trees: Pinus sylvestris

An artistic-scientific observation system by Marcus Maeder and Roman Zweifel

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An artistic-scientific observation system

Sonification and artistic realisation: Marcus Maeder, Institute for Computer Music and Sound Technology, Zurich University of the Arts
Scientific data and analysis: Roman Zweifel, Swiss Federal Institute for Forest, Snow and Landscape Research (WSL)
ICST members of staff involved: Philippe Kocher, Jonas Meyer

The link between trees and various climatic processes is usually not immediately apparent. Trees and plants do not live merely on moisture from rain, sunlight (which drives gas exchange) and nutrients from the soil: they absorb carbon dioxide from the air and produce the oxygen that we breathe, maintaining our climate and biosphere. Gathering eco-physiological data by measuring the local climatic and environmental variables and the physiological processes within a plant in response to changes in these variables has become an important method of researching climate change and vegetation dynamics. It helps to determine physiological thresholds of plants in terms of increasing temperature and consequently drought stress.

Plant physiologists have known that plants emit sounds for several decades now: Many of these sounds are of transpiratory/hydraulic origin and are therefore related to the circulation of water and air within the plant as part of the transpiration process. Each plant species—in fact each plant individual—has its own acoustic signature, related to its structure and to the local climatic conditions. Investigating the acoustic emissions of a tree in response to dynamically changing climatic conditions might reveal biological or physical properties that place these emissions in a broader ecophysiological context and enable us to explain processes that are not yet fully understood.

In our research project *trees: Rendering ecophysiological processes audible*, we combine recordings of acoustic emissions in trees with acoustic representations (sonifications) of ecophysiological data in one single auditory experience, making their correlation acoustically and aesthetically experienceable and explorable. After a first prototype, which we exhibited in San Francisco in 2012 (*trees: Downy oak*), we are now presenting our new sonification system and sound installation, *trees: Pinus sylvestris*. This installation replays ecophysiological measurement data as well as audio recordings of a tree and its local climatic conditions from early summer 2015, the peak of the growth period in our experimentation plant, a Scots pine (Pinus sylvestris) located in the central Swiss Alps in Salgesch in the canton of Valais. The installation is designed as an artistic observation system that transforms ecophysiological data into a generative piece of music. *trees: Pinus sylvestris* makes the normally hidden processes behind a plant's coping with its local conditions experienceable and audible.

The Scots pine in Valais has experienced high mortality rates for some decades now: this phenomenon is believed to be caused by the effects of climate change, e.g. longer drought periods. A downy oak (Quercus pubescens), for example, is able to withstand the current climatic conditions whereas a Scots pine is pushed beyond its physiological limits despite the fact that both tree species have coexisted there for thousands of years. Consequently, shifts in the abundance of tree species are observed. The ecophysiological knowledge acquired is used to explain the underlying processes: Hence the interest in cooperation between a biologist and an artist to study the complex relationship between tree physiology and the climate on one hand and to explore the possibilities of acoustic and artistic representations of ecophysiological processes in trees on the other. Rendering audible the way in which water transport or trunk diameter, for example, are influenced by sunlight, humidity and wind allows us to identify and better understand plants' responses to climatic processes.

trees: Pinus sylvestris will be presented at the UN Framework Convention on Climate Change, 21st Conference of the Parties CoP21 in December 2015, by invitation of French President François Hollande.

Description of work, data and sonification processes used

The installation *trees: Pinus sylvestris* is designed as an artistic observation system that transforms ecophysiological data into a generative piece of music.

At the moment, there exist two versions of our installation: The stereo/IP cam version for two speakers or three headphones and three TFT monitors (Fig. 1, 4.5, 4.6), and the larger spatial audio installation (Fig. 2, 4.1-4.4). The same sonification algorithms are implemented in both versions but are differently mapped on the speakers/headphones and present different video footage. In the stereo version, you will see video footage from two IP cams on the stem of our measurement tree, each focusing on a branch of the plant.

The spatial audio system consists of an octagon carrying 36 self-built omni-directional speakers. It is designed as an accessible three-dimensional speaker array, where virtual sound sources are moved and placed within a defined space, and listeners can walk around inside the system. The speaker matrix that we have developed is a hybrid sound system: An Ambisonics sound field is mapped onto the tube matrix, but some of the speakers are driven discretely. A 24" touch screen (Fig. 3) at the centre makes the installation an explorative, self-explanatory artistic system: The visitor is able to switch sound sources on and off to identify individual phenomena and their sonifications (Fig. 4.1). A time-lapse video (Fig. 4.2) of the tree and its surroundings informs the visitor visually about the local climatic conditions (weather, time of day and light intensity). These images were taken by a so-called tree canopy camera, i.e. a fish-eye camera system that biologists use for measuring the light intensity coming through a canopy to investigate a tree's state of health or the light exposure of plants growing on the forest floor for instance. Furthermore, visitors may observe a graphic representation of the local climatic measurements and the correlations between the individual phenomena (Fig. 4.3) as well as a graphic display of the peak frequencies of the measured acoustic emissions (Fig. 4.4) at different locations along the plant's trunk and branches.

