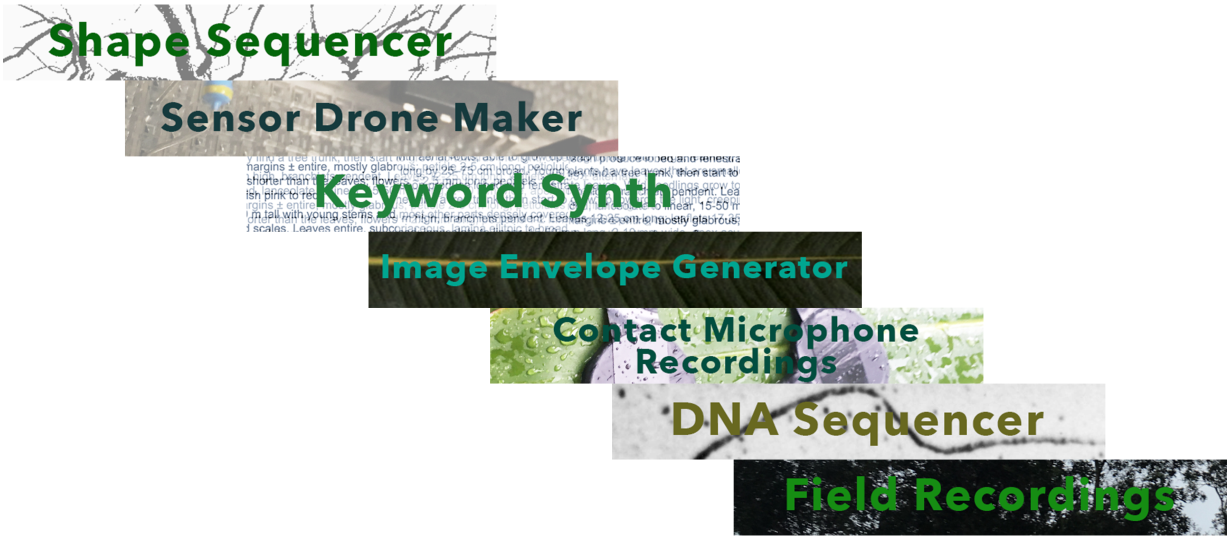
BOTSOT Extended Methodology

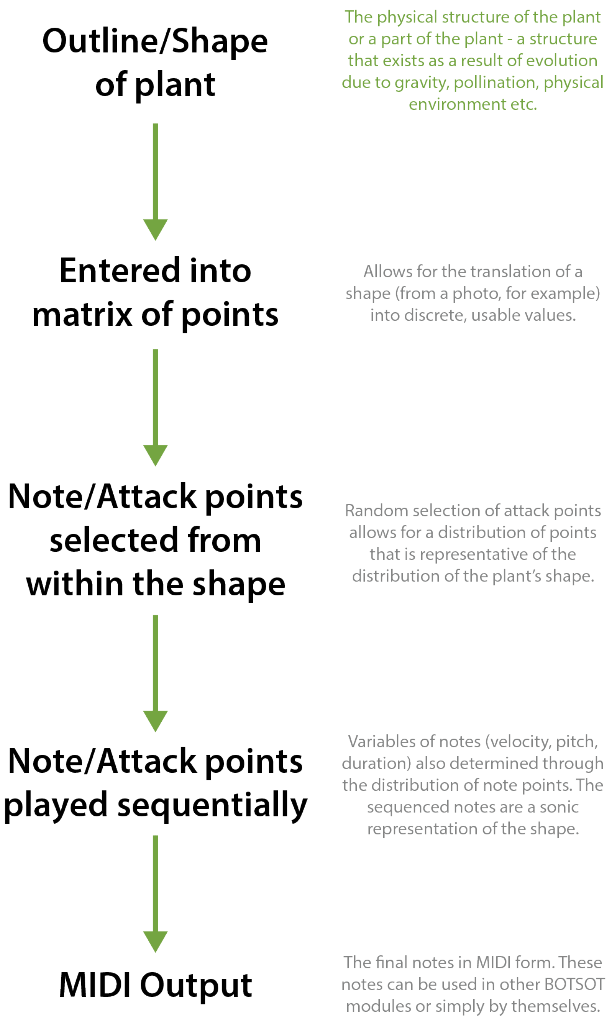
The following outlines the methodology behind all modules currently found in BOTSOT.

