

Biologically-Inspired Computing for the Arts: Scientific Data through Graphics

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Chapter 4

Oh!m1 gas:

A Biomimetic Stridulation Environment

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ABSTRACT

Ants represent a natural superorganism, an autopoietic machine, much like the human society. Nevertheless, the ant society stands out due to self-organization. Ants accomplish the generation of bottom-up structures communicating mainly by pheromones, but they also produce modulatory vibrations. This phenomenon represents a fascinating subject of research that needs to be amplified in order to identify the connections between these social organisms and humans; they share the same environment with humans and participate, thus, in the construction and mutation of posthuman ecology. The human-ant relationship plays an important role in the creation of new ecosystems and the transformations of old ones. Man can approach and embrace this relationship by means of artistic experiments that explore the bioacoustics involved in the social behavior of ants supported by the combination of cybernetics, autopoiesis, self-organization, and emergence.

INTRODUCTION

Media are a contraction of forces of the world into specific resonating milieus: internal milieus with their resonance, external milieus affording their rhythms as part of that resonance. An animal has to find a common tune with its environment, and a technology has to work through rhythmic relations with other force fields such as politics and eco-

nomics. In this context, sensations, percepts, and affects become the primary vectors through which entities are co-created at the same time as their environmental relations. (Parikka, 2010, p. 14)

Oh!m1 gas is an artistic research and audiovisual installation that approaches the self-organization in ants as a cybernetic system with emergent manifestations. Oh!m1 gas is based on a ‘do-it-yourself’ approach of bioacoustics, measuring the vibratory

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sounds and mapping the activity of an ant colony and their relation to the artificial ecosystem where they live. By means of contact microphones and video surveillance interfaced with the computer that feeds this bio-data to two turntables, the life of the ant colony emerges as a soundscape of scratching effects. The source of inspiration for this sound-reactive installation is based on the functional resemblance of the turntable, as an artifact for sound production in human culture, with the stridulatory organ of several highly evolved ants, specifically the *Attini* leafcutter ants, as an artifact for social organization.

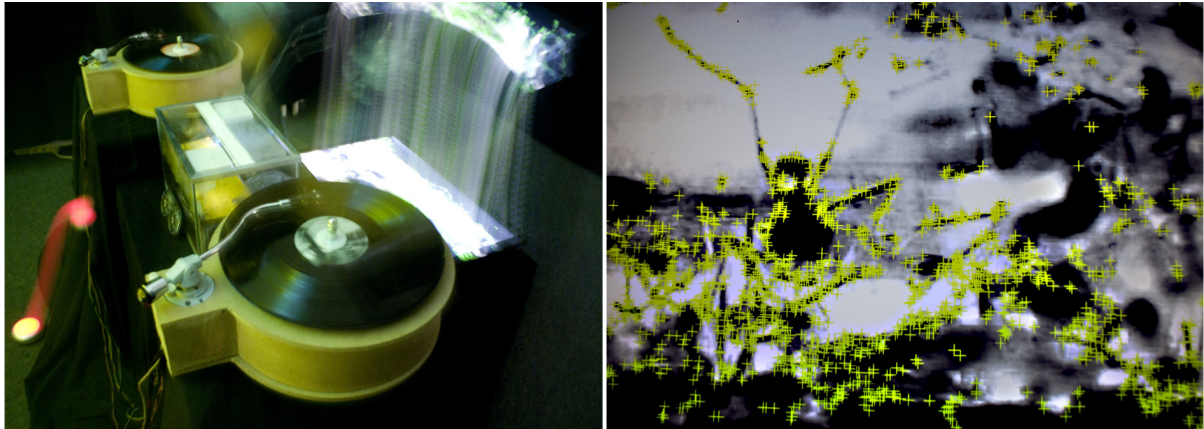
The aim of this artistic research is the exploration of the stridulation phenomena of ants as a modulation mechanism in their self-organization, which can be perceived artistically as well as scientifically like a network of parallel task allocations regulated by local interaction and feedback. My artistic approach is predominantly based on the studies of the first and second wave of cybernetics¹, from Wiener (1948) to Von Foerster (1961), the theory of autopoiesis from Maturana and Varela (1992), which I approached as self-organization in regard to my work, and reflections and abstractions about emergence and its relation to sound creation and propagation in general. Stridulation, is the main bioacoustic focus of my work. In ants, stridulation can be simply put as a stimulus, energy as vibration, which incites decision-making in nestmates. It is a vibratory signal that travels through the soil and the organic material that construct the nest and its surroundings, to stimulate a response. Stridulation is part of the ant's communication repertoire, and along with pheromones and an array of tactile gestures, embodies a social behavior that the human observer and listener can relate to.

The social behavior of ants can be exposed as a complex social soundscape by means of this cybernetic installation based on the observation and audiovisual documentation of their colonial development. This experimental approach has opened new paths for me in understanding the

stridulation phenomena and self-organization in the ant society, and has served as a great inspiration for my artistic practice. The impact of ants in the ecosystems, that we think we have taken for ourselves, can be perceived as a communal agency of chemicals and sounds constantly shifting and rearranging the territories occupied by humans. Moreover, to a great extent the relevance of studying ant stridulation and its social implications relates to territoriality. Territoriality in my work is approached as a concrete autonomous system in space defined by the processes of the unity that constitutes it. This is what Maturana and Varela (1992) called autopoietic system. The territories the ants invade can be defined by the communicational nodes and the invisible markings produced by the propagation of pheromones and sounds in their social network. Therefore, and strictly related to the matter of sound production in ants, such ecosystems can be visualized and can be sensed by analyzing those acoustic and vibratory signals that allow these communitarian beings to regulate their communication and survive in human environments.

It is of great importance to mention that my research focuses on two main aspects: the computable analysis of the sounds ants produce when they organize their labor, and the social significance and scope of stridulation with their potential biomimetic application towards a post-human ecology. Furthermore, relations with the human experience as the producer and interpreter of sounds are emphasized taking into account all the cultural implications involved in this investigation. Important to clarify is that in regard to my theoretical framework I decided not to discuss the fundamental inhumanity that technology and media could have. Despite the fact that I feel such discussion can be complementary, and indeed it would need to be integrated in future discourses, I instead decided to concentrate the experience of my research on the relations to human culture. Finally, the key of this research lies in revealing the connection between scratching, as an aesthetic

Figure 1. Left: a photograph of the prototype installation exhibited in Lab 3 at the Academy of Media Arts in Cologne, Germany. Right: a screenshot of the motion tracking program analyzing the movements of leafcutter ants. The crosses depict the pixels that are being tracked. I customized the program in Max/Msp/Jitter. (© 2008, Kuai Shen Auson. Used with permission.).



expression created by human culture, and the stridulation phenomena produced by ants as a modulation mechanism for communication.