The following table shows the measurement data, the sound characters that we associated with them and how they have been spatialised within the audio system:

Measurement data	**Sound character**	**Playback parameters**
Daylight [RGB brightness]	Atmospheric synthetic sound	Amplitude, controlled by video brightness
Solar radiation [W/m^2]	String-like, synthetic sound	Amplitude
Sun position [azimuth, elevation]	Same	Spatial position
Air temperature [°C]	-	Main volume
Rel. air humidity [%]	Water-like, synthetic sound	Pitch, amplitude
Rain [mm]	Field rec.: Rain	Amplitude, spatial position
Wind [m/sec., azimuth]	Field rec.: Wind	Amplitude, spatial position
Soil water potential [kPa]	Field rec.: Seeping water	Amplitude, placed on discretely driven speakers near ground
Tree branch diameter [µm]	-	High pass filter, applied on sap flow sound
Tree sap flow [g H_2O/h]	Floating water, transposed up and filtered	Amplitude, placed on discretely driven speakers
Tree ultrasonic acoustic emissions/cavitation pulses [dB]	Field rec.: Ultrasonic acoustic emissions, transposed down	Amplitude, placed on discretely driven speakers

Fig. 1 *trees: Pinus sylvestris,* Stereo/headphone version

Fig. 2 *trees: Pinus sylvestris,* spatial audio version

Fig. 3 *trees: Pinus sylvestris,* spatial audio version: Touch screen/data monitoring/interaction module

