Experience of a cloud-avatar: scientific challenges and artistic perspectives

N. DELPRAT [1,2], C. LEROUX [3], S. FDILI ALAOUI [2,4]

[1] Université Pierre et Marie Curie
4 place Jussieu, 75005 Paris, France

[2] LIMSI-CNRS
Laboratoire d'Informatique pour la Mécanique et les Sciences de l'Ingénieur, BP 133, 94235 Orsay, France
nathalie.delprat@limsi.fr

[3] Ecole Supérieure d'Informatique, Electronique, Automatique (ESIEA)
Laboratoire ARNUM, 9 rue Vésale, 75005 Paris, France
claire.leroux@esiea.fr

[4] IRCAM Centre Pompidou
Institut de Recherche et Coordination Acoustique/Musique,1 place Igor Stravinsky 75004 Paris
sarah.fdili.alaoui@ircam.fr

ABSTRACT. This paper presents the design and the implementation of an interactive simulation device for the virtual experience of an evanescent matter. The current prototype is based on a motion capture system and a particle generator for the graphics rendering. It allows for the investigation of various kinds of interactions with an avatar that represents in real time the user's body in the form of a cloud. Questions such as perceptual limits of body recognition and relationships between the avatar material properties and the user's action have been examined. The cognitive implications of this embodied virtual materiality provide many opportunities for creative work and research that will be discussed through an art-science approach.

KEYWORDS: interactive simulation, virtual materiality, body-space relationship, art-science approach, phenomenology, virtual arts

1. Introduction

The simulation of fluid flows (liquids or gases) and their interaction with surfaces remains a challenging issue in engineering applications (automotive design, turbomachinery, aeronautics...) as well in theoretical investigations (turbulence modeling, climate dynamics, flow instability...). Typically, flow simulations rely on the use of numerical methods to solve the complex equations that govern the fluid motion. Different computational techniques are available to simplify this task and to reduce the computational cost [Chung, 2002][Ferziger et al., 2002]. Hence, various kinds of real flow configurations can be studied in virtual experiments with the help of data visualizations and the quality of the simulation is usually evaluated on the basis of the best compromise in terms of physical accuracy, computing times and graphical rendering.

The adaptation of these techniques to computer graphics by Stam and collaborators allows for the simulation of gaseous-like phenomena in real-time applications [Stam, 1999] [Fedkiw et al., 2001]. These physical-based animations are of particular interest for the flow control when the fluid interacts with objects or is submitted to external variations [MacNamara et al., 2004]. Yet, they are computationally expensive and quite difficult to implement. In most computer graphics applications, the visual plausibility (appearance and animation) takes priority over the physical accuracy. In this case, simulations are intent on providing perceptually realistic renderings without parameterizing the physics driving the flow. As an example, cloud-like effects in interactive flight simulators or video games can be performed with models based on particle systems or cellular automaton combined with texture renderings [Harris and Lastra, 2001][Dobashi et al., 2000].

Since the development of interactive simulations and immersive systems, it has been possible to artificially transfer physical properties to an image and to interact with it through different sensorial modalities. In this user-centered context, the correlation between action and perception is essential to transform « virtual » stimuli into a corporeal experience making sense in the « real » space [Noë, 2004] [Sanchez et al., 2005]. Numerous installations in virtual arts and performance works in dance or theater have based their interactive visuals either on fluid dynamics models, mass and spring models or particle models [Dixon, 2007][Momemi et al., 2006]. Bringing physicality into virtual images allows for a kinesthesical experience of unusual perceptive contexts. For instance, one can investigate the intuitive control of virtual matters through the gestural manipulation of video textures [Wei et al., 2009][Jacquemin, 2008]. In most applications, it is possible to interfere with the matter, pass through it or disturb it. These interactions enable the user to *virtually explore* the physical response of the matter to his/her action. In the CLOU*D* project, we propose to explore an interaction of a different nature because the user *virtually becomes* the matter itself through the embodied experience of a cloud-avatar. Out of this virtual transformation emerge novel sensory feedbacks and emotional states that reveal new angles on the expressive potentiality of virtual images for artistic and scientific applications.

To design a cloud-avatar, a real-time simulation based on the motion capture of the user's body is performed and two kinds of clouds can be simulated with the help of a particle generator. According to the physical characteristics of the simulated matter, the avatar preserves a human form (cumulus-like cloud) or becomes a cloudy mass without any perceivable limits (stratus-like cloud). Various virtual modifications of the body density have been tested with respect to the matter properties and audio-visual effects have been added to the simulation. Another innovating aspect to the project is the investigation of interaction modes that are well-suited to the dynamic behavior of a cloud. In particular, we propose to conduct phenomenological studies on what we have called « contemplactions » (for contemplative interactions). The basic idea is to reverse the usual recognition process in virtual reality environments where action is required to virtually exist [Jeannerod, 2003]. In a diffusive medium, low movements are more adapted to maintain the cohesion between form and matter. In the same way, the effect of swift gestures needs time to be identified and meaningfully controlled. For instance with a stratus-avatar, the more you move, the less you know where you are.

