Algorithmic and aesthetic interrelations in the dance piece Stocos

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In the following contribution, the authors discuss their own approaches to establish relationships between space, dance gestures and musical structures. At the core of these relationships lie spatial correspondences both on the level of the physical presence of the dancers and sounds and on the level of the algorithmic mechanisms that underly the choreographic and musical material. These spatial and algorithmic relationships form the basis for establishing aesthetic and behavioral coherences between dance and music.

These approaches are exemplified by the dance performance entitled Stocos. This performance has recently been realized as a collaborative endeavor that relates ideas and methods from algorithmic composition, sound synthesis and computer based biological modeling with dance choreography and improvisation. In the piece, the dancer's gestures explore the network of mutual dependencies that relate them to the musical activities within a three dimension sound space. The activities of the dancers and music relate to each other via underlying processes of brownian movement and flocking behavior. These relations vary in their level of immediacy and complexity and thereby give rise to different forms of coexistence between dancers and music. These range from treating the dancers' bodies as musical instruments whose physical position and movements are directly related to sound spatialization and sound synthesis to endowing the music with a level of agency that allows it to respond to the dancers' behaviors as a performer and improvisation partner on its own.

Introduction and Concept

Stocos represents the third part of a trilogy of dance works that experiment with gesture as a means to connect bodily movement to stochastic sound synthesis and sound spatialization.

Stocos extends this focus by exploring not only relations between natural gestures of the human body and music but also relations between simulation based synthetic gestures and video imagery. In addition to extending the network of gestural relationships, the simulation based approach also serves as a unifying principle that underlies all the activities on stage. The natural and artificial characteristics of the stage arise from the interplay of these algorithmic processes and thereby form a coherent and emergent whole. Accordingly, these processes give rise to the creation of a synergistic environment.

Stochastic Phenomena

The title of the piece *Stocos* comes from a free translation of the Greek term στόχος into Latin characters, a term that refers to the target. This is why the term stochastic points to the degree of dispersion of events when attempting to undertake an objective (for example an arrow hitting a target). So when we speak of a stochastic phenomenon we are talking about a phenomenon that combines a random process with a selective one, ie, how the events are scattered in a partially random fashion (1). Following this reasoning, both genetic change ordered by the protoplasmic changes in DNA, and in general the act of learning and thinking are stochastic processes. So in this sense we can say that nothing new can take part without this random part.

If we transfer this image to the field of instrumental practice we may a similar relationship: the same note written on a staff and that is succesively executed by the same musician on the same instrument will present at each time an indeterminate dispersion of the countless details that conform the unfathomable nature of each sound event. This combination of a selective process with an indterminate one is what keeps the listener's attention in the field of live music at each new interpretation of a work listed on the map of five lines and four spaces.

Xenakis brilliantly developed for this problem in his article On Determinacy and Indeterminacy, and at an even more abstract level Alfred Korzybski with his idea of the map and the territory (2) (1) . Following this approach, in Stocos we tried to recreate this wealth of natural phenomena by using stochastic processes to generate synthetic sounds and generative video from artificial intelligence simulations.

(1) BATESON, Gregory. *Espíritu y Naturaleza.* Amorrortu Editores, Buenos Aires, 1997.

(2) XENAKIS, Iannis., "Determinacy and Indeterminacy", Organised Sound, 1, pp:143-145, 1996.