BACKGROUND

One of the first pioneer works of the nineteenth century, which showed the fascinating world of insects is the seminal masterpiece *An introduction to entomology; or elements of the natural history of insects* by Kirby and Spence (1843, 2005). Then, at the beginning of the twentieth century media theoreticians, cultural philosophers, biologists and artists started engaging in the debate of the perception of technology and their relation to natural systems, i.e., comparing, contrasting and intertwining the biologic with the artificial. From Ernst Haeckel's *Kunstformen der Natur* (1904, 1998) to Jakob von Uexküll's *Streifzüge durch die Umwelten von Tieren und Menschen: Ein Bilderbuch unsichtbarer Welten* (1934, 2010) and to exemplary media discourses from the beginning of this new century, such as Jussi Parikka's *Insect Media: an archeology of animals and technology* (2010), artistic practices and scientific researches

have been sharing ideologies and using common tools to perceive, describe, and document the life of those societies of the minuscule living organisms that resemble our social structures. Since then, inspiration by the mechanical, operational, yet sensual world of insect societies have sparked scientists to open to the artistic spheres. Both disciplines intersect knowledge on common ground, signaling the way to a new era of research that is done not only in the lab but in your garden and in your living room. Strongly supported by the technological capacity of our modern media society and the market's predisposition to make advanced instruments accessible and acquirable for any individual, human beings are now more than ever in the privileged position to undergo experiments in their self-created laboratory environments. I am happy to say that my research is one of these examples.

Inspiration by nature has stimulated humans to be creative since the beginning of civilization. In relation to pioneer experiments in the field of bioacoustics, the Slovenian scientist Ivan Regen was the first to study in 1913 the acoustic propagation of the song of male crickets and their influence on female crickets, using a microphone

to transmit the signals and a telephone earpiece to receive them (Huber, Moore & Loher, 1989). First the industrial revolution introduced global changes, and then the digital revolution extended and connected the cultural and visual artifacts we have massively produced and distributed, so that science and arts were not isolated endeavors anymore. On one hand, this stimulated an artistic approach for scientists and on the other hand, a scientific approach for artists. Biologists working in the field could take pictures and record sounds, reflecting on the aesthetic aspects of the documentation of living beings and natural processes. The technological apparatus was now accessible for both scientists and artists to engage in an abstract interaction with their study subjects. To this respect, the best visual examples worth mentioning that have influenced my own explorations would be the documentary *Microcosmos* by Nuridsany and Pérennou (1996), and the photographic documentation of Wild (2008), as well as the related stories and scientific curiosities about ants and other insects he has published online since 2007 on a regular basis at www.myrmecos.net (2011).

Impelled by the scientific discoveries and the possibility to view the microscopic world from a subjective perspective, the human race began to create a diversity of artistic applications, designed ideas and artifacts that derived from a wide range of mapping the natural with the artificial: from swarm intelligence, cellular automata, the culturing of bacteria, the interaction of neurons to the critical mass effect in social networks, everything seemed to be biologically inspired. To this end, the so called ‘collective intelligence’ of ants has not only been compared to the neurological functionality of the human brain, but it has nowadays established itself as a subject of interest and study for any human endeavor trying to simulate the organization of living organisms in order to replicate its behavior in artificial machines. The debated idea of the superorganism was originally observed only in nature, but nowadays it extends to the artificial realm of posthuman production,

i.e., the networking of cities, brains and bodies with natural environments. For instance, Johnston (2008) discusses several artificial intelligence approaches in his book, such as those of Douglas Hofstadter and Herbert Simon that propose the ant colony as a model of cognition and as a collective information processing system, which can be related to the cognitive processes of the human brain. Furthermore, Johnson (2002) talks about Manchester emerging as the Mecca of the industrialization era in Great Britain mainly because of self-organization and the local interaction of its early inhabitants; the laborers clustered together in their own neighborhoods apart from the riches without a centralized urban planning program forcing them to do so. Academic reflections like these on the relations of ants with manifestations of the superorganism as a multi agent based model mark a celebrated breakthrough in the era of posthuman media culture. Moreover, recognizing the potential relationships of the living with the artificial inspires immense artistic applications profiling political and social purposes, which are not yet fully explored.

During the nineties, projects involving digital media were demonstrating the potential of artificial intelligence and genetic algorithms, thanks to the adaptations and translations achieved by computing programming languages. The highest representatives of these optimizations are the ant colony algorithms. Rendering audiovisual media became a replicating process performed by the computer rather than an analog sequential process of human decision making and design thinking. We suddenly realized the potential of the computer in extending the complexity of nature. The simulation of natural systems was computerized and was mirroring the complex ecosystems surrounding human technology. A need to bring the artificial simulations of the natural out from the lab to interact with the outside world was a consequent and playful thing to do; there was an impetus to observe and test the interaction of the artificial with the biological. A new understanding started

to arise. The more artists and scientists engaged in biologically inspired computing experiments, the clearer the parallels were becoming between the biological milieu of insects and the technological achievements of human culture. Fascinating to point out is that we began mimicking natural functions and repurposing the technical achievements of insects in our techno-social experiences a long time ago already: radio telephony, the morphing architecture of the internet, peer-to-peer networking, the colonization of the stratosphere with satellites (which took advantage of progressive rendering and package distribution of images), transfer protocols and data bit rates, all of these encompass problem solving algorithms inspired by insect behaviors. Artists at the dawn of the twenty-first century reflected on the role of the postmodern times and digital media, and started expressing other levels of intensities and experiences that highlighted the organizational achievements and perceptions of insects. Artists like Andy Gracie (Small Work for Robot and Insects, Autoinducer_Ph-1), Garnet Hertz (Cockroach Controlled Mobile Robot), Nigel Helyer (Host), David Bowen (Fly Drawing Device, Fly Blimps), Timo Kahlen (Media Dirt, Swarm) and Theo Jansen (Strandbeest and all his kinetic creations) combined the biomimetics of sound, space, and environment interactions with insect perceptions to create fantastic techno-biological experiences. They made clear that such biologically inspired artistic research is not only possible, but also an intriguing and enlightening enterprise.

There are many sides to the story of being captivated with insect behavior. To be fascinated with ants is probably a matter of feeling akin to that arduous and never ending altruistic labor for the good of the community. My story started around the turn of the new century, 1999, when I sighted for the first time an army ant colony swarming the Amazon rain forests of my home country, Ecuador. Since then I have been researching their behavior for personal interest, specializing on biomimetic stridulation environments based on the stridula-

tion phenomena of ants. I have been concentrating my work on tropical ants and with the aid of audiovisual computing technologies I embarked on a journey to discover the social interactions that characterize an ant system producing a self-organized network. Throughout this time I have been breeding several ants' species in artificial and simulated environments, from leafcutter ants to weaver ants, using my own "do-it-yourself-technology" in sort of a "trial-and-error" fashion. The learning curve has been difficult, as dealing with living beings that do not speak your language can be frustrating. On the one hand, ants cultivated in your own humanly designed private dwelling can become a pest for your neighbors and you can lose control over their territory. On the other hand, keeping tropical ants alive simulating their original environment implies dedication, time and commitment. Out of 6 colonies I had, only 2 of them still live. I failed either in keeping the right temperature, providing the right food, or in keeping their artificial nest sealed enclosed. Nevertheless, the lessons learned from the mistakes I committed have left me with a great deal of knowledge. It has indeed become an obsession that has taken me on fascinating field trips (mentally and physically) to discover the relationships and differences between the myrmecologic microcosmos and the human perception of the world.