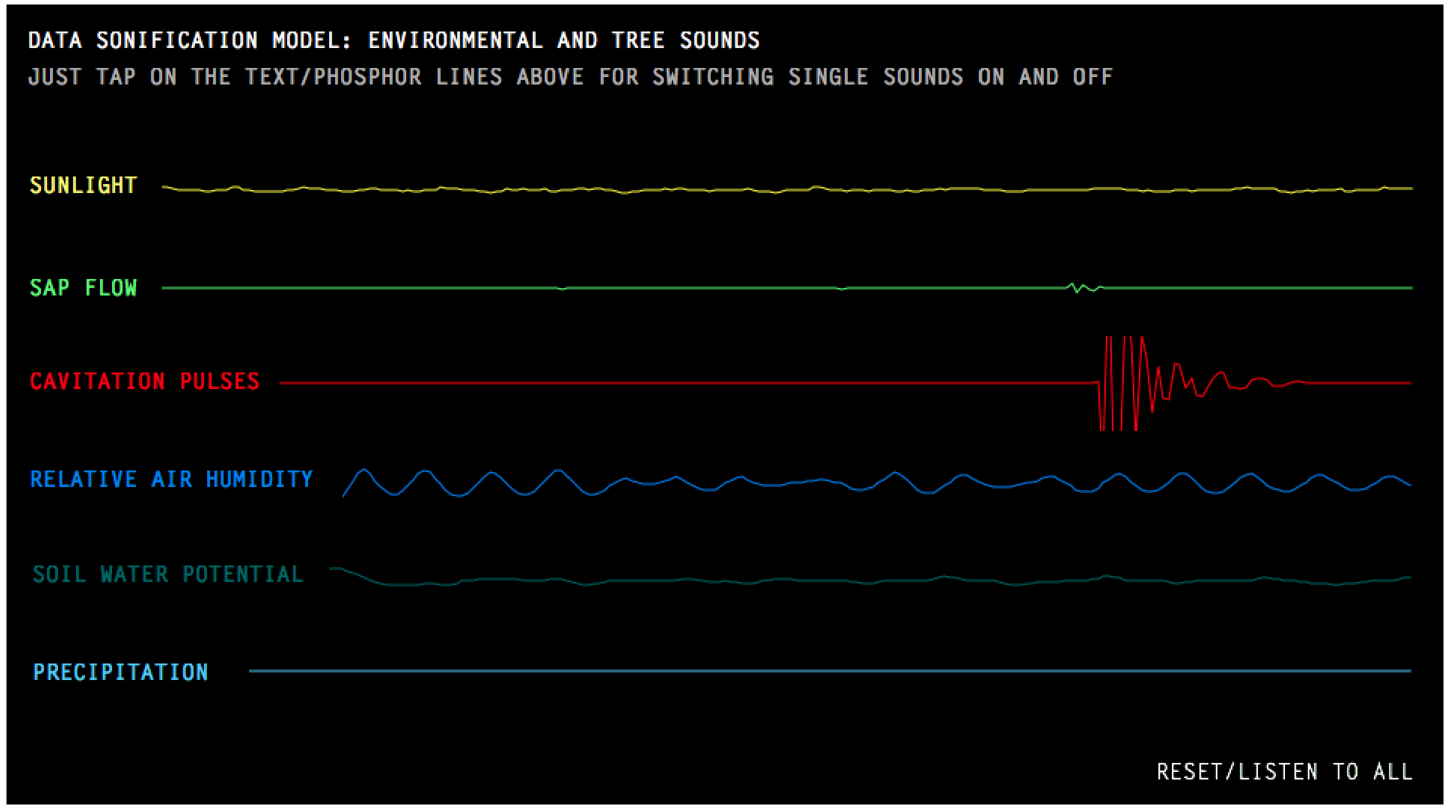

Fig. 4.1 Interaction: Switching sound sources on and off to identify individual phenomena and their sonifications

Fig. 4.2 Time-lapse video

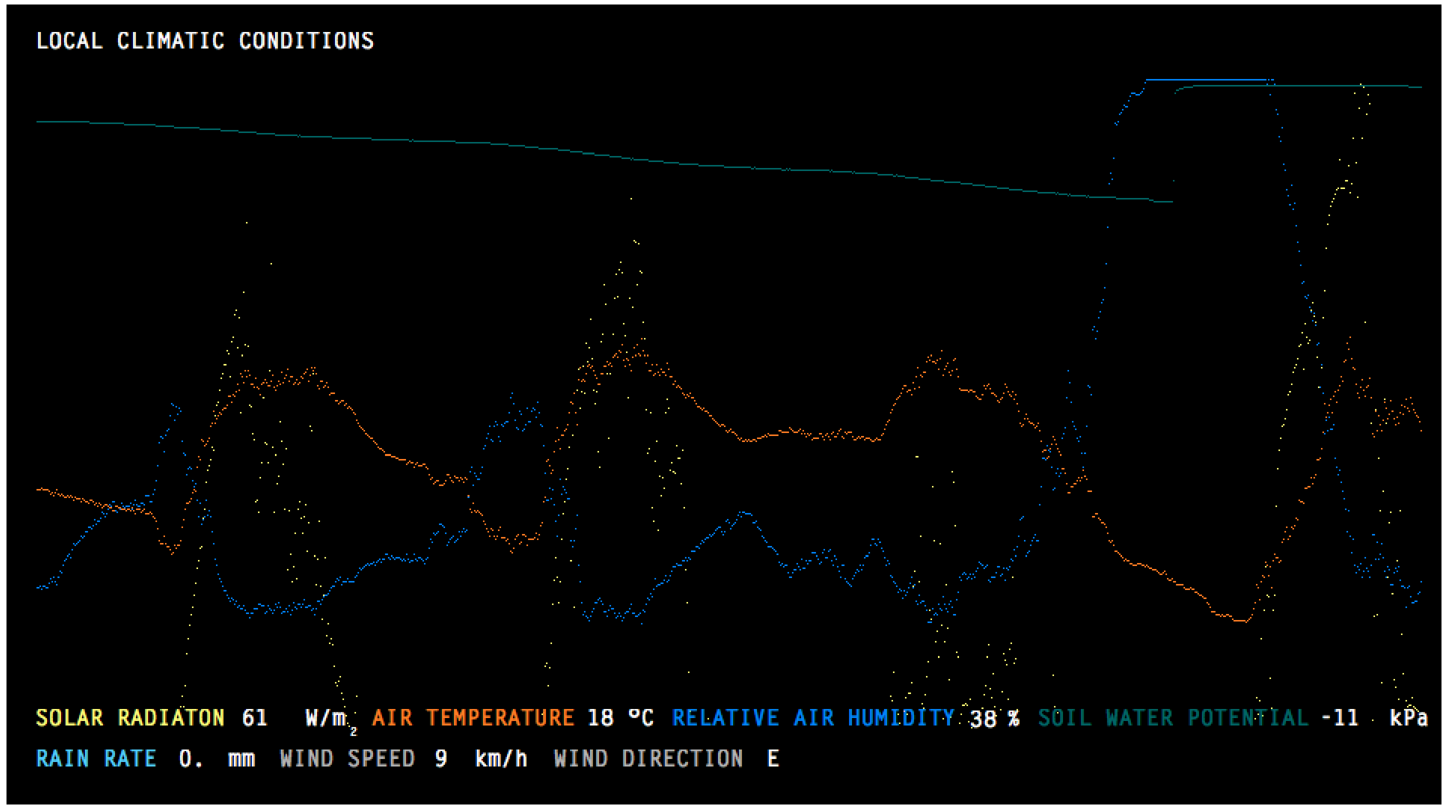

Fig. 4.3 Local climatic measurements and the correlations between the individual phenomena

