12 attaques), et d'intensités (7 nuances). Il est entièrement écrit dans le mode.

Attaques: $\begin{matrix} > & \cdot & \cdot & - & \frown & \gtrsim & \gtrsim & \geq & \dots & \gtrsim & \gtrsim \\ 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 \end{matrix}$
(avec l'attaque normale, sans signe, cela fait 12.)

Intensités: $\begin{matrix} ppp & pp & p & mf & f & ff & fff \\ 1 & 2 & 3 & 4 & 5 & 6 & 7 \end{matrix}$

Sons: Le mode se partage en 3 Divisions ou ensembles mélodiques de 12 sons, s'étendant chacun sur plusieurs octaves, et croisés entre eux. Tous les sons de même nom sont différents comme hauteur, comme valeur, et comme intensité.

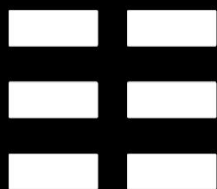
Olivier Messiaen, *Mode de valeurs et d'intensités*
Total Serialism, 1949



Iannis Xenakis, *Achorripsis* (1957)
 Stochastic Music

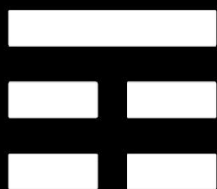
坤

Kun (Earth)



艮

Gen (Mountain)



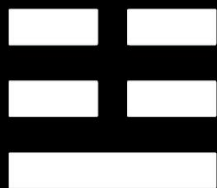
坎

Kan (Water)



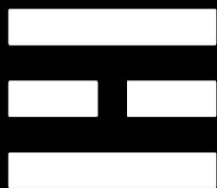
巽

Xun (Wind)



震

Zhen (Thunder)



離

Li (Fire)