The paper is organized as follows: the methodology and approach to this interdisciplinary creative/research project are briefly presented in section 2. Then, the general context of the cloud-avatar experience and its innovative aspects are outlined in section 3. Section 4 describes technical details of the current prototype and experimental findings of the on-going studies are reported in the next section. Finally, artistic perspectives on virtual materiality are further discussed in section 6.

2. Approach and methodology

The objective of the CLOU*D* project is the production of scientific results and artistic realizations, which in terms of end products are of importance for the project development. However, this aspect does not determine the way of conceiving the interaction between the artistic and scientific fields. One of the main challenge concerns the exploration of new territories that may be of help to the emergence of creativity through unexpected combinations. This calls for a collaborative research beyond the classical distinction between artistic viewpoint and scientific method and offers the opportunity to question the creative process in parallel with the implementation of the prototype. Such a kind of crossed construction usually leads to break or to rethink the conventional boundaries between art and science and characterizes what is called an artscience approach [Edwards, 2008][Delprat, 2009]. Due to this particular approach, the CLOU*D* project can be viewed as a catalyst for interdisciplinary investigation (Figure 1).

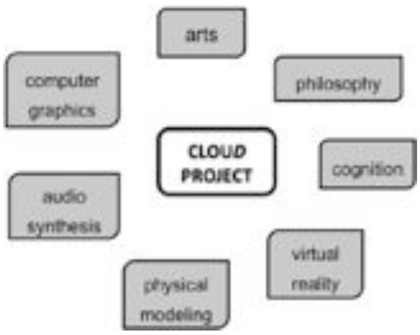

Figure 1. The CLOUD project as catalyst for discipline interaction

Within this context, the organizational and methodological aspects matter as much as the final result and have to be taken into account along with the project advancement. From the early design phase, several workshops were organized in 2010 bringing together people working in a broad spectrum of disciplines and promoting exchanges of ideas on various research themes (from virtual reality to cognitive sciences or art history). These meetings in the form of seminars and informal discussions allowed us to better characterize some features of the current prototype and to refine the concept of cloud-avatar, thanks to the fruitful contributions of all participants. Moreover, they enabled us to plan the main stages of the research project that are: prototype development (2010-11), scientific investigations (2011-12) and artistic realizations (2012-13). Note also that since the beginning, a « logbook » of the project has been done with a systematic video-recording of the seminars and working sessions. It allows for keeping track of the creative/research process and for documenting the work in progress, both from the technical and conceptual viewpoints[1].

3. Context and viewpoint

Due to its original approach, the CLOU*D* project provides many opportunities to think about and experiment new mediations between interaction, perception and action. Adapting ideas and techniques from several research fields, it enables the development of an innovative tool for the virtual exploration of a matter under a fresh perspective. In order to better define the technical and conceptual challenges under consideration, we propose to begin with a brief description of the scientific context and previous related works in artistic performances.

3.1. Interactive digital media

The developed CLOU*D* prototype typically falls under the broad category of interactive simulation devices designed to mediate between visual and audio renderings and the user's gestures. Such responsive virtual environments can be labeled by different terms depending on the degree of merging between the real and the simulated worlds, the sensation of immersion and the realism of the virtual images [Milgram et al., 1994]. Thus, in Virtual Reality (VR) the user is completely immersed inside a synthetic environment. In contrast, in Augmented Reality (AR), he/she can see the real world with virtual objects superimposed upon or composited with the real world. Therefore, AR can be viewed as a variation of VR that supplements reality rather than completely replaces it [Azuma, 1995].