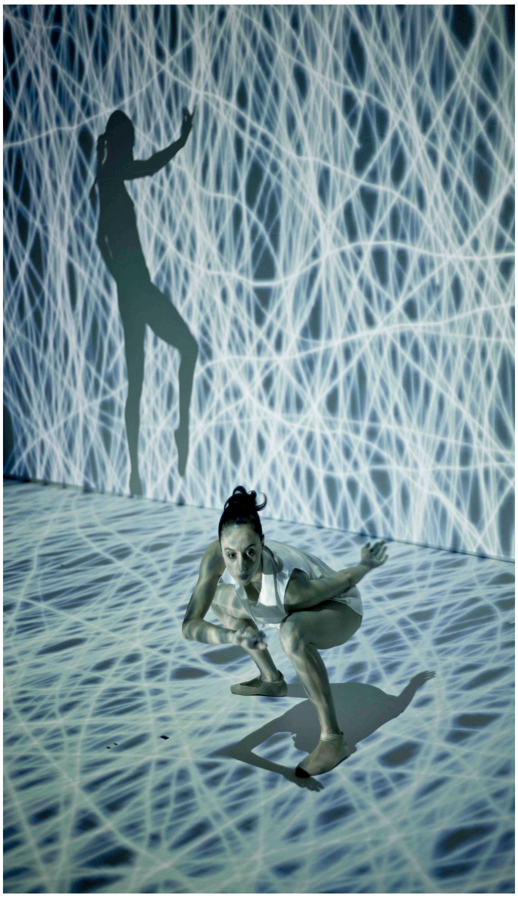
Synergy and dynamical couplings

Stocos is conceived as a network of elements that are co-determined. The term "synergy" refers to the phenomena, when the cooperative activity of several components of a system give rise to a property or behaviour that is unachievable by each component alone [1]. In Stocos, the complexity and turbulence of the performance arises from the dynamical couplings of the dancers, the simulation based entities, and the generative music and imagery. We employ the term "synergistic space" to emphasize the fact that the appearance and behaviour within the performance space is not dominated by one individual activity but rather results from the relations and feedback mechanisms that connect all activities. It is the changing characteristics of these relationships that form the choreographic structure of the performance.

Image 1. A moment in the immersive space of Stocos.

(1) FULLER, Buckminster. *Synergetics - Explorations in the Geometry of Thinking*. Macmillan Publishing Co. Inc. New York, USA, 1979.

Algorithmic Couplings



The simulations that underlie the activities on stage are based on algorithms for modelling the movements of large groups of simple entities in space, in particular, the brownian movement of microscopic particles and the coherent movement of flocking animals. These algorithms form the main generators for creating the acoustic and visual feedback in the piece and they also control aspects of the dancers' movements. Due to the fact, that the main aspects of the piece are based on identical algorithms, the performance is characterized by an algorithmic consistency.

Due to this consistency, interactions among the generative processes that give rise to dance movements, sound and visuals happen at a very immediate and fundamental level.

Image 2. Brownian movement works a model for both sound and visual imagery in Stocos.

Behavioral Couplings.

The stage is inhabited both by human dancers and simulated entities, both of which possess a behavioral repertoire and the capability to perceive and respond to each other. With respect to the simulated entities, the perception based behavioral correspondence is based on computer vision software that detects the dancers' positions, contours and movements (see section 2.2) as well as simulation mechanisms that transform this tracking information into human controlled agents and agent properties (see section 2.3). The human dancers can perceive the simulated agents via their influence on the generative creation of music and visuals. Most of the behavioral relationships throughout the performance involve spontaneous and improvised forms of interactions between dancers, swarm simulations, music and visuals. Depending on the complexity of the simulation, the agents either possess very little autonomy and behave like a physical phenomena that can be

directly controlled by the dancers (see figure 1), or the agents maintain a high degree of autonomy and thereby act more akin to improvisation partners (see figure 2). Due to the simulation's influence on the generation of music and imagery, the agents also act as mediators between the dancers' physical movements and the audiovisual content of the piece. The dancers' role in the creation of the music depends on the degree of the agents' autonomy. If the agents possess very little autonomy, the dancer's bodies act as musical instruments that trigger an immediate sonification. In case of highly autonomous agents however, it is the agents themselves that act as musicians who loosely relate to the dancer's
activities

Image 3. The agents that compose the swarm simulation interact with then movement of teh dancer as partners in a collective improvisation. Each agent (in this case each point in the space over the dancer on teh left) is conencted to an stochastic synthesizer).

Emergent Space

In *Stocos* the space emerges asa product of teh movement of teh entities that populate the stage. On one hand the movement of the dancers constructs and transforms the properties of the immersive space that emerges from the local interactions of the agents that comprise the simulations, both acoustically (digital samples) and visually (agents that compose the swarm simulation). In this sense, as Piaget had it, movement is conceived as a transformation of the perceptual field. As a consequence we can define a perceptual firld as a group of relatonships defined by movements. And finally, following this line of thought to teh formal level, time is the choreography of space.

