Artificial Life within a frame of metacreation on stage

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Abstract

We have developed a scenic installation composed of a virtual environment and an interactive interface to investigate the possibilities of co-creation between performers and interactive **generative** systems. We analyze our creative experience from the artist-researchers point of view in the real-time generative and interactive image field. Our results indicate that the co-creation depends on how the performer perceives the virtual system and how they perceive its influence on this system. Furthermore, the system's creative potential depends on the mechanisms developed by the artist and his interpretation of the interaction data in a metacreation context. Our perspectives point toward the conception of a scenography character.

Keywords

Metacreation, performance, interactive digital art, artificial life, scenography, scenography-character, interfaces

Introduction

Artistic context

The process that produces artistic experiences and artifacts is no longer a secret in the artist's studio. Instead, it can be a system of creation set in motion by the artist and continued when confronted with the materiality of collective participation in exhibition spaces or urban areas. [1] [2]

The advent and popularity of technological tools influenced the development of digital arts. As a result, they emerge as a transdisciplinary approach between design, computer science, complexity sciences, and artificial life.

In participatory works, the viewer becomes an actor in the artwork and can even interact remotely. [4] The interaction is no longer responsive but can be adaptive, conversational, and creative. [5]

The literature gives examples of evolving virtual ecosystems that can be creative and self-organizing systems that can improvise. [6], [7] Some developer-artists seize the computational capabilities of the graphics card in an alternative way to create complex systems and use artificial life algorithms, giving rise to emerging behaviors and impressive endogenous interaction phenomena. [8], [9]

Other developer-artists create or hack interfaces using electronic sensors or mobile devices to establish a genuine, intimate, and active relationship within the technological, social context, and connected networks. [10] Through such interfaces, artists seek an adaptive and dialogic, conversational engagement between the participant and the virtual system to investigate possible relationships with the machine and express the uncertainty of existence through the uncertainty in the work of art.

For Whitelaw, a generative, evolving, interactive system results in an autonomous artwork. He refers to this method of creating autonomous digital works by the term *metacreation*. [11] Such a system contains parameters of appearance and behavior that can be modified according to the interaction with the external environment to the virtual, what Bret calls the sources of exogenous exchange that complement the endogenous interactions between the virtual system's components. [12] This dynamic diverges from the initial instructions given by the artist-developer and may result in unpredictable behavior occurring during the processes. Regarding this *metacreative* process, we will evaluate the creative potential of the virtual part of our scenographic proposal.

Project *Co-évolution, Co-création et Improvisation Homme-Machine* (CECCI-H2M)

The research-creation process described in this article is part of the *Co-évolution, Co-création et Improvisation Homme-Machine* project, led by Chu-Yin Chen. It investigates ways of sustainable behavioral co-evolution with emerging human-machine co-creation. The project proposal merges two research-creation approaches through practice. First, the artist-researcher Silvia Cîrcu's study about choreographic interactions between performers and robots. Second Isadora Teles' hypothesis of an improvised co-evolution between performer and evolving virtual system. This article traces and analyzes the experiments carried out by the two Ph.D. candidates during two artistic studio residencies from the point of view of the artist developing the virtual system and its interfaces with the stage.

During the experiments, the artist-researchers compared their artistic proposals to find convergences and clarify their intentions and ideas. The common goal was the conception of a co-created performance on stage between the performer, an HRP-4 humanoid robot, and an interactive evolving virtual ecosystem. It was also a question of characterizing the possibilities of co-creation between the performer and two types of artificial entities when they are either embodied or not embodied on stage.

The project also aimed to question the design of autonomous and evolving creative tools for performance and improvisation, letting the evolving virtual ecosystem take the form of the performer's alter-ego. We hypothesized that a physical structure for the autonomous and evolving ecosystem on stage would be able to influence the performer's gestures and embody or interface the generative virtual process. (**Fig. 1**).