The CLOU*D* installation offers a virtual environment for experiencing a matter and creating performances where a cloud-avatar interacts with the user. Basically, this kind of performance is called a « digital performance » that is to say « *a performance work where computer technologies play a key role rather than a subsidiary one in content, techniques, aesthetics, or delivery forms* » [Dixon, 2007]. Actually, one can name the user's performance while interacting with the virtual cloud an « Augmented Performance » by analogy with the term « Augmented Reality ». Firstly, it is a performance where the real (the user body) and the virtual components (the cloud simulation) « *imbricate to converge to a complete scenography* » [Jacquemin et al., 2008]. Secondly, it is a performance where the virtual cloud « *augments the expressive range of possibilities for performers and stretches the grammar of the traditional arts rather than suggesting ways and contexts to replace the embodied performer with a virtual one* » [Sparacino et al., 2000]. The literature have witnessed multitude of augmented performances. Pioneering works include those of the E.A.T (Experiment in Art and Technology) group formed by artists such as Robert Rauschenberg, John Cage, Steve Paxton and Lucinda Childs as well as engineers and scientists from the Bell Laboratories. They both collaborated and experimented with technological systems such as television projection, wireless sound transmission, infrared television camera or Doppler sonar (*9 Evenings*, 1966). Later on, a great number of digital performances used advanced computer technologies to allow for body interaction with electronic and digital media. For example, Krueger et al. [Krueger et al., 1985] or Rokeby [Rokeby, 1995] contributed on the emergence of interactive installations centered on body motion i.e. works where motion-sensing systems were used to control or interact with sounds and visuals.

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[1] videos are available on http://vida.limsi.fr/doku.php?id=wiki:projet_nuage_fr

3.2. Data mapping and gestural control

In real-time interactive simulation systems, the data mapping that is to say the link between the user's action and the generated representation, is a key point for a clear and convincing dialog with the digital medium. The constant increase of gesturally-controlled digital *instruments* based on sound or graphical synthesis has required various design strategies for the mapping of the different sensing modalities with respect to a certain coherency**.** For sound and image mapping, most existing works are designed either as sound to image, image to sound or image and sound parallel generation.

Sound to image or image to sound mappings are relationships where either audio analysis provides control information for the image synthesis parameters or *vice versa*. The work of Momeni and Henry [Momeni et al., 2006] provides an interesting approach for image and sound parallel generation that is motivated by a desire of creating an expressive musical and visual instrument. Their mapping strategies involve an independent layer of algorithms with time-varying physical behavior that is affected, explored, or observed with gestures or controllers. Among pioneering performances presenting an immersive installation where the user's gesture controls the spatialized sound environment and visuals, we can refer to the performance of Levin, Lieberman, Blonk, and La Barbara, *Messa di Voce* (2003), Mark Domino's *Silk Road Project* (2004), Baboni-Schilingi's installation *Crossborder* (2007) or Jodlowski's installation, *Grain Stick* (2010).

In a more theoretical perspective, Wanderley and collaborators [Wanderley et al., 2004] reported a review of gestural control of sound synthesis in the context of the design and evaluation of digital musical instruments that can be extended to the gestural control of visuals as well. They assumed that this study is *« a highly specialized branch of HCI (Human Computer Interaction) involving the simultaneous control of multiple parameters* ». They refer to Hunt and Kirk's work in which various attributes of real-time multi-parametric control systems are considered [Hunt et al., 2000]. These attributes are highly relevant to the gesture control strategies elaborated for the CLOU*D* prototype. For instance, there is no fixed ordering to the human-computer dialogue and further practice develops increased control intimacy and, thus, competence of operation.

3.3. Physicality and embodied virtual materiality

Many art and science works propose to add physicality into the virtual component of a performance or an installation by using physical models. The most popular physical models used for sound and graphical synthesis are Mass and Spring Systems (MSS) [Cadoz et al., 1993][Momeni et al., 2006][Jaquemin et al., 2008]. For instance, Henry developed a library on Pure Data and Max-MSP called PMPD that allows for sound and graphical simultaneous synthesis using MSS [Momeni et al., 2006]. He deployed MSS for his visual and musical performances by modeling a quite simple data structure with few masses and interactions that create simultaneously music and graphical feedback. Recent technical improvements in visual synthesis provide more complex data structures by using General Purpose Computing on Graphics Processing Units (GPGPU), which handles computation only for computer graphics, to perform computation in applications traditionally handled by the CPU. These rich and complex data structures, that allow for a modeling with a great number of masses and spring, enables « *rich graphical effects and makes the users or spectators feel like manipulating extensible organic matter* » [Jacquemin, 2008]. Complex fluid dynamics models have also been used for visual interactions within art works. Among them, the device *Calligraphic video* developed by Wei et al. offers graphical visuals based on Laplace heat equation, Navier Stokes equations for turbulent fluids or physical material simulation models such as Guinzburg-Landau equation for magnetic domains [Wei et al., 2009].

