

SUBSTANTIA
PHYSICAL MODELLING LABORATORY

ON
OFF

INPUT

VOLUME

MONO

IN EQ

LOW SHELVE

BAND 1 GAIN

BAND 1

BAND 2

BAND 2 GAIN

HIGH SHELVE

MIDI IN

96. BPM

SOURCE

MIC SAMPLE NOISE

GAIN

HPF FILTER

LPF FILTER

ENVELOPE

IMPULSE

ATTACK

DECAY

SUSTAIN

RELEASE

SAMPLER

PITCH

REVERSE

FORWARD

LAYERS

BOOST

RANDOM

DISTANCE

PROBABILITY

PITCH LAYERING

PLAY/STOP

RECORD

MODEL Separe ▾ MATERIAL Copper ▾

REMAINING

ODD

RESONANCE

EVEN

TUNING 440Hz

FREQUENCY

LIQUIFY

SPEED

INDEX

ACTIVE 9

PROBABILISTIC EUCLIDEAN PATTERN

READ

WRITE

REC/STOP

DELETE

STOCHASTIC

PLAY/STOP

PLUGIN

VST

EQUALIZER

MASTER

LOAD

OPEN

RECORDER & MASTER OUT

SET

REC/STOP

OUT EQ

LOW SHELVE

HIGH SHELVE

BAND 1 GAIN

BAND 1

BAND 2 GAIN

BAND 2

LOAD BANK

SAVE BANK

ASSIGN MIDI

ASSIGN KEY

OPEN MAPPING

LOAD

SAVE

SUBSTANTIA

User Manual



DANGER!
READ CAREFULLY THIS MANUAL
NOT JOKING!!!

INTRODUCTION

Welcome to Substantia!

Substantia (latin: substance), is an electroacoustic physical modelling laboratory with hundreds of models. It is a modal synthesis software with integrated euclidean sequencer and recorder. Although Substantia is not a VST plugin (it's a standalone software) you can connect it with your DAW with a virtual audio driver such as Blackhole or Loopback.

PLEASE READ CAREFULLY THIS MANUAL TO AVOID EAR DAMAGES AND HAVE THE BEST EXPERIENCE WITH SUBSTANTIA.

THEORY

There are around 50 sound synthesis techniques in the world, the vast majority of which is digital based. Modal synthesis is an important form of physical modelling synthesis that in the last years, with the implementation in the modular world, has gained a certain popularity.

The vast majority of modal softwares and modules, so far, have few options and controls.

Some tools give you just inharmonicity and dumping controls, some other give you a few models like a pipe, a plate, a box, and a very small selection of materials: metals, plastic, wood.

Substantia instead has 16 different models and 23 materials, ranging from Aluminium to Nickel, Glass, Marble, Sapphire, Platinum, Gold, Nylon, Uranium Oxide and more, for a total of 368 resonant models. (The list will grow with updates).

Also, Substantia use a great number of filters for high precision hyper-realistic sounds.

We use 100 Resonant Band Pass filter for each voice, for a total of 800 filters (8 voice polyphony)!

What are natural frequencies?

Natural frequency, also known as eigenfrequency, is the frequency at which a system tends to oscillate in the absence of any driving or damping force. The motion pattern of a system oscillating at its natural frequency is called the normal mode (if all parts of the system move sinusoidally with that same frequency). If the oscillating system is driven by an external force at the frequency at which the amplitude of its motion is greatest (close to a natural frequency of the system), this frequency is called resonant frequency.

A normal mode of an oscillating system is a pattern of motion in which all parts of the system move sinusoidally with the same frequency and with a fixed phase relation. The free motion described by the normal modes takes place at the fixed frequencies. These fixed frequencies of the normal modes of a system are known as its natural frequencies or resonant frequencies. A physical object, such as a building, bridge, or molecule, has a set of normal modes and their natural frequencies that depend on its structure, materials and boundary conditions. When relating to music, normal modes of vibrating instruments (strings, air pipes, drums, etc.) are called "harmonics" or "overtones".

The most general motion of a system is a superposition of its normal modes. The modes are normal in the sense that they can move independently, that is to say that an excitation of one mode will never cause motion of a different mode. In mathematical terms, normal modes are orthogonal to each other.

In physics and engineering, for a dynamical system according to wave theory, a mode is a standing wave state of excitation, in which all the components of the system will be affected sinusoidally under a specified fixed frequency.

Because no real system can perfectly fit under the standing wave framework, the mode concept is taken as a general characterization of specific states of oscillation, thus treating the dynamic system in a linear fashion, in which linear superposition of states can be performed.