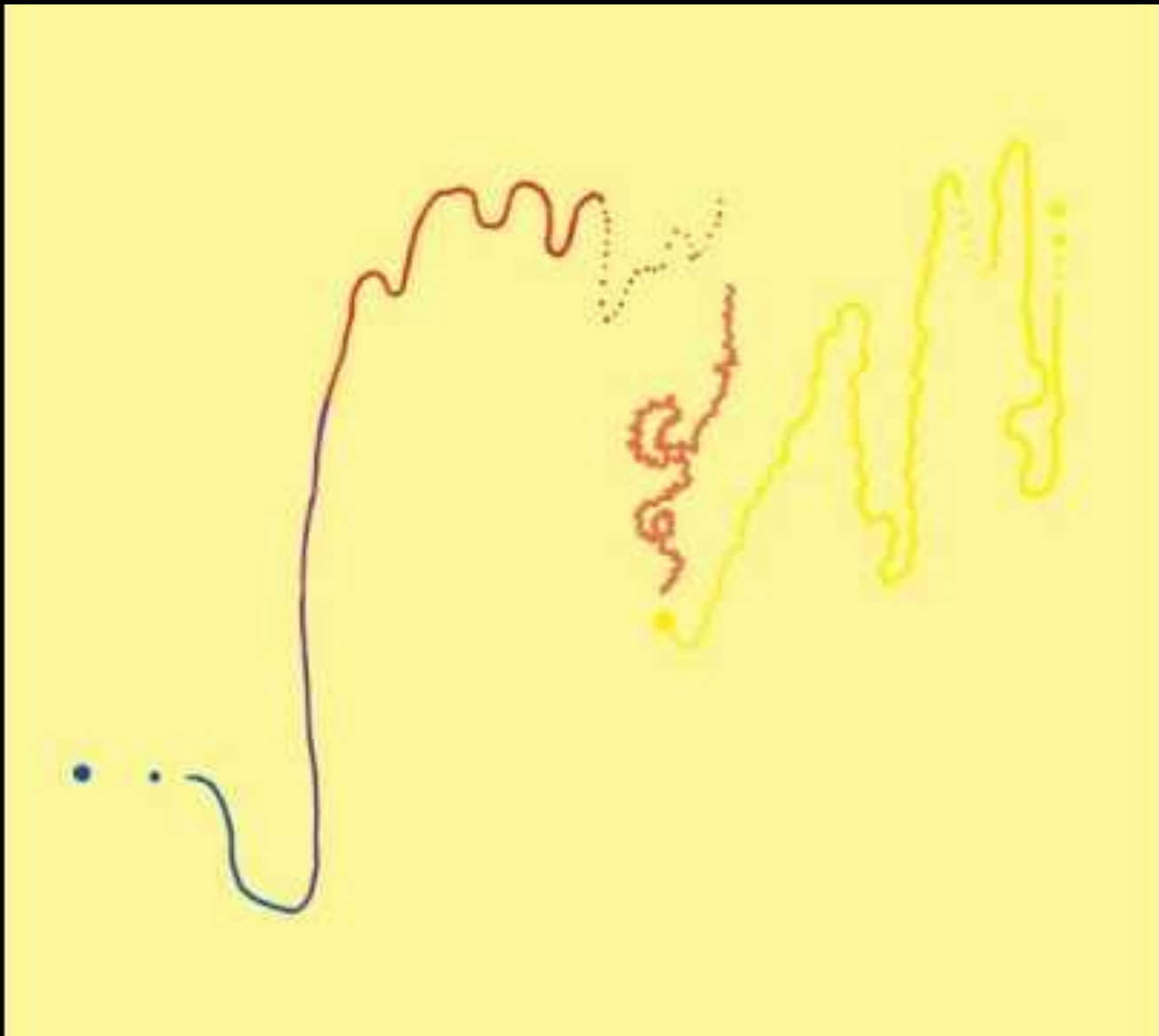
兌

Dui (Lake)



乾

Qian (Heaven)



John Cage, *Aria*

Aleatoric music, indeterminacy, 1958

Algorithmic Composition Approaches

Algorithmic Composition Approaches

Mapping, Conversion Rules

Arithmetics (inversion, retrogradation, counterpoint)

Proportionality

Isolation of musical parameters (deconstructivism)

Combinatorics

Probability, stochastic procedures, randomness

Other mathematical models (e.g. fractals)