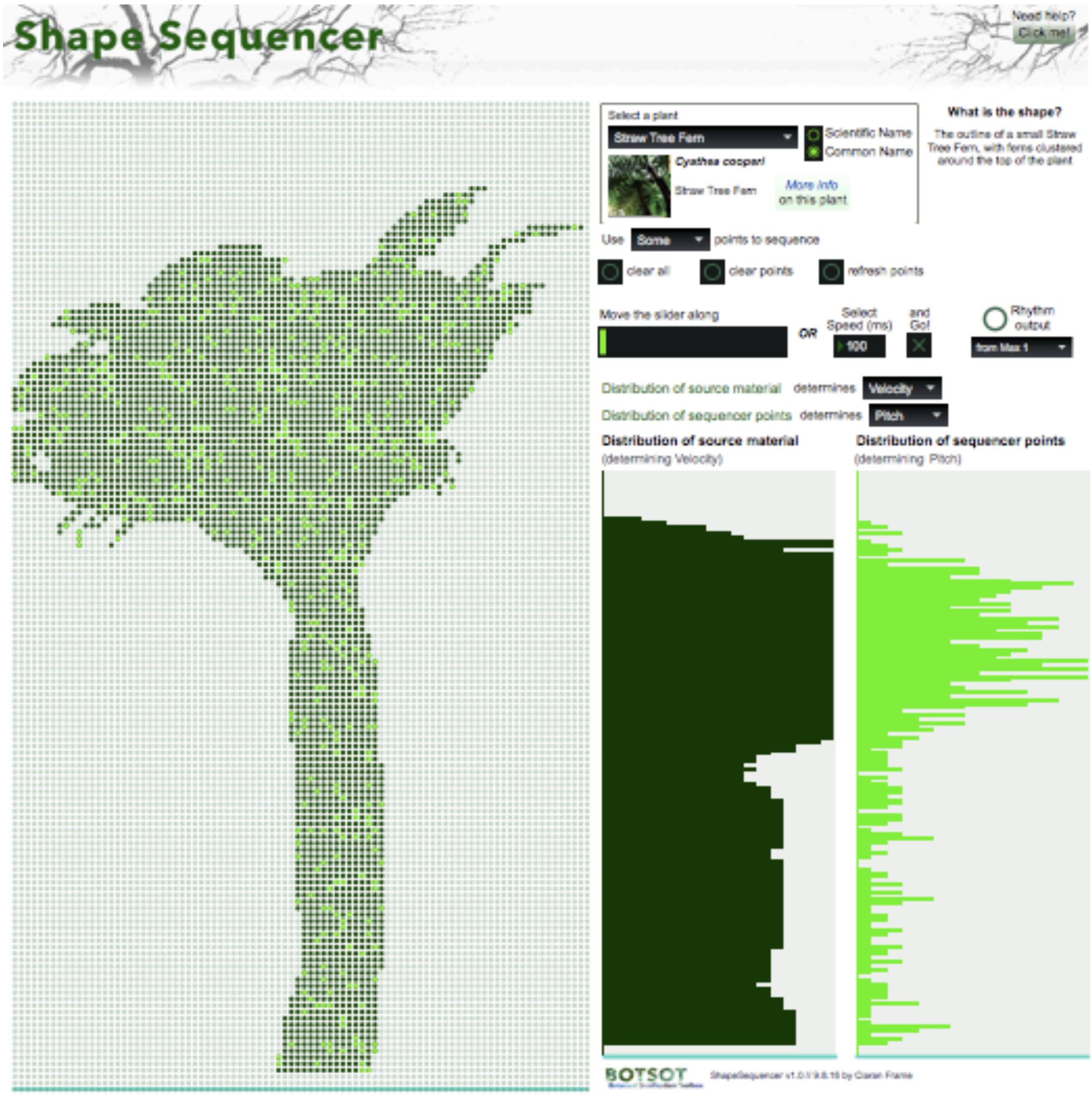


Shape Sequencer

The Shape Sequencer takes a characteristic structure from a given plant species (such as a flower spike from the Coast Banksia), and translates the shape into notes. Within the chosen shape, points can be sequenced at a chosen tempo. When the sequencer reaches these points, a note is triggered. The pitch, duration and velocity of these notes is determined through the distribution of the chosen shape. The result is an accurate sonic representation of the physicality of a plant, where denser areas of the shape (for example, the top of a Sydney Gum) have a greater amount and intensity of triggered notes.

The Shape Sequencer is a simple note-generating machine that operates as a form of extension to the traditional MIDI sequencer. It uses a large matrix of pixels based on a graphic representation of any structure in order to trigger MIDI notes. A slider moves vertically through the matrix, crossing points on the shape that trigger notes. These points cannot be manually selected, and are instead picked at random within the shape. This in turn allows for an accurate sonic representation of the shape through randomly distributed points. The small amount of user input includes basic functions like tempo and number of points, but uses an intentionally simple interface that contains only general vocabulary as opposed to music-specific or plant-specific terms. The Shape Sequencer was used in *Treehugger* for the generation of 'tinkles', using the shape of a palm tree as a means of creating the notes.




Shape Sequencer
Need help?
Click me!
Select a plant
Straw Tree Fern
Scientific Name
Common Name
Cyathea cooperi
Straw Tree Fern
More info
on this plant
What is the shape?
The outline of a small Straw Tree Fern, with ferns clustered around the top of the plant
Use
Some
points to sequence
clear all
clear points
refresh points
Move the slider along
OR
Select Speed (ms)
100
and Go!
Rhythm output
from Max 1
Distribution of source material
determines
Velocity
Distribution of sequencer points
determines
Pitch
Distribution of source material
(determining Velocity)
Distribution of sequencer points
(determining Pitch)
BOTSOT

DNA Sequencer

The DNA Sequencer turns sections of a plant's DNA sequence into rhythmic values. Much like the bases of DNA are translated into proteins in living organisms, the bases of DNA are in this case being translated into rhythmic values - for example, Adenine might translate to a crotchet whereas Guanine might translate to a semiquaver. 'Noncoding' DNA makes up a large percentage of any given genome, thus, sequences of DNA are chosen based on their relevance to the species - for instance, a particular sequence that is said to contribute to a Jacaranda's purple coloured flowers.

The DNA sequencer is a simple rhythm machine based upon the unique genomes of every plant. All sequences of DNA from any living organisms can be broken down into four 'bases' – Adenine, Guanine, Thymine and Cytosine. These four simple molecules form what is commonly known as the 'building blocks' of life. The DNA Sequencer takes these remarkably simple yet powerful building blocks, and translates them into rhythms. Not only are these sequences unique, they also inherently have a lot of patterns and repetitions – a feature that is very much suited to the creation of rhythm.