As classical examples, there are:

- In a mechanical dynamical system, a vibrating rope is the most clear example of a mode, in which the rope is the medium, the stress on the rope is the excitation, and the displacement of the rope with respect to its static state is the modal variable.
- In an acoustic dynamical system, a single sound pitch is a mode, in which the air is the medium, the sound pressure in the air is the excitation, and the displacement of the air molecules is the modal variable.
- In a structural dynamical system, a high tall building oscillating under its most flexural axis is a mode, in which all the material of the building - under the proper numerical simplifications- is the medium, the seismic/wind/environmental solicitations are the excitations and the displacements are the modal variable.
- When relating to music, normal modes of vibrating instruments (strings, air pipes, drums, etc.) are called "harmonics" or "overtones".

Most dynamical system can be excited under several modes. Each mode is characterized by one or several frequencies, according to the modal variable field. For example, a vibrating rope in the 2D space is defined by a single-frequency (1D axial displacement), but a vibrating rope in the 3D space is defined by two frequencies (2D axial displacement).

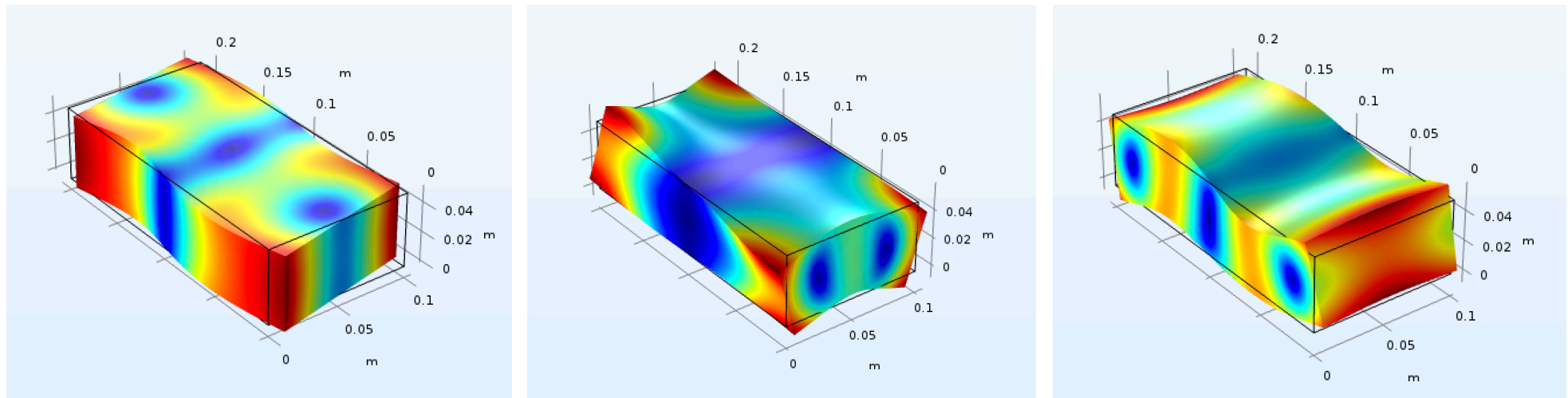
A mode of vibration is characterized by a modal frequency and a mode shape. It is numbered according to the number of half waves in the vibration. For example, if a vibrating beam with both ends pinned displayed a mode shape of half of a sine wave (one peak on the vibrating beam) it would be vibrating in mode 1. If it had a full sine wave (one peak and one trough) it would be vibrating in mode 2.

In a system with two or more dimensions, such as the solid pictured below, each dimension is given a mode number.

In linear systems each mode is entirely independent of all other modes. In general all modes have different frequencies (with lower modes having lower frequencies) and different mode shapes.

In a one-dimensional system at a given mode the vibration will have nodes, or places where the displacement is always zero (pictured in blue). These nodes correspond to points in the mode shape where the mode shape is zero. Since the vibration of a system is given by the mode shape multiplied by a time function, the displacement of the node points remain zero at all times.

When expanded to a two dimensional system, these nodes become lines where the displacement is always zero. (Wikipedia)



Different modes of a solid

To make theory easy:

Every system has natural modes of vibration (on all axis) which depend on the geometry and size of the system and its material (density, elasticity etc.). Engineers use modal analysis to discover the weak points of a system. Let's say for example a washing machine. It's important to know the frequencies at which the drum centerpiece will resonate, causing a severe displacement and possibly a mechanical failure.