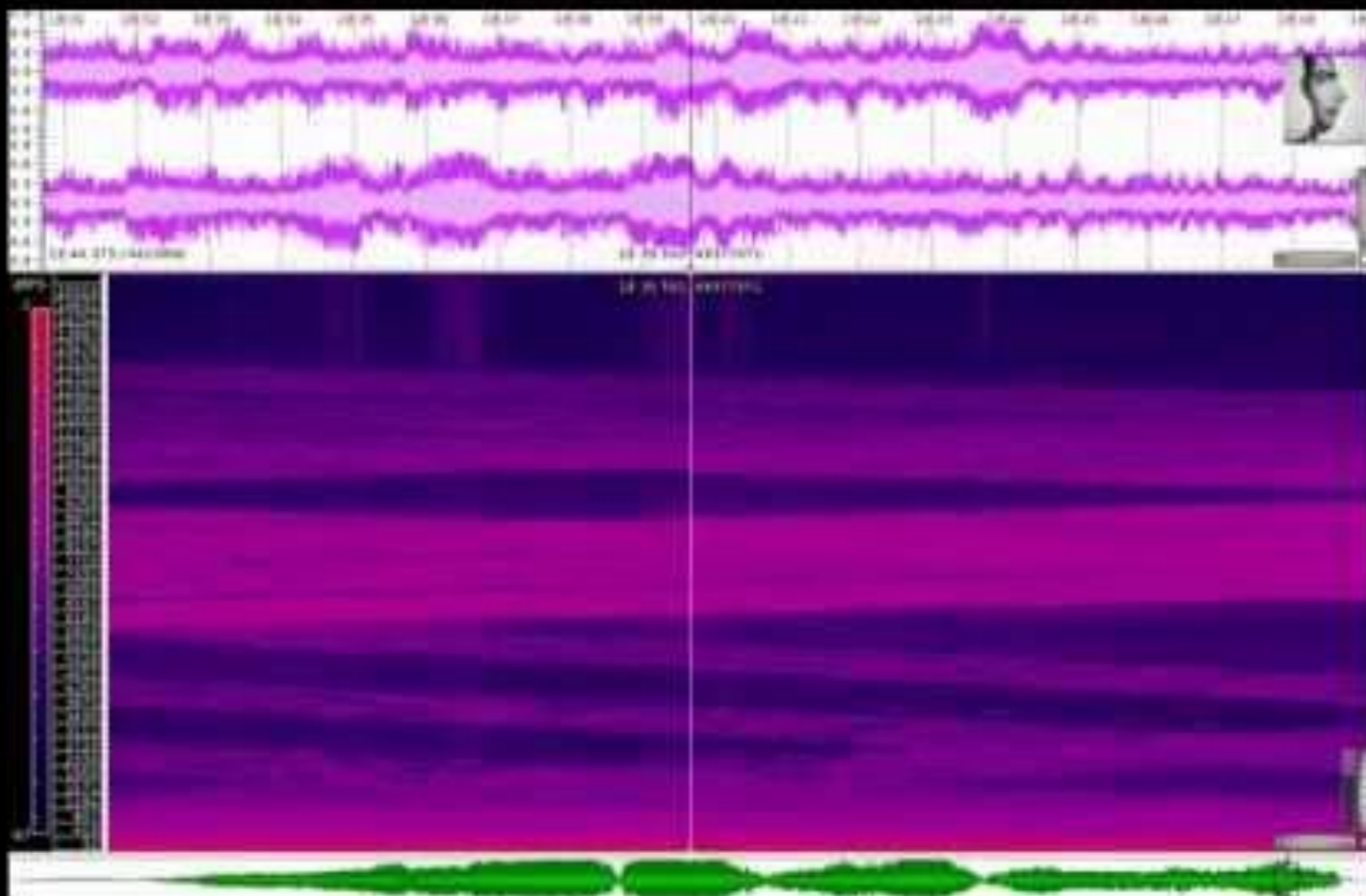
Algorithmic Music in the Computer Era

Lejaren Hiller - *Illiac Suite* for String Quartet (1956)

