

Marco Buongiorno Nardelli

L'Indifferenza dell'Amore Cosmico

(The Indifference of the Cosmic Love)

*Version I: for flauto d'amore (or flute(s)),
cosmic rays and electronics
(arbitrary duration)*

to Ginevra Petrucci for the Flauto d'Amore Project

Program Notes

"L'Indifferenza dell'Amore Cosmico" ("The indifference of Cosmic Love") develops on two separate levels, a cosmic and a human one, as a dialogue between two physical systems. The cosmic sounds come from high up and are "performed" by cosmic rays through a detector connected to a computer system and appropriate software. The human sounds are performed by the flutist and are meant to create a rich contrapuntal opposition to the unpredictable cosmic sounds. Given the nature of the cosmic ray detection the performance is necessarily undetermined and improvised following detailed instructions in the generative score. No two performances will ever be alike.

Performance Notes – Cosmic rays (electronics)

Cosmic rays are high-energy protons and atomic nuclei which move through space at nearly the speed of light. They originate from the sun, from outside of the solar system and from distant galaxies.

The cosmic ray performance relies on a cosmic ray detector connected to a computer via OSC. The computer runs a python software that controls all aspects of the performance, including multi-channel and immersive spatialization playback (free and open-source code on GitHub).

The cosmic ray detector is a self-contained apparatus that employs plastic scintillator as a detection medium and a silicon photomultiplier for light collection. It is powered via USB and used in conjunction with the provided software allows to make interesting physics measurements. The total cost of each counter is approximately \$100. The detector can be built by the performer (it is originally conceived as a simple, physics-motivated machine- and electronics-shop project for university students and schools). Instruction for the built can be found here: <http://www.cosmicwatch.lns.mit.edu/>. Alternatively, a detector will be sent to the performer before the concert. A simple software simulator is also part of the software package for rehearsal purposes.

Cosmic rays "perform" a score made of a sequence of prerecorded gestures that follows an optimized path on a unique network of pitches generated on the fly for each performance. For more information about the music-theoretical background of network topology in musical spaces see [1,2].

The performer can choose the sounds that make the sample library of the cosmic stream, however, there should be a set of samples of sounds that would roughly span the full range of the instrument and two more sets of more percussive/noisy sounds. The choice of effects or any form of sound manipulation is left to the performer.

The electronic performance consists of 13 scenes as movements of a concerto – the transitions between scenes is controlled by the performer via a pedal.

Sound should be spatialized on multiple speakers. Ideally it should come to the audience from high up and from all cardinal directions. The performer should also be amplified, and her sound should come from a rack of speakers at a lower height.

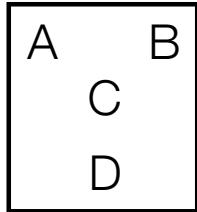
[1] M. Buongiorno Nardelli, *Topology of Networks in Generalized Musical Spaces*. Leonardo Music Journal, 30, 38-43 (2020).

[2] M. Buongiorno Nardelli, *Tonal harmony and the topology of dynamical score networks* (2021), at <https://arxiv.org/abs/2006.01033>

Performance Notes – Flauto d'amore (flute(s))

Notation is undetermined in pitch, choice of pitch within the indicated register is left to the performer, to adapt dynamically to the accompaniment of the cosmic ray sequences.

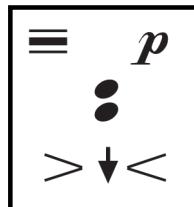
Notation is based on a gesture elements as displayed below. Each element is comprised of up to 4 performance directives arranged geometrically in a rectangle: A. register, B. dynamics, C. sound, D. expressive markings:



- A. If present, indicates the register of the sound(s): it can be also interpreted also as a starting register or ending register for the gesture
- B. If present, indicates the dynamics
- C. Main sound
- D. If present, indicates the expressive quality of the gesture.

If one of the characteristics is not present, it should be chosen by the performer.

As an example, here is a gesture with one or more dyad multiphonics sounds in the middle register, piano and with a downward variation in intonation:



Gestures can be repeated ad libitum, with complete freedom of pitch choice to adapt dynamically to the accompaniment of the cosmic ray sequences. All indications should be interpreted creatively by the performer; however, dynamic markings should be followed as much as possible.

A full description of the symbols is given in the next pages.

Each score section should be played for a similar amount of time, thus the graphical density of gestures in each section will determine the pace at which the performer will execute the individual gestures.

Register

- ☰ High
- ☰ Middle
- ☰ Low

Dynamics

ppp pp p mp mf f ff fff sfz

Expressions

<i>rallen.</i>	accelerando, rallentando	<↑>	variation in intonation (up or down)
<i>accel.</i>		>↓<	
	legato	↘↗	generic downward (upward) motion: glissando, arpeggio, melodic line, etc.
	tenuto	→→	
	crescendo	○→	nulla - crescendo
	decrescendo	→○	decrescendo - nulla

Sounds



with voice (at, above or below pitch) – can be played as the traditional blow+sing or as a more intense gesture (singing/shouting inside the flute) depending on dynamics and texture.



one-tone trill (one tone up or down), semitone trill down, semitone trill up;
trills should be started only after establishing clearly the pitch center



From ***ppp*** to ***mp*** “Sciarrino trill”: play a fast trill on D/D# with the right hand while fingering a note with the left hand – from ***mf*** to ***fff***, tremolo between arbitrary pitches or double trill



single, double and triple tonguing



fast pitch bending (exaggerated vibrato) or enharmonic trill



regular and short accent



regular sound (a dirty or breathy sound can be used as well)



key slap (open and closed embouchure) – with air

- whistle tone
- ◊ natural harmonics
-  spectral multiphonics
-  dyad multiphonics
-  flutter tongue
-  fast runs (bursts of grace notes of arbitrary length)
-  jet whistle from *mf* to *sfz*, else, tongue stop
- air or noisy sound with mouth into (mouthpiece) or onto the flute (body) – use of mouth noises is encouraged
- ▼ tongue pizzicato
- ✗ key click (no air)
- ▲ ▷ ▨ short, medium and long pauses

The score is dynamically generated for each performance by running the python code Cosmic-SCORE.py. The code generates multiple graphs (one for each section) in a randomized fashion, so no two scores (and hence performance directions) will ever be the same. The final score sections consist of a graph in single vector graphics format that can be opened in a web browser or imported in any word processor program (Word, PowerPoint, etc.) or SVG image processor (Illustrator, Inkscape). It is made of an ensemble of boxes (nodes) connected by directional paths. Each node contains a gesture element as described above. The paths provide choices on the direction the performer can follow in the execution of the piece.

Alternatively, the score can be also produced in form of tablature, to facilitate the reading of the sequences. Both versions are appropriate for the performance, and although different, they offer the same expressive freedom. The choice should be made by the performer on what version to use.

In the following I present the scores obtained with a seed for random number generators equal to 21521