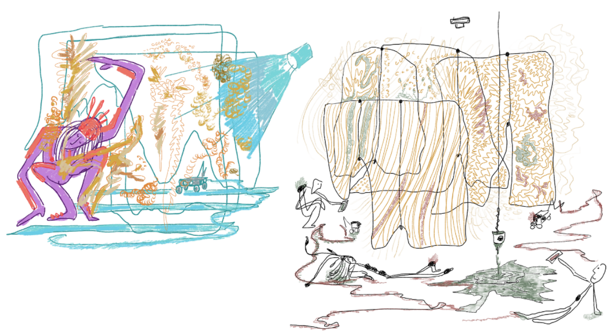

Figure 1. Two different sketches represent our conception of the three elements of the stage together: performer, interface, and scenography. ©Isadora Teles de Castro e Costa, 2021

Experimentations

Experimental Plan

The experimental plan to set up a creative and improvised interaction between performer and artificial entities consists of:

- Develop, separately, three prototypes of "species" for the virtual ecosystem and their mode of intra-species interactions.
- Develop three interface prototypes for interacting with elements on stage and embodying the same virtual system in the form of objects that can be manipulated, played, and penetrated by the performer's gestures.
- To study the possible co-creative and adaptive interaction relationships between each "species" of the virtual system and the performer.

The proposal aimed to use metaphors of emotional states to imagine the shape and behavior of the different species that would inhabit the virtual world. The technical goal was to find ways of expressing the sensation that they are possessed by or act according to one of the emotions mentioned through each species' form and action. Once we clarified the species' shapes and corresponding behaviors, the next step was to create and test the algorithms that could correspond to such sensitive expressions.

Creating a graphical simulation of a complex system must consider the technical challenge of animating and making many autonomous elements interact. Moreover, it requires considerable computing power, which increases exponentially with the number of individuals. Therefore, we developed the virtual universe using mainly graphical shaders for the image synthesis.

Graphic shaders enable the programming of the graphics card to generate images by calculations performed in parallel. [13] We have experimented with fragment shaders and then with compute shaders. Compute shaders allow us to get the complex image and behavioral animation qualities that are difficult to achieve by other techniques because they exploit the computing power optimized by the graphics card. An essential reason for the choice of the technical tool was the existence of examples of simulation of common biological phenomena with the subjects treated by artificial life using such a technique.

Compute shaders are used for scientific simulation, bioinformatics, and simulation of complex dynamical systems. [14] However, such references in the artistic field are rare, and steps of technical adaptation are required.

Virtual environment

Particle system with fragment shaders

We designed the first prototype to express the "dream" or the state of trance. To do this, we have conceived a type of behavior that shows wandering flight, describes a lightness in the movements, and would be contrasted with another species which would represent "fear". This behavior leads us to think of the imaginary flight of fairies, a dance of birds or leaves heaving in the wind.

To set up this "imaginary fairies" system, we started by programming a particle system using fragment shaders within the touchdesigner software. Fragment shaders make it possible to deal with many dynamic pixel data, but there can be no interaction between them or exchange of information.

The particle system components have basic properties of physical simulation, such as mass, velocity, and lifetime. They are influenced by forces external to the system, which can attract and guide them. An exciting aspect of the behavior of this particle system is that if we increase the particles' scale and the force of attraction, the collective behavior becomes an organic mass concentrated on a flow of energy. This shape, green on a red background, is reminiscent of a pulsating organ (**Fig. 2**).

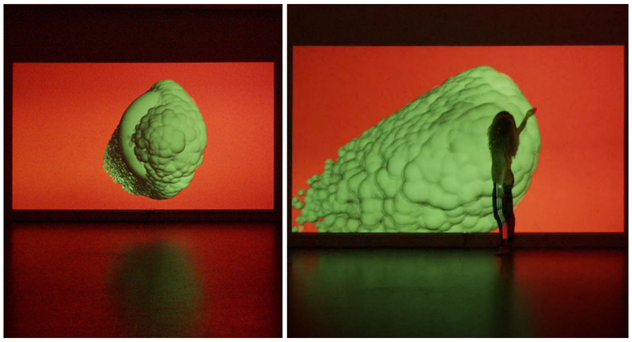

Figure 2. Recurring shapes during our experiments. Organ-like mass of fragment shader particles is depicted in green. ©Isadora Teles de Castro e Costa, 2021

This particle system behavior was not inspired by cell behavior, but it has emergent collective properties vastly used to model dynamic natural phenomena. [15] In our case, it behaved like a pulsating organism or animal organ thanks to specific behavioral parameters explored through improvisational interactional and "tweaking" on stage.