The range of physicality covers by physical modeling enables the intuitive understanding of the control relationship between the user and the simulation system. This understanding is based on every-day corporeal experiences and practical knowledge of the underlying mechanisms associated to physical objects or phenomena. For instance, virtual musical instruments [Cadoz et al., 2000][Arfib et al., 2005] can be manipulated in a physically plausible way that enhances the sensation of *playing* with the digital medium. Novel interaction modes can also be tested to augment the user's body. Thus, the Vocal Augmentation and Manipulation Prothesis (VAMP) allows a singer to gesturally control his/her voice with the help of a sensor glove [Jessop, 2009]. In the performance work *Messa di Voce*, the performers' voices are transformed into animated graphics that can be gesture-manipulated [Levin et al., 2004]. Voice visualization through computer generated graphics or voice embodiment through gestural control provide different ways to virtually explore a sound « materialization », perceived as an extension of the user's body. In the CLOU*D* project, the user's gesture controls a virtual matter that represents at the same time his/her body. One of its distinctive characteristics from related works is that the matter properties have a significant impact on the user's behavior and that the persons perceive themselves as an extension of the matter. Thus, the virtual experience of the matter brings out new perspectives on the body-space relationships and participates in the « *production of new affects - or better new affective relations - that virtualize contracted habits and rhythms of the body* » [Hansen, 2004].

4. CLOU*D* prototype

The first step in the design of gesture-based digital interfaces is to implement systems for capturing the user's movements and identifying them. The analysis of the gesture characteristics allows for developing mappings between the acquired data and the real-time visual or sonic renderings. The second step concerns the choice of an efficient and controllable simulator for the output data. In the CLOU*D* project, the central challenge is to provide a dynamic representation - *the cloud-avatar* - that relies on the capture of the user's body and whose rendering is time-varying with respect to the physical properties of the simulated matter. In its current form[2], the prototype is based on real-time technologies that are commonly used for augmented performances. As discussed in the following, its novelty does not lie in its technical elements but rather in its technical potential to explore unusual sensibilities through digital media.

4.1. Motion capture and graphical rendering

There exists a wide variety of devices for reliably capturing the motion of a person. The most common systems are based on infrared cameras such as the Kinect. They present specific advantages depending on the context of use and on the developed applications. Thus, three-dimensional systems like Optitrack or Vicon [Qian et al., 2004] allow for accurate body tracking while motion sensors, such as accelerometers or gyroscopes in WII modules, are well-suited for the tracking of fast movements performed by a specific body part [Belivacqua

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[2] CLOU*D*_M1 developed in 2010 with the help of Julien Pousse and Quentin Vidal (student engineers, ESIEA)

et al., 2007]. For the CLOU*D* prototype, an Optitrack motion capture system composed of twelve circular cameras is used to track the user's motion. The calibration of the cameras is performed with the help of the Optitrack Arena software. This software locates thirty-four reflective markers dispatched on the user's body (Figure 2). It creates the user's skeleton in space and sends the marker 3D positions via its communication protocol NatNet (Figure 3).

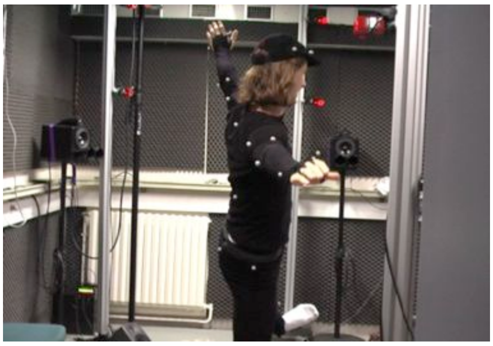

Figure 2. CLOUD system installation at LIMSI

We used OSC (Open Sound Control) protocol to transmit in real-time the position information from Optitrack to a gesture analysis Max-MSP patch and a gesture synthesis C++/OpenGL program. The graphical feedback has been performed using the OpenGL library and an open source particle generator (SPARK), which provides a realistic rendering of fire, rain or smoke. This particle generator has been adapted to simulate a cloud-like matter by adding cloud transmitters. Let us recall that Max-MSP is a visual programming language for music and multimedia developed and maintained by the software company Cycling 74[3]. Max-MSP represents the most common software tool used by the artistic and scientific communities engaged in digital and creative works. Thus, this software environment is deeply integrated and designed for academic or artistic programs that are concerned with interactive/new media works. For this reason, the interdisciplinary CLOU*D* project has anchored its interactive interface into the development mode of Max-MSP.