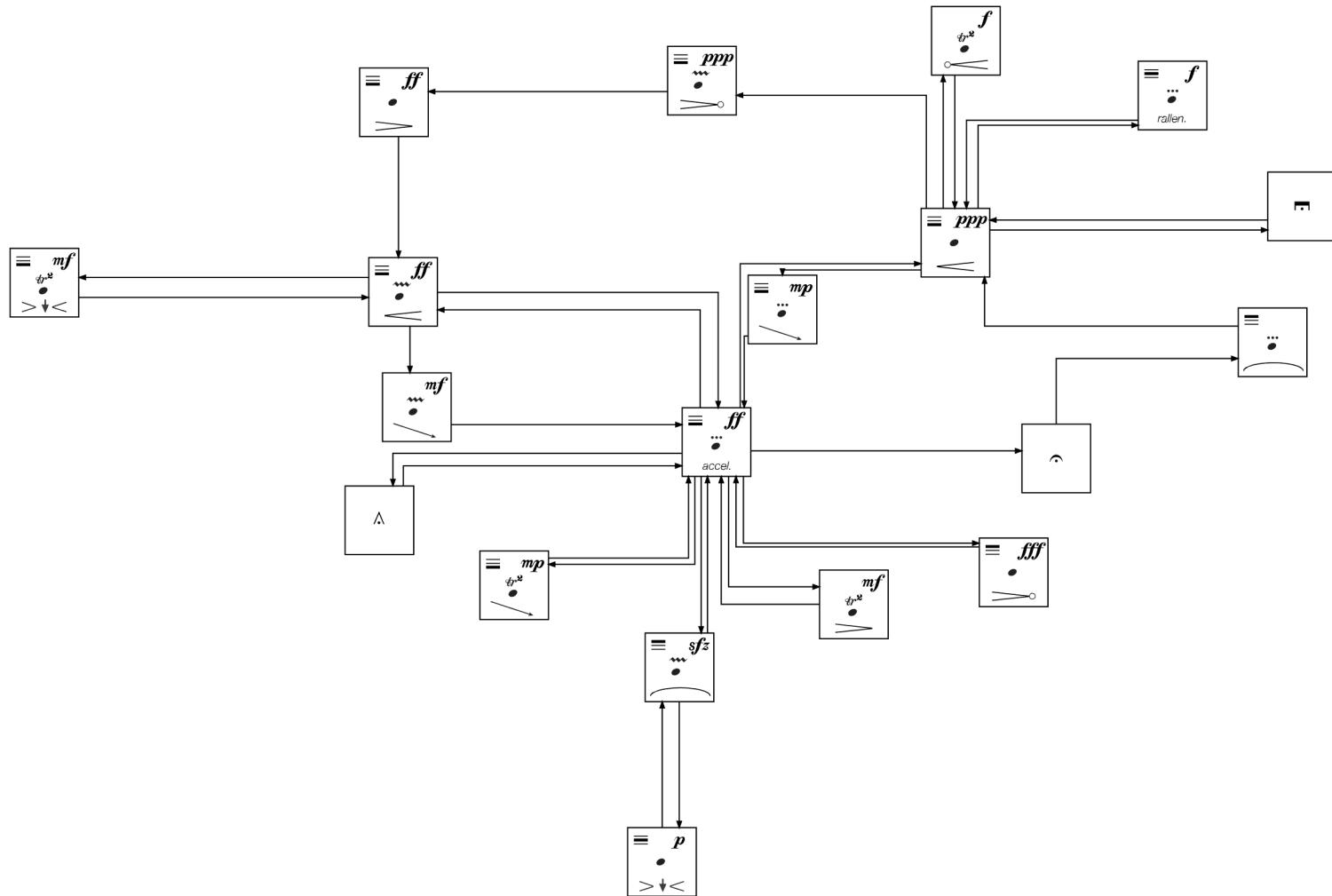
Finally, flute(s) must be amplified to enhance both acoustic and mechanics sounds.