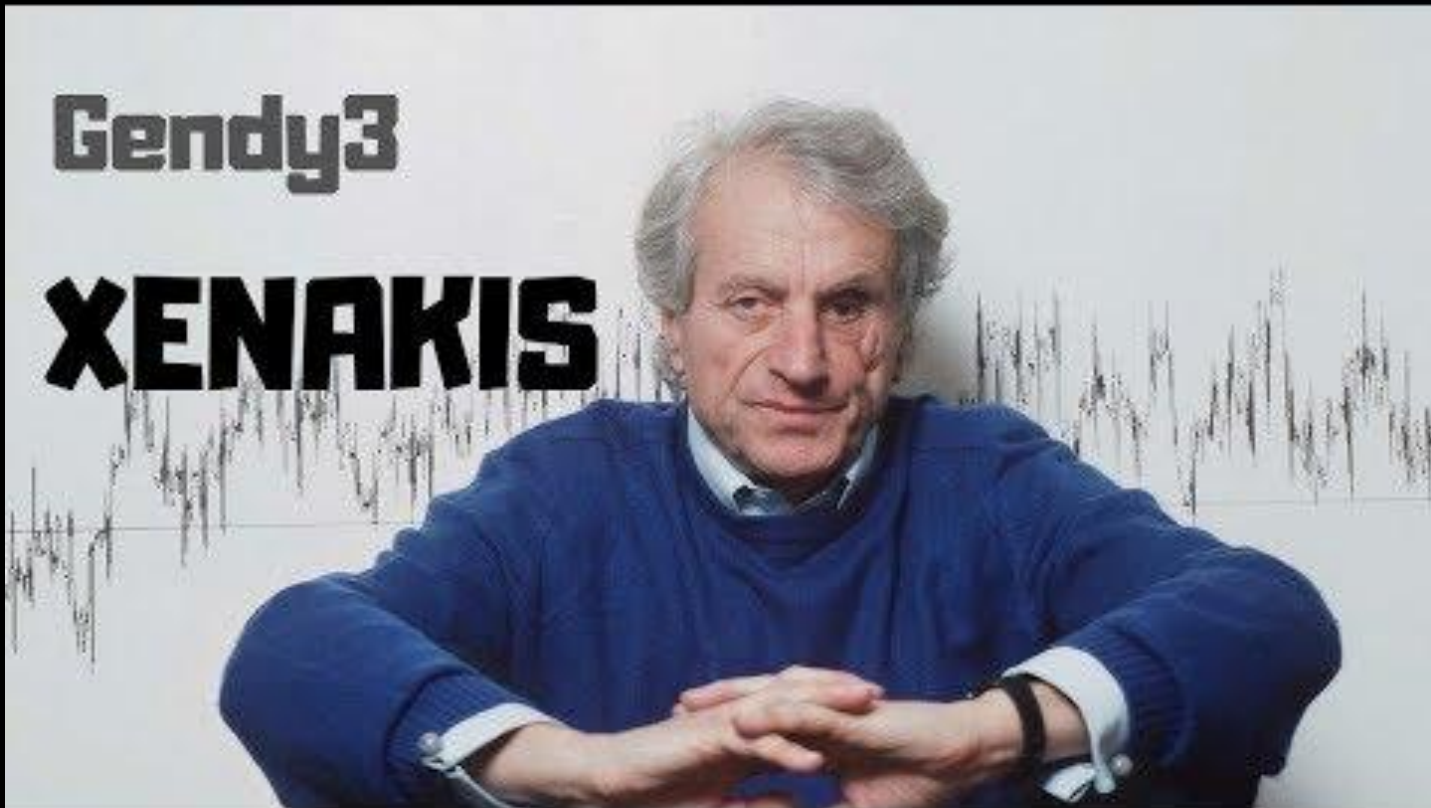
Fourth experiment: *tanto presto che possibile*

Lejaren Hiller: *Illiac Suite*, 4th experiment

For string quartet, 1956



Barry Truax, *Riverrun* (1986)
Digital Realtime Granular Synthesis



Iannis Xenakis, *Gendy 3* (1993)
Dynamic Stochastic Synthesis



Karlheinz Essl, *Lexikon Sonate* (1992-2020) ([+info](#))
Realtime Interactive Composition System



