Modeling Sonobotanic Plants - Towards a General Model of Expressivity of Transient Objects

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ABSTRACT

Sonobotanic plants experience the events in their lives mostly in the acoustic domain. Due to the difficulties encountered studying them in the wild, the most promising and practical approach is to model their acoustic behaviour and life context in soft- and hardware. This paper describes the development of such speculative recreations of the complex behaviour of sonobotanic plants, in order to gain deeper understanding of the (at times enigmatic) observed behaviours. We also report on presenting incarnations of these works in artistic contexts, such as installations.

Keywords

Predictive Sonobotanics, evolving responsive systems, biological growth models, memory models

1. INTRODUCTION

Sonobotanics is still a widely unknown science; it studies plants whose life experience is predominantly in the auditory domain. Since the 1970s the core research in this area has been carried out by Prof. Dr. Hortensia Audactor; despite difficulties with publishing her results, she has collected a substantial body of research about the growth patterns, communication behaviour, and other characteristics of these plants.

The single biggest problem in sonobotanics research is that sonobotanic plants are extremely sensitive to their environment, to the extent that they seem to 'dislike' being used as guinea pigs for western science. While this clearly proves their intelligence, it forces sonobotanic researchers to find alternative methods of investigation. The authors have thus founded the area of Predictive Sonobotanics, which attempts to create models of sonobotanic plants with the eventual aim of predicting the behaviour of sonobotanic plants. By comparing the behaviour of the models with that of the plants, aspects of the model can be validated, and deeper understanding of the subtleties in sonobotanic plant behaviour can be be gained. This paper describes the first models created, that of the *"Periperceptoida Dendriformis Sensibilis"* and the *"Periperceptoida Dendriformis Imaginaris"*.

2. BOTANICAL DESCRIPTIONS

From [1]:

Periperceptoida Dendriformis Sensibilis

Sound plant, whose appearance manifests itself primarily in the acoustic domain. Its stalk is expressed as a sound which is most similar to a woodwind instrument, whereas its leaves have a soft, rustling kind of sound. Its flowers sound like high pitched glassdrops. Furthermore, the plant has a 'voice' with which it can respond to perceived voices from other (e.g. human) beings. Its physical appearance consists of a transparent ball, with long haulms (its sense organs) coming out, in shades of blue and red with yellow ends.

Periperceptoida Dendriformis Imaginaris

Sound plant, directly related to *Periperceptoida Dendriformis Sensibilis*. Its appearance in sound is very similar to the *Sensibilis*, except *Imaginaris* does not react to voice-like sounds. The defining characteristic of *Imaginaris* is that it appears to be directly connected to exactly one specimen of *Sensibilis*, as its sound emanations are identical to the sounds of this *Sensibilis*. Note that the two Periperceptoidae need to be physically far apart; they do not thrive in the same garden. The physical appearance of the *Imaginaris* is again similar to that of the *Sensibilis*, but with less and more slender haulms.

3. THE MODEL

Our model consists of four parts: the physical object which mimics the visual component of the *Periperceptoida*, the model for its growth, based on the sensor data, the model for its reaction to sounds and its memory of them, and a model for interaction between the plants.

The software model is created in SuperCollider3 [3]; the necessary hardware consists of the physical object (including a USB sensor board and microphone), a computer (either Linux or MacOSX) and an audio interface (see figure 3).