The void in the background of the virtual environment suggested an organ in preservation in a jar, isolated but still "alive" (**Fig. 2**). The erratic movement of the system and its emerging collective form caused the sensation of a living organ. The emerging shape was caused by the unstable and non-treated data obtained from the capture of the performer by the Kinect, which controlled parameters inherent to the particles, such as their maximum speed, their mass, and the constants of attraction towards the attractors. This phenomenon of data instability was the positive cause of the pulsating impression of the particle system's organic form.

Particle system with compute shaders

Our second experiment modeled a particle system whose position information was calculated by a compute shader. The change in technique aimed to establish an endogenous interaction among the particles and the virtual environment. For studio residences, the particles could not perceive one another and adapt their behavior to the other's presence or proximity.

The difference between compute shaders and other types of shaders (vertex, geometry, and fragment shaders) is that they do not fit into the render pipeline. The compute and the fragment shader have similarities, but they were designed for different purposes.

The compute shader allows us to use the GPU to perform calculations that are not necessarily related to 3D or image processing. This technique is the so-called GPGPU for General-Purpose computing on Graphics Processing Units. In our case, we used it to calculate the position and velocity of a particle system guided by a mathematical function that generates organic flow, which can be used to simulate fluids.

We were inspired by the systems of particles moving in a Curl Noise. The technique is often used for dynamic non-autonomous systems such as fluid simulation or the displacement of the sand. In our case, we used it as a wind force to guide the particle movement. The wave variations and their organicity helped us get a prototype of the aimed behavior: an impression of a self-organized multi-agent system [14], [16] (**Fig. 3**)

Figure 3. Choreographic exploration in interaction with compute shader particles. The performer modified the parameters of a curl noise function. The noise guided the movement of the particles. ©Isadora Teles de Castro e Costa, 2021

We tested the interaction between the performer's motion capture data and the second prototype of the "dream" species. Two joints of the performer were linked to two behavior parameters of the particle system. The elbow position controlled the direction of the Curl noise that guided the system's movement, and the knee position influenced the direction of the noise and the friction, that is, the damping of particle velocity.

These interaction links allowed an interesting synchronization between the movement of the particles and the performer's gestures. We were able to identify a notion of rhythm in the interaction with the friction variable of the particle's properties. The movement of the arms influenced their direction, giving the impression of a dance master to the performer.

Cellular automata with compute shaders

The second species that would integrate the virtual ecosystem represents "fear". Our main issue was finding a way to create a virtual agent that leaves patterns and traces on a surface by its growth or displacement. We wanted to represent fear as something that spreads on surfaces and leaves traces of infectious and unhealthy appearance, reminiscent of mold.

The modeling of the behavior of *Physarum polycephalum* was our main inspiration. It is a single-cell organism that can exhibit the formation of complex and emerging growth patterns. [17] The first step in modeling such behavior was to set up a cellular automaton system to establish the basis of an optimized algorithm for endogenous perception and interaction between virtual individuals. Arsiliath suggests this method in his *Psychobiotik* workshop, where the goal is to build a complex system of autonomous agents with compute shaders. We tested two variations of the cellular automata. One is based on the concept of cyclic cellular automata, and the second is based on Langton's Edge of Chaos article. [18], [19]

The peculiarity of the cellular automata algorithm is that, depending on the combination of parameters of interaction behavior with neighboring cells, it can generate a large amount of different emerging patterns in a complex way and, therefore, difficult to predict by the artist. Consequently, one would have to manually test a wide variety of rule combinations to visualize the possibilities and choose a specific type of behavior corresponding to an intention, in our case, the internal emotional state of the performer.

The plethora of pattern possibilities emerging from several interacting entities is one of the issues studied by genetic algorithms (exploration of “landscapes” or “landscapes” of possibilities), mainly when they are used as an aesthetic evaluation technique in interactive generative processes. [20] However, during the interactive experience, the performer explored this landscape of possibilities with his gestures. We observed a negotiation between the intention of his movements and the projected pattern generated by automata's rules, conditioned by the position of the performer's joints (elbow and knees). (**Fig. 4**).

