Açores, A Systemic Island
Paper

Topic: *Hybrid system*

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Abstract
This paper explores intricate behavioral complexity observed in both natural and artificial workspaces. Interfacing real-time webcam images with a particle system creates a mixed reality system. Morphological changes in the environment act as catalyzer influencing particle clustering, and subsequently, sonification of particle connectivity. In short, the environment – and in this implementation, the island of *Açores* – is thought of as a massive self-regulating generative system. We express fascination with its unpredictable yet coherent behavior. Some significant notions underpinning this work are coexistence of natural and artificial systems, remotely responsive systems and complexity and adaptation. *Açores* implements these concepts as a large-scale real-time web-driven audiovisual installation. We comment on earlier and contextual work and provide some implementation details.

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Key words: generative nature, surveillance, sonification, mapping, influence, particle systems

Main References:
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$E = mc^2$

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Abstract
This paper explores intricate behavioral complexity observed in both natural and artificial workspaces. Interfacing real-time webcam images with a particle system creates a mixed reality system. Morphological changes in the environment act as catalyzer influencing particle clustering, and subsequently, sonification of particle connectivity. In short, the environment – and in this implementation, the island of *Açores* – is thought of as a massive self-regulating generative system. We express fascination with its unpredictable yet coherent behavior. Some significant notions underpinning this work are coexistence of natural and artificial systems, remotely responsive systems and complexity and adaptation. *Açores* implements these concepts as a large-scale real-time web-driven audiovisual installation. We comment on earlier and contextual work and provide some implementation details.

1. Introduction
Açores is a hybrid incorporating ideas of remote perception, surveillance technology, exploratory programming, real-time image analysis, data visualization and sonification. In addition, our approach considers particular physical locations as systemic entities and evaluates them as found complex dynamical systems. Physical dimension is a critical parameter, for example, we might focus on how small groups of humans interact given particular social conditioning. Otherwise, we could tune in to cyberspace macroscopic systems like global networks or physical-space macroscopic systems like the atmospheric conduct of the earth.

The opening chapter of *Hidden Order*, John Holland's seminal book, suggests viewing New York City as an adaptive complex dynamical system. A myriad of free running processes (social, financial, food supply, public transport…) all contribute successfully to continuously reestablish the city as a self-organizing systemic entity, "a city is a pattern in time" [12, p. 1].

The work documented in this paper suggests viewing the rhythms of the earth as patterns of time – the cycles of day and night, the tides of the ocean, the visual effect of coalescing molecules in clouds, the split-second magic moment when natural and electric light are in perfect balance – in short, we are fascinated by the unpredictable but coherent changes in morphology and behavior of natural phenomena.

Our work explores complex dynamical systems (CDS) as they are found abundantly in nature, they express aesthetic potential because they afford particular levels of qualitative complexity (in terms of morphology and behavior) – they exhibit self-organizing structures, most often, they produce unpredictable yet coherent behavior.

CDS are typically supported by a critical mass of small simple components – think of a society of ants [11, p. 231], the billions of nerve cells in the human brain or the immeasurable number of water molecules in a cloudy sky. Such systems create order out of chaos – from the simple local interactions between simple components we yield global emergent phenomena and emergent functionality. We might create conceptual bridges between musical composition and CDS [5] or interpret captured implicit natural behavior as a musical control structure [7]. *Açores* suggests a systemic approach to natural environments by viewing them as complex dynamical systems (image 5).

2. Earlier work

Amsterdam harbor was the site of a series of earlier surveillance-based works, including the movie *Dusk* (2006), the mixed-reality installation of the same name and work exploring the notion of sequential photography [6]. Dusk is created entirely of live images taken from the Internet. Activity in the Amsterdam harbor is tracked over a time span of exactly 24 hours. A program reads the current image and compares it to the previous one in computer memory. In case of significant change, the image is saved to disk and added as the next frame of the movie in progress. Then, that image acts as a reference for the next one, and so on until 24 hours have passed.