Graph score

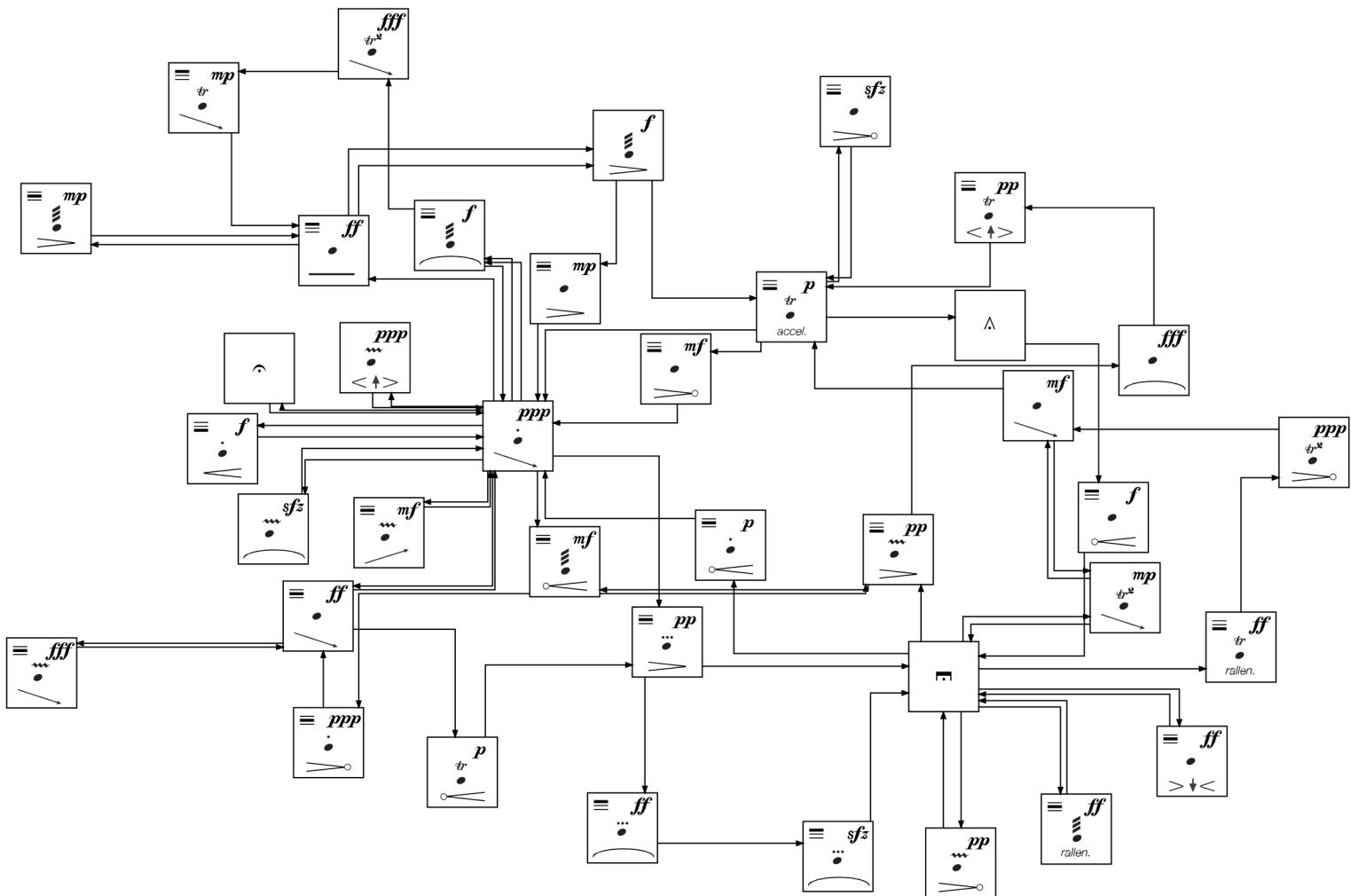
Seed = 21521

SILENCE
DARK

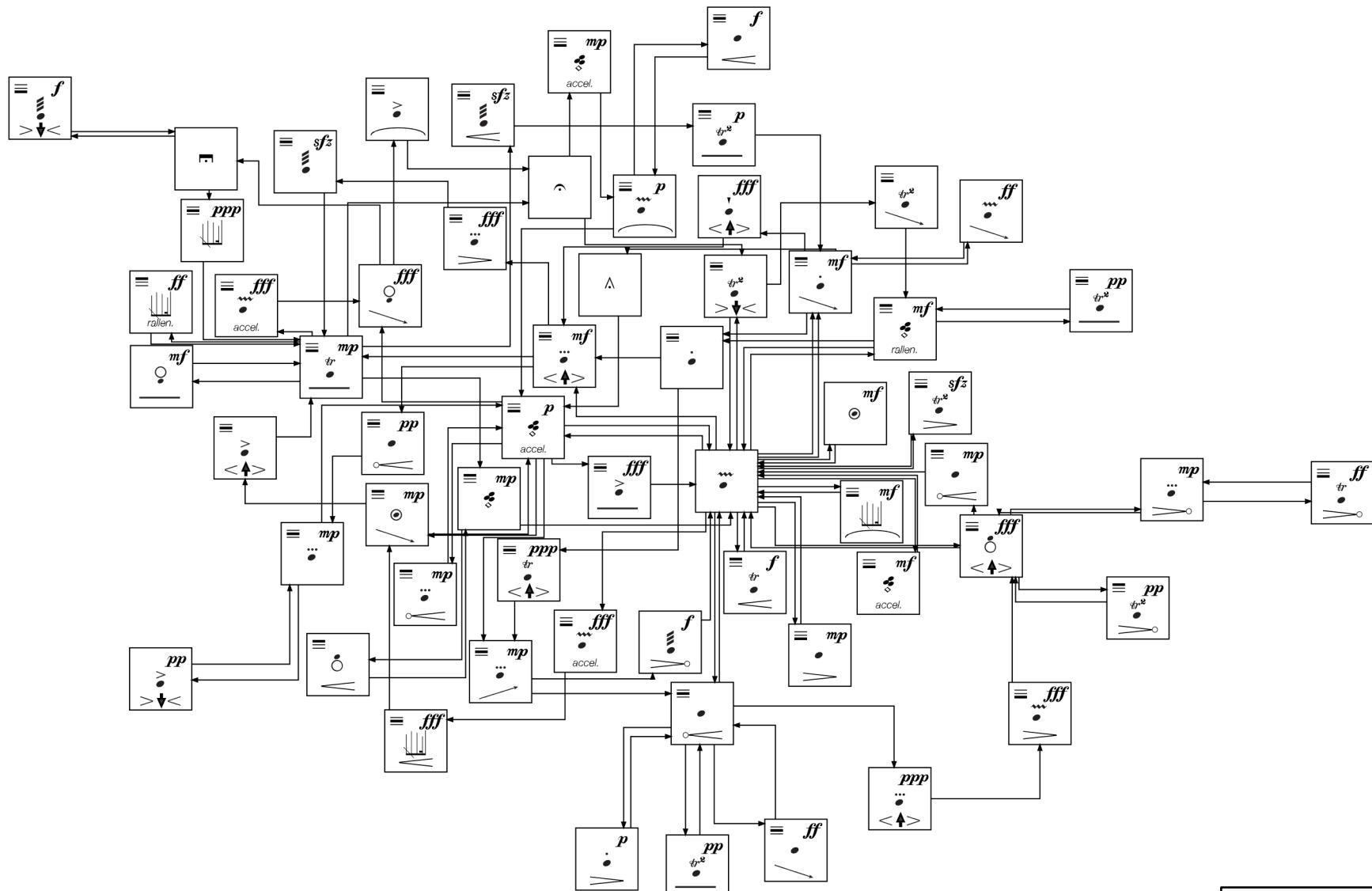
PEDAL



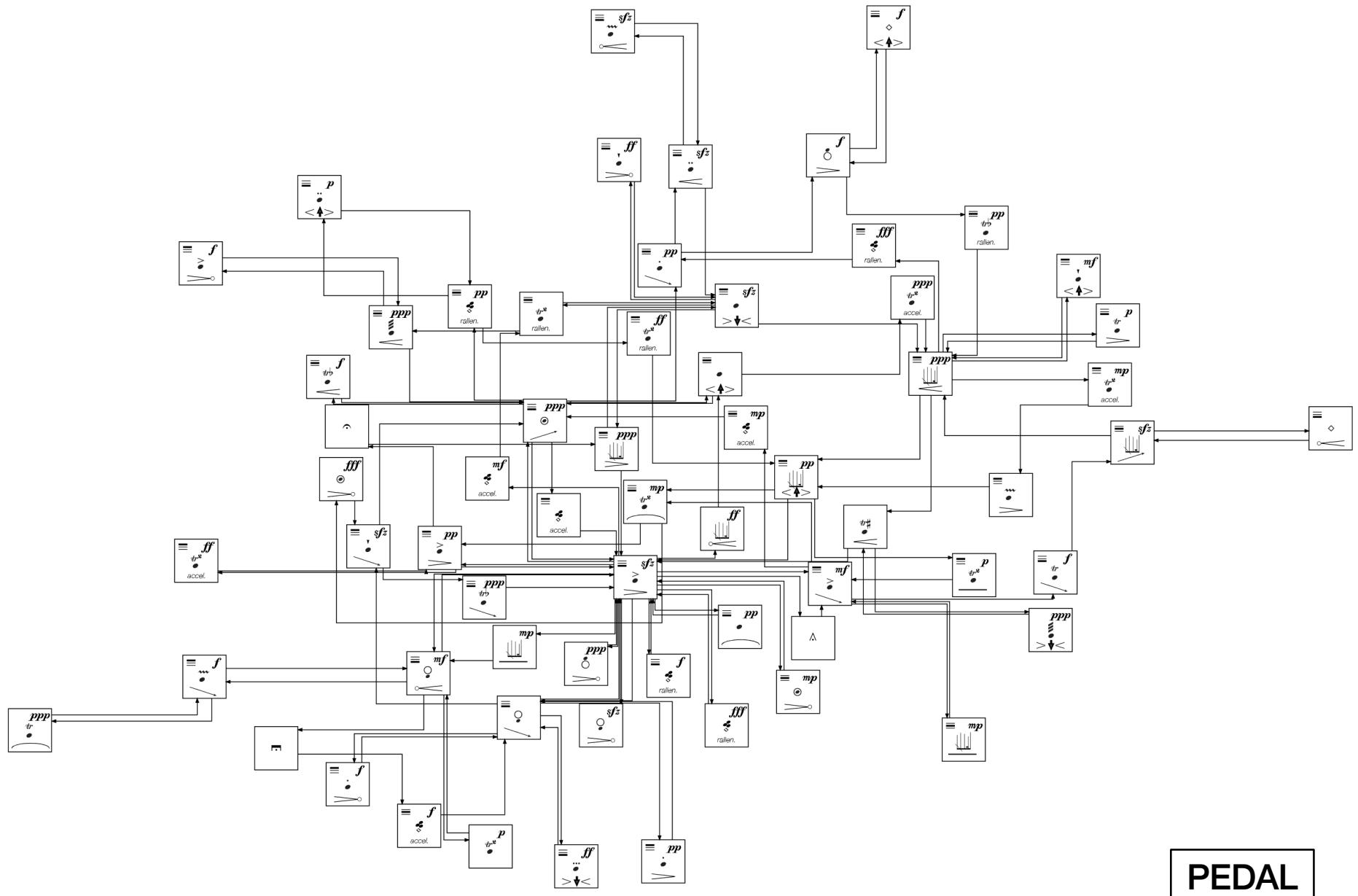
PEDAL

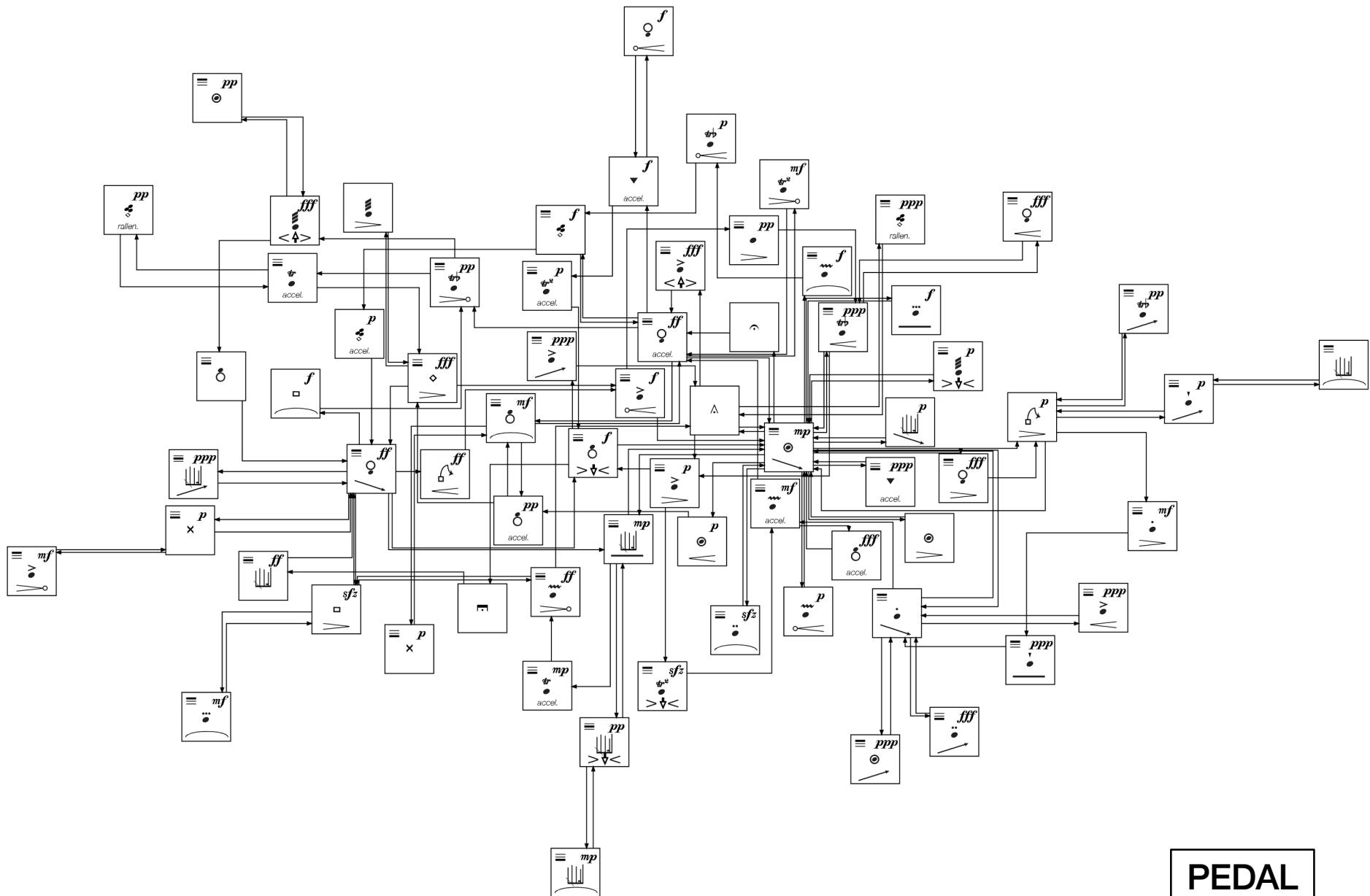


PEDAL

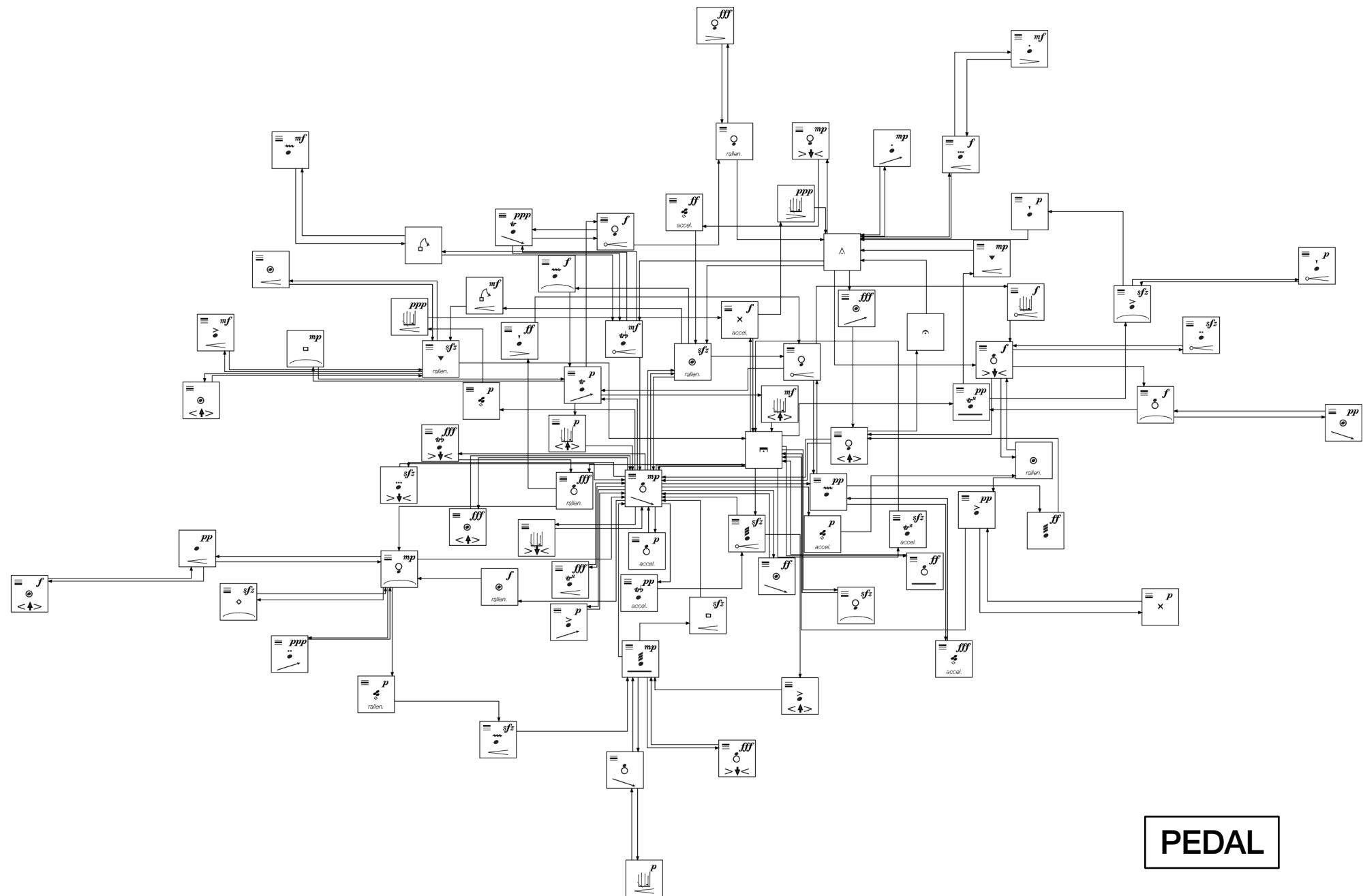


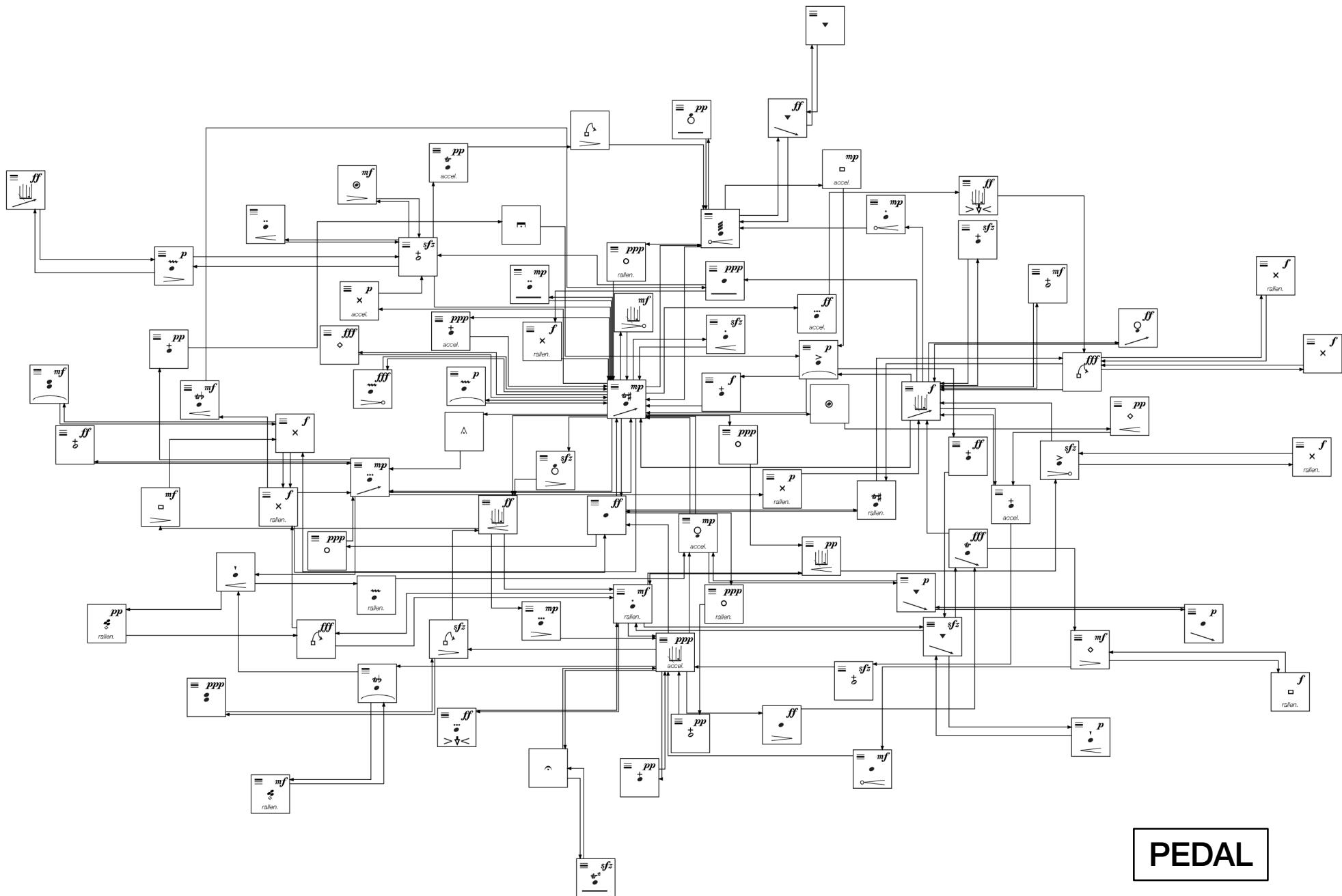