En *Stocos* el espacio surge como un producto del movimiento de las entidades que populan el escenario. Por un lado, el movimiento de las bailarinas construye y transforma las propiedades del espacio inmersivo que emerge de la cooperación local de los agentes que componen la simulación, tanto a nivel acústico (muestras digitales), como visual (agentes que conforman la simulación enjambre). En este sentido, como ya indicó Jean Piaget, el movimiento es concebido como una transformación del campo perceptivo. En consecuencia, podemos definir un campo perceptivo como un grupo de relaciones determinado por movimientos en el espacio (1). Finalmente, siguiendo este razonamiento y trasladándolo al ámbito formal, el tiempo es la coreografía del espacio.

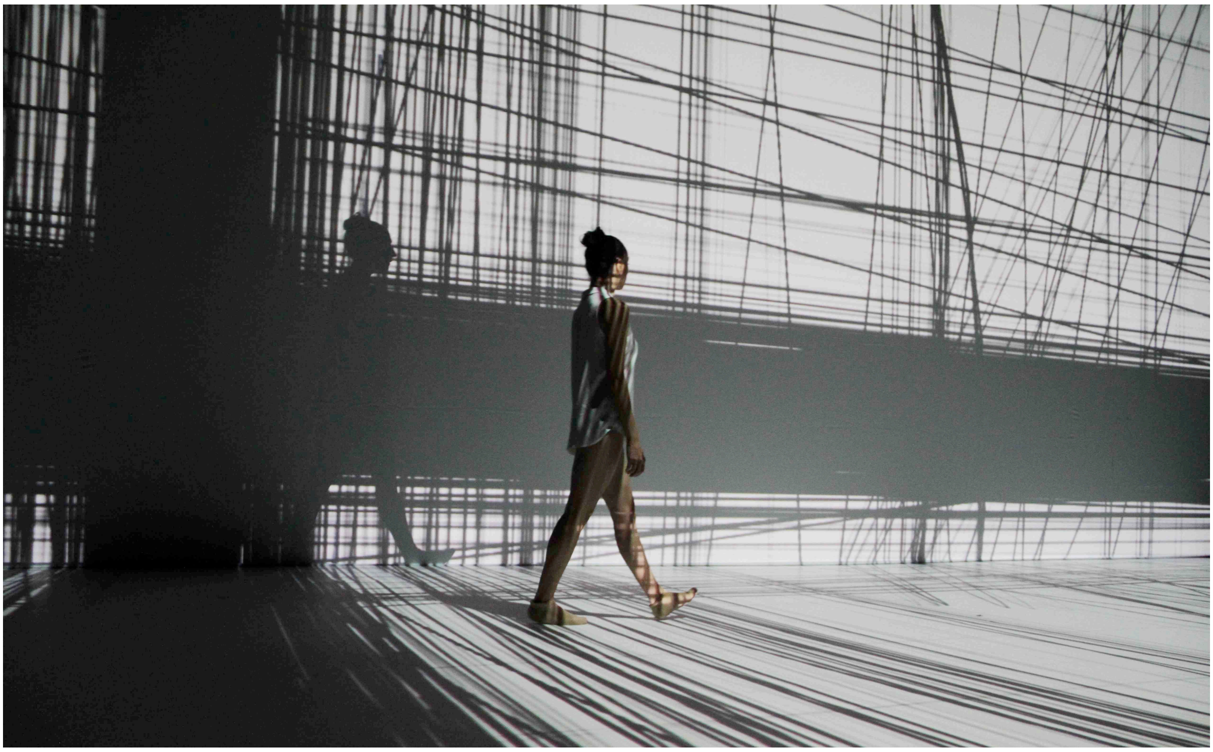


Imagen 4. Seamless projection on wall and floor follwing the dancer's walk

The appearance of the stage manifests itself via an acoustic and visual merging of the physical and simulation space. This merging is achieved by aligning spatial characteristics of the dancers and the stage with the spatial characteristics of the simulation.

(1) PIAGET, Jean and INHELDER, Bärbel. *The child's Conception of Space.*Norton Library.New York, 1967.

The musical composition is realized as an acoustic space that surrounds performers and audience. In addition, the stage is divided into distinct acoustic regions that allow the dancers to chose and modulate different sound material based on their position in space (see image 5).