***Image 1 and 2**: Amsterdam harbor*

Surprisingly, an impressionistic undertone emerges given a low-resolution camera and occasional interference and glitches in the transmission channel. Fascinating imagery unfolds as electric lights illuminate the darker stage of twilight. Consequently, the movie suggests a developing atmosphere conditioned by human (cultural) as well as ambient (natural) phenomena. Image transitions evocating variable color content and fluctuating degrees of abstraction are inherently emergent qualities. In essence, Dusk may be thought of as a generative work of art built out of three interacting components; (1) the harbor as a 'found' systemic machine, (2) the environmental conditions and (3) the Internet (see images 1 and 2).

As an mixed-reality installation, Dusk views harbor activity as a complex finite-state machine: a myriad of interacting local and more global ship trajectories provide the impression of witnessing the behavior of an apparently self-sustaining and self-organizing macroscopic system. A program samples and compares consecutive images, computes an 8-bit gray-scale image holding the absolute value of the image intervals, pixel-by-pixel. A 256-element brightness histogram is computed next, and, finally, this data is reorganized into the topology of a 16 by 16 matrix. A distributed agent-based system runs in parallel with the computer-vision component. When any two agents connect in 2D space (given a specific sensitivity) they consult the matrix as to change the values of their respective angles. Therefore, the dynamics in the harbor mediates influence by modifying the interactivity between agents.