STRIDULATION AMPLIFIED

A Cybernetic Instrumentation of Collectivity: The Noise of Self-Organization

Any object, material or organ that produces sounds can potentially become a musical instrument. It depends on its intention, design, adaptation and function. We do not need to define music in order to know what it means. For this purpose we just need to know that music is part of our culture and that music is a form of social communication. Ants can

also potentially create music with their stridulatory organ. Ants use stridulation to modulate their main forms of communication (Hölldobler & Wilson, 1990). Every ant species produces distinctive frequencies at different intervals, and even every individual in a colony develops a distinctive stridulatory organ with a unique stridulation pattern. Research by Ferreira, Poteaux, Hubert, Delabie, Fresneau and Rybak (2010) revealed evidence that there is morphological distinctions for every organ of the *Pachychondyla* workers they studied and there is also a degree of specialization in the stridulatory signals they produced. Hölldobler & Wilson (1990) state that so far stridulation has been identified in numerous species pertaining to the following five subfamilies of ants: Myrmicinae, Pseudomyrmecinae, Ponerinae, Ectatomminae, Nothomyrmecinae (as cited in Markl, 1973). Furthermore, the stridulation behaviors that have been mostly studied belong to the following genera of ants: *Atta*, *Acromyrmex*, *Pachychondyla*, *Pogonomyrmex*, *Messor*, *Tetraponera*, *Aphaenogaster*, *Leptogenys*, *Ectatomma* and *Solenopsis*

(Hölldobler & Wilson, 1990; Keller, 2009). The stridulatory organ occurs at the point of articulation between the third and fourth segments of the ant's abdomen: the scraper or plectrum lies underneath the posterior region of the third abdominal section, while the *pars stridens* or ridged file surface is located on the anterior part of the fourth section (Keller, 2009). Stridulation in ants, as a form of social communication, is an amplification process that can be approached as a feedback system, based on cybernetics, that allows the local transmission of vibratory signals from one colony member to another. It is actually a mechanism modulating the transmission of pheromonal messages within the colony's communication network, in order to reinforce tasks or recruit workers depending on the perturbations of the environment.

Communication by pheromone emissions is the primary form of communication in ants. It is a semiochemical form that from time to time needs to be reinforced by another gesture. The secondary, gestural form of communication in ants is tactile communication, which is usually performed

Figure 2. Left: a supersoldier and a minor of the leafcutter ant, Atta Cephalotes. This picture shows the polymorphism in this species. Right: the location of the stridulatory organ of a major of the same species, which was trying to cut my finger. Photographs were taken in the Yasuni rainforest in Ecuador. (© 2011, Kuai Shen Auson. Used with permission.). The inset of the stridulatory organ was hand-drawn, then vectorized. Adapted from "The Ants", Hölldobler B., & Wilson E.O., 1990, Cambridge: The Belknap Press of Harvard University, p. 256. (Copyright 1990 by Bert Hölldobler and Edward O. Wilson. Used with permission.).



in close encounters. Thus, stridulation manifests separately from these two communication forms only when they cannot function properly, like when nestmates are trapped in such a way that the only possible transmission of information is to stridulate for help (Hölldobler & Wilson, 1990). What this points out is that the vibratory signals complement other social expressions, yet stridulation can also appear as a singular gesture if the case requires so; stridulations are complementary and also instinctive, when it is necessary to reinforce a message, or when there is a state of emergency to convey. Take for instance humans, where gestures or caresses accompanied by tender words when we are in love, or screaming and punching when we are attacked or hurt by strangers become examples of modal communication that reinforce the intensities of specific expressions. These expressions derived from either love or stress, evoke social bonding, mainly recognition or rejection, which are not only manifested by humans and other animals with keen aptitude for social bonding, but are also present in the behavior of the individual organisms that make up the ant colony. Ants can express themselves individually and by doing so they amplify a message to the colony.

The ant colony is a cybernetic organization, where each individual is in permanent contact with each other and exchanges information based on proximity and local interaction. Therefore, an ant colony generally responds to stress and perturbations by summing up individual reactions collectively, the colony amplifies its actual parallel operations so that redundancy in actual task performance arises. Redundancy in parallel operations means too many ant workers end up doing the same job after a recruit call or alarming signal was initiated (Hölldobler & Wilson, 1990). In relation to the use of stridulation, this is what happens: when foragers and guards outside the nest perceive something unusual, the pattern of reaction consists of rocking the abdomen up and down so that the scraper, resembling a sharp object

similar in function to the needle of a turntable, rubs against a ridged surface of parallel ribs, producing a chirping sound. This action produces sonic vibrations at different intervals, which every individual decides to perform depending on many factors. It is a complex relationship between the perception of an ant of its surroundings and the changes unfolding in it. This individual manifestation is different for every species, worker and colony, depending on the ecosystem where they live.

When ants decide to stridulate, the sonic effect is a sound wave that expands because it activates a chain reaction amplified by all the members of the colony. All the levels of labor division in the colony get alerted. As a consequence, the speed and effectiveness of workers finding the right job to do increase, thus protecting and defending the queen becomes a priority. The allocation of tasks for the rest of unassigned workers, undecided workers, or workers who were recently recruited to the scene, is then achieved via self-organization. Every single ant perceives and decides on its own which task to choose as the system transits from a warm alerted state to a cool stable one. This auto-regulation can only function if there is an initial signal that amplifies an alert, resulting in a chaotic chain of disordered events that have to settle down and find homeostasis. Redundancy, thus, can be explained by cybernetics. The following observation is based on the analysis of Wiener (1948) to explain heat regulation in a thermostat, and other fluid fluctuations: when there are too many workers performing the same task, which is the case at the beginning of an active alert, then the excess of ants doing one job tends to cancel out over time by moving on to the next available unattended task, so that at the end balance is restored. Consequently, at the beginning of the alert a positive feedback was in progress: the signal was amplified, it was getting stronger until a peak was reached. At this stage, a negative feedback loop regulates the system, lowers the alert, and brings it back to its original state. The key advantage of ants over a compared human

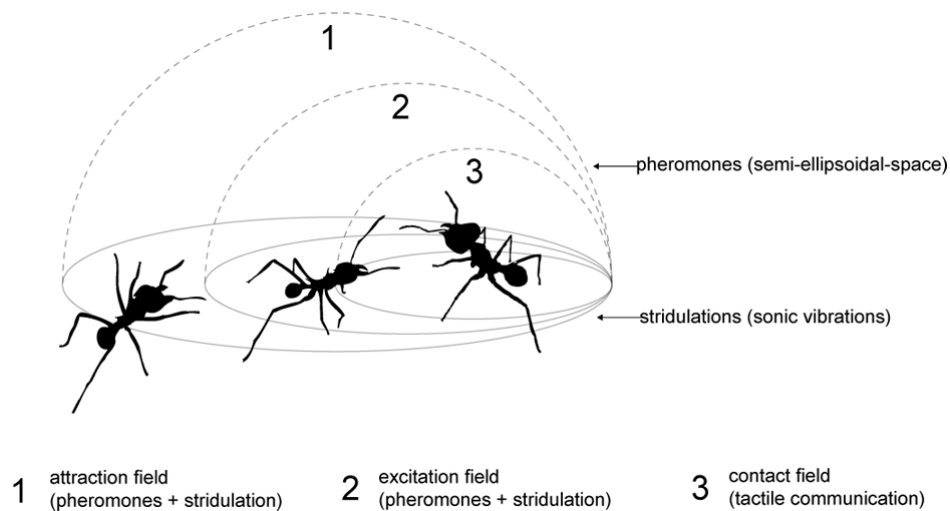
equivalent in such redundant problem-solving situations is the quantity of agents involved in an action plus the limitation of decision making determined by their basic brain power. Ants are numerous to the millions but they are simple agents with limited brain power, and their empathy and altruism is unique.