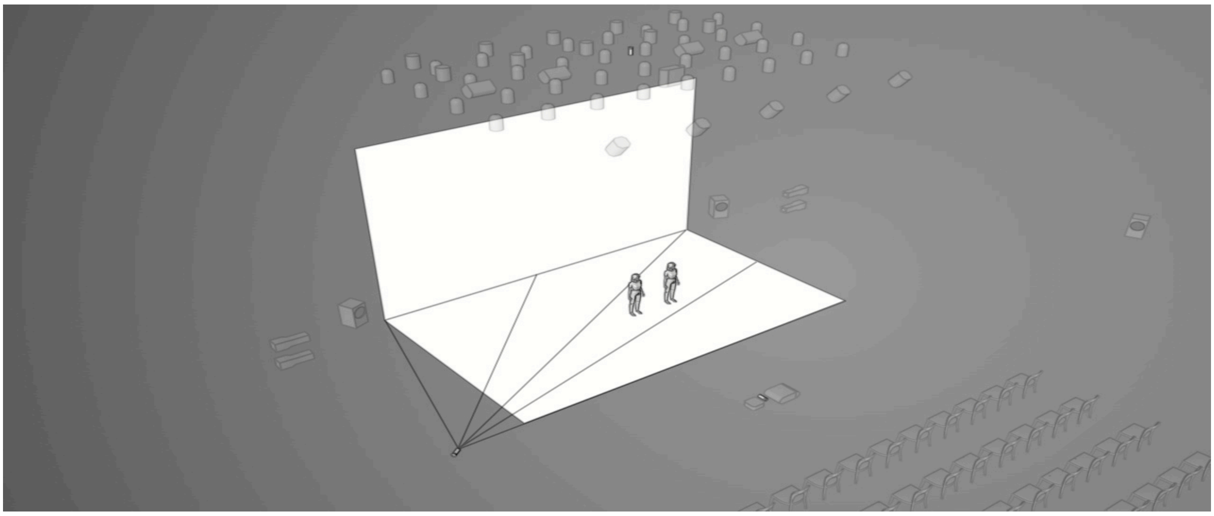


Image 5. Tracking Regions. The stage is divided into several tracking regions which are associated to different sounds.

The appearance of the stage manifests itself via an acoustic and visual merging of the physical and simulation space. This merging is achieved by aligning spatial characteristics of the dancers and the stage with the spatial characteristics of the simulation. This alignment controls both the spatial mapping of the video tracking based information and the spatial projection of music and imagery into the performance space. The musical composition is realized as an acoustic space that surrounds performers and audience. In addition, the stage is divided into distinct acoustic regions that allow the dancers to chose and modulate different sound material based on their position in space. The projections of the visuals are superimposed with the stage floor, the stage background and the dancers' bodies. As a projection on the entire stage, the video image creates an immersive and responsive visual environment that supersedes the visual appearance of the physical space and the dancers (see image 1). As a stage projection within the vicinity of the dancers, the video image coalesces into clearly confined shapes that appear as visual counterparts to the dancers. By aligning simulation space and body space, the video image is projected solely on the dancer's body. In this situation, video imagery and the dancer's physical body merges into a single entity whose appearance posseses both natural and artificial properties (see image 6).