Figure 3. Skeleton extraction

[3] http://cycling74.com/whatismax/

4.2. *Cloud simulation parameters*

The classification of real clouds is quite complex with more than ten categories (genera) that can be further subdivided into species and varieties [Petror-Pinney, 2006]. The cumulus and stratus types, that exhibit noticeable differences in their physical appearance and properties, have been simulated at first. With the particle generator, the compactness of the cloud can be changed through the modification of the particle density distribution. Moreover the action-reaction delay can be controlled through the value of the particle flow emission. Hence, two pre-set kinds of clouds have been developed. They provide the real-time rendering of a virtual cumulus and a virtual stratus (Figure 4). For the cumulus-like simulation, the particle life time and size are chosen such that the resulting avatar always appears in the form of several small clouds attached to the user's body. Conversely, in the stratus-like simulation, there is mainly one dispersed cloud (continuous matter such as fog). The Max-MSP patch maps in real time the gesture data with the rendering parameters. This mapping allows for an interaction between the user's gesture and the cloud feedback. Additionally, a direct modification of the simulation parameters can be done via the Max-MSP interface. Thus, the lifetime of each transmitter, the size and color of the particles can be changed in the general flow or modified for one transmitter only. The activation or deactivation of each transmitter is also proposed, providing partial changes in the avatar appearance.

Figure 4. Cloud-avatars : cumulus-type (left) and stratus-type (right)

5. Virtual experiments with a cloud-avatar

The ability to perceptually experience an imaginary process is one of the most radical changes caused by virtual reality systems. For instance, it is now possible to virtually act in a so-called *thought experiment,* that is to say an experiment conducted within imagination to explore potential implications of an assumption [Brown, 1993]. The project described in the paper aims to study such an exploration through the question « *what would happen if my body had the density of a cloud?* ». The purpose here is not to escape from reality to move into the realm of fantasy through a sense of disembodiment. On the contrary, the focus is on our capacity to perceive and internalize new corporeal sensations and new body-space relationships. Although virtual, the body modification relies on the properties of a real matter whose simulation has to be convincing in order to make sense of this *new way of being*.

5.1. Matter density and bodily limits

In much games or interactive experiences, the visual appearance of the user's avatar and its behavior are inspired by the human anatomy and motion. Generally, the representation of the avatar is based on a mechanical description of the human skeleton and a dynamical or geometrical interpretation of its movements [Pina et al., 2000] [Ventrella J., 2011]. When the motion data are captured in real-time, the avatar is created from the generation of the user's body skeleton or the extraction of the user's body external shape. In the CLOU*D* project, the avatar is neither intended to preserve a human form nor to exactly mirror the user's movements. Its form depends on the physical characteristics of the simulated matter and varies with respect to the speed of the user's motion or the existence of « external » perturbations. Hence, the cloud-avatar enables the exploration of a broad range of representations, from transformations in which the body is clearly discernable to *non-anthropomorphic* images where the loss of bodily references is significant[4].

Among the tested renderings of compact clouds, we have more particularly experimented what we have called the « excited-cumulus » (Figure 5). It represents a middle state between highly evanescent matter with high reactivity and very dense matter with strong inertness. In this case, the cloud-avatar mimics both the human appearance and behavior. The user can play with his/her new bodily density and try to adjust his/her gestures with respect to the fluidity of the simulated matter. Here, the usual relationships between body and space are not fundamentally modified and the virtual body limits remain always discernable. On the one hand, the cognitive feedback of this gestural exploration is close to the one reported for intuitive manipulation of virtual textures [Wei et al., 2009] On the other hand, the cloud-avatar allows for an inner sensation of the matter that is unique to its mapping with the user's body. For instance, when the particle lifetime is short, the cloud-avatar responds to the user's gestures with a strong reactivity. Thus, the user is intent on moving faster and has the feeling of being « inwardly » excited.

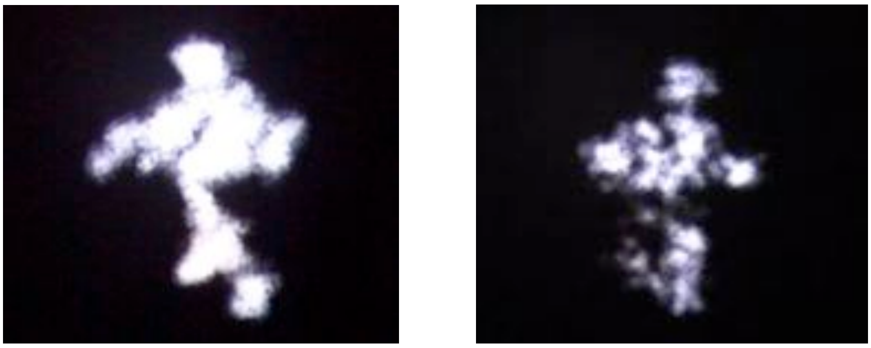

Figure 5. Excited-cumulus with different densities

[4] videos are available on: http://vida.limsi.fr/doku.php?id=wiki:projet_nuage_fr