Amplifications have to be de-amplified over time, as is the consequence in any communication system of hyperactive, hot and resonating living beings. The decibels of a high pitched signal cannot be too loud for long periods of time, for we would become deaf. There has to be a regulatory process to turn the volume down. The regulation in the ant system exists because there is a response for every action. They are organisms of a greater social organization. Ants could arguably be seen as trivial machines, but be aware that they do adapt and shape to the conditions of the environment, suggesting there is a level of perception, affects, memory and behavioral actions which challenge the human understanding of the ants' social interaction. That is why it is important to study stridulations in ants to see how far these influence their social behavior, how far these could inspire the design of artifacts that help establish

interspecific communication channels, and help in the experimentation of stridulation models for human social interaction. At the beginning it may seem ants are chaotic in their decisions, saturated and overcrowded, but after a while the system achieves knowledge of itself and manages to balance and self-organize. To this extent, according to Hölldobler & Wilson (1990) ants know how to regulate the colony's task allocation by balancing performance and energy invested, in order to do what is best for all. Nevertheless, this greater organization cannot achieve homeostasis, without the amplification of messages originating from initial chaos and disorder. Amplification is a linear process that can become noisy, and in relation to societies and technology, it needs to be modulated so that clear communication channels can be established.

Normally, these positive and negative feedback loops present in the cybernetic ant system, are achieved by means of modal communication: the combination of semiochemical communication (pheromones), tactile rituals and stridulation. Together they reinforce signals that are context specific. This means that communication in ants is multicomponent, almost always occurring as

Figure 3. Graphic representation of the multicomponent communication in ants, imagined as invisible atmospheric fields created by the combination of pheromones and stridulations. (© 2011, Kuai Shen Auson. Used with permission.).



a combination of the three forms (Hölldobler & Wilson, 1990). This suggests each form appears in the communication act to clarify any of the other forms already present in the exchange of information. Thus, the message is recognized from other situations, because it is rich in chemical, tactile and sonic information describing a specific context. Because the system of communication in ants is still lacking advanced research and field experimentation, it is so important for independent researchers, artists and scientists to undergo experiments with audiovisual media and ants. This can definitely open up new paths for collaboration. We need to pursue a network of knowledge that resonates our cultural perception of the techniques involved in the social communication of ants.

For artists involved in scientific research, this picture of ant's communication system becomes a wonderful open network of possibilities. Ants' network of possibilities should be viewed as networks of relations, a milieu enhanced by pheromones and stridulations. Ants create networks in the complex natural milieu they inhabit connected by a multiplicity of relations. This has served as inspiration for the creation of the ant colony algorithms, which optimize urban transportation systems and provide solutions to the traveling salesman problem. Technology and communication as a medium is in itself a milieu, it can be represented as a computable ecosystem. An ecosystem amplifies its presence in order to differentiate itself from other ecosystems: amplification as delimitation. Deleuze and Guattari (2004) observe the expansion of the rhizome and its roots as an artistic model for reflection because it is a remarkable example of natural unity characterized by connection, heterogeneity, multiplicity, and rupture. Humans take advantage of audiovisual media to deterritorialize themselves, whereas ants do it to define their territories. We are connected by invisible threads in front of the computer without ever leaving home or our workstations. Yet we amplify our messages via online social networking. We resonate. Ants construct

micro-empires, like ancient civilizations did, by succeeding in the operation system and organization of message-carriers: the worker ant transports organic material, which is indeed a container of messages, back to the nest; another worker cuts the leaf and stridulates a recruitment signal, which is transmitted from the closest ant in the foraging area to the closest ant back in the nest. Social behaviors resonate in nature, as well as in the digital worlds constructed by man.

About Resonance: Natural Vibrations versus Acoustic Perceptions Influenced by the Cultural Environment

*In his pioneering research on vibrational communication, the German physiologist Hubert Markl discovered that the substrate-borne stridulatory signals of *Atta* workers can release specific behavioral responses in the recipient nestmates, but the semantic content — that is, the message signaled by the sender and the meaning of the signal for the receiver — varies according to its situational context. (Hölldobler & Wilson, 2009, p. 233)*

Visualizing the sound wave spectrum of stridulations is a challenge. For me, an artist working with media, that task becomes less complicated, for media artists in general have a tendency to play and experiment with audio recording devices. As an example, one could record with a directional microphone the area where the ants are stridulating and in post-production (pray to your dearest deity!) filter all the background sounds out with special software. This task is supremely frustrating, if you want to record ants in the field. In most of the cases you end up with a shouting choir of rainforest creatures. It is unavoidable; the rainforest is not a silent ecology. Though interesting for artistic applications involving pre and post-production skills, these results are rendered useless when the goal is to capture the sounds of ants dwelling on the ground. For the

purposes of my studies I have found the laboratory environment most beneficial. Usually in a scientific lab one has at his disposal a selection of apparatuses that suit the accurate purpose of measuring vibrations, the best example is the laser Doppler vibrometer. Other secondary gadgets are accelerometers and contact microphones, better known as piezoelectric sensors. These are my favorite choice. Piezoelectric sensors and films are small and light, thus relatively inconspicuous for the colony. They can be amplified and can be applied directly to the surface where the vibration is occurring. Additionally, piezoelectricity is a mechanism that can absorb as well as produce vibrations, providing the right conditions to act as a conversational artifact for the ants.

Where reception of sounds is concerned we want to have a substantial clear recording of the acoustic communication of ants. The attention to undesired sonic effects in the surroundings and its restless overall resonance is of great matter. Like I mentioned before, no ecology is silent. Recording ant sounds in the rainforest, even equipped with the right piezo sensors, is very difficult, for the whole rainforest is made out of organic resonating materials, materials that vibrate and insects that vibrate, too. Therefore, the best environment to record stridulating ants is inside an acoustically

isolated chamber, or sound studio for that matter. My experience is based on piezo sensor recordings of leafcutter ant colonies of the species *Atta sexdens* and *Atta cephalotes*, which were bred and kept in controlled conditions. Using either one or a combination of all the following sound-proofing materials I tried to dampen the energy of the vibrations: rubber or cork mats, different kinds of polystyrene, and accustomed granular layers of plaster. Interestingly a couple of times I presented the installation with a factor of unpredictability. When the recording surface where your ants stridulate (piezo sensors located in the nest without isolation) is mixed with the sounds produced by the audience, the combination of overlaying sounds initiates a reverberating sonic experience, very similar to the ants themselves, evoking an emergent resonant environment. These experiments in recording can be defined as stridulation environments, because they mimic the use of sound waves in the social communication of ants and are unpredictable in nature.

Studies regarding stridulation research in ants point out that the primary function of the stridulatory organ is the production of information in the form of vibrations, that is energy, and that ants do not possess a specialized hearing organ, rather they perceive those vibrations with their

Figure 4. Photographs of the installation as part of the 6th edition of the Piemonte Share Festival “Smart Mistakes” in Turin, Italy. (© 2010, Kuai Shen Auson. Used with permission.).



legs (Hölldobler & Wilson, 2009; Ferreira, Poteaux, Hubert, Delabie, Fresneau & Rybak, 2010). Therefore, what ants perceive are vibrations in the form of energy transmitted across the ground. This leads me to believe that the ant body is a resonating body, which is enhanced by the stridulatory organ as an artifact for encoding and decoding energy. The whole exoskeleton of the ant becomes an apparatus for resonance, transmitting energy from one ant to the other, thus being able to produce oscillations with larger amplitudes. From a mechanical point of view, the ant becomes a vibrating agent that produces sound waves that expand and carry information. Additionally, stridulation makes the ant's body resonate acting as a pneumatic mechanism, specifically when it comes to efficiently cutting rough vegetation or excavating hardened terrains (Hölldobler & Wilson, 2009). It is energy that informs and sets materials in motion. The vibrations produced by the stridulatory organ travel along the body making the ant's mandibles vibrate like the cutting blades of a razor machine. At this point one could see a parallel to human invention and the functionality of many tools we have created for different purposes. With respect to artists, this magnificent portrait of ants as social resonating agents for the creation of resonating spaces and biomimetic environments may be of great inspiration.