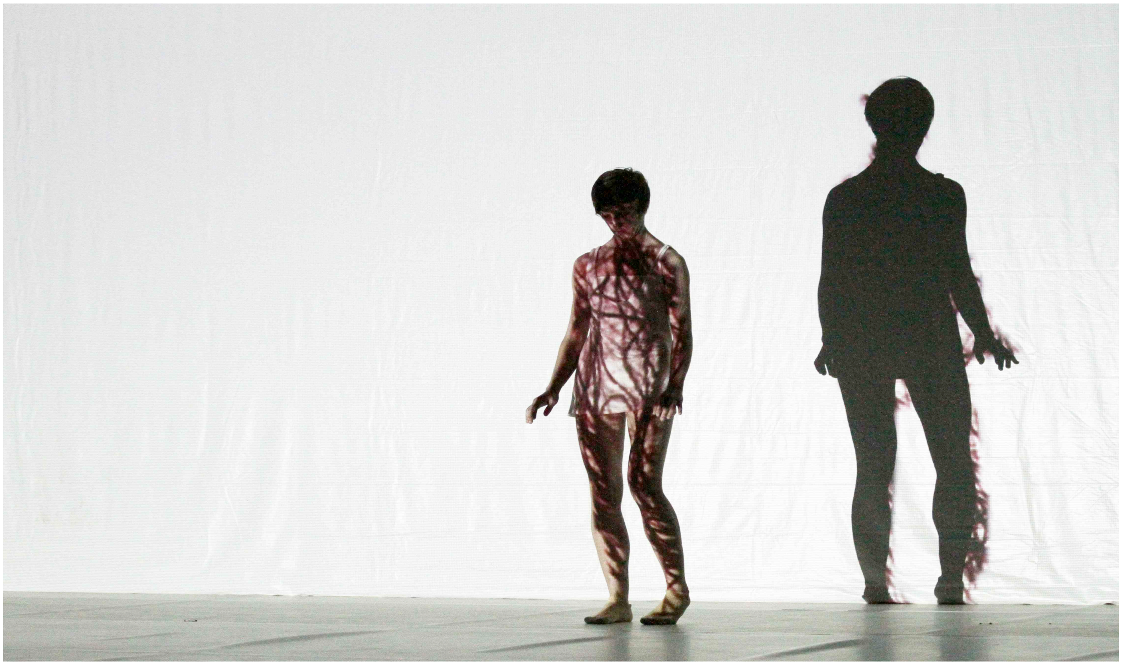


Imagen 6. La simulación adopta forma de patrones de vasos sanguíneos y se confina interactivamente en el cuerpo de la bailarina.

Stochastic Sound Synthesis in Stocos: Construction of a music for the eye.

The music of the piece combines life generated and precomposed acoustic material. This material is synthetically generated via a method of sound synthesis entitled Dynamic Stochastic Synthesis. This method has initially been devised by Iannis Xenakis (1)(2) and employs simulated brownian motion as a stochastic mechanism to modify individual digital samples and thereby directly manipulate the sound pressure curve of an audio waveform. According to this method, the waveform is polygonized via a number of breakpoints (see image 7). Each of these breakpoints is constantly perturbed by two random walks that control the amplitude and duration of the waveform. The values generated by the random walks are delimited by so called mirror barriers.

For Stocos, this method of sound synthesis has been implemented in the Supercollider programming environment by one of the authors. The implementation was necessary since the unit generators that implement this Xenakian method of producing sound that form part of the standard Supercollider environment suffer from several simplifications that limit the flexibility of Dynamic Stochastic Synthesis. Our implementation of Stochastic Synthesis has been specifically customized and extended for Stocos.

(1) XENAKIS, Iannis. *Formalized Music*. Revised Edition, Pendragon Press, New York, USA, 1992.

(2) LUQUE, Sergio. "The Stochastic Music of Iannis Xenakis". Leonardo Music Journal, Vol. 19, MIT Press, Cambridge, USA, 2010.

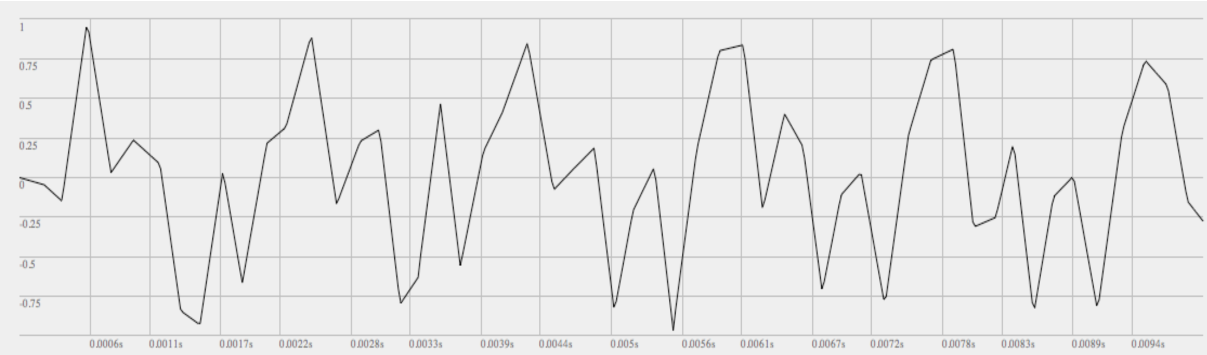


Image 7. Pressure time curve of a sound wave of 100ms length generated using dynamic stochastic synthesis. The wave is articulated by 10 breakpoints that are successively perturbated.

