Being There & Being With: The Philosophical and Cognitive Notions of Presence and Embodiment in Virtual Instruments

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ABSTRACT

In this paper, we will discuss two main concepts, associated with the development of Virtual Worlds, which are "Presence" and "Embodiment". Presence is stamped as the sense of "Being there", that has to be reconstructed in Local world to render Distant Worlds accessible by networked or mediated communications. "Embodiment" could be the property of a Virtual entity to be incorporated by human as a second nature. We will show then, how (1) the first situation can be seen as a definition of "immateriality" and its correlative concept of infinity, (2) the second situation can be seen as a definition of "tangibility" with its correlative concept of instrumental embodiment. After exploring the complementary properties of these situations in detail, we will focus on the second one, identified as "the instrumental situation". We will propose some of its relevant properties, those that are able to trigger the sense of embodiment, as the main property supported in the real physical world by the feature of "tangibility". Consequently, we estimate that "embodiment" is more important than the tangibility in itself and we examine some criteria able to help us to recreate them in digital representations.

1. HUMAN-WORLD FUNCTIONNAL RELATIONSHIPS

Let start with a rough look at the diversity of the tasks humans can perform when they interact sensorially, cognitively and physically with the real world. We may observe that they could be represented along an axis putting the emphasis on two complementary situations (Figure 1):

- The immersive situation, in which humans are at the center of a surrounding world, such as when we are exploring large landscapes, mainly through exteroceptive sensory channels such as vision and audition, (Figure 1 on the left of the horizontal axis)
- The vis-à-vis situation in which humans are interacting with a vis-à-vis objects, in hand, supported by physical contacts and interactions through the proprio-tactilo-kinesthetic sensory-motor modality, such as haptic, tactile and gestural interactions (Figure 1 on the right of the horizontal axis).

The path from the first to the second (and vice-versa), that is a usual daily experience, is not so trivial to analyze and implies deep transformations in the cognitive human-world relationship.

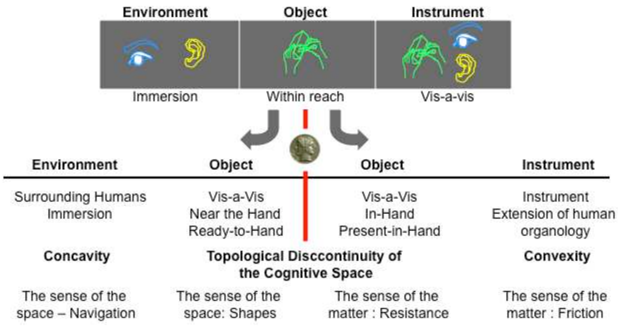

Figure 1. From Immersive to the embodied instrument: a bilateral complex cognitive process.

We propose first an exercise that consists in a course along this path from the left side to the right side in order to bring out some relevant features of the complexity of the cognitive processes going from the sense of "being there" to the sense of "being with", and vice-versa.

1.1 Being there ?

On the left part of the scale axis, the concept of immersive environments (Figure 2), is placed, based on large spatial spaces in which spatial properties are essential: sizes, scales, large free body motion, etc. leading to body oriented VR platforms. The main task characterizing such situations are environment exploration, including localization, navigation, path finding.

The aim is to be able to perform the task of exploration of a "landscape" as well as possible, as immersed within them (landscape, cities, houses, other bodies). The basic principles are: free motion as much as possible (position changing) in a 3D space, no occlusion for these free motion and the perceived results, free focus of observation (scale changing), knowing where we are (self localization). The concerned perceptual channels are visual and/or acoustical via 3D sounds.

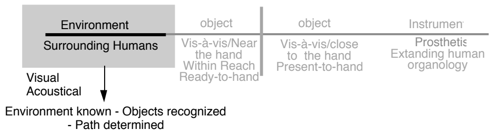

Figure 2. Immersive situation: environment as surrounding humans and exteroceptive exploration tasks

1.2 Being with ?

On the extreme right of the scale (Figure 3), the vis-à-vis object is now close in hand or "present-to-hand" and its exploration allows to extract other features such as rigidity, fluentness, weight, which are more physical than geometrical properties. Objet recognition and identification of physical features is performed by means of physical manipulation, such as squeezing, stretching, hitting, etc. and proprioceptive and kinesthesic sensory modalities.

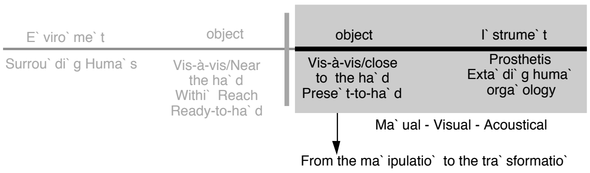

Figure 3. Physically-oriented manipulation task

We reach the concept of intimate instrumentality. Here, the focus is put on the physical manipulation of objects. Physical means that what it is expected is based on the physical behaviors of objects; vibrations, deformations, sticking, fractures, resistance to the displacements, dynamics of collisions and of hitting, cohesions, ways of deformations (elastic, plastic, etc.). This type of task corresponds to "ergotic[1] tasks" in Cadoz's typology [1], in which there is an energetic exchange between the humans who act on an object (directly or via an intermediate physical organ), which is significant as well as for the performance task than for its results.