Ants have six legs, and at the end of their legs they have a tarsus with claws that functions as a foot that can grip to almost any surface. The tarsus is covered with microscopic sensitive hairs that enable ants to sense the material they touch. As a result, this suggests that ants perceive other levels of intensities regarding vibrations transmitted through resonating materials and bodies. How exactly they interpret these vibrations is context-related and deals with every ant's individual perception acting as a member of the colonial organism, and how it reacts to the perturbations in the environment. Wheeler (1912) was the first to see the ant colony as a superorganism that

maintains its identity in space, acting and emerging as a whole like a cell or an individual. Moreover, throughout his investigations he was one of the first to recognize the different sensibilities of ant individuals working for the colony. The main distinction to be made here is that ants primarily perceive vibratory sounds, whereas humans primarily perceive airborne sounds. Let's take music for instance. We humans subjectively embrace and appreciate musical compositions, each of us with his or her own hearing capabilities and imagination. Our acoustic perception is strongly shaped by personal experiences and an acquired level of music knowledge. The sounds transform into feelings and recall memories. Augoyard and Torgue (2005) using sociological and psychological analysis refer to this sonic effect as anamnesis. A musical composition carries along memories for the listener, our brains start to connect and reconstruct past experiences so that a temporary meaning emerges in relation to a specific moment in life associated to a musical experience. To this extent, sounds converge in our brain in relation to the knowledge of music that the listener possesses. Nevertheless, how humans give meaning to what we hear, is and still will be a debate. It is not a process we can objectively define, for each human in the world interprets music and sounds in a different way. The human sense of hearing can be educated and it develops according to context, that is, cultural environment. Even among classical musicians with gifted auditive senses, music emerges as past memories, movements, flavors or feelings, to virtualize a re-centered fictional universe and give substance to a composition of sounds, always shifting, always changing depending on experience.

For ants the situation is not much different, at least concerning the development of an organism/organ shaped by the territorial limitations and conditions of a determined ecosystem. In the case of the highly evolved ants, specifically the leafcutter ants whose workers are polymorphic, the stridulatory organ develops naturally according to caste

specialization and the pressures of the environment in which the colony lives (e.g., minors or minor ants will develop a smaller stridulatory organ in contrast to majors and soldiers who develop bigger organs). The signaling pattern of stridulation varies according to ant's size, caste and species but also according to the structure of the organ, for not every organism in the colony is born with the same physical features (Hölldobler & Wilson, 2009; Ferreira, Poteaux, Hubert, Delabie, Fresneau & Rybak, 2010). Specialized soldier castes in *Atta* have the biggest organs because they are strongly developed defense units. The stridulating frequencies of *Atta cephalotes* specimens oscillate from 2-5 kHz, documented for minors (about 4 mm of body length), to a maximum energy of 38-46 kHz, documented for supersoldiers (about 18 mm of body length). These results are based on indoors' recordings isolating the ants inside custom-made polystyrene casings, and were done in the scientific station of the national park Yasuni, as well as in my atelier, using directional microphones and amplified piezo sensors respectively.

Bergson (1998) reflected on the limitations of humans' cognitive capabilities: the generalization, a tendency to find likeness and similarity in forms of organic and inorganic matter, that which generates and that which is being generated are views of the mind attempting to imitate the operation of nature. Hence, we may be able to recognize, depending on your personal perspective, more than just a few generalized behaviors that seem to be the same in humans as well as in ants regarding the perception of sound arising from the interactions of masses. Human social environments, where activity is high like in a street market, are influenced by the complex interaction of sounds; the closer the radius of interaction is, the more effective the organization develops and the clearer the message becomes. Of course there are many signals in a street market that distract you and influence the intensity of interaction and the desire to interact. The vivid sounds of a street vendor attract and disperse crowds, lure into

personal contact. It becomes a struggle of forces: the perception versus the interest, a negotiation of forces. Hence, your behavior is conditioned by the events unfolding in the market environment and by your determination to find what you desire. The intensity of interaction within this scheme of organization can raise the potential for conflict. We speak, we negotiate in tongues; sound waves carrying messages to convince. It is a fascinating orchestration of sounds, resonating energy catalyzed by individuals interacting with the environment. There has to be a regulation of this conflict, a transformation into settlement. When some play of words and rhetoric resonate better than others, that is when decision making becomes easier and conflict transforms into settlement.

Now take for instance the colonies of leafcutter ants in the rainforests, which can be attacked by other ants, mostly army ants, which prey on their larvae. This is a territorial conflict, a conflict for survival characterized by units of defense and attack resonating their bodies and fighting. Both colonies want the same thing, to breed, expand and reproduce. But they want it only for their own species. Conflict is an everyday issue for ants and reaching settlements with aggressors is not part of their nature. Rather the outcome of the conflict between army ants and leafcutter ants is that either one has to be defeated. It is not always about extermination, but about recognizing who lost territory and is stronger than the other. It is a measure of forces that not always end up in a massacre. To respond to the imminent presence of predators, these colonies of leafcutter ants produce more soldiers, as a defense mechanism, than controlled colonies bred and studied in laboratory conditions, which normally do not suffer a constant menace. Thus, environment interaction plays a key role in the construction of an ant colony.

If we go back to my reference of Bergson, we can see that the sound waves of a convincing speech in the case of the street market vendor can relate to the waves of army ants attacking the leafcutter colony in the rainforest. Both resonate

in the receiver, break the unity of organization, condition its behavior and influence the action to be taken. The environment affects the media of the colony: the army of resonating agents act like sensors reading external perturbations and informing about dangers and casualties, workers start to defend or attack, guard the nest, rebuild the breached architecture. Reaching a settlement in a conflict, as in the case of the street market, mirrors the operation of leafcutter ants reacting to the attack of predators in order to achieve homeostasis.

We all have a general understanding, sometimes vague and abstract, of how sound affects our psyche. Frequently what you hear is what you want to hear and not necessarily what you must hear. As social beings we rely on social learning and this predominantly depends on our cultural background and education. This influences our perception of sounds, because depending on where we are from, our cultural education let us understand certain sound compositions better than others. This is by no means a rule, rather it is a convenience that highlights the importance of the environment interacting with the organs/organisms involved in a conversation. Stridulation is context specific for ants and it is an organic intervention, a rhizomatic dispute, a semantic challenge. The individual notes, which manifest a musical composition, played by any human-made instrument, constitute a combination of patterns, in which each individual chord has a harmonic quality with the interpretation potentially linked to the listener's cultural experience (Augoyard & Torgue, 2005). Furthermore, the contextual sphere in which everything takes place, plays a major role in the process of auditory perception, regardless if we are listening to our own conversations, soundscape creations or listening to ants stridulating. Consequently, the actual interpretation of the resonating events relies on the listener, who then becomes the receiver and author of decoding the acoustic message while interacting with the cultural context. Von Foerster (1961)

repeatedly proclaimed that the listener, not the speaker, determines the meaning of a proposition. When social beings establish an interconnected channel, a conversational milieu, both the listener and the speaker, while interacting with each other instantiate an environment of conditions. A cybernetic ecology arises, where the two become one symbiotic organism, which once conformed tries to negotiate the meaning of its natural existence in a yet-to-be-defined ephemeral string of time and space.