On an algorithmic level, the constraints on the simulated brownian movements that give rise to the synthesized sounds are modified by the activity of the simulated agents. Each agent is coupled to one stochastic synthesizer via a variety of relationships. One relationship maps an agent's vertical position to the position of the synthesis mirror barriers. Another relationship employs the similarity among the agent's velocities to control the step size of the synthesis random walks. A third relationship connects the spatial trajectories of the agents to the spatialization of the synthesized sounds via the octophonic speaker ring.

Another extension of the stochastic synthesis model that has been created for Stocos allows the dancers to interactively control the synthesis algorithm. As a result, the process of sound synthesis and the spatial projection of the resulting sounds is tightly intertwined with the dancers' activities.
Finally the compositional structure of the music is generated via temporal patterns that also affect the behavioral properties and visual rendering of the swarm simulation creating a feedback loop that in the end affects the stochastic synthesis themselves.

All these relationships allow the listener to build a musical experience of synesthetic character, which Xenakis has called a music for the eye in relation to his polytopes(3). In the context of Stocos this an emergent phenomenon that allows us to see the music and hear the bodies of the dancers and the fleeting local interactions of the agents that make up the swarm behavior simulations .

(3) XENAKIS, Iannis. *Music and Architecture*. Compilation, translation and commenatary by Sharon Kanach. Hillsdale, New York: Pendragon Press, 2008.

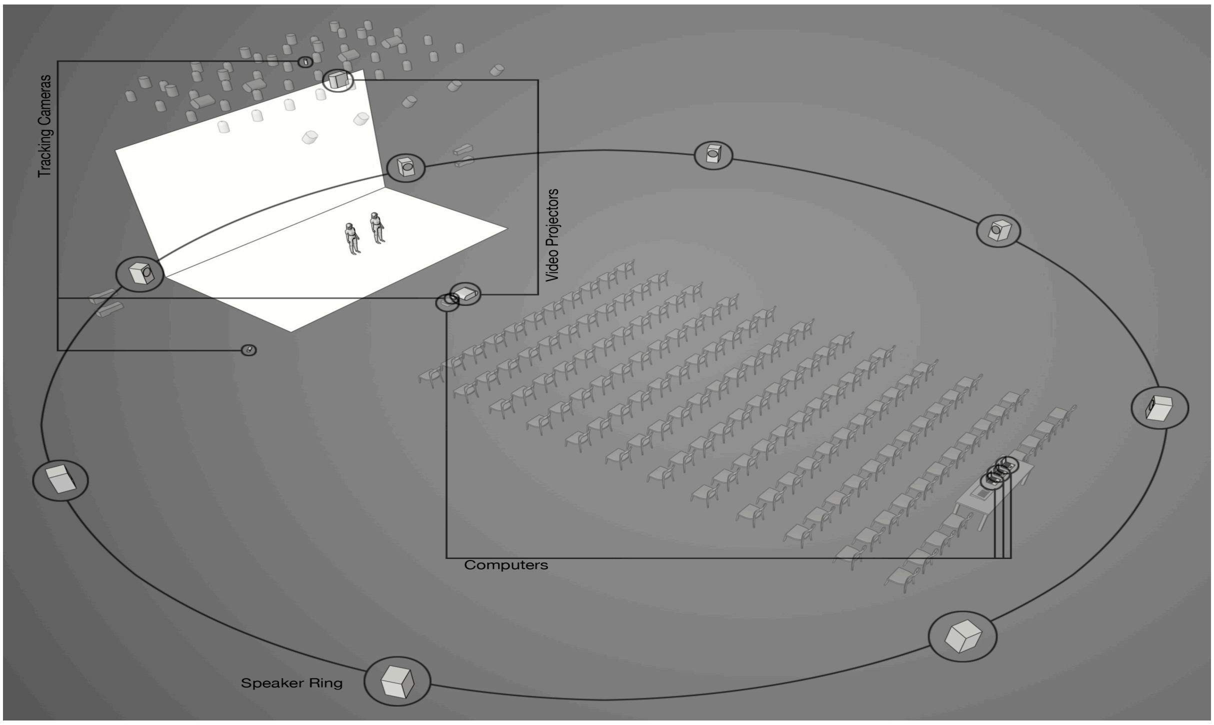


Imagen 8. Set up scheme.