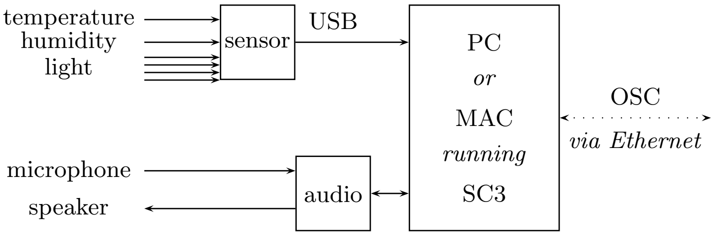


Figure 1: The technical setup for a single plant model

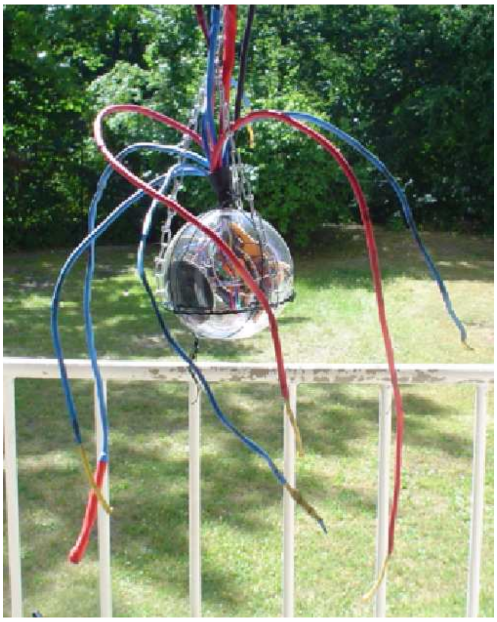


Figure 2: The physical model of the *Periperceptoida Dendriformis Sensibilis*

3.1 Physical

The physical model (figure 2) of the *Sensibilis* consists of a plastic ball with a diameter of 10 cm. A small speaker (diam. 5 cm) is mounted inside, as well as a sensor-to-USB board, the CUI [4], and a microphone preamp. The sensors are outside of the ball, inside haulms made from shrinkable tubes, fortified with iron wire. The model uses 4 light sensors, 1 temperature sensor and 1 humidity sensor, and an electret microphone for sensing sounds. The physical model of the *Imaginaris* simply consists of a plastic ball with a diameter of 10 cm with a small speaker inside. The model also features haulms, but they only have a visual function.

3.2 Growth

The plant consists of three elements: the stalk, the leaves and the flowers. The growth of each is determined by the weather conditions. This is a slow process: the plant needs a certain amount of heat, water and light to grow. On the other hand, its development can be hindered by excessive heat, water or light; either accumulating over time, or in critical situations directly. Growth is not endless; after a certain time, the plant reaches its maximum for the season and the plant starts to decay. When it has decayed, i.e. lost all its leaves and flowers, and its stalk has been reduced to a minimum, after a certain amount of time a new cycle can start. The stalk continues to grow over a number of seasons, but only slowly.

Table 1: State transitions. $5.rand2$ denotes a random value between -5 and 5. $seasons$ indicates the number of seasons the plant is alive. $stalk$, $leaves$ and $flowers$ denote the size of the respective part of the plant (the size can be from 0 till around 100).

element	transition	condition
stalk	$0- > 1$	after decaytime
	$1- > 2$	after decaytime
	$2- > 0$	if $stalk < 15 + 5 * seasons$
leaves	$0- > 1$	if $stalk > 5.rand2 + 15 + 5 * seasons$
	$1- > 2$	after decaytime
	$2- > 0$	if $leaves < 1$
flowers	$0- > 1$	if $leaves > 5.rand2 + 30$
	$1- > 2$	after decaytime
	$2- > 0$	if $flowers < 1$

Each element of the plant is expressed by its own sound. Its size is reflected by the length of the pattern that is heard, i.e. the number of notes that are played with its sound. Everytime the pattern grows by a note, one note from the pattern is chosen at random, and replaced with two new ones, according to predetermined replacement rules. Because of the difficulties in observing how these sound pattern evolve in natural sonobotanic plants, and the low number of recordings usable for analysis, this is only a first approximation.

3.2.1 States and Transitions

Each element can be in one of three distinct states of growth: growth (1), decay (2) and hibernation (0). A transition between hibernation and growth happens in the case of the stalk after a certain amount of time. The leaves make a transition after the stalk has grown with a certain amount, similarly the flowers start to grow after the plant has already grown a certain amount of leaves. A transition from growth to decay happens after a certain amount of time; in the case of the leaves and flowers, this amount depends on the time the stalk still has to grow, at the moment of transition from hibernation to growth. The transition from decay to hibernation is for the leaves and flowers when the plant has lost all leaves and flowers. For the stalk this transition is based on the decay to a certain minimal size, dependent on the age of the plant. See table 1 for an overview.

3.2.2 Development

The model develops with each timestep Δt. First the sensor data are scaled to be within the range from 0 to 1. Then they are checked versus certain critical limits: the first limit is that for long-term accumulative damage, i.e. simulating the effect of prolonged coldness or dryness or similar. The second limit is that for immediate effect of serious weather conditions, such as intense freezing or heavy rain. Crossing the first limit only reduces the amount of growth, crossing the second limit directly affects the plant's elements.

The growth process is two-staged, inspired by experience models adopted from roleplaying games. The plant gathers "growth points" depending on the weather conditions, as described above, and if the amount of "growth points" has reached a certain threshold, the element of the plant grows.