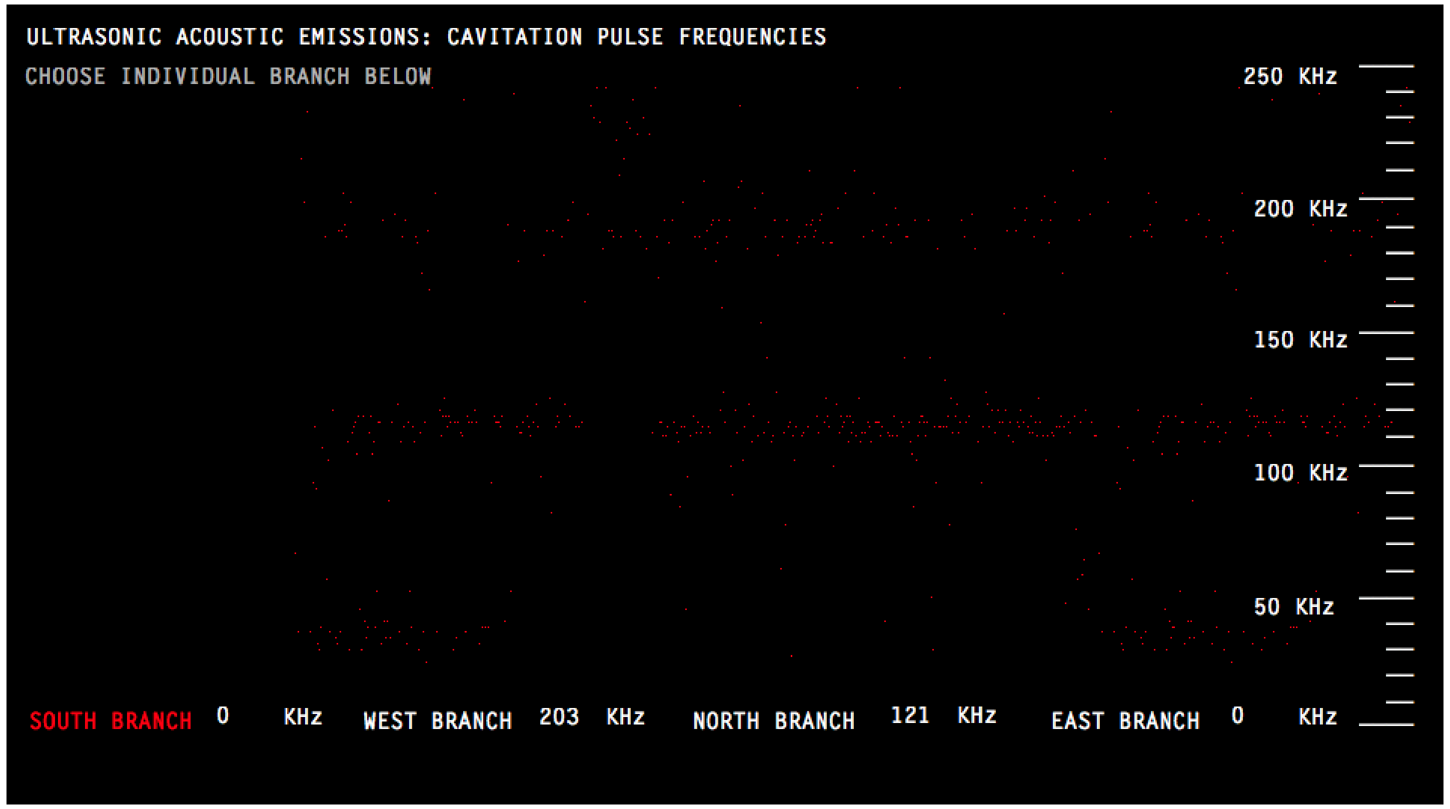

Fig. 4.4 Peak frequencies of the measured acoustic emissions

Fig. 4.5 IP cam view of the stereo/headphone version

Fig. 4.6 Touch screen/interaction module of the stereo/headphone version

The sonification system uses a combination of different sonification techniques: Playback of audifications of original acoustic emission recordings (by transposing them into the audible domain) as well as parameter mapping sonification, whereby the parameters of a sample player and the sound distribution system are controlled by the data flow (amplitude, pitch, spatial position etc.).