Body gestures and music.

The musical gesture as a both functional and expressive body movement that triggers the emission of sound has maintained a prominent role as an imaginary and metaphorical aspect in purely electronic music, in that it allows the composer and audience to relate an acoustic perception to a performative experience. The base of this idea is probably the existence of a common substrate for both phenomena, sound and body movements. The first and more intuitive explanation deals with playing instruments, since music in its origins is inseparable to manipulating objects in order to produce sound (the arrival of computers as an abstract instrument for music in quite a recent thing indeed), the coordination of movements necessary to master an instrument conforms in itself a very sophisticated choreography that involves both the sense of body position and motion (kinesthesia) as well as taction. Even we talk an unconscious miniature choreography is performed by the organs of the vocal tract in order to produce understandable phonemes. We could also track this phenomena evolutionarily relating it with the unconscious inferences that our brain performs in order to know the physical activity that causes a sound . The aim of this inferences is very likely connected to the survival of the species. So it could be said that a gesture unleashes a configuration of the body in space ,in the case of dance, or the excitation of a vibratory body in the field of sound (1). Gestures in Stocos play a very prominent role both as an aesthetic and expressive element of the performance as well as an algorithmic aspect of the underlying simulations

The dancers' activities form an integral part within the network of relationships that underlie the generative creation of music and imagery. The simulation based approach in the piece is reflected in the development of their movements. During highly formalized sections of the choreography, the dancers organize their spatial movements and gestural patterns strictly according to algorithmic rules that are derived from the simulation of brownian movement. These random walks are used by the dancers to "walk" among the different parts that comprise previously composed dance variations and thereby give rise to reverberations of the original choreographic structure. Both of the dancers employ different random walks, which results in two quasi similar movement patterns. The algorithmic procedures that are followed by the dancers have been created in Supercollider.

Image 9. The swarm simulation synchronized with the stichastic sound synthesis behaves similar to rain that is perturbed by gusts of wind.

(1) PALACIO, Pablo and ROMERO, Muriel. "Structural Aspects in *Acusmatrix*". In *Cairon 12, Journal of Dance Studies.* Madrid: CENAH- Universidad de Alcalá, 2009.

For their improvised movements, the dancers heavily relate to the behaviours of the simulated entities that manifest themselves in the changing acoustic and visual properties of the stage.

Depending on the characteristics of the simulation, dancers and simulated entities relate to each other differently. Simulations that mimic the behaviour of physical phenomena respond very directly and predictably to the activities of the dancers. These simulations allow the dancers to amplify the spatial extension, duration and intensity of their movements. Those simulations that model highly autonomous agents respond to the dancers activities in less predictable ways. In these situations, the human dancers relate to the agents as artificial dancers. Depending on the quickness and strength with which the simulation responds to the human dancers, these artificial dancers act as improvisation partners or independent soloists.

The dancer's presence and activities play an important role for the creation of the music. Throughout most of the piece, it is via the dancers influence on the behaviour of the swarm simulation that they indirectly affect the creation of the music. In this situation, the dancers' musical role resembles that of a conductor, who tries to control a more or less compliant orchestra. During other sections of the performance, the swarm simulation cedes control of the music entirely to the dancers. In these situations, the dancers' gestures are directly linked to sound synthesis. The dancer's bodies become musical instruments and their gestures become musical gestures. In combination with the segmentation of the stage into different acoustic regions, the dancers' movements through space change the characteristics of their "instrument" bodies and thereby reveal new acoustic qualities of their gestures.

Simulation of Natural Phenomena and Artificila Intelligence: *Swarm behaviour*.

The computer simulations that have been developed by the authors for this piece model the movements of large groups of simple entities in space, in particular, the brownian movement of microscopic particles and the coherent movement of flocking animals. The implementation of these simulations is based on a C++ simulation library that has been developed by one of the authors as part of a research project about swarm based music and art (1).