But what an engineer considers a “weak point”, is a “strong point” for a musician!

Natural modes of vibration tell us about the sound of objects.

We can use the same tools that structural engineers use every day to perform modal analysis, to predict the natural modes of vibration of any solid with any (isotropic) material we want, and then use the data to craft virtual models.

This is essentially what Substantia uses to create hyper-realistic sounds.

Samples vs Resonators

Suppose you want to use a big Tibetan bowl in your electroacoustic piece.

You can buy one, or you rent a studio and sample the one they have.

You put your microphones in place, press record on your DAW and use a mallet to strike the bowl.

But of course you need to record multiple samples because you need different dynamics, maybe 7 or 8 from *ppp* to *fff*.

Then you decide to make an experiment rubbing a little metal chain on the bowl; you like the sound and then again you must record 7 or 8 samples with different dynamics. But hold on! You also want to use different gestures. Fast, slow... again you must sample everything. And what about that metal sponge, and the keychain in the bag? You record and record and record....

Then you back home with your samples (some hundreds) and you need to map them to your sampler.

Suddenly you realize you forgot to record a soft mallet... but you can't go back to the studio.

You can't try to filter your sound because a filter will touch the original harmonics of the bowl and will make it sound dull.

Also you realized that you really wanted to sample the smaller bowl in the studio to get different tones. But recording time was over.

A sample is like a photography, Once it's done, it's done.

Of course you can edit the sound and use effects, but the more you transform it, the more it will sound unnatural.

A different approach is to use modal synthesis.

If we model a bowl in a Multiphysics software we can do a modal analysis and later program a bank of resonators with the data.

The big difference between a physical model and a sample is that with the sample you can't separate the resonating body (the bowl) from the exciter (the

mallet, the metal chain), while with a physical model you have a virtual bowl that can be excited later with any sound you want and you will not notice the difference with the real one!

Also with a physical model of the Tibetan bowl you are not limited to brass, but you can use a great number of materials from Aluminium to Zinc...

Often, resonators oscillators are just excited with an impulse. This is nice for some sounds, but it's a very bad limitation.

With Substantia, you can excite the models in three different ways:

1) WHITE NOISE

This can be enveloped as a short impulse, or with long times. The sound change from a strike, to something similar to a blow of air.

2) SAMPLES

You can use the sound of chains, keys, leaves, mallet and water (and many more) to excite your resonators and the effect, as you will hear, is hyper-realistic. Also you can make pitch layers of the same sample (up to 10 layers) and create a texture, or take random bits of your sample to create more surreal sounds.

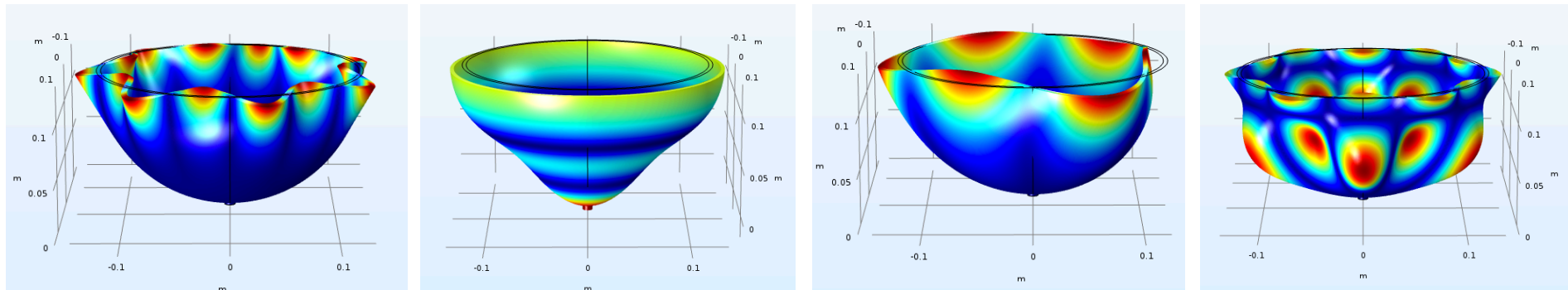
3) CONTACT MICROPHONES

Even better than sampling, you can use a contact microphone (I use the excellent Schertler mics) to excite the resonators in realtime.

Please note: you must use precautions to avoid nasty feedbacks! Use headphones or a very careful microphones/speakers placement.

You could use also normal microphones, but these are not the best for the kind of sounds you will need to excite the resonators.

A pair of contact mics will give you a nice stereo effect.