We create our own world out of the input we absorb from the cybernetic chain of events latent in the surrounding environment. Social beings like ants are interested in this resonance of events. Individuals select and filter what they want to hear, or receive. If we compare ants to simple machines that are preprogrammed to compute and can identify only two different frequencies from the environment, as a binary computing resort, what we end up with are merely sensing machines with a specific objective. But if we add a set of social algorithms to these machines and an environment with conflicts, then we can play around with the idea of potentially creating organisms which have the capacity to organize themselves. The principle of the creative resultants postulates the product is not just the sum of the elements involved, but represents a new creation, something genuinely new, which could appear every time we do the same equation (Pask & Von Foerster, 1961). Even though ants can be compared to intelligent machines, and they are approached as such in behavioural models, they are in fact simple essential agents acting sometimes individually and erratically, like us humans, so that sometimes they create things that are not expected. They are constantly changing, resonating, reading the signs from the environment in search for invaders, prey or predators. Ants establish a nonverbal communication with their ecological milieu and the first signal to alert the colony of an unwanted presence is the most simple and instinctive one: to sound the alarm, stridulate. When you get scared,

you will instinctively shout, too. Social behaviors have a relationship with the environment. Social behaviors are influenced by the resonating events and the conflicts that emerge from the relationships of the social agents with the environment.

THE TURNTABLE AS A BIOACOUSTIC ARTIFACT FOR STRIDULATION

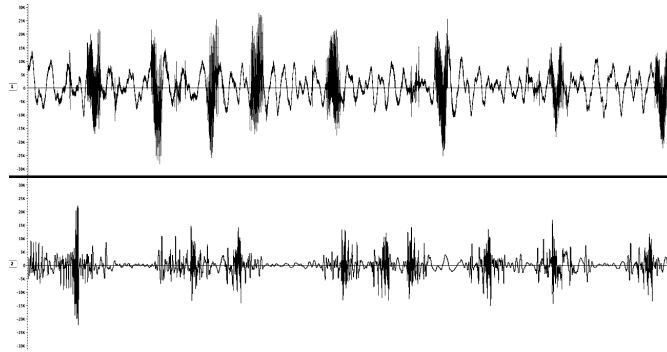
Scratching and Stridulations: Approximations, Differentiations and Materializations

Music can be considered nonverbal communication and the use, or even abuse, of amplified sounds definitely belongs to the diverse array of bioacoustic strategies we encounter in the world of living organisms. Even organic and artificial materials, which do not strictly fall in the category of animated-mobile-living beings, can influence and contribute to the propagation of sounds. I am referring here to leaves and twigs as organic materials, or plastic and concrete as artificial examples. In order to learn how to interact with the resonating material our world is constructed with, we are compelled to create a relationship with the environment. Ants take advantage of their resonating bodies made out of chitin, an organic polymer of a glucose derivative, to produce and receive vibrations, whereas humans have also created an equivalent medium to store vibrations, a material that in its construction resembles the *pars stridens* of the stridulatory organ. A music record or vinyl is made out of an organic compound known as polyvinyl chloride, and it is inscribed with grooves and canalizations that contain the phonography of a musical composition. Once played by a turntable, the needle interacts with the vinyl's fractal surface and transmits sound waves to an amplification system. In relation to the stridulatory organ, the mechanism of contact and material interaction are the same. It was then

revealed to me that these two materials, namely chitin and vinyl, could be related. After this realization, I delved into turntablism to compare the different scratching sounds with the stridulation frequencies produced by ants, focusing on the expressions rather than the musical content. Scratching is a form of expression that contributes to a sort of swarming in humans, for instance the gathering of crowds in a concert or in a DJ competition. Moreover, scratching reinforces the transmission of lyrical content inciting a reaction in the crowd.

Social beings share information by any means possible, whether it is for summoning soldiers as a preventive response to attacks, or for singing a traditional song to a child. The production of sound waves in ants is just one of many possible mechanisms for the transmission of messages and it has proven to be effective in circumstances where tactile, gestural or other kind of visual communication is not possible. Similarly, scratching is a technique that complements other lyrical expressions and it can also be mastered to manifest by its own means a diverse arrangement of sonic effects, moods and sensations, what is known as turntablism. Thus, through the experimentation with scratching, the turntable has become an artifact for the translation of energy and the transmediality of ideas. Rhythms and beats, clapping, shouting, singing, drumming, stridulating (in ants) and scratching (in humans) represent information that contains messages in need for interpretation, codified and transmitted through air, physical objects or organic material. Ants and humans encode communication and take advantage of tools and instruments to create and share vibratory/acoustical compositions. Additionally, airborne sounds are everywhere and can be misinterpreted, cancelled out, or just regarded as plain noise for living beings who are not interested in listening to certain sound manifestations. This is where the art of amplifying the sounds of ants, with the aid of an instrument of sound production, plays a relevant role in the realm of interspecific

Figure 5. Four seconds of stridulation (top): sample values of one major soldier of *Atta cephalotes* isolated in a polystyrene box; recorded at 44.1 kHz, 16-bits, using an amplified piezoelectric sensor connected to the computer. Four seconds of scratching (bottom): sample values of baby scratch technique on a 12 inches Hip-Hop vinyl played at 33.3 rpm; recorded at 48 kHz, 24-bits, using a turntable connected directly to the computer. (© 2011, Kuai Shen Auson. Used with permission.).



communication: the transformation of stridulation into airborne sounds that humans can listen to, reflect upon and enjoy.

The turntable, as a sound production artifact with its appropriate amplification, can transform the mood of a group of dancers; same is the case for stridulating ants, when resonating social agents incite the mobilization of the colony to a new territory. Colonies of *Atta cephalotes* produce fantastic concerts composed by a rich variation of high-pitched vibratory sounds, singing and stridulating together like a communal scratching machine (<http://kuaishen.tv/stridulations.mp3>). Ants, like the carpenter species *Camponotus* who do not possess a stridulatory organ, but engage in body rapping, rock their exoskeleton and mandibles against the walls of the nest to be able to produce sounds that can alert nestmates (Hölldobler & Wilson, 1990). A fundamental dialect between milieus and living beings has to be created in order for the actors to coevolve with the ecosystem and materialize a relationship.

Taking into account the respective similar functions for sound production in ants and humans, there is a hidden mechanism that relate these two forms. On the one hand, stridulating ants have to be sensed by their nestmates in order for the

system to work. On the other hand, the so called turntablism has to be listened to by the people in order for the scratching to be influential in the behavior of the dancers. To this extent, a system materializes if the elements, members, agents, cells, organs of a sensorial apparatus are able to interact with each other and most importantly if they can be interrelated and establish a conversation. Conversations affect and impulse the transitory states of social beings. To these means, a conversation is indeed bioacoustic communication, for it is a natural form for sharing information, both in humans as in ants. Pask (1969) introduced his conversation theory to approach architecture, specially referring to Gaudi's Parque Güell in Barcelona that succeeds establishing a dialogue with its visitor, as an example for informational ecologies and augmented environments, which allow the flow of space and time provoking in the actuating inhabitants a pleasure for exploration, cooperation and self-organization. Everything in this planet is interrelated and contains potential information that just needs to be amplified or accordingly translated in order for the message to be decoded and interpreted. Bioacoustic communication stems from the complex society we belong to; it is an emergent product of active

information exchange and feedback mechanisms within the network of living organisms, which can foster new experiences.