(1)BISIG.D, NEUKOM.M, and FLURY.J. "Interactive Swarm Orchestra - A Generic Programming Environment for Swarm Based Computer Music". In Proceedings of the *International Computer Music Conference*. Belfast, Ireland, 2008.

One of the main benefits of this simulation library is its ability to enable the creation of highly customized swarm simulations that can be extended and modified during runtime. These simulation can easily interact with other software due to their OSC based control and communication mechanisms. In the case of Stocos, the behaviour and visualization of the simulations change fundamentally throughout the piece. These changes are synchronized with the musical composition via OSC commands that are sent from a Supercollider based program.

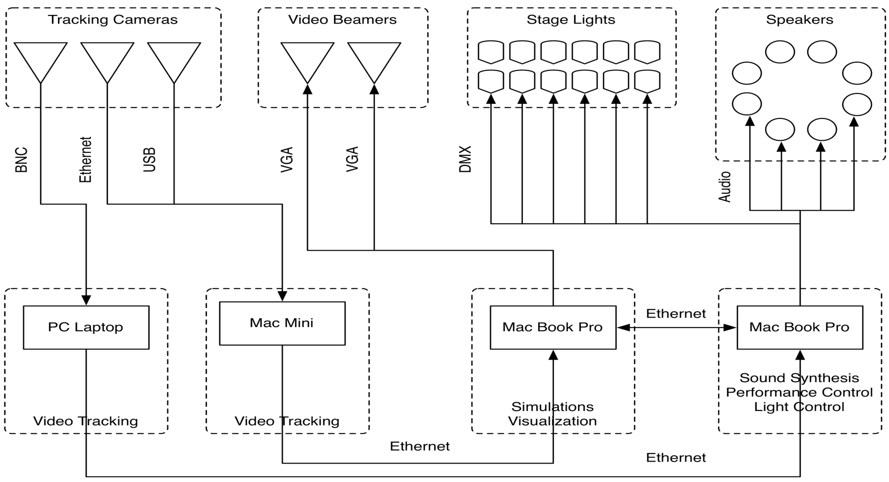


Imagen 10: Communication Setup. A schematic depiction of the computers' tasks and their communication with the light setup, video projectors, tracking cameras and speakers.

Several agent behaviors and simulations have been specifically designed for this piece. Most of the new behaviors deal with the capability of the agents to respond to the presence of the dancers. Agent creation and destruction behaviours serve to change the number of simulated agents depending on the dancer's movements. In most cases, no movement causes the destruction of agents whereas large movement triggers the creation of agents. Other behaviours cause the agents to experience forces of attraction and repulsion in relation to the dancers' body contours. The creation of tangential forces causes agents to follow the body contours. Attraction forces pull agents towards particular features of the body contours such as the tip of the head or the center of the fastest moving body part.

The simulations that have been created for the performance differ with respect to the number of swarms and the number and type of agent behaviours involved. Those simulations that implement only tracking based behaviours are highly responsive and predictable. They therefore tend to resemble physical phenomena that can be directly manipulated by the dancers. At the other extreme there are simulations that combine tracking based behaviours with typical swarm behaviours that control interactions among the agents themselves. These simulations exhibit a much higher degree of behavioral diversity and complexity and their response to the dancers is less predictable. In this case, the simulated agents participate in the performance as artificial dancers that possess a high degree of autonomy.

Conclusions

The realization of Stocos was motivated by our curiosity whether ideas from algorithmic composition and generative art can be transferred to contemporary dance and vice versa. In particular, we were hoping that by sharing and interrelating the same generative processes among dance, music and imagery, the piece would exhibit a high degree of aesthetic coherence and dynamic synchronicity rather than drift apart into different activities that compete for the audience's attention. The notion of musical gesture that played a central role in the previous two pieces provided a very fruitful context for the creation of the current work. The phenomena of a moving body whose energy trajectory triggers and modifies perceivable phenomena is very well suited to link algorithmic abstractions with a performative experience that is very familiar to both the dancers and the audience. The decision to employ simulations of brownian motion and swarm behaviour is based on this gestural focus of the piece.

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