Some natural modes of vibration of a bowl in aluminium

Settings

Before you start to play with Substantia it's essential to set some preferences.



At the top of Substantia you will find the DSP preferences.



FIRST OF ALL set I/Ovs and SIGvs to 1024 (at the right of the preferences bar)

These are the I/O vector size and signal vector size used to/from and inside the software.

Because we use a great amount of filters it's important to set large vectors to give the CPU the necessary time to process the sound.

Othewise you could hear no sound at all or nasty glissandos when you press a key.

This will not effect the latency in a dramatic way.

Other settings:

Select your audio interface I/O: Substantia work in stereo both in input and output.

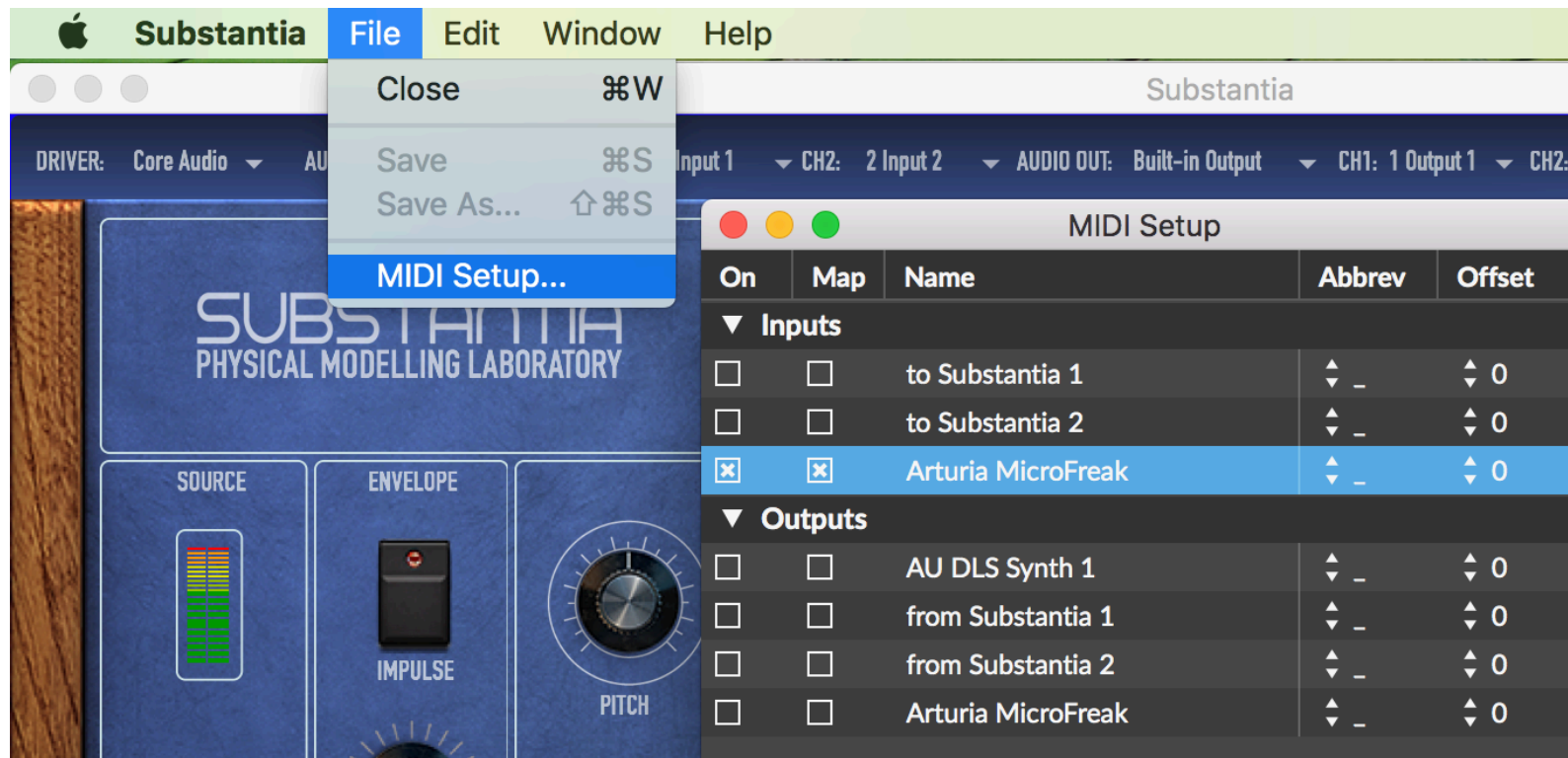
If you use a single contact microphone you can set MONO in the input channel preferences

NOTE: FOR FINE ADJUSTMENT OF POTS USE SHIFT+MOUSE



When you change your audio interface, turn OFF and ON again the software, in order to restart the DAC

MIDI Setup



In the FILE menu, select MIDI setup to choose your keyboard and controller.