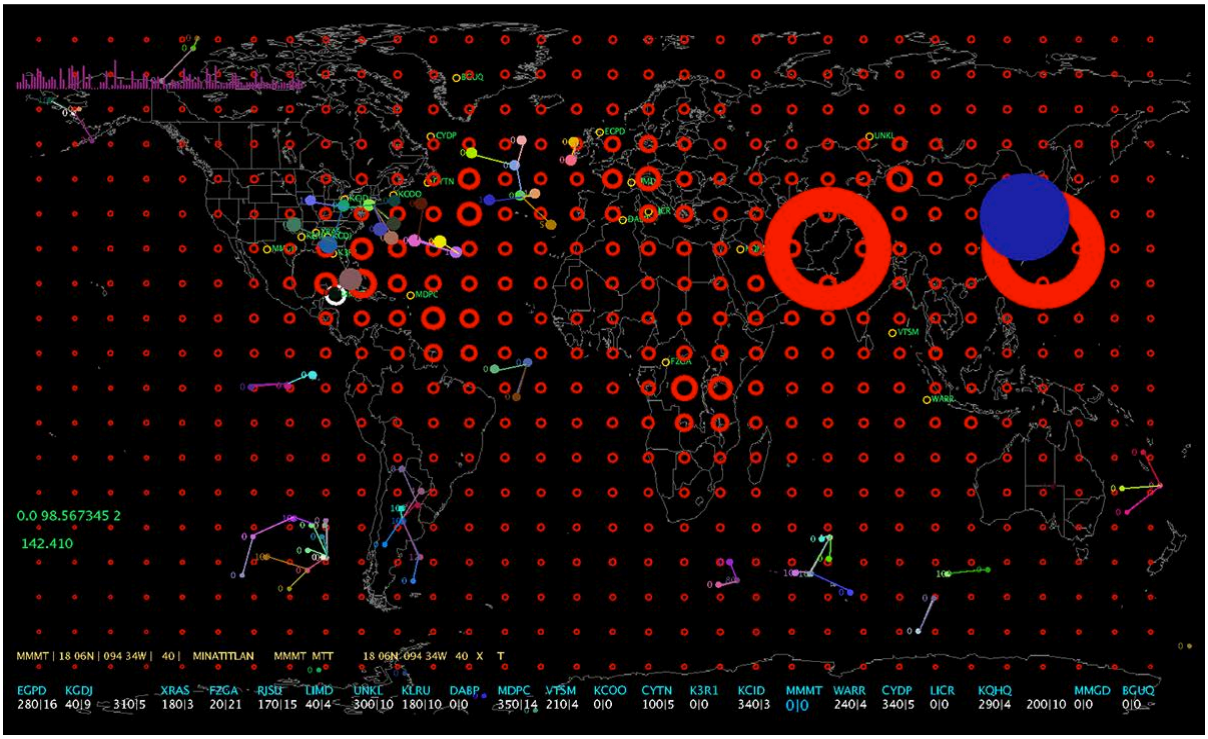

Image 3: *Snapshot of WindChime installation*

Another significant example of large-scale mixed-reality work is WindChime, a real-time web-driven audiovisual installation [7]. Weather data from many world locations is gathered from a server and accommodated in a dynamic visual representation. The dynamics of the wind at specific world locations exercises influence over a mass of floating particles in a virtual parallel world. Particles in turn influence the production of complex sounds. In effect, a rewarding aesthetic experience results from the appreciation of the intricate interplay of two complex dynamical systems: one of natural origin (the earth), the other of cultural design (the program). Image 3 displays a snapshot showing a map of the world, data analysis and currently clustering particles.

Later, Antarctica (image 4) was chosen a critical location supporting the synthesis of emergent imagery – viewing nature as the ultimate generative system [6].

Still another orientation was to take photographs using Google Street View (GSV), a technology created by Google in 2008. By 2012 twenty petabytes of image data were collected and made available in an online database. It becomes possible to return to particular locations where I resided over the years, wherever in the world. Even the resolution of my search is scalable, for instance, going back to a particular country, a specific neighborhood or even a private address. Therefore, a blend of tele-presence and time travel seems to underpin GSV functionality. Various detailed assemblies were generated by taking spatial photographs by circular scanning of a location – individual images are captured, in steps of 45 degrees, so 8 images result to see a location full circle. Images are organized in a regular grid structure or, occasionally, as a panoramic stretch.

Image 4: *Antarctica*

3. Contextual work

An excellent resource detailing early work in sound scape studies, environmental acoustics and acoustic communication is compiled in the Truax' handbook of acoustic ecology [20]. Sound as generative force of constructive, semantic and emotional communication has been intensified over recent years. For example, studies include interdisciplinary research involving the consideration of sound in the wide ecological environment [16], architectural and urban planning and hybrid environments of public Sound Art [4].

Michails offers a survey of works of media art exploring of ecology, information aesthetics and data visualization, including, online environments with real-time data mapping [14]. Carlyle explores online sound maps creating a re-assembled sonic geography, the apparently inherent abstractions of the 'view from above' can be dislocating: for example, relations can be established between components in the environment and the weather. The invisible can be rendered audible perhaps because sound might always already be cartography [8].

Adhitya aims to integrate sound into the urban design and planning process through the creation of audio-visual maps by way of sonification [2]. Process steps include image rasterisation and parameter mapping leading to the construction of an *Urban Sonic Code* – all with user-supplied parametric control. In particular, a mix of sound-scape recordings and abstract acoustic modeling techniques – merging ecological sound and instrumental timbres. Research results indicate the power to evoke feelings and recognition.

Earth Lab – Artists as Catalysts is a recent major collection of artistic projects dealing with key issues pertaining to global ecosystems - the exhibition presents new and unconventional ways of looking at the entirety of our Blue Planet. The Earth itself is viewed as a laboratory for unanticipated knowledge generation. From an interview with a curator we learn: "Living organisms are confronted with inert materials; invisible parameters have an effect on processes in the exhibition, and factors whose influence is all too visible can be discussed. And "Mrs. Coincidence" is the guide! There are sculptures out of physical material and out of data; you can find installations and interactive settings and ever-changing processes that support the idea of considering the Earth as a lab" [1].