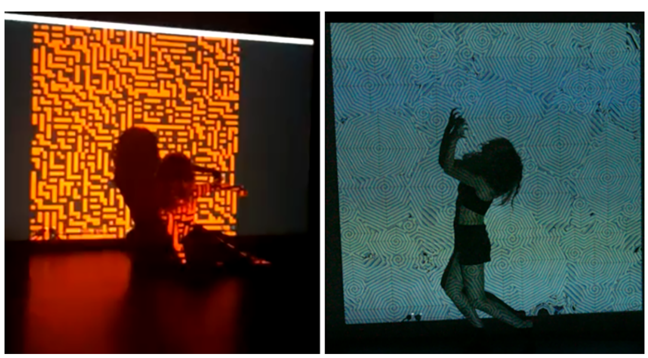

Figure 4. Choreographic exploration in interaction with compute shader cellular automata. The performer’s movements modified the parameters of the systems’ behavioral rules ©Isadora Teles de Castro e Costa, 2021

Conclusions about the virtual environment

Developing a particle system through fragment shaders was a stage of learning and appropriation of the technique. The system was used during the experimentation with the performer and opened aesthetic perspectives for the further development of autonomous agents.

Once we understood and appropriate the technique for calculating particle behavior with the fragment shader, the texture buffers and separately rendered geometry instances allowed us to switch to the compute shaders to calculate the behavior of virtual environment elements.

We used the cellular automata algorithm as an intermediate step in the appropriation of the technique of building a base algorithm optimized to create endogenous interactions. However, given the interesting patterns that emerge dynamically according to the exploratory exogenous interaction modifying endogenous interaction rules, this algorithm will be used as a component of the virtual ecosystem.

The usage of the Cellular Automata behavior will require an evaluation of its patterns' expressive and poetic function. We will also need to assess the interaction terms to preserve the artistic intention to express the internal state of the performer. The discussion is ongoing, but we will possibly add this new kind of emotion to the virtual ecosystem following the experiments in the studio.

The intermediate stage of development of the prototype corresponding to the state of "dreaming" has also instigated thoughts. The particles produced with the fragment shader showed us the plastic potential of such a technique for building systems. Of course, we may use distinct levels of autonomy in qualifying different types of virtual individuals. However, a physical simulation operation without collision limitations nor a high degree of autonomy can also be a rich source of raw material for creating geometric shapes and masses in interaction with the performer. The variation in autonomy levels among the virtual elements was essential to have a more malleable species, such as digital clay or raw material that could be turned, like a vase on a potter's wheel. Although clay is not an autonomous or living material for the potter, it presents physical properties and possibilities of plastic derivation rich in creative potential when modeled and glazed.

Likewise, the potential for plasticity of the particles' behavior, which were attracted and recalled by the symbolic representation of the performer in virtual space, made us question the condition of the autonomy of a virtual material conducive to creation. How exactly is a virtual simulation of clay matter, for example, more or less fruitful to co-creation than the simulation of a collective of ants or cells when manipulated or influenced by a performer?

Interaction interface

Tested hypothesis

First, we designed an electronic collar that captured the acceleration data of the performer and transformed it into a rhythm of luminosity using two LED strips.

Nonetheless, the performer's interaction with the collar was not perceptible, and this fragile structure did not adapt well to the performer's movements. (**Fig. 5**). Given the priority of connecting his gestures to the virtual system, we conducted interaction tests by capturing movement with the Kinect sensor. It allowed us fruitful interactions and gave us some leads about the gestures' links with the virtual system. Furthermore, the interaction with the Kinect provided clues on the plastic potential of virtual forms and their ability for enjoyment by the performer (**Fig. 5**).

Figure 5. Two moments of experimentation with the Kinect (left) and with the electronic-interactive necklace (right) ©Isadora Teles de Castro e Costa, 2021

Despite interesting interaction experiments with the Kinect, we wanted to keep the possibility of allowing the performer and director to improvise with sensitive interfaces. To explore the creative possibilities of the incarnation of the virtual on stage, the creation of sensitive scenographic objects that can be manipulated and played was important as a hypothesis to allow us to have a margin of movement in terms of layout on the stage on the performer's body. (**Fig. 6**).