Software Authorization

In demo mode the software will work for 8 minutes (after that you must restart it).

To authorize your copy follow carefully these instructions.

Go to www.giorgiosancristoforo.net/software and buy the software with Paypal.

The price is only 14.99€

After 24/48hrs you will receive a mail from softwares@giorgiosancristoforo.net (set this address as safe in your email account, in order to receive mails from this address and not marked as spam!). The mail will be sent to your email account that you use with PayPal.

To unlock your software press REGISTER YOUR COPY in the top menu, at the far right of the window.

A window will open.

First input your PayPal email, then the serial, as is with spaces.

Email is case sensitive.

When the software is successfully authorized you will see: SOFTWARE AUTHORIZED in the window.

AUTHORIZATION PROCESS (please read carefully)

Step 1) Go to www.giorgiosancristoforo.net and pay for the software with Paypal

Step 2) In 24/48 hrs you will receive an email with your serial number (changes my apply during holydays)

Step 3) Enter your email address
(the one you have used for your papyal transaction)

Enter Email

Step 4) Enter your serial number (to paste press CTRL + CLICK > Paste)

Enter Serial Number

SOFTWARE IN DEMO MODE
In DEMO mode this software will quit after 8 minutes

0 min

8 min

AUTHORIZATION PROCESS (please read carefully)

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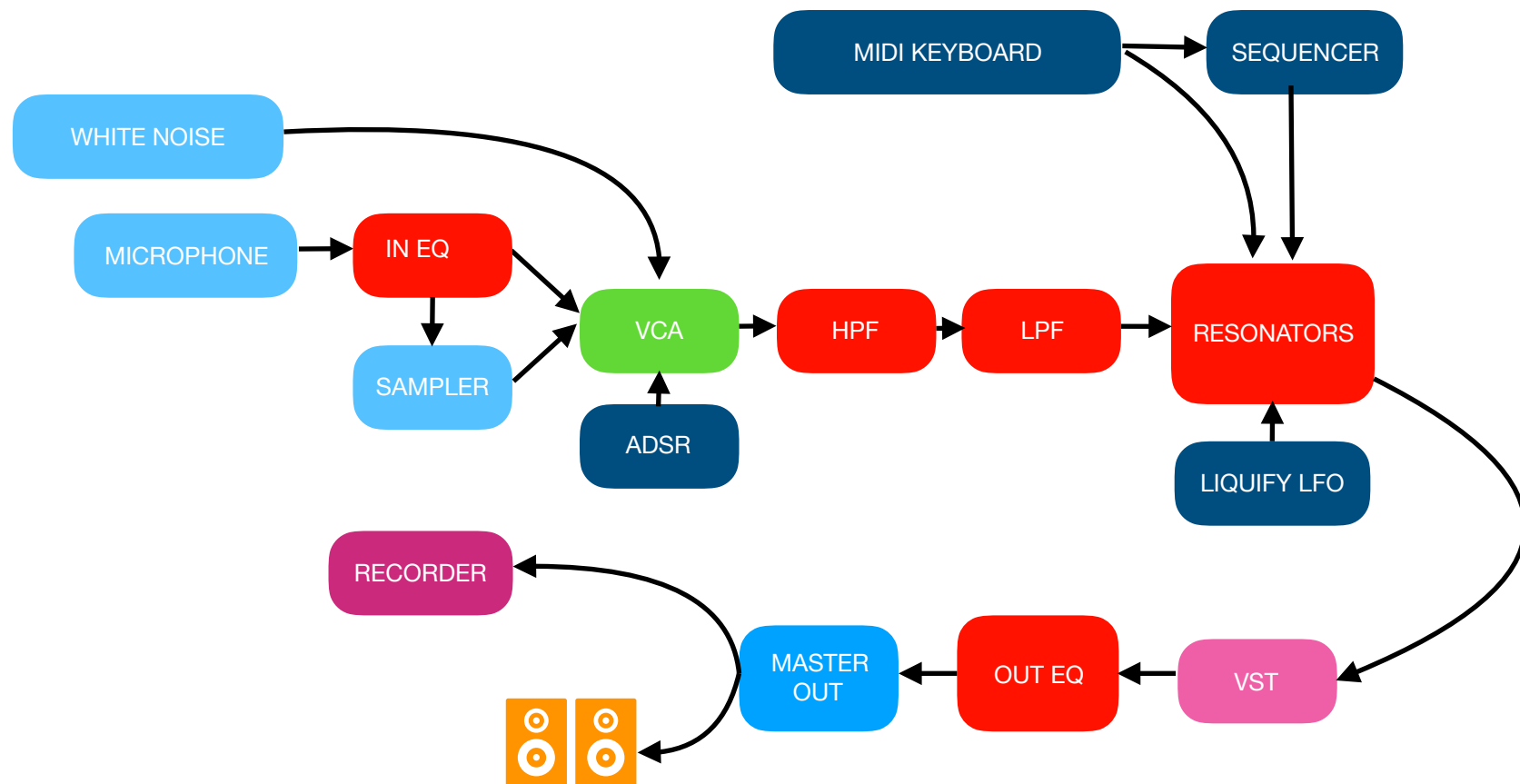
0 min