PEDAL

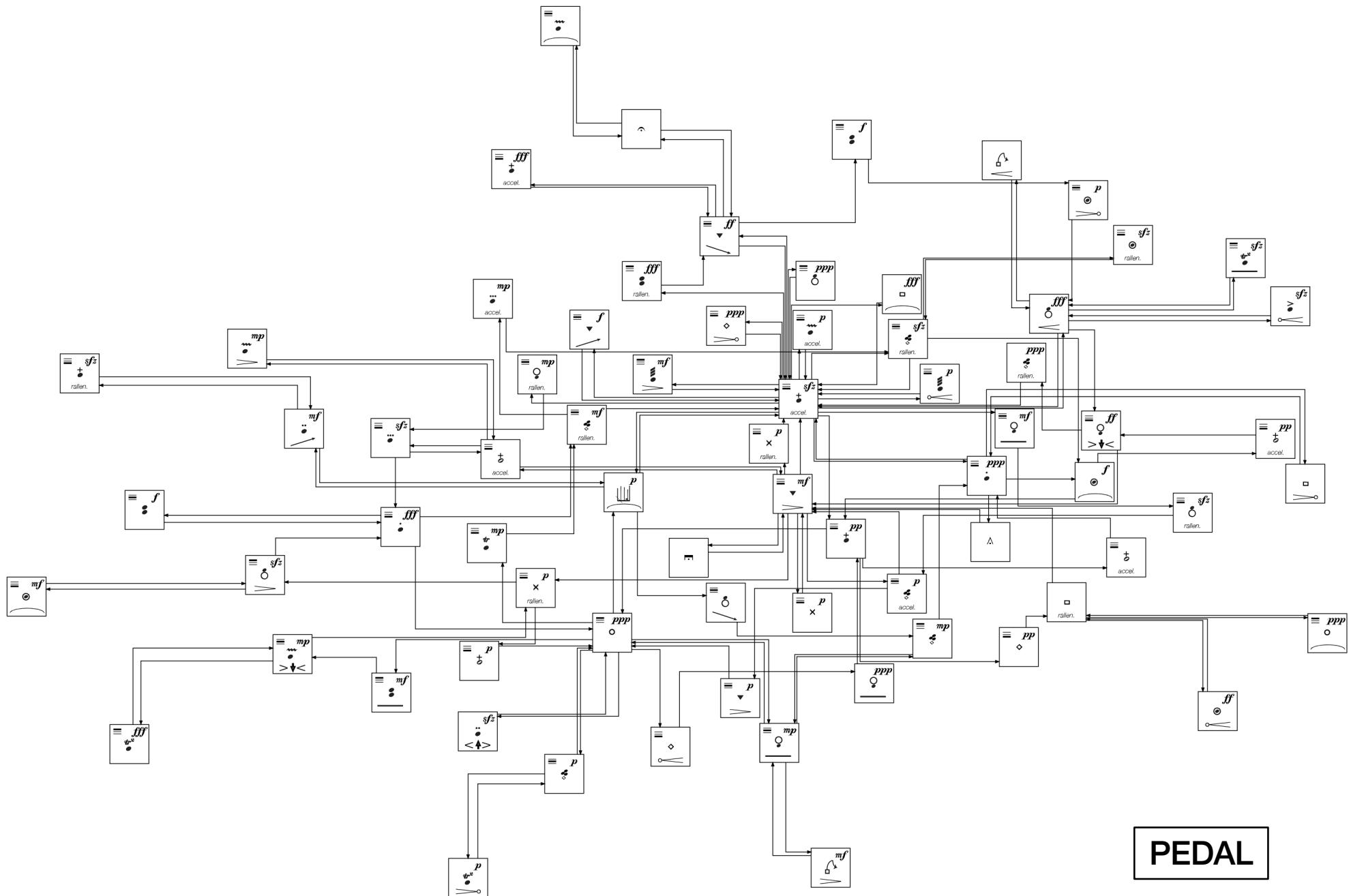


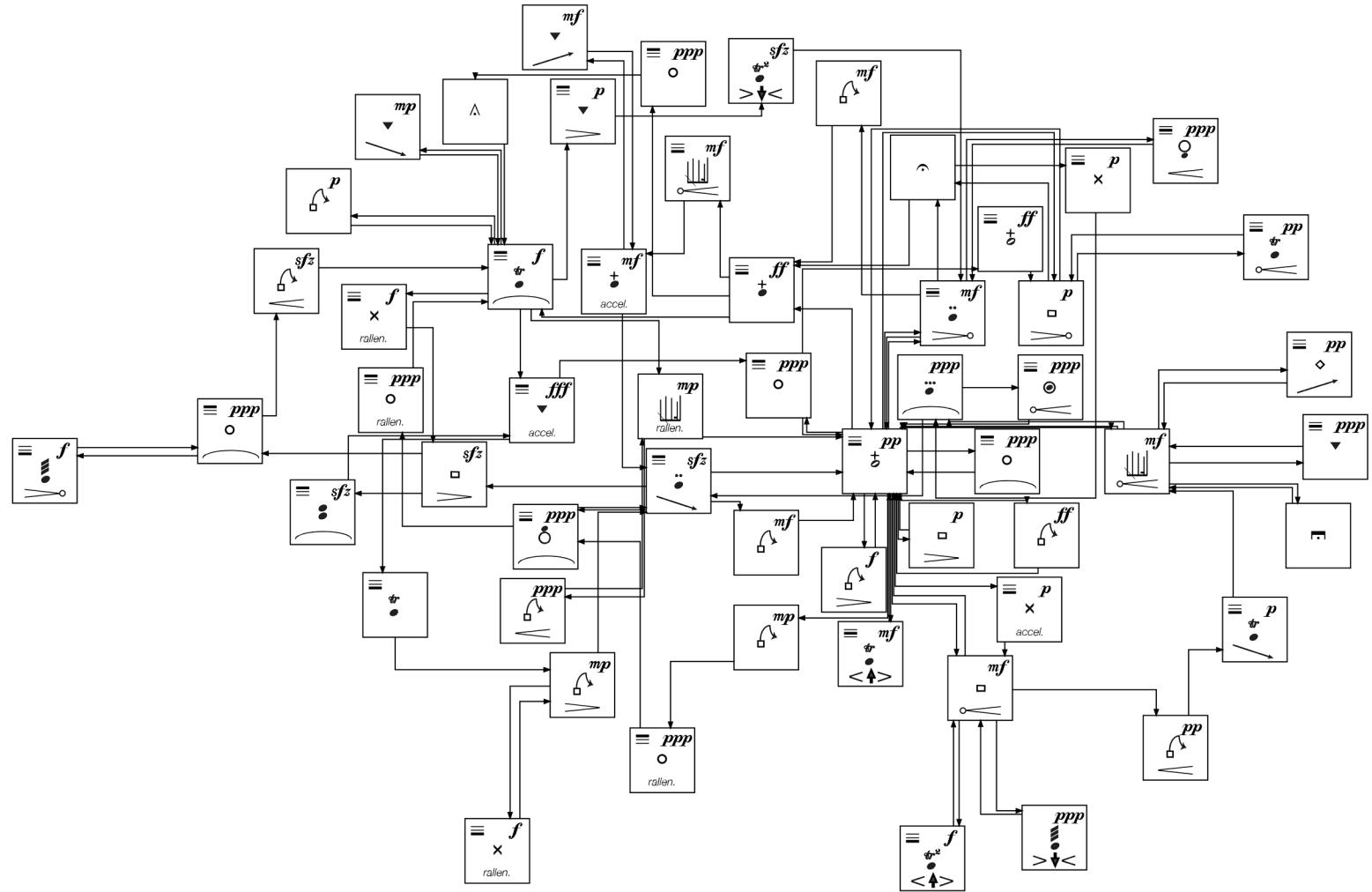


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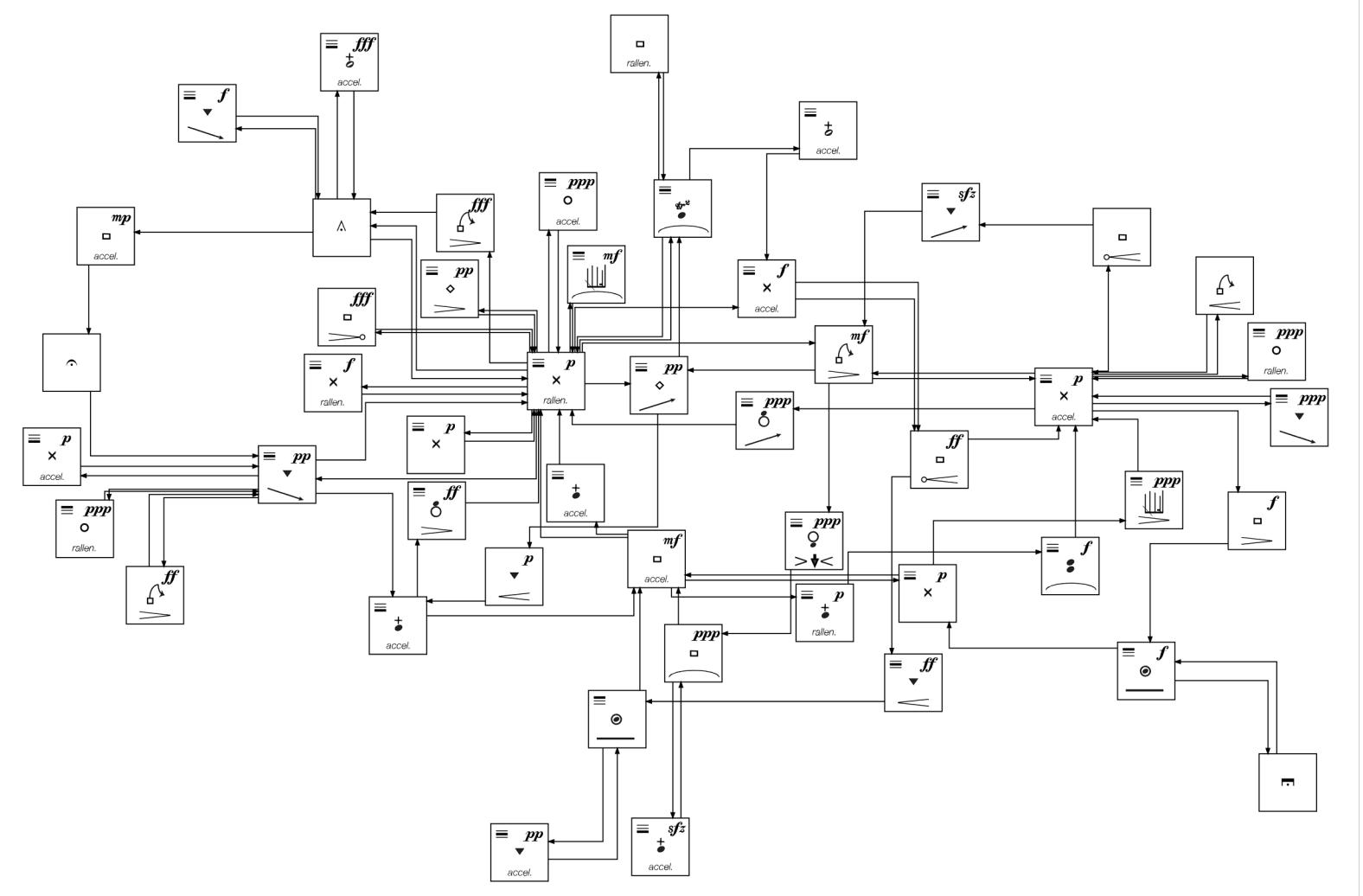




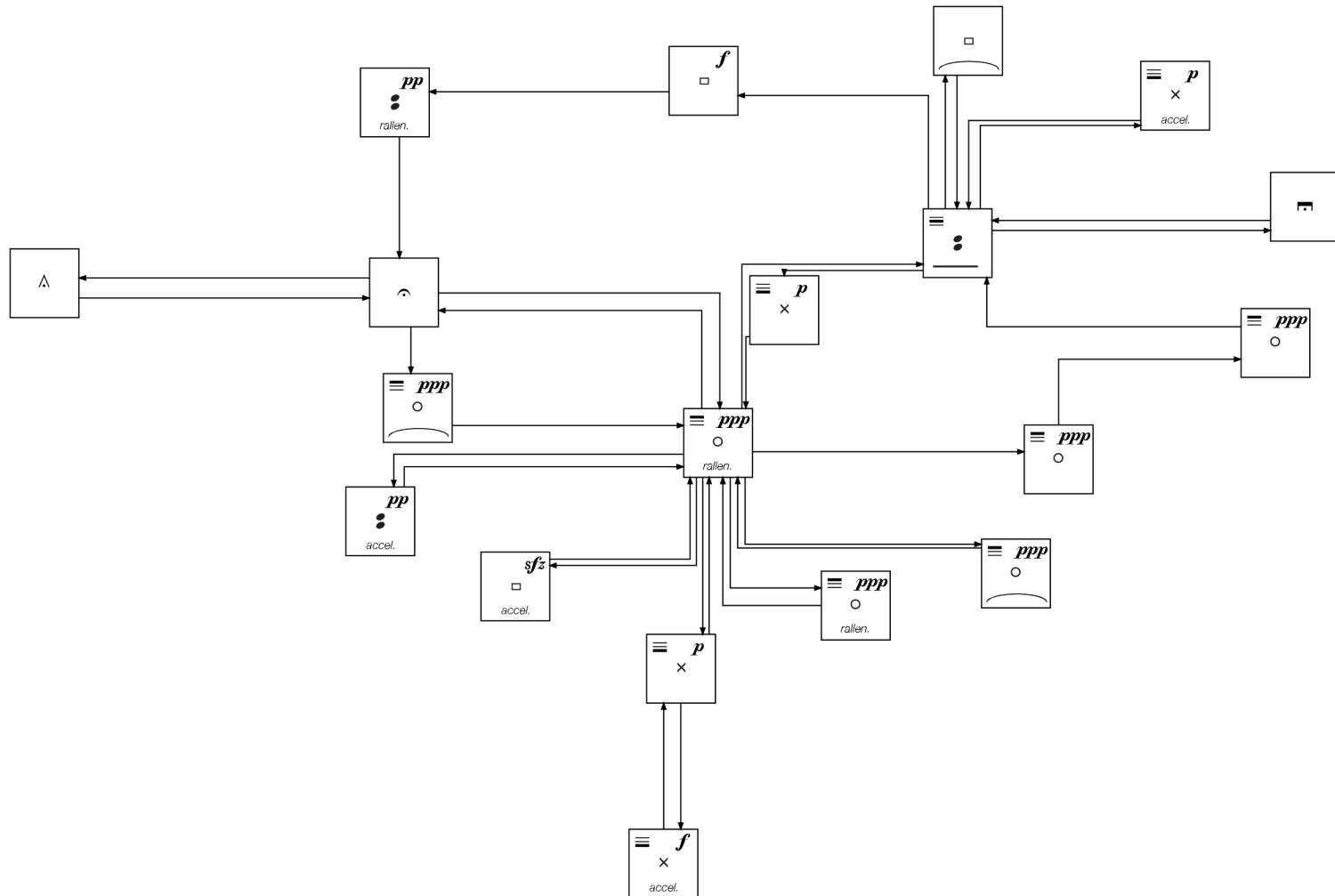




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SILENCE
DARK

PEDAL

Tablature score

Seed = 21521

NOTE: In the tablature score the performer can choose to move both horizontally and vertically, forward and backwards, and to switch between rows (columns) if there are parts of the edges in common.

SILENCE
DARK

PEDAL

$\equiv mp$ 	\wedge	$\equiv mp$ 	$\equiv mp$ 	$\equiv mf$ 	$\equiv mf$
\wedge	$\equiv ff$ 	\wedge	p 	p 	$\equiv fff$
$\equiv ff$ 	f 	f 	$\equiv mp$ 	p 	$\equiv mp$
\wedge	$\equiv fff$ 	$\equiv fff$ 	$\equiv ff$ 	$\equiv sfz$ 	$\equiv mp$
$\equiv ppp$ 	$\equiv \dots$ 	$\equiv mp$ 	\wedge	\wedge	mf
\wedge	$\equiv mp$ 	$\equiv sfz$ 	$\equiv mp$ 	$\equiv mp$ 	$\equiv mp$