The sequences themselves originate from plants surrounding the University of Sydney main campus. When this data is collected, there is always a large amount of 'non-coding' DNA present within the sequence (as is the case for all living organisms) – that is, DNA that does not directly translate to proteins and thus characteristics and unique aspects of a particular species. For this reason, the DNA sequencer aims to use extracts from sequences that share a meaningful relationship with the plant (for instance, a section of the DNA sequence responsible for the purple colour of flowers on the Jacaranda). In this way, a meaningful representation of the sequences within a given plant species can be formed through a relatively small sample of data.

DNA Sequence

The building blocks of life. Determines transcriptions of proteins and in turn, every facet of a given species.

↓

Extract taken from sequence

Chosen by looking at what makes a particular species or genus unique or by finding notable characteristics of the plant expressed in DNA (for instance, a sequence that gives the Jacaranda it's purple colour).

↓

Bases assigned rhythmic values

Rhythmic values can be chosen, or generated randomly. Each base assigned it's own value, allowing listeners to 'hear' the patterns found within the DNA Sequence - a sequence that is naturally based on patterns.

↓

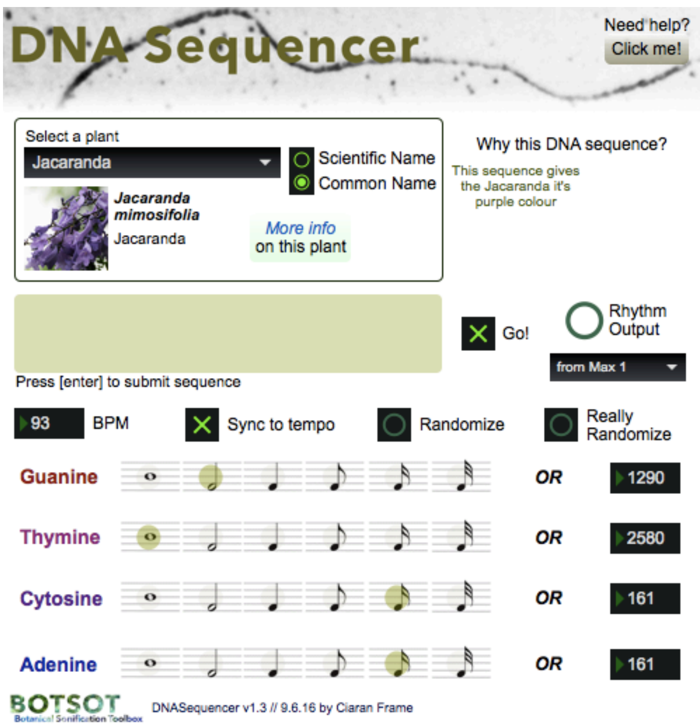
DNA Sequence 'sequenced'

Much like a ribosome translates DNA into mRNA, the sequencer works through each of the bases and 'translates' them into rhythms.

↓

MIDI Output

The final rhythm in MIDI form. This rhythm can be used in other BOTSOT modules or simply by itself.



Keyword Synth

The Keyword Synthesizer is a simple synth controller that creates a unique sound for any plant species through a series of algorithms based on keyword searching. By taking the most common 200 words from descriptions of plants and rating them against predetermined sound criteria, the variables of a synth can be automatically generated based on a scientific description of any given plant. In this way, each species receives it's own electronic tone colour, representative of the objective physical characteristics of the plant.

Descriptions have been chosen as a data set in this module because of their ability to objectively and scientifically capture aspects of any given plant that may seem obvious to any person, but are in fact difficult to translate when considering sonification and a musical toolbox. The module uses Tal's *Noisemaker* plugin[1], a freely available software synth that allows for basic manipulation of waveforms and filters.

The link between language and tone colour is often hard enough for a composer to discern, let alone a computer. In order to sonify descriptions, the most common 200 keywords (usually adjectives, often scientific) were extracted from descriptions of plants. These were then used in a Python script that referred back to a database of manually entered numbers that determined the 'fitness' and connotations of each word (as below).