5.2. Inner space/outer space

The matter appropriateness is more difficult with a stratus-like cloud because the reliance on the diffusive properties of the cloud constrains the movements of the user. In a continuous medium, the matter smoothes out the form and slow movements are required to interact with the avatar. Moreover, when the particle time life is long, the user must remain immobile in order to recover his/her avatar in its original « human » form. Hence, without a particular attention on the gesture effects, the recognition of the body is lost very quickly. The dissolution between the cloud-avatar and the space enhances the sensation of immersion into the matter but the user's ability to perceive his/her influence on the cloud is reduced. The same sensory feedback can be investigated with an interactive zoom effect that allows for a variable vision scaling according to the user distance from the screen. This automatic adjustment enables the user to explore the cognitive limit beyond which the intimate connection [Fels, 2000] with the cloud-avatar is lost (Figure 6).

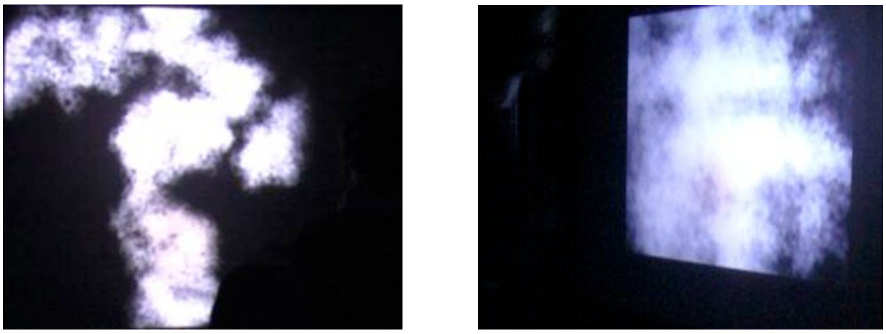

Figure 6. Zoom-effect on a cumulus-avatar (left) and a stratus-avatar (right)

Another kind of body-space relationship can be experienced through the addition of gravity in each space direction, via the Max-MSP interface. When applied to the vertical velocity component, gravity effect generates a smoke rendering whereas on the x and y-axes, a wind-effect is perceived. In this case, the particle dispersion provides a simple way to fill the space with the evanescent matter with respect to the user's movements. This allows for more complex interactions with the cloud-avatar that expands in the space and whose form is altered by the perturbation (Figure 7). A wind-like sound can be added to the simulation and combined to these effects. Its control (sound intensity and frequency) is performed with the user's hands. As expected, the addition of the audio modality partly changes the experimentation, reinforcing the sensation of dispersion and lightness.

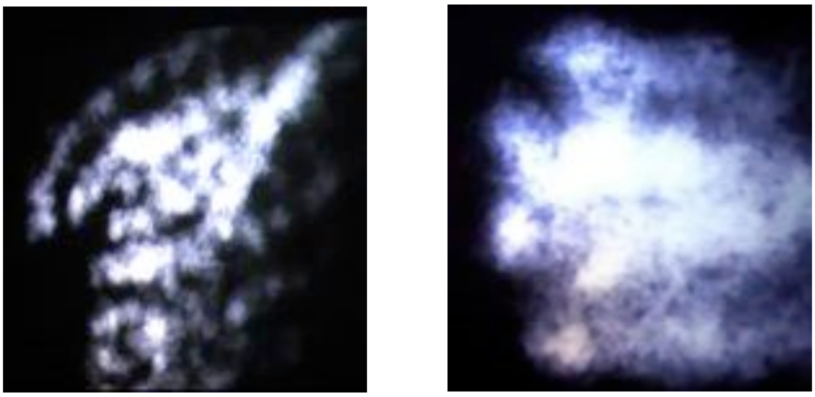

Figure 7. Wind-effect on a cumulus-avatar (left) and a stratus-avatar (right)

5.3. Cloudy gesture

Abstract forms of the user's body can be investigated when some transmitters are deactivated. As expected, the incomplete representation of the cloud-avatar is more confusing even though the body parts are still identifiable. Moreover, it makes the user feels like moving into the matter rather than being the matter itself (Figure 8). To reinforce the link with the partial cloud-avatar, one may choose to map the quantity of motion of the user with the cloud gravity. This has been done in a specific CLOU*D* application where a dancer can generate a cloud and interacts with it. The Max-MSP interface receives the markers positions and processes the gesture analysis by computing gesture descriptors related to dance movement characteristics. These descriptors are meant to be mapped to the virtual cloud input parameters. When the dancer moves in one direction with sufficient energy, the cloud reacts to the energy supplied by the performer and has more « weight » according to this direction. The quantity of motion being the amount of detected motion in time, it is perceived in dance as the energy of the performer's movement. Other descriptors such as the extension of the body can be mapped to the cloud density and color [Volpe, 2003].