PEDAL

$\equiv sfz$	\square	$\equiv pp$	\circ	$\equiv ff$	$\equiv ff$	$\equiv ff$	$\equiv ff$
$\ddot{\bullet}$	\square	$\ddot{\bullet}$	\circ	\bullet	\bullet	\bullet	\bullet
$\equiv f$	f	p	sfz	p	fff	mp	f
$\ddot{\bullet}$	\square	$\dot{\bullet}$	$\ddot{\bullet}$	\bullet	$\ddot{\bullet}$	\bullet	\bullet
$\equiv sfz$	ppp	mp	ppp	ff	ppp	pp	sfz
$\ddot{\bullet}$	\bullet	$\ddot{\bullet}$	\bullet	\bullet	$\ddot{\bullet}$	$\ddot{\bullet}$	$\ddot{\bullet}$
$\equiv pp$	ff	ff	fff	\wedge	fff	fff	mf
$\dot{\bullet}$	$\dot{\bullet}$	$\ddot{\bullet}$	$\ddot{\bullet}$	\wedge	$\dot{\bullet}$	$\dot{\bullet}$	$\dot{\bullet}$
$\equiv mp$	p	ff	mf	pp	ppp	sfz	f
\bullet	\bullet	$\ddot{\bullet}$	\bullet	$\ddot{\bullet}$	\bullet	$\ddot{\bullet}$	$\ddot{\bullet}$
$\equiv pp$	mp	ppp	fff	mf	mp	sfz	ff
$\dot{\bullet}$	$\ddot{\bullet}$	\square	$\dot{\bullet}$	$\dot{\bullet}$	$\dot{\bullet}$	$\ddot{\bullet}$	$\ddot{\bullet}$
$\equiv sfz$	fff	mp	sfz	fff	sfz	mf	sfz
$\ddot{\bullet}$	\bullet	$\dot{\bullet}$	\bullet	$\ddot{\bullet}$	$\ddot{\bullet}$	$\dot{\bullet}$	$\ddot{\bullet}$
ppp	fff	ppp	fff	mf	ppp	sfz	sfz
\bullet	\bullet	$\dot{\bullet}$	\bullet	\bullet	\bullet	\bullet	$\ddot{\bullet}$

PEDAL

$\equiv pp$	$\equiv mp$	$\equiv fff$	$\equiv sfz$	$\equiv pp$	$\equiv mf$	$\equiv pp$	$\equiv fff$	$\equiv f$	$\equiv mp$	$\equiv ppp$
$\equiv mp$	$\equiv fff$	$\equiv mp$	\equiv	$\equiv mp$	\equiv	$\equiv pp$	$\equiv ppp$	$\equiv mp$	\equiv	\equiv
$\equiv ff$	$\equiv f$	$\equiv mp$	$\equiv fff$	$\equiv p$	$\equiv sfz$	$\equiv p$	$\equiv mf$	$\equiv sfz$	$\equiv pp$	$\equiv ppp$
$\equiv sfz$	$\equiv mp$	$\equiv mf$	$\equiv mp$	$\equiv ff$	$\equiv pp$	$\equiv ff$	$\equiv p$	$\equiv ff$	$\equiv pp$	$\equiv sfz$
$\equiv pp$	$\equiv f$	$\equiv tr$	\equiv	$\equiv mf$	$\equiv mp$	$\equiv mf$	$\equiv pp$	$\equiv pp$	$\equiv pp$	$\equiv pp$
\equiv	$\equiv ff$	$\equiv mf$	$\equiv p$	$\equiv mp$	$\equiv mp$	$\equiv p$	$\equiv fff$	$\equiv pp$	$\equiv mp$	$\equiv pp$
$\equiv mf$	$\equiv f$	$\equiv tr$	\equiv	$\equiv mf$	$\equiv p$	$\equiv mf$	$\equiv p$	$\equiv pp$	$\equiv f$	$\equiv pp$
$\equiv mp$	$\equiv mp$	$\equiv mp$	$\equiv mp$	$\equiv mp$	$\equiv fff$	$\equiv pp$	$\equiv fff$	$\equiv pp$	$\equiv >$	$\equiv pp$
$\equiv fff$	$\equiv fff$	$\equiv mp$	$\equiv mp$	$\equiv mp$	$\equiv fff$	$\equiv pp$	$\equiv pp$	$\equiv mp$	$\equiv tr$	$\equiv pp$

PEDAL

$\equiv pp$	$\equiv ppp$	$\equiv ppp$	$\equiv pp$	$\equiv ff$	$\equiv pp$	\curvearrowleft	$\equiv sfz$	$\equiv f$	$\equiv sfz$	$\equiv sfz$
$\equiv ff$	$\equiv f$	$\equiv ff$	$\equiv f$	\diamond	$\equiv f$	\curvearrowleft	$\equiv f^*$	\diamond	$\equiv f$	$\equiv mf$
$\equiv sfz$	$\equiv sfz$	$\equiv sfz$	$\equiv fff$	$\equiv mf$	$\equiv pp$	\curvearrowleft	$\equiv mp$	$\equiv ppp$	$\equiv ppp$	$\equiv fff$
$\equiv ff$	$\equiv pp$	$\equiv ff$	$\equiv ppp$	$\equiv mf$	$\equiv mf$	\curvearrowleft	$\equiv ppp$	$\equiv pp$	f	\diamond
$\equiv ppp$	$\equiv ppp$	p	$\equiv p$	$\equiv ff$	\curvearrowleft	\curvearrowleft	$\equiv mp$	$\equiv pp$	$\equiv mp$	$\equiv f$
$\equiv ff$	$\equiv sfz$	$\equiv f$	$\equiv fff$	$\equiv f^*$	$\equiv p$	\wedge	$\equiv p$	$\equiv f$	$\equiv mp$	$\equiv f$
$\equiv f$	$\equiv f$	p	$\equiv mp$	$\equiv pp$	$\equiv mp$	\curvearrowleft	ff	$\equiv sfz$	$\equiv pp$	$\equiv fff$
$\equiv p$	$\equiv sfz$	$\equiv pp$	$\equiv fff$	$\equiv sfz$	ff	\curvearrowleft	$\equiv fff$	$\equiv pp$	$\equiv pp$	$\equiv pp$
$\equiv f^*$	$\equiv f^*$	$\equiv f^*$	$\equiv ff$	$\equiv f$	$\equiv mp$	$\equiv pp$	$\equiv pp$	$\equiv pp$	$\equiv pp$	$\equiv pp$
$\equiv f$	$\equiv fff$	$\equiv ppp$	$\equiv ff$	$\equiv p$	$\equiv ff$	\curvearrowleft	$\equiv pp$	$\equiv pp$	$\equiv pp$	$\equiv pp$
$\equiv sfz$	$\equiv ppp$	$\equiv ppp$	$\equiv mf$	$\equiv mf$	$\equiv ppp$	\curvearrowleft	$\equiv ppp$	$\equiv pp$	$\equiv pp$	$\equiv pp$

PEDAL

$\equiv ppp$	$\equiv fff$	\equiv	$\equiv sfz$	$\equiv fff$	$\equiv ff$	$\equiv fff$	$\equiv f$	$\equiv ppp$	$\equiv p$	$\equiv fff$
>	<			<^>	accel.	<^>				
 accel.										
$\equiv fff$	$\equiv p$	\equiv	$\equiv mf$	$\equiv mf$	$\equiv fff$	$\equiv mf$	$\equiv mf$	$\equiv p$	$\equiv p$	$\equiv p$
$\equiv fff$	$\equiv ff$	$\equiv sfz$	$\equiv p$	$\equiv ppp$	$\equiv ppp$	$\equiv ppp$	$\equiv p$	$\equiv p$	$\equiv sfz$	$\equiv ppp$
>	<	>^<		accel.	>	accel.	>^<			
p •	f	f	mp		f	mf		mf	ff	mf
$\equiv ppp$	$\equiv fff$	\equiv	$\equiv ff$	$\equiv mf$		p	$\equiv ppp$	$\equiv mf$	$\equiv f$	$\equiv f$
•	>	<^>		accel.		>		•		pp
p •	f	f	mp	p	p	mf	pp	p	ppp	ppp
				>^<						
$\equiv fff$	$\equiv ppp$	\equiv	$\equiv ff$	$\equiv sfz$	$\equiv mp$	$\equiv ppp$	p	$\equiv ppp$	$\equiv ff$	$\equiv ppp$
>										
rallen.										
p •	f	f	f	p	p	mf	pp	pp	pp	pp
$\equiv ff$	$\equiv fff$	\equiv	$\equiv pp$	$\equiv mf$		p	$\equiv ppp$	$\equiv f$	$\equiv ppp$	$\equiv ff$
	>	<^>		rallen.						
$\equiv p$	$\equiv fff$	$\equiv pp$		$\equiv ppp$		p	$\equiv ppp$	$\equiv mp$	$\equiv sfz$	$\equiv sfz$
x	>	<^>								
p •	f	f	f	mf	pp	p	pp	pp	p	sfz
$\equiv ppp$	$\equiv ppp$	\equiv	$\equiv ff$	$\equiv mf$	p	p	p	p	sfz	$\equiv ppp$