Joris Strijbos' *IsoScope* is an outdoors kinetic sound-and-light installation built from

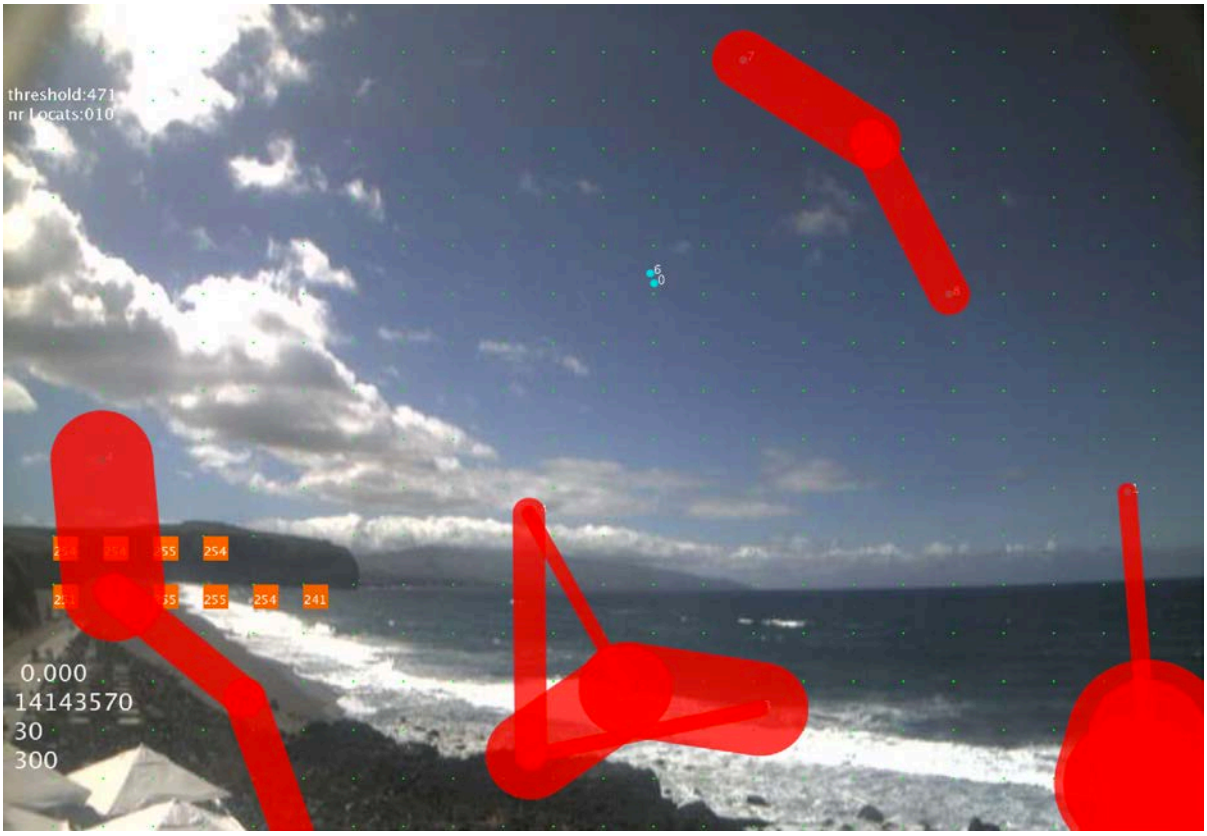

Image 5: *Captured webcam image frame showing clustering particles and active locations (orange squares) in the sensor array.*

multiple interacting robotic wind objects generating emergent generative behavior. It associates with weather conditions and blends considerations of augmented experience, generative audiovisual functionality and, in general, artificial life [18].

Tango Apart: Moving Together [9] is an interactive digital art system that has connects communicating parts in different physical locations providing an aesthetic communication channel for creative participation. A version at CHI2016 connected Leicester, UK and two locations in California. Shared initiative (from multiple participants using mobile phones) and influence from multiple remote locations is accommodated in a distributed generative system.

A diversity of relevant ideas was addressed in the 2015 Machine Wilderness event (terminology borrowed from cultural geographer Ron Horvath) – essentially about the coexistence and interaction of the natural/biological environment and contemporary science and technology (Machine Wilderness Symposium, [13]).