8 min

Substantia signal flow

Before entering in the details of the software, let's see the signal flow.

As you can see this is far from the classic synthesizer flow. The VCA with its ADSR is at the beginning of the flow, its role is to shape the exciter envelope and not the final stage of the sound. The HPF filter is used to cut away low frequencies before entering in the resonators. This is especially important when you use the sampler or the contac microphone (you have also an EQ). The LPF instead is useful when you use the NOISE with an impulse envelope, to simulate a soft mallet. Right after the resonators you can load a VST effect (reverb, delay etc), and then you can Equalize your final sound with a semi parametric EQ, identical to the one at the beginning of the flow.



Exciters

To make some sounds you need first to select the exciter that will cause the modal engine to resonate.

You can use 3 different sources as exciters:

1) WHITE NOISE

This can be enveloped as a short impulse, or with long times. The sound changes from a strike, to something similar to a blow of air.

2) SAMPLES

You can use the sound of chains, keys, leaves, mallets and water (and many more) to excite your resonators and the effect, as you will hear, is hyper-realistic. Also you can make pitch layers of the same sample (up to 10 layers) and create a texture, or take random bits of your sample to create more surreal sounds.

3) CONTACT MICROPHONES

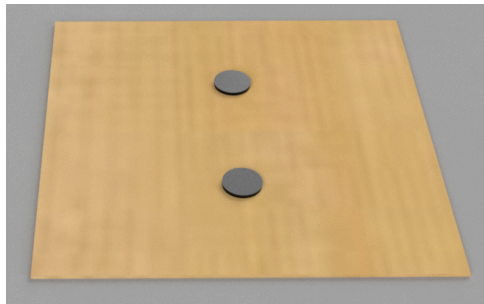
Even better than using samples, you can use a contact microphone (I use the excellent Schertler mics) to excite the resonators in realtime.

You can use also normal microphones, but these are not the best solution.

Please note: you must use precautions to avoid nasty feedbacks! Use headphones or a very careful microphones/speakers placement.

Working with Contact Microphones

Contact microphones are the best way to work with Substantia (but not the only way), mind that there are contact microphones and contact microphones. I suggest you to work with a pair of high quality microphones. They are expensive, but if you work with electroacoustic music you will find them useful for a lot of reasons. Among the best ones I can suggest Schertler and AKG microphones. But even if you have cheap microphones you can still do a lot of wonderful things. The very difference between pro and consumer contact microphones is their bandwidth and their dynamic range.



A pair of contact microphones is an ideal solution because everything inside Substantia is stereo. If you feed a stereo resonator with a mono signal you will get a double mono output. But if you use two microphones you will get all the full advantages of a stereo sound.

Gestures will be spatialized and everything will sound much better.

An ideal way to place microphones is to get a plywood square (30cm x 30cm and few mm thick) and place the two microphones like in the picture at the left.

You will then turn upside down the plywood and use your hands and objects on the opposite side, where you can touch all the surface without touching the microphones. Try to scratch, rub, tap the surface... or use small objects, little chains, coins, guitar strings...

A NOTE ON DYNAMICS: When using the microphone the overall output volume of the sound is an interaction between the actual velocity you have used with the keyboard AND the intensity of your action on the microphones (the same applies for the sample volume in the sampler).

With 0 velocity you will hear no sound, but also without making sounds with the microphones, you will hear no sound. They work together.



At the top of the user interface you can see the controls of the audio input channels.