Table 2: Weather influence on growth. gp indicates number of growth points, $value$ is the mapped value from the sensor, gr is the growthrate, dr the damage rate, $size$ denotes the size of the element ($stalk$, $leaves$ or $flowers$) and Δt the timestep with which the model is calculated.

weather parameter	effect
within limits	$gp + value * gr * \Delta t$
<> 1st limit	$gp * dr^{\Delta t}$
<> 2nd limit (state 1,2)	$size * dr^{\Delta t/200}$
<> 2nd limit (state 0)	$size * dr^{\Delta t/1000}$

Table 3: Influence of "growth points" on the size of the elements

state	condition	effect
state: 0		nothing
state: 1 or 2	if $gp > size + 20$	$gp - 20$, $size + \Delta t * gr$
state: 2		$gp -= 2 * \Delta t$
	if $gp < size - 20$	$gp + 10$, $size - \Delta t * gr$

The threshold depends on the current size of the element. In the decay phase, growth points are lost with each time step, and once it is below a certain threshold, the size of the element is reduced.

These two processes are summarized in tables 2 and 3.

With this model, the researcher can vary parameters for the growthrate and decaytime, in order to approximate the behaviour of the real plants more closely. Here it should be mentioned that at the transition from state 1 to 2, the growthrate is tripled (and in that state actually functioning as decayrate), and set back to its original value at the transition from state 2 to 0. The decaytime for the stalk can be set at the start of the experiment, the decaytime for the leaves, is set at its transition from state 0 to 1, and depends on the time that the stalk has been in state 1 and its decaytime, like this:

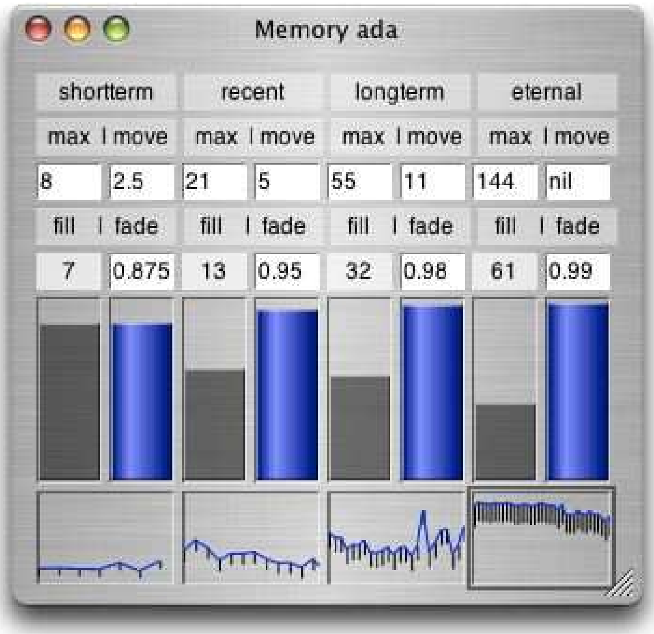
```
decaytime_leaves =
   (decaytime_stalk - time_state_1_stalk)
    * (0.3.rand + 0.6 );
```

Similarly the decaytime of the flowers at the transition from state 0 to 1, depends on the decaytime of the leaves. At the transition from state 2 to 0 of the stalk, its decaytime is set to:

```
decaytime_new = decaytime_old * ( 1 + 0.25.rand2 )
```

3.3 Memory

The microphone signal is analysed with a simple vocoder. The resulting data is put into a database of acoustic memory traces ("phrases"). As a reaction, the plant may respond with the same phrase (or a different one) in synthesized form; e.g. as grains exciting the channels of a filter bank, or as continuous sinusoids. Currently, the physical sound production mechanisms of sonobotanic plants are completely unclear, so the synthesis methods used are chosen for relatively simple approximation to the few recordings of the actual sounds; better data will be needed here.



Memory ada

shortterm		recent		longterm		eternal	
max	move	max	move	max	move	max	move
8	2.5	21	5	55	11	144	nil
fill	fade	fill	fade	fill	fade	fill	fade
7	0.875	13	0.95	32	0.98	61	0.99

Figure 3: GUI representation of the state of the plant's memory

The plant has hierarchical levels of memory for audio traces, from short-term through recent, long-term, and eternal. New traces are first stored in short term memory, along with a time stamp and a strength value. When a trace is remembered, it is strengthened, and having accumulated strength, it may rise into the next higher memory level. As the plants grow, memory size limits come into effect: new entries compete with older ones for space, and weaker traces will be forgotten.