Stridulation is nothing more than vibration energy produced by two objects rubbing against each other. Scratching is the production of sounds using a turntable and moving a music record back and forth, so that the needle rubs against its surface. The energy produced from these simple physical mechanisms has a potential to develop into complex forms. Both stridulation and scratching possess emergent properties that can instantiate new stages of social interaction. The emergence of stridulation in ants is a mechanical gesture that can produce sounds similar to the following turntablism techniques: the baby scratch, the chirp scratch, and even the tear scratch. The materials used by both forms of communication are strikingly similar. Chitin is a natural polymer, a derivative of glucose, and it is the material from which the exoskeleton of ants are made, including the stridulatory organ. Vinyls are made of thermoplastic polymers and provide a surface which is easy to be carved in order to encode signals. The profile of the *pars stridens* approximates the grooves and canalizations of the vinyl. I started to experiment with these two materials and a soundscape driven by movements and stridulations emerged, a soundscape that only existed when the computer communicated with the biological system of the ants. By introducing technology, sensors and artifacts, like the computer and the turntable, I managed to explore a different realm of interspecific communication. Oh!m1gas is a sound reactive installation that depends on the activity of the ant colony, thus becoming an interdependent, interrelated, milieu of resonance with a finite life. The installation works only because the ants work, and according to the labour of the colony, the sounds produced are always different, always evolving.

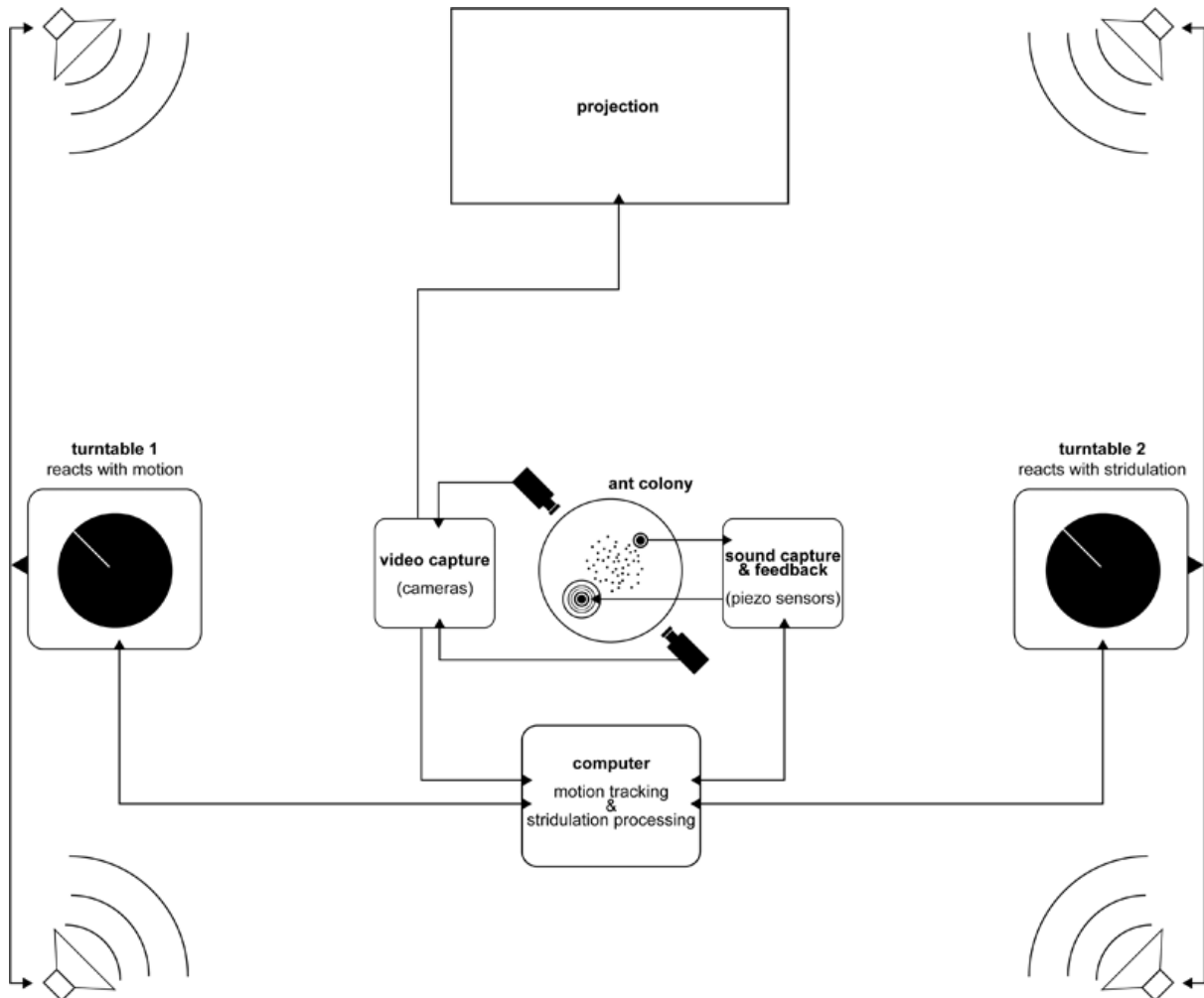
Oh!m1gas is a cybernetic installation that listens to the communication network of ants and is capable of showing visually and acoustically

how they self-organize by expressing emergent forms of music: a soundscape that explores the relation of our human-made technological media with insect media, understood as a natural milieu of social organization, cooperation and intensities of relationships. It can be experienced as a cybernetic ecology, where the ants' movements and stridulations are interfaced with a computer that archives the digital data from video cameras and piezo sensors and feeds these to the turntables. It is a cybernetic ecology, because the ants are part of this environment and the artificial presence of surveillance cameras and piezo sensors are adapted and appropriated as part of their territory. But in its essence, it is a biomimetic stridulation environment with the ants performing as scratching DJs, supported by a computer system running an adapted program based on computer vision algorithms that tracks movements and maps frequencies emerging from the ant colony when they sense the vibrations of the turntable². In this regard, the sounds produced by the turntables are amplified as an emergent process that allows tiny bits of information to become bigger bits of information, whose resonance is not predictable. Amplification is a natural action that allows the migration of information far beyond the constraints of a certain social group or species. Amplification strengthens the intensity of messages, increasing its loudness and reinforcing intonation, in order for the audience to perceive, interpret, and participate in the exchange of information. During the ages of our planet social beings have learned to amplify their messages to reach an ample audience, to have a resonance, either developing internal/external organs or using instruments. The best examples are the stridulatory organ in ants and the turntable in humans.