Keyword Synth

	Score /10 for synth connotations									Specific connotation values to be scales against fitness scores									
Descriptor	Waveform	ADSR	EQ	LFOs / Vib	Intensity	Range/Poly	Evolution	Overall Quality	Pass? (use?)	Waveform Sine > Noise 1 > 10	ADSR Smooth > Sharp 1 > 10	ADSR Transitions Short > Long 1 > 10	ADSR Simple > Compl 1 > 10	EQ Low > High (where 5 is flat) 1 > 10	EQ Notch > Pass 1 > 10	EQ Simple > Compl 1 > 10	LFOs Frequency Slow > Fast 1 > 10	LFOs Amplitude Small > Large 1 > 10	Intensit Small > 1 > 10
large	7	6	9	9	10	7	5	Great	✓	7	6	5	2	4	8	1	1	3	
native	5	2	4	3	3	5	4	Very Poor	✓	3	0	0	0	0	0	0	0	0	
deciduous	3	7	3	3	3	4	7	Very Poor	✓	0	3	8	2	0	0	0	0	0	
wide	8	8	7	9	8	10	7	Great	✓	6	1	9	2	3	9	2	1	7	
lobed	6	7	4	5	3	3	4	Poor	✓	3	2	7	9	0	0	0	3	6	
red	2	2	4	2	6	2	2	Horrendous	×	0	0	0	0	0	0	0	0	0	
simple	8	8	5	7	8	8	9	Great	✓	1	5	5	1	5	3	1	2	2	
veined	7	3	2	4	2	5	3	Very Poor	✓	4	0	0	0	0	0	0	0	0	
serrated	10	8	5	8	9	6	7	Great	✓	8	9	2	9	7	2	8	7	4	
aggressive	10	9	6	7	10	5	7	Great	✓	8	7	3	3	6	8	7	4	3	
corky	5	3	6	3	2	2	2	Very Poor	✓	6	0	0	0	4	3	7	0	0	
monoecious	1	3	2	2	2	4	3	Horrendous	×	0	0	0	0	0	0	0	0	0	
dense	8	6	9	8	9	8	7	Great	✓	2	7	3	2	3	6	3	2	7	
spherical	6	3	2	4	1	1	4	Very Poor	✓	4	0	0	0	0	0	0	0	0	
persistent	3	8	2	6	4	4	7	Poor	✓	0	7	3	7	0	0	0	8	2	
solitary	5	8	7	5	3	9	7	OK	✓	1	6	5	1	8	2	1	1	1	
grey	4	6	6	4	7	4	5	Poor	✓	0	2	7	2	4	4	2	0	0	
annular	4	3	3	6	4	4	8	Poor	✓	0	0	0	0	0	0	0	5	4	
large	8	7	9	9	10	8	7	Great	✓	7	6	3	3	4	6	2	3	6	
segments	5	8	6	9	7	6	9	OK	✓	8	7	2	9	6	2	9	6	3	
drooping	5	7	4	5	8	4	9	OK	✓	2	4	8	4	0	0	0	2	4	
long	4	8	4	7	5	5	9	OK	✓	0	2	9	2	0	0	0	1	2	
curved	9	7	5	4	4	4	8	OK	✓	3	2	8	3	6	4	3	0	0	
blunt	8	7	8	5	9	4	7	OK	✓	1	8	4	1	2	8	2	2	1	
fleshy	7	5	6	4	7	4	5	Poor	✓	5	5	4	5	4	7	4	0	0	
pendent	2	4	3	4	4	5	3	Very Poor	✓	0	0	0	0	0	0	0	0	0	
acute	6	8	8	7	8	5	9	Great	✓	9	8	2	3	7	1	2	8	8	
mucronate	7	10	6	4	5	4	4	Poor	✓	7	8	3	3	8	3	5	0	0	
pink	5	1	2	1	3	2	1	Horrendous	×	8	0	0	0	0	0	0	0	0	
blue	3	1	5	2	7	3	1	Very Poor	✓	0	0	0	0	2	7	2	0	0	
small	5	7	9	6	7	7	6	OK	✓	2	4	6	1	9	3	1	9	2	
pinnate	4	3	5	5	5	6	4	Poor	✓	0	0	0	0	7	3	6	7	2	
obtuse	9	7	5	7	6	7	5	OK	✓	6	8	3	3	6	2	4	7	6	
glossy	6	3	7	8	4	3	2	Poor	✓	1	0	0	0	8	7	3	8	5	
smooth	10	8	8	6	7	3	2	OK	✓	1	2	8	1	5	8	3	2	4	
shinning	8	5	8	7	7	4	3	OK	✓	1	4	6	2	8	8	3	8	7	

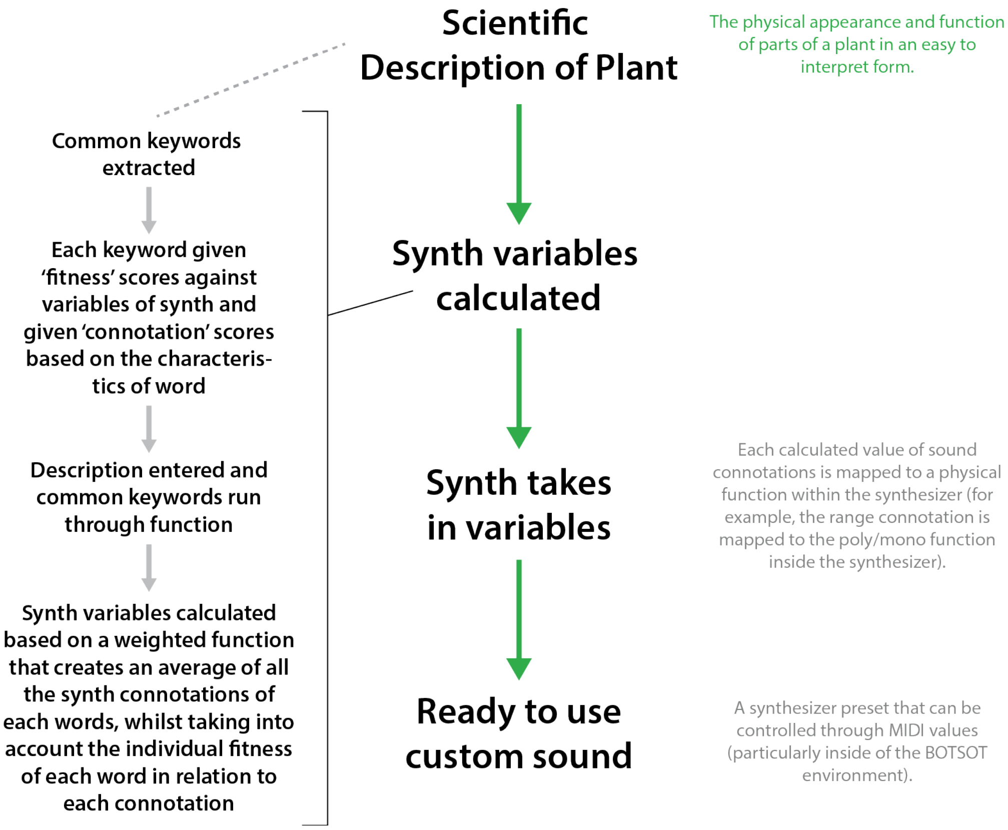
The connotation 'categories' used in the Keyword Synthesizer were all to do with variables within a basic synthesizer, that is:

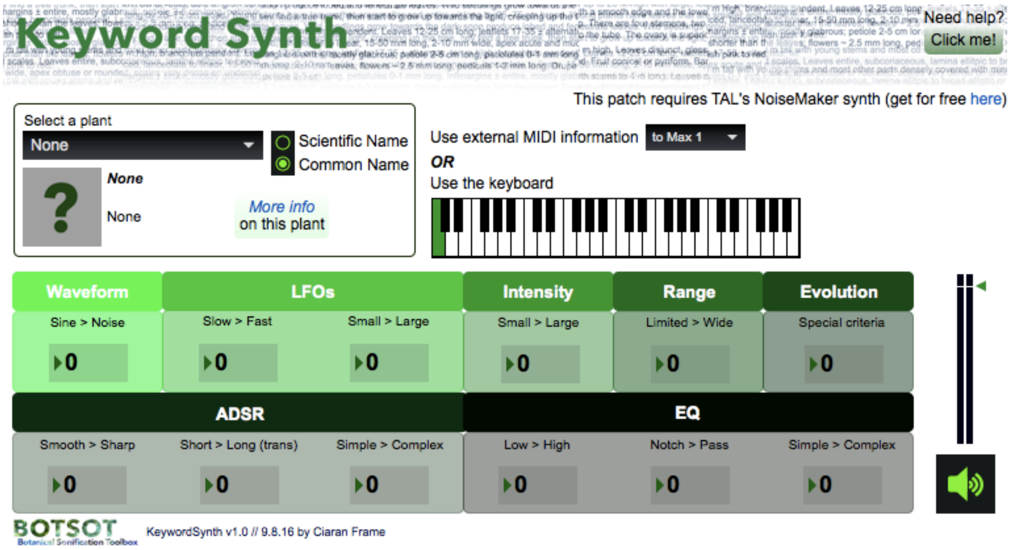
- Waveform (Sine–Noise on a scale of 1–10)
- ADSR (Smooth–Sharp on a scale of 1–10)
- ADSR (Simple–Complex on a scale of 1–10)
- ADSR Transitions (Short–Long on a scale of 1–10)
- EQ (Low Frequency–High Frequency on a scale of 1–10 where 5 is a flat response)

[1] TAL, *TAL-NoiseMaker,* (September 2016), https://tal-software.com/products/tal-noisemaker.

- EQ (Notch–Pass on a scale of 1–10)
- EQ (Simple–Complex on a scale of 1–10)
- LFO Frequency (Slow–Fast on a scale of 1–10)
- LFO Amplitude (Small–Large on a scale of 1–10)
- Intensity (Small–Large on a scale of 1–10)
- Range (Limited–Wide on a scale of 1–10)
- Evolution (Item specific scale 1–6)
  - 1 +
  - 2 + > - > +
  - 3 + > -
  - 4 - > +
  - 5 - > + > -
  - 6 -

Descriptions could be entered into the Python script, which would extract the weighted average score for each of these categories based upon the previously entered data. More on the process can be found in the diagram below.

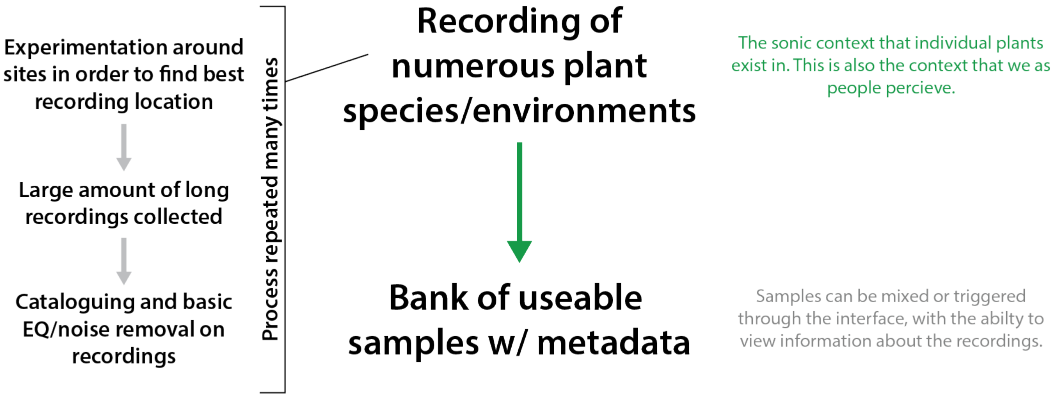

Scientific Description of Plant
The physical appearance and function of parts of a plant in an easy to interpret form.
Common keywords extracted
Each keyword given 'fitness' scores against variables of synth and given 'connotation' scores based on the characteristics of word
Description entered and common keywords run through function
Synth variables calculated based on a weighted function that creates an average of all the synth connotations of each words, whilst taking into account the individual fitness of each word in relation to each connotation
Synth variables calculated
Synth takes in variables
Each calculated value of sound connotations is mapped to a physical function within the synthesizer (for example, the range connotation is mapped to the poly/mono function inside the synthesizer).
Ready to use custom sound
A synthesizer preset that can be controlled through MIDI values (particularly inside of the BOTSOT environment).