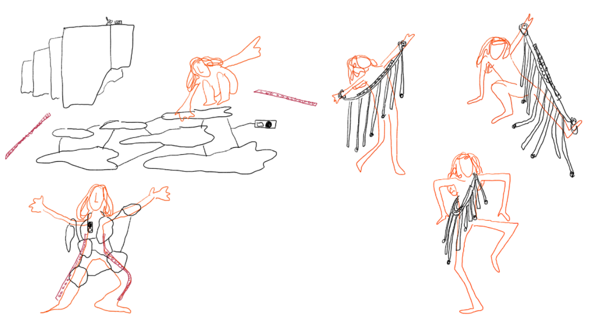

Figure 6. Two different sketches represent how we imagined the interactive interfaces being manipulated by the performer ©Isadora Teles de Castro e Costa, 2021

Prototype 3: Communication between connected mobile devices and virtual system

To test our hypothesis of a modular, fragmented, and sensitive scenography, we needed connected devices allowing reliable communication and resistance to the movements and gestures of the performer. We, therefore, considered devices linked to mobile technologies as a hypothesis to solve this problem.

We tested the portable device interaction hypothesis during the second studio residency (**Fig. 7**). The performer had to hold the devices during our experiments, limiting his movements. For example, for the on-screen drawing interaction, the performer had to look at the screen of the portable smartphone. We do not yet know if this constraint of movement limitation is an interesting creative path. However, although this limitation seems unconstructive to the dancer, it reflects our daily use of portable devices.

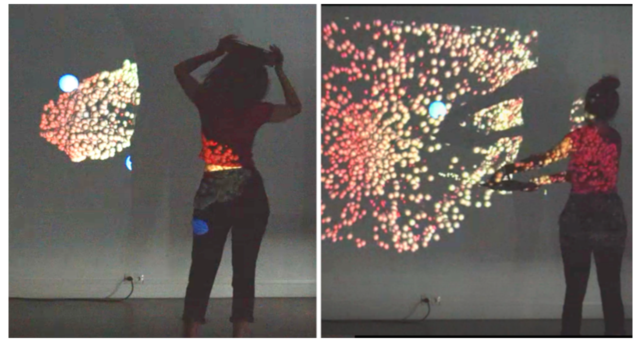

Figure 7. Experiments of choreographic interactions with fragment shader particle system through the manipulation of a tablet. ©Isadora Teles de Castro e Costa, 2021

Conclusions about interface interaction

The use of this portable device by the dancer on stage led to the following observations:

On the one hand, the public or anyone connected to the web server could act as an attractor to the behavior of the virtual environment, partially controlling it from their smartphone. It would be an aspect of active participation of the spectator in the performance. On the other hand, we could use multiple cell phones more easily accessible to create connected objects or costumes. The function or the appearance of these smartphones would thus eventually be "recycled".

In our co-creation context, the exploration of the creative possibilities and the potential gestures that these portable devices allow remain to be deepened during the next residency, together with an evaluation of the theoretical issues that their use gives rise to. For example, if we fix them on parts of the performer's body, what type of movement can the sensors of the portables acquire and make usable by the virtual system? The interaction by their sensor motivates an original use of cellphones, or would daily gestures persist?

Results

For Whitelaw, metacreation as an artistic technique is theorized as a creator method because the artist creates a creative process: "Familiar tropes of endless novelty and metacreation reappear; often the works are somehow autonomous; once made, they make themselves". [11] This creativity is developed in a different timeframe than we planned to study. Therefore, before establishing a co-creation between the virtual system and the performer, we must consider a co-creation stage between the artist-developer and his generative system. We believe it is necessary to establish a vocabulary specific to the generative system and the performance to characterize the emerging aesthetic phenomena resulting from the virtual system's functioning in interaction. The ability to describe a moment of creation and adaptation between the performer, the artist-developer, and the generative system turned out to be necessary in our case study.

Although we have developed several types of virtual systems, they took on new meanings, and those new issues arose during the studio experience. Before establishing a potentially autonomous and emerging system, the question of the perception of virtual autonomy by the performer and the physical characteristics and conditions of communication by the interface are essential aspects that we must test in situ. Therefore, these variables can promote or jeopardize performance and the co-creation process.