Figure 8. Partial cloud-avatar (left) and cloud generation related to the energy of the dancer's movement (right)

5.4. Perceptual ambiguity

The significant impact of the virtual matter on the user behavior is of great interest for several reasons. First of all, the cloud-avatar is never perceived as a mirror-image because it has its own physical properties that the user has to take into account to interact with. Thus, the experience of a stratus-avatar makes the user slow down his/her gestures and sometimes, makes him/her inactive to take back control of the cloud (Figure 9). This unusual behavior may destabilize persons who are accustomed to usual VR environments. It enables to direct the user's attention to his/her own body and to enhance the user's sense of presence and immersion, even though the avatar represents a cloudy mass [Novak et al., 2003]. With CLOU*D*, the perceptual ambiguity does not originate from a loss of spatial references but is mainly based on the experience of an in-between state: the awareness of presence through the cloud response and the sensation of disembodiment through its dispersion.

This ambiguity offers the user to virtually experience an « intermediate » imaginary state - between perception and imagination - that is specific to the virtual dimension. Such a contemplative interaction, that we have named « *contemplaction* », is an illustration of the image adjustment to imagination defined by the philosopher Lambert Wiesing in order to characterize the new imagination faculty related to virtual images [Wiesing, 2010]. It is consistent with the description of the « (...) *slow imaginary deformation that imagination* *procures to perceptions* », described by the french philosopher Gaston Bachelard in his work on material and dynamic imagination, that was the starting point for the CLOU*D* project [Bachelard, 1943]. This aspect as well as the unusual interactions experienced with cloud-avatars are worthy of further consideration, in particular in the context of psychological theory and comportemental studies [Card et al., 1983].

Figure 9. Stratus « contemplaction »

6. Perspective on Virtual Arts

In most cultures, clouds symbolize imagination, thoughts that drift for a while hanging in the air. Clouds take on as many forms as the forces that animate their mass and particles. Since they reflect light, shape and colour can be perceived. Their shape mainly results from the cloud type while their visual appearance depends on their density. Another parameter involved in the perception of shape is distance. It must be sufficient so as to be able to distinguish the contours of the cloud. Therefore, shape in terms of contour, texture and colour is visible only from an external point of view. If the cloud is seen, it is also felt and experienced in different ways according to the person's past experience, beliefs or culture. It brings back memories, announces a catastrophe or, on the other hand, life-saving rain. Nowadays in an urban context, it is mainly perceived negatively, obscuring the blessed sun, depriving us of its rays and the colours that surround us. Here, it is no longer the cloud shape but its density that is perceived. We thus become aware that its parts differ from its whole[5] from its global form as put forward in Gestalt theory [Guillaume, 1937].

From the beginning, the CLOU*D* project was intended on providing a platform for artistic creations - visual arts, performance, performing arts, total art... For this purpose, we planned a final version of the prototype that would be as configurable as possible, regarding the types of cloud, density, persistence of mass, shape, color, particle models, response time, gravity, sound... The more malleable the prototype will be, the greater the area of freedom for the artists. We are particularly interested in the types of interactions at work in immersive installations of virtual art. In the following, we briefly present some previous works that explored in different manners the relationships between body and virtual materiality.

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[5] A well known maxim involved by [Stengers, 2008] « *The whole being more than the sum of the parts* »

6.1 Stimulating-type interaction

In *Videoplace* [Popper, 2007], Myron Krueger created a graphically-generated desert world in which full-body participants could superimpose the silhouettes that their movements left on the screen (1974 version). It was absolutely new in arts and was one of the pioneering experiments in virtual reality that he called « artificial reality » as of 1973. One of the applications was particularly interesting: it was possible to draw with one's body and superimpose one's traces until saturation of the screen (Figure 10). We qualify this as a stimulating-type interaction because it leads to the increase in movements of the participants, up to gesticulation. More recently, a similar installation of Mehmet Akten *Body Paint*[6] has been very popular, mainly because the link created between cyberspace and the user is immediate. But disinterest comes along with the depletion of resources (full screen, a series of gestures made, visual renderings exhausted). For this kind of interaction, the only way to prolong the user's interest is to integrate it into a live performance, or to change the nature of the interaction into something else, as we do in the CLOU*D* project.