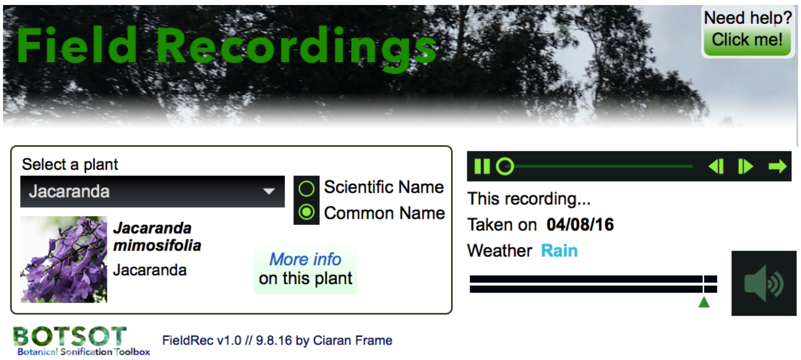

Keyword Synth
Need help?
Click me!
This patch requires TAL's NoiseMaker synth (get for free here)
Select a plant
None
Scientific Name
Common Name
None
None
More info
on this plant
Use external MIDI information
to Max 1
OR
Use the keyboard
Waveform
Sine > Noise
LFOs
Slow > Fast
Small > Large
Intensity
Small > Large
Range
Limited > Wide
Evolution
Special criteria
ADSR
Smooth > Sharp
Short > Long (trans)
Simple > Complex
EQ
Low > High
Notch > Pass
Simple > Complex
BOTSOT
Botanical Sonification Toolbox
KeywordSynth v1.0 // 9.8.16 by Ciaran Frame

Field Recordings

Field recordings exist within BOTSOT in order to provide a sonic anchor for the listener. Recordings of sounds that we hear every day from plants (for instance, the rustling of leaves) are important to the toolkit, as they act as a foundation for the context in which the other, more abstract sounds exist in.

Field recordings were extracted over a period of five months in order to capture audible environmental sound surrounding many of the plant species. Within BOTSOT, users may play these sounds from an archive of recordings. Additionally, with the unlocking of the patch, the recordings can be triggered through means of MIDI information from other modules.



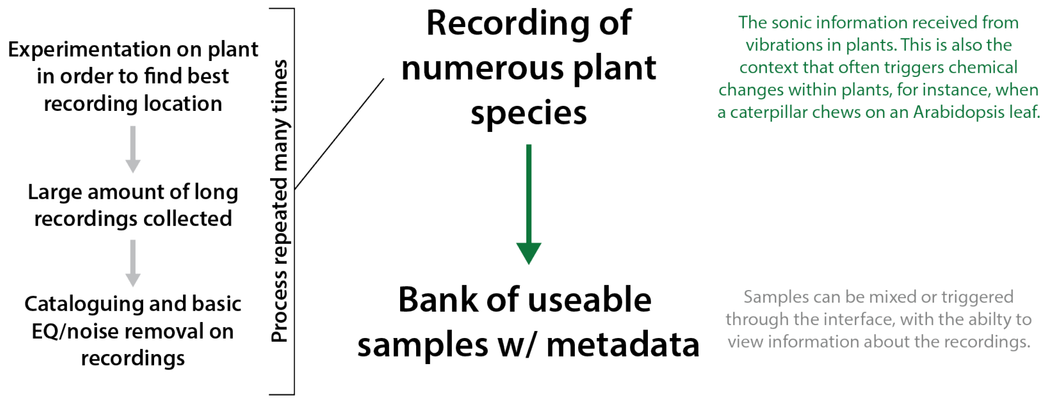


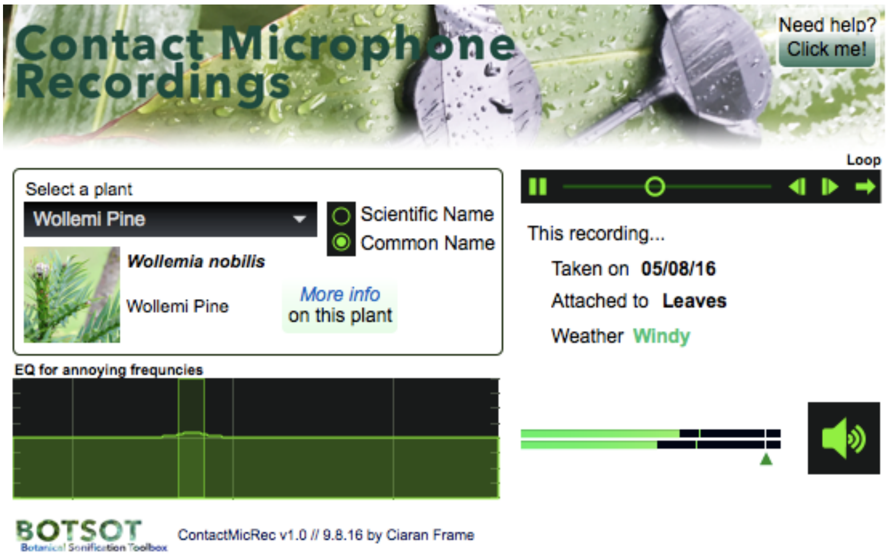
Contact Microphone Recordings

Contact microphones can uncover minute sounds and vibrations through the use of an extremely sensitive diaphragm. By placing these microphones on and around different species of plants, unique sounds and contrasting resonances can be observed - sounds that would otherwise go unnoticed.