Memory size depends directly on the size of the plant: the larger the plant, the larger its available memory; as a plant decays, it will also lose memory. Short term memory size is correlated to the number of leaves of the plant; typically, short term traces are forgotten randomly, unless they are being accessed very soon after initial entry. Long-term memory is correlated to the stalk size; here, younger traces tend to be forgotten more easily. Important traces rise into eternal memory; here, memory traces may remain for very long times without being accessed, activated only very rarely.

This collection of memory traces make up a large part of the plant's identity, so the software model makes memory backups regularly to avoid loss of valuable simulated life cycles.

A number of more subtle aspects are still not clear enough to be modeled yet, such as how association between memory traces work; models of the cognitive faculties of sonobotanic plants are still very much the object of speculation. Here, the predictive experimental approach seems particularly promising.

3.4 Interaction between plants

The current understanding is that an *Imaginaris* is always a direct mirror of its *Sensibilis.* During an exhibition that took place simultaneously in Berlin and Cologne, two pairs of *Sensibilis* and *Imaginaris* mirrored each other across the two gardens. This was achieved by sending the commands from the SuperCollider language on each side to SuperCollider synths on both sides. This enabled a small bandwidth communication between the two gardens.

4. EXPERIMENTS

During an exhibition of the models during the *Experience Art!*-exhibition in Art Center Berlin Friedrichstrasse, we had the opportunity to test the models in fairly controlled and stable weather conditions over an extended period, after previous exhibitions enabled us to create and debug the models.

First thing to notice was that the sensors, as they are not calibrated, provide fairly different ranges of measurement. This suggests that it is wise to use a calibration period to determine the normal range of the perceived weather conditions, in order to do proper scaling and setting the limits for damaging weather conditions.

In figure 4, we see a graph of the development of one of the plant models, *Moma.* In the weather state we see a clear daily pattern of all the weather parameters, especially of the light intensity. The growthrates for the different elements of the plant were 0.006 for the stalk, 0.011 for the leaves and 0.015 for the flowers, the decaytime was set to 18 days initially. We can clearly see that with these parameters, in the stable weather conditions of the Art Center Berlin, the plant grows healthily and develops a sound amount of leaves and flowers. If it were to stay in this environment, we would see how with each season the stalk grows further (notice that at the start the stalk had a size of approximately 9 and at the end of the season has come to be circa 15).

5. CONCLUSIONS AND FUTURE WORK

A first model for the sonobotanic plant: *Periperceptoida Dendriformis* was presented. The model shows promise, though systematic comparisons with real sonobotanic plants still need to be carried out.

There are still several interesting aspects that we have not implemented in the model yet, such as the suspected preferences of the *Periperceptoida* for certain types of sound [5], and their emotional behaviour as has been observed: talking to the plants has shown to excite a plant, which is beneficial to its growth, though too much excitement can stress the plant and hamper its growth. Furthermore, the interaction and communication between different *Sensibilis* individuals (as has been observed recently by Audactor [2], which is also suspected to occur over large geographical distances!) will need to be modelled as soon as we have more detailed information about these observations made in Prof. Audactor's garden. Finally, we plan to model other members of the sonobotanic plant family than the *Periperceptoida Dendriformis* soon.

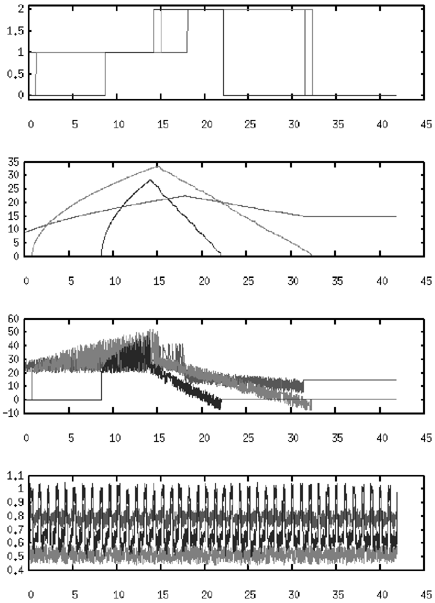


Figure 4: The development of the plant model *Moma*. The first plot depicts the states of the different elements (gray: *stalk*, light gray: *leaves*, dark gray: *flowers*), the second the size and the third the growth points. The lowest plot indicates the weather state, as measured by the sensors (gray: temperature, light gray: humidity, dark gray: light). On the x-axis is the time in days.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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