Finally, let us contextualize with much earlier work encompassing open natural spaces – Richard Long, Hamish Fulton and Robert Smithson are major figures in Land Art, an art practice that documents, navigates and manipulates the physical environment, for example, through the creation of large-scale sculptural installations using materials found in the actual landscape. Long-term interaction between a critically chosen natural environment and man-made intervention, as spread across time and space, is dramatically exposed and documented in Spiral Jetty, Robert Smithson's seminal monumental land art. The appreciation of 'distance' comes into play: "The world seen from the air is abstract and illusive" [10]. From the notion of distance to surveillance and dislocation is only a small step.

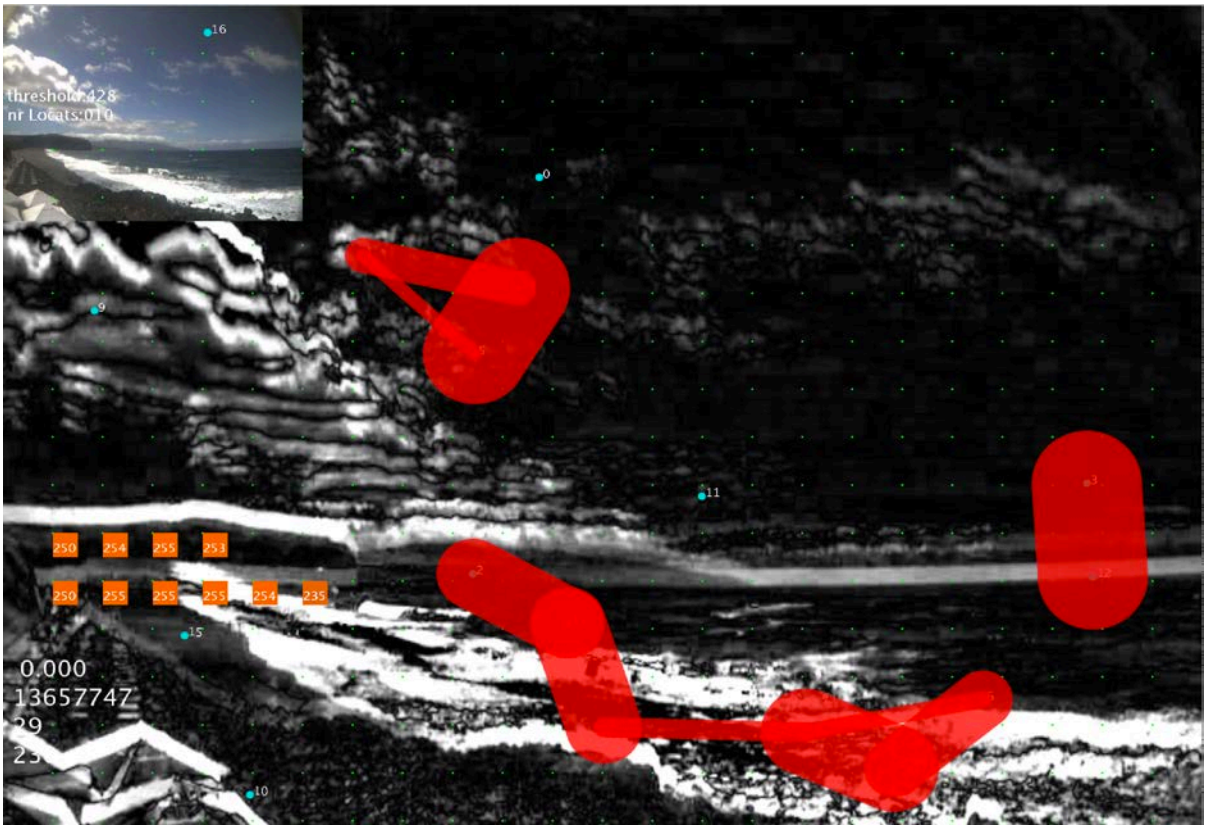

Image 6: *Gray-scale visualization of the brightness interval between two consecutively captured color frames, live image in the top-left corner, active locations in the sensor grid and associated particles.*

4. Implementation

Açores is implemented in a blend of processing [15] and SuperCollider [21], the processing part handles the online image-gathering process, runs the image analysis routines and communicates the results to SuperCollider via Open Sound Control. SuperCollider computes real-time sonification.