These control the volume, mono/stereo and equalization.

!!!! It's important to cut low frequencies when using microphones because they are not useful to feed the resonators. !!!!

The ON/OFF switch at the right is the main DAC switch. If you change audio interface, simply turn it off and on to restart the DAC.

At the far right there is a led to monitor incoming MIDI notes.

You will not monitor directly the incoming signal from the microphone (you can do that with your audio interface mixer), also you will not hear anything until you play some notes on the keyboard (set the ADSR with some degree of decay, sustain and release, by default is in IMPULSE mode).

Not monitoring the incoming signal could seem strange but it is done on purpose.

This will force you to listen directly to the resonators response and will give you immediately a precise idea of the effect.

In order to use the MIC input please select MIC in the SOURCE panel at the left.

You can further adjust the gain of the source (for all the sources) and use the filters.

The High Pass Filter is very useful with microphones and samples. As I told you, low frequencies are not useful and could cause unwanted effects on the resonators.

The Low Pass Filter is especially important when you use the NOISE source with ADSR in IMPULSE mode. This will soften the mallet simulator.



**Danger
Noise
hazard**

READ THIS VERY WELL!

A final note on MIC input.

If you plan to use the MIC input to use speakers, I warn you of potential huge feedbacks!

Also if you use semi-open headphones, feedbacks can be a problem.

You must use caution in both cases, avoid high volumes and care of mic/speaker placement.

I will not be responsible of the misuse of this software that could cause damages to your ears or your PA system.

NOTE: FOR FINE ADJUSTMENT OF POTS USE SHIFT+MOUSE

Working with the Sampler



Using the internal sampler is another way to excite the resonators. You can sample the sound coming from the MIC inputs, or load a sample (drag and drop the sample file into the waveform window at the bottom of the sampler).

The sampler will automatically play in loop once you drag and drop a sample in it.

You will find a collection of sound samples in the zip you have downloaded to make some experiment and understand what kind of sounds are nice with Substantia

PITCH controls the speed and pitch of the sample from 0.1 x sample frequency to 2 x sample frequency

REVERSE play is possible with a switch.

LAYERS and PITCH layering:

In reality this is not just one sampler but 10.

Once you have recorded your sample you can choose how many instances you want to play with the LAYERS switch. Adjusting then the PITCH LAYERING control will randomize the speed play of the instances creating a texture of sound.

By default the sampler will play all the sound from the start to the end point of the loop.

But you can randomize the loop points with RANDOM. This will randomize the loop points each time that a NOTE ON message is received from the keyboard or from the probabilistic euclidean pattern sequencer.

NOTE: DISTANCE regulates the step function of the “drunk” function, PROBABILITY regulates the chances of a new loop point for every NOTE ON.
NOTE: SAMPLES ARE NOT STORED IN THE PRESET. WRITE THEM AND RELOAD THEM.

Working with the NOISE



A convenient NOISE generator can be selected in the SOURCES panel as exciter.

Just like the MIC and the SAMPLER, the sound of the NOISE generator is passed into a VCA and the VCA is controlled by a classic ADSR, triggered by NOTE ON messages (from the keyboard or the SEQUENCER).

By default the SOURCE is NOISE and the ADSR sets to IMPULSE MODE.

IMPULSE button simply quickly set the ADSR to a very short Decay to be used with the NOISE source.

This simulates a hard mallet and it's a convenient way to test and play the different resonators.

If you adjust the ADSR parameters to different settings then you will clearly hear the noise stimulating the resonator, in a way similar to breath blowing inside a flute (only that this flute has shapes and materials very different from traditional ones).

With some proper settings you can get the same sound that The Orb used in Toxigene ;)

The HPF and LPF filters in the SOURCE panel can be useful to shape the noise sound.

In IMPULSE mode of the ADSR, the LPF can be used to soften the mallet.

The VCA is velocity sensitive.

NOTE: FOR FINE ADJUSTMENT OF POTS USE SHIFT+MOUSE

I.

The Resonators



At the core of Substantia there are 800 (!) resonant Band Pass Filters.

These filters are programmed with data stored in the program.

There are 16 models and 23 materials for a total of 368 models that you can play with. Each model was designed with a CAD and then analysed with Multiphysics software to get the Eigenfrequencies and the modal participation factors. The number of the models is not definitive. New models will be added in the next releases.

The plan is to give you at least 500 modal resonators.

At the top of the window you can chose the model and the material.

There are classic shapes like pipes and bowls and very unusual shapes like the TOPY¹ cross and other strange objects like pyramids with 6 faces or serpentes. I designed the shapes to get the most different sounds.