Contact microphones are a unique and fascinating way of detecting vibrations in any resonant body. In the case of plants, they provide an interesting insight into the structure and constitution of any given species on a very small scale. Recordings were made over many months, with information surrounding how the recordings were made also added to the files.

The module functions in a similar way to the Field Recordings module, with the added ability to EQ the recordings on a graphic equalizer. This was seen as an important addition to the module, as it not only allows for the refinement of the sound, but also for the discovery of interesting resonances within the recording. By nature, the contact microphones capture vibrations of any given structure on the plant, and the addition of the EQ may lead to a greater understanding on the user's part of the inner resonances and unique characteristics of the vibrations being produced by the species.

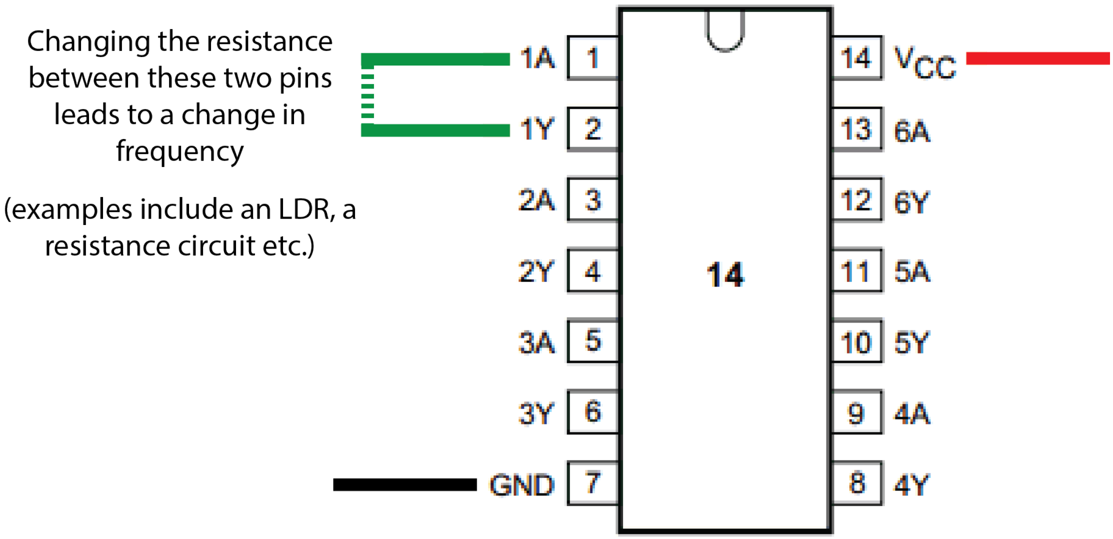

Experimentation on plant in order to find best recording location
Large amount of long recordings collected
Cataloguing and basic EQ/noise removal on recordings
Process repeated many times
Recording of numerous plant species
Bank of useable samples w/ metadata
The sonic information received from vibrations in plants. This is also the context that often triggers chemical changes within plants, for instance, when a caterpillar chews on an Arabidopsis leaf.
Samples can be mixed or triggered through the interface, with the abilty to view information about the recordings.


Contact Microphone Recordings
Need help? Click me!
Loop
Select a plant
Wollemi Pine
Scientific Name
Common Name
Wollemia nobilis
Wollemi Pine
More info on this plant
This recording...
Taken on 05/08/16
Attached to Leaves
Weather Windy
EQ for annoying frequncies
BOTSOT
Botanical Sonification Toolbox
ContactMicRec v1.0 // 9.8.16 by Ciaran Frame

Sensor Drone Maker

Plants exist on very different time scales to people. We associate change in plants with seasons, and find it difficult to observe change on a smaller scale. The Sensor Drone Maker forms drones, an augmented musical technique, and applies them to changes in plants that occur over a longer period of time. A wide variety of sensors are used to collect slow-changing data, which is then converted to sound through analogue techniques. A comparison of these recorded sounds allows for a sonic understanding of changes that occur over time in particular species of plants.

The Sensor Drone Maker relies on the capturing of data surrounding the unseen chemical and environmental changes of a plant and sonifying them in real-time. Numerous sensors were used when creating content for the module, with the analogue synthesis of sound (almost always using a 555 timer or Hex-Schmitt trigger) being captured through a mixer and interface. The simple circuits were built on breadboards, and usually relied on variable resistance to provide a means of variation in sonification (as seen below).



Within the module, the drone maker functions much in the same way that the other 'recordings' modules do, playing back drones from an archive that includes information about the recordings. Overall, it was found that the most effective way to use the drones was to make multiple recordings over time and observe the changes through comparison of results (as can be seen in the Crabapple arrangement).

Light **Moisture** **Gas** **pH**

The ever changing variables surrounding a plant - variables that act as stimuli and enactors of change and chemical composition.

Data collected/processed from various locations around species

Process repeated over time

Analogue conversion to sound

Analogue is used becuase of it's relationship with the sensor data. It is also a good vehicle to explore long, droning textures.