The different sonification modules are implemented in a set of Max/MSP patches, which replays ten days' measurement data. For an adequate (temporal) experience of the most important processes, the speed of the running system is increased up to 1000 times the normal time speed, i.e. the 10-minute measuring intervals. Environmental data is mapped on the outer side of the tube matrix, while tree data is played back on single speakers of the system, according to the spatial position and geographic orientation of the sensors on the plant.

The sounds that we used to sonify the measurement data can be divided into two groups: field recordings (rain, wind and plant sounds) and synthetic sounds. A larger number of phenomena do not manifest themselves acoustically, and it was a challenging task generating metaphorical sounds that portrayed a single phenomenon, for instance sunlight or air humidity, in the best way. For sunlight, for instance, we took a string-like sound; for air humidity, a transformed and filtered burbling sound of a creek. All sound sources have a specific static or dynamic location within the array. The sun sound moves across the firmament, from east to west; wind comes from varying directions, louder if strong, softer if weak. As the sun rises, transpiration within the tree starts, and sap flow noises become louder. When the diurnal course reaches its peak at noon, cavitation pulses start, later decreasing during the course of the afternoon.

Our sonification experiments show that immediate and intuitive access to measurement data through sound and its spatial positioning is very promising in that it offers new forms of data display and generative art works. It is a fascinating experience to spend time in the system listening to the interplay of sounds and the phenomena that they represent during the growth period: the experience lasts about 20 minutes. Besides the diurnal course of the tree's response to sunlight, there are many other recognizable patterns: As it gets drier, the cavitation events grow longer, sometimes lasting deep into the night; the stressed plant needs more time to refill with water from the soil. Likewise, there are more cavitation sounds when the plant is well drained and exposed to full sunlight than in very dry periods.

Staging, setup, spatial and technical requirements – spatial audio version

Fig. 5

Fig. 6

Description of staging, setup, spatial and technical requirements

Both versions are ready to transport and require no technical equipment for presentation at exhibitions. All that is needed is a 230 Volt socket. Both versions require a quiet space easily accessible to visitors but protected from disturbance from passers-by (for example not a noisy entrance area). The ideal area would be a closed exhibition room inside a museum or similar. The spatial audio version needs to be hooked to the ceiling—it requires four mounting points/drill holes capable of carrying 5-10 kg each. For the necessary room dimensions, please consult the images on the previous pages (Fig. 5-6). Both installations will fit into a large car or a small transporter, which will need to be rented. The installations cannot be transported by train or airplane (very fragile and bulky/oversized). Accurate packaging material must be calculated in the transportation budget.

Link to download of supplementary media files

http://www.domizil.ch/trees.zip

Containing:

Sonification_Pinus_sylvestris_excerpt.mp3: Sonification of 24h, normal speed of installation
the_details_pinus_sylvestris.mp4: Marcus Maeder introduces the stereo version of trees: Pinus sylvestris

People

Roman Zweifel studied Biology at the University of Zurich and at the ETH Zurich, where he gained a PhD for his ecophysiological work *The Rhythm of Trees*. He has strong expertise in the physiological research of forest ecosystems. Roman Zweifel has focused on whole-tree gas exchange, mechanisms of water flow and storage in trees, incl. stomatal regulation, and wood anatomy to link tree water relations and growth and carbon balance. He is heavily involved in research into the way in which continuously measured stem radius changes (measured using a dendrometer) are mechanistically linked with growth and tree water relations. His current research activities are focused on linking tree physiological processes with the processes on the forest ecosystem level.

http://www.wsl.ch/info/mitarbeitende/zweifel/index_DE
http://natkon.ch/

Marcus Maeder studied Art at the University of Applied Sciences and Arts of Lucerne and is currently pursuing a Master's degree in Philosophy at the University of Hagen. Maeder runs the music label domizil, which he co-founded in 1996 with Bernd Schurer. He has worked as an editor and producer for the Swiss radio station DRS and has been working as a curator and research associate at the Institute for Computer Music and Sound Technology since 2005. His artistic work focuses mainly on sound art, computer music and the artistic and media extensions of the term. As an author, Maeder has written on a number of topics in the fields of cultural studies, aesthetics, media philosophy, sound art and artistic research.

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