The hypothesis of creating an interface began with the idea of having a means of exchanging data between the stage and the virtual environment. We designed the interaction interface's appearance and function to represent the performer's emotions through movement sensing. During our experiments in the studio, we realized that the interface objects' presence on stage fell within a broader framework than that of communication with the virtual ecosystem. We were confronted with constructing the meaning of the performance in general (in contrast with the virtual environment sensing function alone). The projected virtual environment and the interface became the scenography of the performance. Therefore, they had to be considered together with the performer's environmental perception and the meaning of her movements.

We developed some of the interfaces during the studio experience and tested them in the initial phase. This experience allowed us to steer our expectations and assumptions based on the materiality of the stage and the performer's body; the creation was, thus, more applied and more suited to the desired artistic situation. In addition, we identified the constructive or ineffective constraints of movement induced by interfaces from interaction observations made in the studio. Finally, they allowed us to consider the performer's action according to arising hypotheses about the interface and embodiment of the virtual system on the stage.

Through conversations and an interview with the performer, we noticed that the perception of co-creation was more present when the interaction was more straightforward, more transparent, and more responsive to the performer's actions. This impression might be explained by the stage layout, which was not very ergonomic or not very consistent with the idea of an exploratory and improvised creation with the virtual system. Indeed, we projected the image of the virtual ecosystem on a screen located behind the dancer. This setup generated confusion and conflict of attention linked to the sharing of focus between the bodily creation of the moment and the follow-up of the exploratory interaction with the virtual. For the performer, the dynamic lived between being a spectator of an interactive installation and that of a dancer who focuses on his presence and his expressive gesture on stage.

The shared attention between the real and virtual environments turned out to be unconstructive and, therefore, uncreative. This observation made us consider the possibility of spatializing the projection on the stage through the fabric of the performer's costume (**Fig 8**).

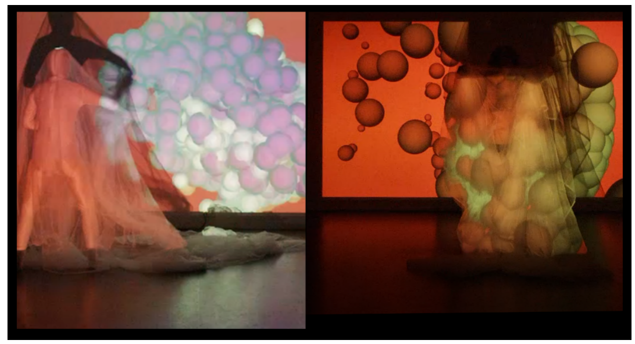

Figure 8. Experimentations with the projection of particle simulations over white and translucent fabric ported by the performer ©Isadora Teles de Castro e Costa, 2021

The first impressions of this ongoing test are already promising. They outline a path towards the resolution of the interaction problem by perceiving the scenography. This scenography attracts the performer's commitment to co-creation. We believe that the performer must perceive the virtual environment as a colleague and the interaction interface as a tool. These beliefs led us to the hypothesis of creating a *scenography character* incorporated into the scene as a situated and active element, mixing screen and interface. We believe that such a hypothesis is essential for co-creation as constructing an autonomous evolving virtual ecosystem. Moreover, if the virtual system is not perceived as autonomous or not at all, how can it be in creative dialogue with the performer?

Discussion

Our experimentation in the studio gave us clues to understand the conditions conducive to co-creation. We recognized three initial critical aspects of the scenic environment conception:

- the **scenography** (how the performer and the audience perceive the virtual)
- the **interface** (how the virtual perceives the "real")
- the programming of the virtual system (creation of the **behavior** of virtual entities and its **endogenous** and **exogenous** interaction modalities)

Given the prototype state of species and interfaces, the artist developer intervened to calibrate the interactions and test new relationships between the collected data and the parameters to improve the configurations of the virtual system. The INREV team studied the artist developer's presence as an **operator or mediator** of the relationship between the performer and the generative system. It represents a concept and a model in its own right within the co-creation dynamic between the participant and the interactive device. [21], [22] The sensitivity and perception of the mediator enter as a variable in the evolution of performance.

The concept of performance co-created between the mediator, the performer, and the generative system gives us indications on how to incorporate a virtual system on the stage. For example, can or should this type of hybrid scenography have a mediator? Can he participate in the performance while being on stage? Furthermore, we could use the operator's mediation on the perception of the performer's data by the virtual system to design an evaluation function (fitness function) aiming to characterize the adaptability of the virtual system and its species as part of the implementation of an evolutionary step by genetic algorithm.