Autechre-ish Pd patch by Human Koala

Autechre, *Reniform Puls*

Draft 7.30, 2003



Brian Eno & Peter Chilvers, *Trope app* (2009)
Ambient, Generative music



```
// 01 Nathaniel Virgo
{LocalOut.ar(a=CombN.ar(BPF.ar(LocalIn.ar(2)*7.5+Saw.ar([32,33],0.2),2**LFNoise0.kr(4/3,4)*300,0.1).distort,2,2,40));a}.play//#supercollider

// 02 LFSaw
{Splay.ar(Ringz.ar(Impulse.ar([2, 1, 4], [0.1, 0.11, 0.12]), [0.1, 0.1, 0.5])) * EnvGen.kr(Env([1, 1, 0], [120, 10]), doneAction: 2)}.play

// 03 Tim Walters
play{({|k|({|lily=SinOsc;y.ar(i*k*k,y.ar(i*k**i/[4,5])*Decay.kr(Dust.kr(1/4**i),y.ar(0.1)+1*k+i,k*999))!8).product!16).sum}!16)}//#supercollider

// 04 Nathaniel Virgo
b=Buffer.read(s,"sounds/allw1k01.wav");play{t=Impulse.kr(5);PlayBuf.ar(1,b,1,t,Demand.kr(t,0,Dseq(1e3*[103,41,162,15,141,52,124,190],4)))!2}

// 05 Batuhan Bozkurt
play{f=LocalIn.ar(2).tanh;k=Latch.kr(f[0].abs,Impulse.kr(1/4));LocalOut.ar(f+CombC.ar(Blip.ar([4,6],100*k+50,0.9),1,k*0.3,50*f));f}//44.1kHz

// 06 Batuhan Bozkurt (refactored by Charles Celeste Hutchins)
f={|t|Pbind(\note,Pseq([-1,1,6,8,9,1,-1,8,6,1,9,8]+5,319),\dur,t)};Ptpar([0,f.(1/6),12,f.(0.1672)],1).play//#supercollider reich RT @earslap

// 07 Thor Magnusson
play{x=SinOsc;y=LFNoise0;a=y.ar(8);(x.ar(Pulse.ar(1)*24)+x.ar(90+(a*90))+MoogFF.ar(Saw.ar(y.ar(4,333,666)),a*XLine.ar(1,39,99,99,0,2)))!2/3}

// 08 Charlie Hoistman
Ptpar(({|i|Pbind(\scale,[0,2,4,7,9],\degree,Pseq(32.fib.fold(0,10),4)+(2*i+i)-10,\dur,1+2**i%2/6)})!4).flat).play // #supercollider

// 09 MCLP
```

VVAA, sc140, supercollider oneliners ([download](#))
Generative Music

Algorithmic Computational Approaches

Mapping, Conversion Rules

Arithmetics (inversion, retrogradation, counterpoint)

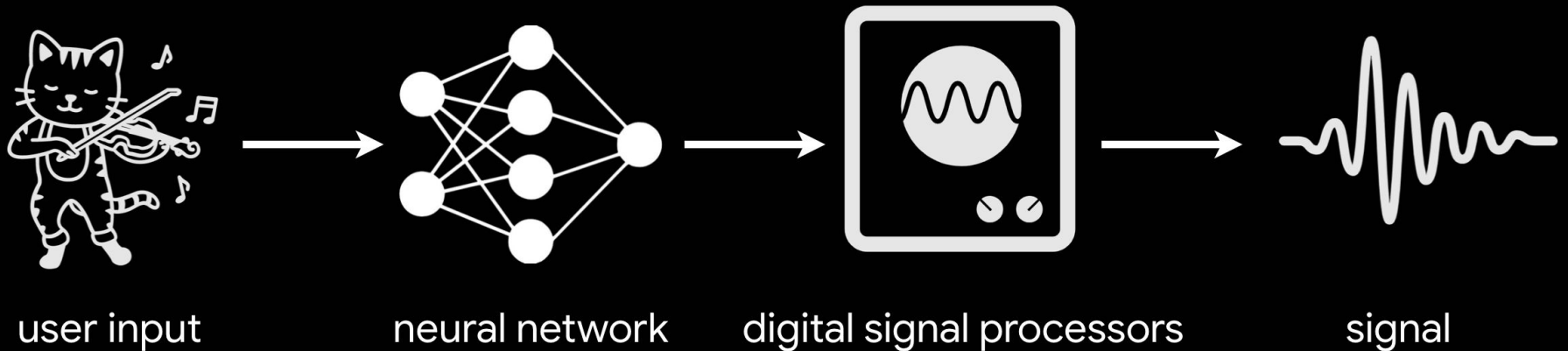
Proportionality

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SOUND DESIGN // SOUND SYNTHESIS



A sound morphing example...



DDSP, [Differentiable Digital Signal Processing](#) (2020...)

DSP + Deep Learning, Google Magenta Team

Towards Creative Computers



François Pachet, *The Continuator* (2003)
Machine improviser in-style



IAMUS (melomics), *Hello World!* (2011)
Computer composition using evolutionary models

Thank you!

angel.faraldo@upf.edu

Presentation's additional materials available [here](#).