PEDAL

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\equiv	$\text{gr} \bullet$	sfz	$\equiv ppp$	$\equiv ppp$	$\equiv ppp$	$\equiv mp$	$\equiv ff$	\wedge	$\equiv p$	$\equiv mf$
		$\text{gr}^x \bullet$ $> \downarrow <$	\circ (\smile)	\circ $\circ \swarrow$	$\square \curvearrowleft$	$\square \curvearrowright$ ralien.	$\dot{\bullet}$		\square	\bullet $\geq \circ$
	sfz	mf	$\text{gr} \bullet$	p	f	mf	ff	f	ff	sfz
	\square	$\square \curvearrowleft$	$\text{gr} \bullet$	\square	$\square \curvearrowleft$	$\square \curvearrowright$	$\square \curvearrowleft$	$\square \curvearrowright$	$\square \curvearrowleft$	$\square \curvearrowright$
	mf	f	mf	\square	ppp	\square	mp	\square	p	\square
	\square	\square	$\text{gr} \bullet$	\square	$\square \curvearrowleft$ $> \downarrow <$	\square	$\square \curvearrowleft$	\square	$\square \curvearrowleft$	\square
\equiv	mf	sfz	mp	ff	f	p	ppp	$\text{gr} \bullet$	ppp	ppp
	$\dot{\bullet}$	$\text{gr}^x \bullet$ $> \downarrow <$	\square	$\dot{\bullet}$	\times	\times	\circ	$\text{gr} \bullet$	\circ	\circ
	f	sfz	p	mf	pp	ff	pp	p	f	ppp
	$\square \curvearrowleft$	\bullet	\times	$\square \curvearrowright$	$\square \curvearrowleft$	$\square \curvearrowright$	$\square \curvearrowleft$	\times	\times	\circ
	p	sfz	p	mf	ff	sfz	p	$\text{gr} \bullet$	f	$\text{gr} \bullet$
	$\text{gr} \bullet$	$\text{gr}^x \bullet$ $> \downarrow <$	\square	$\square \curvearrowleft$	$\dot{\bullet}$	\square	\times	$\text{gr} \bullet$	$\square \curvearrowleft$	$\text{gr} \bullet$
	f	\square	$\text{gr} \bullet$	mf	pp	pp	\square	$\text{gr} \bullet$	f	$\text{gr} \bullet$
	$\square \curvearrowleft$	\square	$\text{gr} \bullet$	$\square \curvearrowright$	$\dot{\bullet}$	\square	\square	$\text{gr} \bullet$	\times	$\text{gr} \bullet$
	\square	$\text{gr} \bullet$	ff	ppp	ff	sfz	mf	$\text{gr} \bullet$	mp	$\text{gr} \bullet$
	\square	$\text{gr} \bullet$	$\text{gr} \bullet$	$\text{gr} \bullet$	$\dot{\bullet}$	\times	$\text{gr} \bullet$	$\text{gr} \bullet$	$\square \curvearrowleft$	$\text{gr} \bullet$
	ppp	mp	ppp	ppp	ppp	sfz	$\text{gr} \bullet$	\square	ppp	$\text{gr} \bullet$
	\circ	\square	$\text{gr} \bullet$	\circ	\circ	\bullet	$\text{gr} \bullet$	\square	\circ	$\text{gr} \bullet$
	ff	p	ppp	pp	ff	p	pp	$\text{gr} \bullet$	ff	$\text{gr} \bullet$
	$\dot{\bullet}$	\square	$\square \curvearrowleft$	\square	$\dot{\bullet}$	\times	$\text{gr} \bullet$	$\text{gr} \bullet$	$\text{gr} \bullet$	$\text{gr} \bullet$

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p	<i>ff</i> =	<i>ppp</i> =	<i>ppp</i> =	<i>ppp</i> =	p	<i>pp</i> =	<i>p</i> =	<i>ppp</i> =	<i>p</i> =
<i>p</i> x accel.			<i>pp</i> =	<i>mf</i> =	<i>sfz</i> =	<i>ff</i> =	<i>ppp</i> =	<i>fff</i> =	
<i>p</i> x accel.			<i>pp</i> =	<i>ppp</i> =	<i>ppp</i> =	<i>fff</i> =	<i>f</i> =	<i>ppp</i> =	<i>f</i> =
<i>f</i> x accel.				<i>ppp</i> =	<i>ppp</i> =	<i>fff</i> =	<i>f</i> =	<i>mf</i> =	<i>f</i> =
<i>c</i>		<i>fff</i> =			<i>ff</i> =	<i>p</i> =	<i>f</i> =	<i>ff</i> =	<i>sfz</i> =
			<i>ppp</i> =		<i>f</i> =	<i>f</i> =			
		<i>fff</i> =	<i>fff</i> =						
				<i>ppp</i> =	<i>p</i> =		<i>f</i> =		
	<i>ff</i> =	<i>pp</i> =							

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sfz □ accel.	pp ● accel.	$\equiv \text{p}$ ×	sfz □ accel.	\wedge	$\equiv \text{ppp}$ ○ (—)
pp ● accel.	$\equiv \text{ppp}$ ○ rallen.	pp ● accel.	$\equiv \text{f}$ × accel.	■	$\equiv \text{ppp}$ ○ (—)
○	$\equiv \text{p}$ × accel.	□	sfz □ accel.	$\equiv \text{ppp}$ ○ accel.	sfz □ accel.
pp ● accel.	$\equiv \text{ppp}$ ○ (—)	$\equiv \text{ppp}$ ○ (—)	pp ● rallen.	$\equiv \text{p}$ × accel.	sfz □ accel.
\equiv ● —	$\equiv \text{ppp}$ ○ —	sfz □ accel.	$\equiv \text{ppp}$ ○ —	$\equiv \text{ppp}$ ○ rallen.	sfz □ accel.
pp ● accel.	sfz □ accel.	$\equiv \text{p}$ × —	sfz □ accel.	sfz □ accel.	

PEDAL

SILENCE
DARK

PEDAL

Compositional design and algorithmic notes

This piece embodies the idea of performers and audience as active co-creators of the artistic event. This idea has developed over the years, starting with my miniature opera **Unknown, a journey** (<https://www.materialssoundmusic.com/copy-of-installations>) and has now found an evolutionary path in the concept of musical spaces as networks, that has become the foundation of my artistic and music-theoretic research in the past few years [1,2]. In **L'Indifferenza dell'Amore Cosmico**, every aspect of the performance is defined by two key elements: a network of nodes with a specific connection topology, and the determination of the optimal path that visits every link connecting any node at least once. Once the parameters of the execution have been defined the performers are highly encouraged not to stop at the first generation of the score(s) but explore how different choices of the parameters would result in the final performance.

The network structure used in the generation of the previous score is produced using the Barabasi-Albert model for the generation of random scale-free networks [3] but other models are also implemented in the score-generating program. The Barabasi-Albert model incorporates two important general concepts, growth and preferential attachment: growth means that the number of nodes in the network increases over time; preferential attachment means that the more connected a node is, the more likely it is to receive new links. Nodes with a higher degree have a stronger ability to grab links added to the network. The resulting topology is fundamental in the analysis of many musical spaces [1,2]. This topology is also central to the determination of the optimal path that guides the performer through the graph: we solve here a route optimization problem to find a shortest closed path or circuit that visits every edge of the graph we have generated. When the graph has a Eulerian circuit (a closed walk that covers every edge once), that circuit is an optimal solution. Otherwise, the optimization problem is to find the smallest number of graph edges to duplicate (or the subset of edges with the minimum possible total weight) so that the resulting multigraph does have a Eulerian circuit.

- [1] Buongiorno Nardelli, M. (2020). Topology of Networks in Generalized Musical Spaces. *Leonardo Music Journal*, 30, 38-43. Also available at <https://arxiv.org/abs/1905.01842>.
- [2] Buongiorno Nardelli, M. (2021). Tonal harmony and the topology of dynamical score networks. *under review*. Also available at <https://arxiv.org/abs/2006.01033>.
- [3] Barabasi, A., & Albert, R. (1999). Emergence of scaling in random networks. *Science*, 286, 509-512.

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is a composer, media artist and computational physicist who brings a platform for Art/Science integration rooted in his profound and extensive expertise in development of scientific and artistic software and his vision for sustainable community software development. He is University Distinguished Research Professor at the University of North Texas, with academic appointments in Physics, Chemistry and Composition, and a member of iARTA, the Initiative for Advanced Research in Technology and the Arts and of CEMI, the Center for Experimental Music and Intermedia. His scientific research activities range from the design and discovery of novel materials for 21st century applications in renewable energy, environment, nano-electronics and devices, to the development of advanced electronic structure theories and high-throughput techniques in materials genomics and computational materials design. As a music theorist he is a pioneer in the application of complexity theories and big data analysis tools to the structure of music as a generalized mathematical space. As an artist, he is internationally recognized for his music/new media installations, and his artistic research is rooted in the duality "music as data, data as music", including the translation of scientific data and processes into sonic, and potentially artistic, material. See www.materialssoundmusic.com, www.musicntwrk.com and ermes.unt.edu for more information and to learn about his other projects.