Consecutively captured images are analyzed (in terms of respective pixel brightness) as to infer the location and amount of image fluctuation over one time step. A grid of “virtual light sensors” detects pixels featuring a brightness interval (absolute value) higher than a particular parametric threshold – figure 6 shows a gray-scale image reflecting the brightness intervals between two consecutive frames. This list of locations is sorted according to brightness and a specific “gesture” results, it is visualized as a curved object. Gestures capture the dynamics of the image, or more precisely, they reflect the implied momentum of a given physical ecosystem where land and sea interact.

Capturing the dynamics of the image is an adaptive process; the threshold level scales up or down according to the number of pixels collected below the threshold, we target gestures sizes of 3 to 7 elements. This procedure of self-regulation produces wave-like behavior in the image analysis algorithm, more precisely, reflecting how complexity in the environment interferes with the dynamics of self-regulating sensing.

Conceived as a mixed reality system, natural artifacts are interfaced with synthetic artifacts; a variable collection of free-floating particles. Particles are subject to forces of attraction and repulsion, non-linear forces since the effect is much larger given close particles than far away ones. The Particle class in the present implementation extends functionality of the TRAER.PHYSICS [19] external library for processing (Traer Physics Library 3.0).

Particles coalesce into variable clusters, depending on a global *sensitivity* value. Managing sensitivity is also an adaptive process. At every process cycle, we compute the current

difference between the current frame and the previous frame. We then compare the current value to the previous value – in other word, we compare the amount of change (global brightness interval) with the current value of global change – again, this consideration is congruent with our principled intention of *focusing in change.*

$$\delta = || \frac{| \ c_t \ - \ c_{t+1} \ |}{c_t \ + \ c_{t+1}} ||$$

Equation 1.

The expression in equation 1, computes relative changes in consecutive sample intervals by taking the absolute difference divided by the sum and normalizing the result to a floating-point number between 0 and 1. Then sensitivity is scales up or down according to whether current level of change is higher than previous level of change. Therefore, information gathered from image analysis does not contribute directly to the global behaviour of the particle system; therefore, the natural environment might be considered a catalyser influencing though not controlling the artificial world of the particles – both systems actually merely coexist.

Any two particles temporarily link when their distance is below the threshold of the sensitivity value. At the moment this connection is first established, an OSC message is sent to SuperCollider where an FM-synthesis object is instantiated and sound signals the event. A process of real-time sonification thus explicitly reflects variable connectivity between particles and, in turn, echoes implicitly changes in the global physical environment. Parameters in the frequency modulation synth (carrier frequency, modulation frequency, modulation depth, modulation index) are conditioned by particle derived data: x-position, y-position and a vector documenting distance and angle to a given neighbor particle.

5. Conclusion

We might contemplate on nature as “a generative system beyond computing”. The Açores project explores and interfaces the emergent complexity of natural cyclic behavior with interaction particles. In turn, particles assemble into temporary clusters subject to sonification. How do we evaluate the hybrid system suggested here? Overall functionality in terms of aesthetic appeal issues from the fluctuating correlation between interlocking (1) macroscopic cycles (day/night) and (2) lower frequency cycles of shifting clouds and oscillating ocean waves. Since our appreciation of perceived dynamics follows a pattern of recognition and surprise, the on-looking spectator is equally engaged in a process of oscillatory behavior. Dynamics in the environment interface with dynamics in the particles system – a fascination develops because the system displays a blend of anticipated events in addition to unpredictable behavior. Then, in conclusion – art, like nature itself – could be referred to a “qualitative oscillator”.

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