The studio development experience allowed us to consider the performer's expectations and needs and helped us build an emotional bridge between him and the virtual system. Then, we added the **familiarization** with the functioning of the system step in the interaction experience plan. At this moment, the artist-developer explained to the performer how the system worked, how it was developed, his inspirations, and the links that united the simulations of artificial life and the digital art systems created on these principles. After this introduction, the performer was able to forge personal and informed links with the virtual and led the interactions based on his new knowledge. The learning and exploration phase have been shortened, and new clues for co-creation have emerged, which Edmonds calls the adaptation and **dialogue phase**. [5]

An influential performer's need was to perceive his influence on the rhythm of the particles. She felt that this influence existed at times and weakened at others. The moments when she rediscovered this interaction became moments of creative awakening, driving new gestures. This need expressed by the performer motivated the start of creating a shared **vocabulary**, mentioned in the **Results** section of this article, which served as a bridge between the programming of the virtual environment behavior and the scenic language of dance. This need manifested by experience suggested the idea of introducing parameters into the behavior of virtual entities that could be identified as the "rhythm" of the virtual by the performer. How can we identify rhythmic characteristics in the language of virtual autonomy simulations to make the interaction with the dancer more transparent and more constructive with a view to co-creation? Other concepts from the vocabularies of complex systems and performance modeling were exchanged, such as autonomy, incarnation, form, and flow. The possible **practical links between the performance domain and the simulation domain** through those concepts will be built and discussed during the subsequent studio experiments.

At the end of the first residency, we presented an excerpt from our experiments and received constructive **feedback** from the *Centre des Arts d'Enghien-les-Bains* and INREV teams. As spectators, they problematized the surface of the projection and how we staged this projection. We realized that the performer also perceived this problem during a team discussion. The new question could thus be formalized from the angle of the perceived virtual environment by the performer: how an interactive and behaving scenography can contribute to a better perception of the stage? How can it **encourage a dialogic/adaptive improvisation** on the performer's part, not only at the level of the interaction interfaces but also at the level of the projections?

This feedback was considered for the second round of studio experiments when we tested projections on fabric in space and the performer's costume. In addition, the new environmental spatialization tests have been promising and are in line with our goal of building **co-creation conditions**.

Conclusion and Perspectives

The goal of designing a scalable virtual ecosystem shifted to creating the virtual environment and building some form of onstage incarnation to support the performer's adaptive engagement. Our new research-creation hypothesis is to develop the evolving virtual environment so that its embodiment on stage allows spatialized perception and interactions with the performer. For example, suppose we want the scenography to be played, touched, and manipulated by the performer and be autonomous, acting and reacting to the stage environment. That assumes that it becomes an actor on stage. We call this outline a *scenography-characte*r. The dialogue will be established not only by the attention that the performer pays to the virtual environment projected on a screen or himself but also because in inhabiting the stage, the virtual induces constraints and the suggested possibilities, which are as many attempts to confront these two elements.

The expression of emotions was initially implemented by following a process of a metaphoric description. We tried to transcribe emotional sensation through virtual behavior from the point of view of the artist-developer. These descriptions changed during the studio experience thanks to observations and exchanging ideas with the performer in an improvised situation. The expression of emotions was co-created at the level of the initial programming of the virtual entities' behavior, within the limits of the emotion-behavior metaphor set up by the artist-developer. The scenography intends to express the alter-ego of the performer during an evolutionary transformation; its implementation will be our next work step. During the studio experience, we adapted the goals and methods of the virtual system and the interaction interfaces, considering:

- The limitations of the initial proposals through the materiality of the experience,
- the expressive needs and intentions of the performer/director,
- The discovery of the weak points and new potentials of the creation when it is situated.

The characteristics of the behavioral scenography described in the article make us think of a new way of interpreting its design. Our new hypothesis is to integrate this scenography conception with the *mise en scène* conception. The optimal place for this inventive step would be the experimentations in the studio in dialogue with the performer, in the form of a *scenography-character*.

Acknowledgments

This work benefited from the support of EUR ArTeC and the assistance of the French State generated by the National Research Agency under the future investment program bearing the reference ANR-17-EURE-0008.

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