Some models will make very simple and tuneable sounds, other will create beautifully complex inharmonic sounds.

As you will hear, different materials and shapes with give you, not only different timbres, but also different intonations. Depending by the material, the density and the elasicity is different, so the speed of sound is different. The resul is a different tone. This is why we have a separate TUNING facility.

(With FREQUENCY you can change the tuning).

A button will turn on a 440Hz reference tone. It's up to you to tune your instrument, or leave it as is.

Personally I love the fact that different objects made with different materials will have “their own sound”: a timbre a tuning. This is what happens in the real world if we collect a number of objects and we try to use them as musical instruments.

The Resonance knob controls the level of the resonance of the filters.

Different materials have different resonance values.

For example Aluminium tends to have long tails, while LCP plastic or Nylon will have very short ones.

Platinum, Lead and Uranium are very heavy and dense and hence are more damped.

WARNING: HIGH RESONANCE VALUE + FAST NOTES = FILTERS FEEDBACK

At the left and right of the RESONANCE control you will find the ODD and EVEN control of the modal frequencies. You can lower only the ODD or the EVEN harmonics to shape the sound.

¹ In memory of Genesis P. Orridge

LIQUIFY is a simple sine LFO that make a soft FM modulation of the filter center frequencies. This is very similar to the sound you get when you strike and move a metal pot full of water.

The Probabilistic Euclidean Pattern Sequencer



The Euclidean rhythms in music were formalized by Godfried Toussaint in 2004 and is described in a 2005 paper "[The Euclidean Algorithm Generates Traditional Musical Rhythms](#)". The greatest common divisor of two numbers is used rhythmically giving the number of beats and silences, generating almost all of the most important World Music rhythms, (except Indian).

The beats in the resulting rhythms are as equidistant as possible.

In order to work with the sequencer you must first input some notes. Press REC/STOP and use your keyboard of the virtual keyboard on the software, to create a sequence of notes. You can input as many notes as you want. Their number is not related to the rhythm's steps of the sequencer. When you have recorded the notes press REC/STOP again and press PLAY.

To set the number of active beats use the potentiometer at the centre of the sequencer

I really don't like the feel of hearing the same phrase repeated over and over, so I had a couple of ideas on how to improve the traditional euclidean sequencing with a few more options.

Pressing STOCHASTIC and setting PROBABILITY the sequencer will change the ACTIVE STEPS (the number of beats) randomly at each NOTE

ON message
(PROBABILITY here decides the chances to get a change at the current event).

ROTATION rotates the active steps sequence.

You can randomize the sequence with RANDOM, or set it to FFWD to play the recorded sequence.

When you record the notes, the sequencer will record also their velocity.

The Sequence is not stored in the preset, you must reload it manually with READ.

You can save it on your HD, of course, with WRITE.

NOTE: FOR FINE ADJUSTMENT OF POTS USE SHIFT+MOUSE

The final stage:

VST – EQ and MASTER OUT / RECORDER



From the Resonators the sound is routed to a VST host to use a reverb, delay or any other effect with Substantia.

Of course you can route the master out to Fantastic Voyage using a virtual audio interface like Blackhole or LoopBack (former Soundflower).

Then the sound is routed to an EQ identical to the one used in the input channel. At the end we have the master out with a sound recorder.

The final stage gain can be set with a fader.

The recorder will record an AIF files @24 Bits.

To record, simply set a file name with SET, and pres REC/STOP.

To finish recording press again REC/STOP.

FOR FINE ADJUSTMENT OF POTS, USE SHIFT+MOUSE

MIDI AND KEYBOARD MAPPING

In the lower bar you will find buttons to assign MIDI CC to the Substantia interface (and to save and load your mappings).

To map a potentiometer or fader click ASSIGN MIDI, select with the mouse the control you wish to map, and simply move your controller pot or fader in order to map it.

NOTE: TO EXIT MAPPING PRESS “ESC” on your keyboard.

Remember to save your mapping on a file with “SAVE”

STORING, LOADING and SAVING PRESETS



To store a preset press SHIFT + mouse click on one of the little squares of the lower bar.

To recall a preset simply click the stored preset

LOAD BANK load a bank of presets in memory

SAVE BANK save a bank of presets on your computer

NOTE:

SAMPLES and SEQUENCES ARE NOT STORED IN THE PRESET.

WRITE THEM AND LOAD THEM MANUALLY.

HAVE FUN!

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Fabio Ricci
Christian Duka
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