Figure 10. Videoplace (1974) - Myron Krueger

6.2 Passing-type interaction

Besides generating forms, the participants may erase them or disperse them according to their movements. In the ground projection *Cloud tamer* from Florent Trochel[7], moving in one direction creates clouds and in another, disperses them (Figure 11). When the passer stops, more and more particles are generated. During the day, the installation is almost unnoticeable due to the surrounding light and the density of the motion swiftness. At nightfall, it reveals itself when the motions slow down and the clouds in the sky disappear in the darkness. Visually, this installation is close to our project but it is only a part of an architectural element and thus inessential. It lives without the benefit of those who activate it. In the CLOU*D* project, we want to engage the user in a very deliberate behavior. Moreover, the clouds are simulated in real time whereas there are filmed sequences in *Cloud tamer*.

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[6] http://www.msavisuals.com/body_paint
[7] http://www.lesiteducube.com/atelier/article.php3?id_article=15

Figure 11. Cloud tamer (2005) - Florent Trochel

6.3 Play-type interaction

Most installations in virtual arts operate on a virtual playful relationship for experimenting: at least, one must want to try. Some installations rather focus on the investigation on the relationships between the user and the virtual environment, like the works of artists such as Catherine Ikam, Eduardo Kac, Maurice Benayoun, Luc Courchesne, Kenneth Rinaldo... For instance, in *Uzume* by Petra Gemeinboeck (Figure 12), the user facing a screen plays with an abstract form made of chaotic curves, that does not really respond to his/her solicitations as described by the artist: « *Rather than simulating a world-like scenario, the environment constitutes a situation of encounter in which there are neither specific rules to guide the participant's interaction with the unruly surroundings, nor any pre-designed roles for the participant to inhabit. The relationship between the participant and the system develops through surprising, ambiguous interplay*. » [Gemeinboeck 2004]. It is quite different within CLOU*D*, because the user knows the properties of the virtual matter and has an intuitive understanding of the cloud response.

Figure 12. Uzume (2004) - Petra Gemeinboeck

6.4 Contemplative-type interaction

We are mainly interested by the matter itself and we try to perceive it in a new way. Fifteen years ago yet, the artist Char Davies explored this direction in her piece of virtual reality *Osmose: subterranean Earth* [Davies, 1996]. On the one hand, she wanted to enlarge the perception of visitors [Nov'Art, 1997]. On the other hand, she made people live a new journey experience. Two kinds of interface allowed this experience: a head-mounted display and a motion-tracking vest that goes along with the motions of breathing. Its breadth leads the observer into images and created worlds by the artist. She explained: « *We wanted Osmose to be a solitary, intimate experience, one in which connection is made to the "depths" of one's own self, not to other people*. » [Davies, 1996]. It is this same original attitude of « contemplaction » that we have experimented. However, within CLOU*D*, the world is not closed, there is no narration; only maybe a way to lead the observer - step by step - into the blurred and abstract world of his/her cloud-avatar.

7. Conclusion

The CLOU*D* project concerns a cross-disciplinary research on virtual materiality. It addresses various technical and conceptual issues on the embodied exploration of an evanescent matter though the design of a cloud-avatar. The prototype described in the paper allows for experiencing virtual changes in the body density with the help of a motion capture system and a cloud simulation. Thanks to the control of few parameters of a particle generator and the mapping between the user's gestures and the cloud rendering, two kinds of cloud-avatars can be simulated: the cumulus-avatar and the stratus-avatar. Combining density, gravity and zoom effects, a wide range of different avatar forms can be tested. Due to their « material » properties, many variations can occur in their interactive response to the user's action, affording a great deal of freedom for expressive and creative performances.

A qualitative evaluation of the cognitive impact of the cloud-avatar on the body-space relationships has already shown specific correlations between the matter characteristics and the user's behavior. For instance, the adjustment of the gesture speed according to the matter density is clearly observed. Furthermore, the degree of controllability of the avatar appears to be highly related to the cloud type. Thus for the stratus-avatar, the user has to share control of the performance with his/her avatar to remain engaged with it. This mutual influence leads to a conversational mode of interaction [Johnston, 2008] in which contemplative action or immobility is the most appropriate stance to meaningfully communicate with the cloud.

Virtual experimentations with a cloud-avatar allows for an intuitive awareness of matter that reveals some aspects of the user's individuality and emotional states through the body language. They trigger perceptual paradoxes or propose new cognitive contexts with no point of reference in the real world. Lastly, they provide new relationships between imagination and perception, enabling us to virtually experiment the cloud-matter in an imaginary space. These investigations have to be pursued with further experimental studies in cognitive sciences and will be complemented with artistic realizations. For that purpose, the current prototype is being enriched by new audio and visual interactions. We are also interested in increasing the autonomy of the cloud-avatar by changing its physical properties over time and we have planned to test different models for the cloud simulation. Once developed, we hope that the CLOU*D* system will be a stimulating tool for art-science collaborations and will support innovating explorations in the field of virtual materiality.

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