Bank of useable samples w/ metadata

Samples are created that have the abilty to illustrate changes in chemical and environmental composition that are either not on our temporal scale, or cannot be detected without sensors.

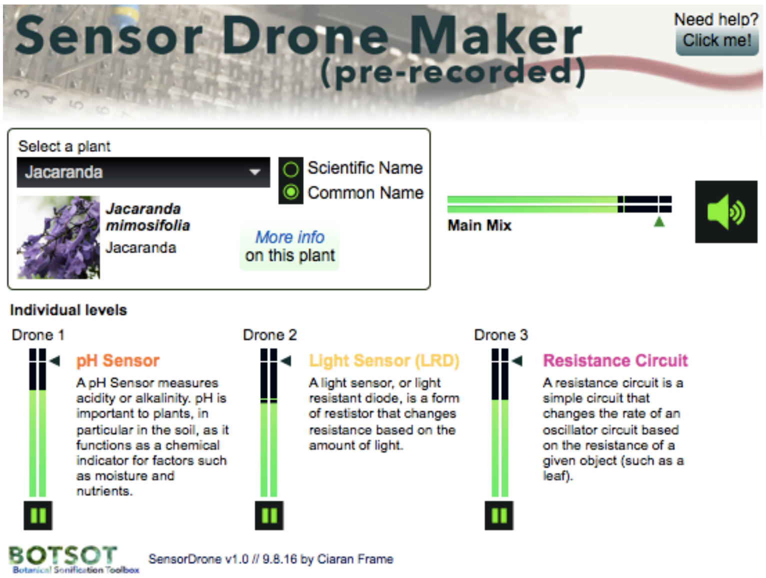

Sensor Drone Maker
(pre-recorded)
Need help?
Click me!
Select a plant
Jacaranda
Scientific Name
Common Name
Jacaranda mimosifolia
Jacaranda
More info on this plant
Main Mix
Individual levels
Drone 1
pH Sensor
A pH Sensor measures acidity or alkalinity. pH is important to plants, in particular in the soil, as it functions as a chemical indicator for factors such as moisture and nutrients.
Drone 2
Light Sensor (LRD)
A light sensor, or light resistant diode, is a form of restistor that changes resistance based on the amount of light.
Drone 3
Resistance Circuit
A resistance circuit is a simple circuit that changes the rate of an oscillator circuit based on the resistance of a given object (such as a leaf).
BOTSOT
Botanical Sonification Toolbox
SensorDrone v1.0 // 9.8.16 by Ciaran Frame

Image Envelope Generator

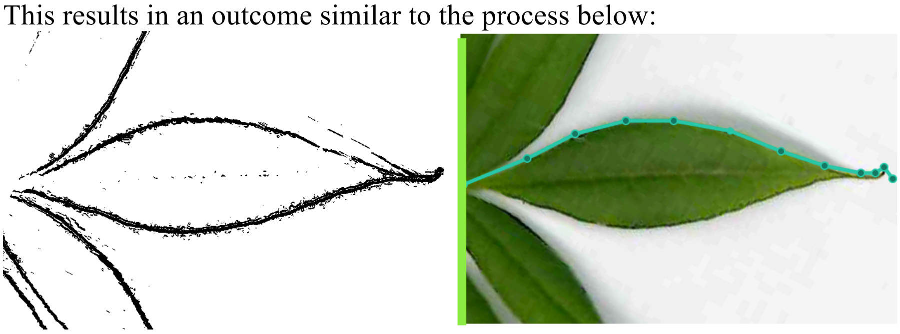
Any given species of plant may have any number of remarkable patterns and shapes, whether it be the curve of a leaf or the ripple in bark. All of these profiles and structures serve a purpose to the plant, and are present as a result of evolution. The Image Envelope Generator takes a simple image of a plant, and applies image analysis in order to find the most prominent edges. From this edge, an envelope is drawn and 'played back' through MIDI data, eloquently sonifying the given profile from a plant.

The Image Envelope Generator was designed as a means of sonifying simple shapes and structures from photos of any species of plant. The input for this module is a simple photo of a visible aspect of a plant species. From this image, an envelope plat is created that can then be 'read' as musical information in the form of MIDI. This MIDI CC (continuous control) information might determine any number of things, and has been mapped to pitch and effects levels in the arrangements within this portfolio.

The module relies very heavily on the 'sci-kit image' Python library[2], specifically, the 'Canny edge detector'. This edge detection algorithm uses a multi-staged process based on Gaussian filters to find the most prominent edges of any given image. Images are called and applied to a simple function:

```
findedges = feature.canny(jacardanaleaf, sigma=3)
```

This results in an outcome similar to the process below:



[2] Scikit-image development team, "Canny edge detector," (*Scikit-image*, October 2016), http://scikit-image.org/docs/dev/auto_examples/edges/plot_canny.html#sphx-glr-auto-examples-edges-plot-canny-py.

Photo of important or interesting aspect of plant

A physical element or structure of the plant - an element that's physical shape has formed as a result of evolution, and makes the plant unique to others.

↓

Outline found through edge-detection

A Python script determines the most prominent outline in the image based on image manipulation and the use of the OpenCV library. Most prominent edge enetered into a linear envelope in Max.

↓

Outline 'played' as an evelope over time

A slider reads and scales the values along the line and converts them to MIDI information.

↓

MIDI Output

The final outline represented in MIDI form. This envelope can be used in other BOTSOT modules or in a DAW.