CONCLUSION

Their force is in mutual support and mutual confidence. And if the ant stands at the very top

Figure 6. Diagram of the setup for the installation: the lines show the connection of information and the arrows show the directions of transmission. (© 2011, Kuai Shen Auson. Used with permission.)



of the whole class of insects for its intellectual capacities; if its courage is only equalled by the most courageous vertebrates; and if its brain — to use Darwin's words — "is one of the most marvelous atoms of matter in the world, perhaps more so than the brain of man," is it not due to the fact that mutual aid has entirely taken the place of mutual struggle in the communities of ants? (Kropotkin, 1987, p. 11)

Interspecific communication with other social beings is still an unknown territory, we need to explore it. We need to experience the perceptions

and sensorial apparatuses of complex societies that can inspire our technology, and that can be augmented by it. Ants have a relation with humans, but it started as a troubling, misled, relation since the beginning of the institutionalized studies of entomology. Sleigh (2001) describes briefly the difficulties of the imperialist colonization in Africa because of the conflict and threat posed by the insect world to white man during their invasion, embodied mainly by the numerous and everpresent emergence of ants in Congo and Uganda as the most resilient and strangest of all tropical insects opposing to Europe's domination. Our anxiety to alienate them is a result of their non-hierarchical

organization challenging our centralized world; a mistake of our illusory superiority. We have to stop addressing concepts of superiority or intelligence when we approach other living beings that are social, too. We should rather see what relations ants can have to the world of humans, and how intense these relations can be in terms of growth, development and transformation.

How can we produce a self-organizing milieu where the artificial and the biological can complement each other? Do we really need to use a self-organized machine or is self-organization a unique social phenomena of the natural kingdom and its organic living beings only? These two questions are explored in my piece, yet the answers are not definite. It is imperative to say that further research needs to be done. We cannot limit ourselves to believe that only several few species of ants possess the communicational instinct for stridulation. Likewise, we cannot just limit our technological capacity to the massive production of artifacts to indulge our human laziness; we have to find new uses for those commercial products that satisfy our needs and repurpose their functionality in order to interact with the ecosystem in novel ways. There are many channels to be explored and connections to be made. Most important, and following Kropotkin's philosophy, mutual aid should be the basis to create collaborative networks of research for non-hierarchical experimentation.

Humans can see potential uses for any natural model. We can approach, embrace and imagine biological principles and behaviors through experiments within the fields of bioacoustics and biomimetics and apply them to human design. To this extent, stridulation is perhaps one of the most underestimated communication mechanisms found in certain social insects with great potential, and it definitely needs to be revived, celebrated and amplified. The cybernetic application of bioacoustics and computing arts has helped me approach the natural phenomena of stridulation in ants to create a complex audiovisual experience that presents an emergent nonhuman social interaction as a resonant acoustic environment. The

artistic aim was the creation of a self-organized soundscape based on the integration of surveillance technology inside a colony of ants. In this regard, the project succeeded in capturing and digitizing the social gestures of ants and provided a metaphorical audiovisual representation of their self-organization. Nevertheless, as a scientific research it lacks an objective focus of study of the stridulation phenomena in the *Attini* species of leafcutter ants. Moreover, it also lacks a methodological scientific framework without being tempted by anthropological associations. Yet, the relations between scratching and stridulation were made clear. It is a hybrid approach, indeed. The artistic research took over the scientific rigor, which is inexistent in my work, and extrapolated the gathered scientific data into the human realm of interpretation.

Biologically inspired art can indeed extend into the social, cultural and political spheres of humanity. Therefore, humans must pursue the investigation of sonic environments that affect our conscience and social behavior. Oh!m1gas has the purpose to communicate the interrelation of sonic effects in the postmodern human-ant ecosystems based on the relatedness of scratching as a cultural expression in humans, and the phenomena of stridulation in ants as a modulatory mechanism in their self-organization. To this extent, I justify that my artistic intentions towards my research opened a new world of possibilities in the readings and the applications of biological driven data. But this artistic research still needs to prove itself valuable as a scientific discipline. Of course, on the one hand bioacoustic communication can impulse creativity and can potentially stimulate channels for interspecific communication between humans and ants. But on the other hand, more experimentation is encouraged based on this actual approach but with more attention to the objective analysis of the biological data.

How objective can we be in the analysis of biological data when our subjects demonstrate more than mere instincts? Drawing conclusions from the study of such a complex subject, can

become impartial when your research becomes a passion and obsession, as my case depicts, rather than an objective analysis. I sympathize with ants and this inspires me to dwell on the passionate expression of art, instead of focusing on the impartial documentation of behaviors. Maybe this is not an issue, if your practices are not restrained by science. For this reason, I succeeded in documenting and expressing my results artistically, but lacked the scientific rigor to exercise a universal methodology. My artistic research on the stridulation of ants deals essentially with subjectivity and perceptions. At the end the perception of sound becomes a slave of subjectivity when the human is the observer and controller of the experiments. Therefore, the relevant question is how to unbound oneself from the causality of this vicious circle of being inside your own thought (Bergson, 1998). The way I see it, science and arts can support each other marvelously and work together, but never become one ultimate single discipline. It is in their authentic environments that they succeed, and yet combining them creates an interdisciplinary experience that can yield fantastic insights into the meaning of life and the expressions of nature. It is sort of a sociological, anthropological, ethological condition, which I know many others must also deal with. The reckoning of being a living being who is open to sense the intensities and manifestations in its social environment and the relations between nature and culture is the lesson to be learned and the ultimate issue to be considered in future researches of this kind.

My work with ants is open, it has always been, therefore it cannot be closed. I just began this new relationship, therefore it cannot end. I hope that my research serves for future generations, who want to listen carefully to the environment to design new forms of sonic art without the restriction of approaching social beings, especially ants, as subjects of study, but as collaborators in the creation of new ecosystems.

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KEY TERMS AND DEFINITIONS

Attini: The singular denomination for the tribe comprising 13 genera of leafcutter ants, including the highly evolved *Atta* and *Acromyrmex* (e.g., Attini is a tribe > *Atta* is a genus > *Atta sexdens* is a species).

Autopoiesis: This is the fundamental term introduced by Humberto Maturana and Francisco Varela to originally describe the nature of living systems. It derives from the Greek *auto*, meaning self, and *poiesis*, meaning creation or production.

Bioacoustics: The combination of biology and acoustics to study the production of sounds in living beings.

Biomimetics: The observation and analysis of nature, its processes, models and systems for the application of its biological principles and behaviors to human design.

Cybernetics: An interdisciplinary field that studies regulatory systems. In relation to my research, it refers to the definition by Norbert Wiener: control and communication in the animal and the machine.

Emergence: The arising of complex systems and patterns out of simple interactive relationships. Emergence is the formation of a higher organization with a bottom-up structure, whose outcome cannot be deduced from the sum of its parts.

Homeostasis: The state achieved by an organism by regulating its internal conditions using feedback to stabilize its health and functioning.

Myrmecology: It is the scientific study of ants and it is a branch of entomology (the study of insects).

Polymorphism: The occurrence of different forms among the members of the same colony.

Scratching: The production of distinctive sounds by moving a vinyl record back and forth on a turntable, usually by means of manual gestures. Scratching originated from the hip hop culture during the late 70's.

Semiochemical: Any chemical substance that carries messages or information, which can only affect individuals of the same species involved in the exchange of information.

Stridulation: The action of rubbing together certain body parts. This mechanism can produce vibrations and resonance, depending on the structural form of the objects involved in the contact. This behavior is typically associated with many species of insects, including cicadas, spiders, crickets, beetles and ants.

Turntablism: The creation of music using turntables in a distinctive manner, not just playing records.

ENDNOTES

¹ Briefly put, the first wave of cybernetics initiated the study of regulatory systems and how the transmission of information, and feedback with the environment play a role in the evolution of these. The second wave of cybernetics delved into the self-organization of the systems and how these identify, reflex and auto-produce themselves.

² I designed the motion tracking program with Max/Msp/Jitter 5.0, using pixel tracking differentiation based on the computer vision algorithms of Jean Marc Pelletier (<http://jmpelletier.com/cvjit/>).