1.3 The fuzzy figure of the notion of "object"

This imaginary course along a scale axis allows to identify two sides separated by a cognitive frontier. Onto this frontier (Figure 4), the fuzzy notion of "vis-à-vis object" is being cognitively negotiated, as it is, like the Janus, either looking on the left, toward "immersion" and "surrounding environment", or on the right, toward "instrumental situation". We identify this frontier really as a cognitive gap.

[1] Do not confuse "ergotic" and "ergodic". "Ergotic" is a term coined by C. Cadoz to name a type of interaction functionality on which physical energy ("erg" is an unity of energy). In gestural interaction between a human and an object, this function integrates the haptic (or gestural) perception and the physical (or gestural) action.

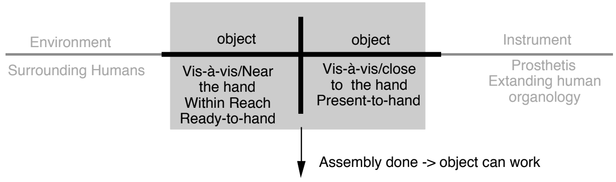

Figure 4. The fuzzy state of vis-à-vis object: the transition from "near-in-hand" to "present-in-hand" via "ready-to-hand"

On the left of this frontier, the notion of "object" starts to be cognitively constructed, not as a part of the environment but as it is considered near the body, "ready-to-hand". The size of the possibly manipulated thing is smaller than the environment, near to the size of the hand or a part of the body. Relatively to the human body, it plays the role of a "vis-à-vis". In that situation, the relevant main task is to recognize or identify the spatial and topological features. Such exploration is performed through spatial actions (positioning) and exteroceptive sensory channels (vision). On the right of the frontier, once the position of vis-à-vis established, the object exploration and recognition of the surface state (rugosity, micro shapes, sharp edges, etc.) is taking over from "in hand situation" by manipulation such as palpating, brushing, skimming, etc., and by tactile sensory channels

During a brief instant, "object" could be either a part of the surrounding environment just be near the hand (or near the body) –said "ready to hand" – or "an object in hand", prelude of an instrumental situation.

The transition between the both sides of the frontier is the location of a task discontinuity that is the selection task (Figure 5).

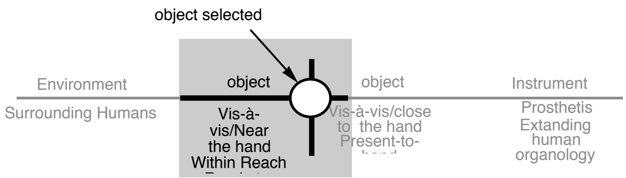

Figure 5. The selection task

The transformations consists in – at least – for the human, to become an instrumentalist when object in hand, and symmetrically, for the object, to become an instrument. We see that both transformations – of the human and of the object - are correlated, simultaneous and non separable. The human remains instrumentalist as long as the object remains an instrument and vice-versa. The reverse transformation occurs when the object being unhanded comes back to a part of the environment and the instrumentalist comes back to a human performing other tasks.

1.4 Three criteria for featuring the "immersive/Vis-à-vis" transformation

The reversible transformation that occurs when crossing the "immersive / vis-à-vis" frontier, separate spaces of very different nature. Here are three criteria that allow to distinguish between these both sides:

1. In the immersive space – the human-centered philosophy - the human-world relationship is an overview rela-

tionship, insisting on the extensiveness – we can say the infinity – of the space. Spatial properties are essential: sizes, scales, large body motion, etc.
2. In the instrumental space, the human-objet relationship is centered, neither on the human nor in the object but more at the place (the frontier) of their physical coupling, insisting more on the "intensiveness" of the energetic coupling Temporal properties are essential: frequencies bandwidth, reaction delay, etc.
3. The duality of both situations is also traced by another duality, we called "the concave/convex transformation". It consists in the fact that: (1) in immersive one, the environment surrounding humans and that containing things appears as concave to the human; (2) conversely, when things become as a vis-à-vis and ready-to-hand, they appear as convex. And then, we want to use hands to explore the non seen parts, either by tactile or by rotating the object which is in front of us.

We will show then, how (1) the first situation can be seen as a definition of "immateriality" and its correlative concept of infinity, (2) the second situation can be seen as a definition of "tangibility" with its correlative concept of instrumental embodiment.

2. THE COMPLEXITY OF THE TRANSFORMATION FROM AN OBJECT TO AN INSTRUMENT

We will now discuss the main characteristics of both situations, focusing more on the instrumental situation, with the aim of being able to reconstruct it within the field of computerized tools.

The intimate relation between human and object during the performance of an instrumental task (i.e. a task performed by means of an instrumental human-world relationship as defined before) leads to the emergence of cognitive features such as those of the embodiment process or of considering the instrument as a second nature [2]. Indeed, the process articulates the following stages: (1) seeing or hearing an object, distant in space and thus constituting a part of the environment, (2) choosing it, (3) touching it and grasping it, (4) manipulating it and (5) using and playing it in the performance of the task, and this process is everything but trivial. In that process, the object is progressively transformed in an instrument, so being a part of the human body ("*his second nature*") and the human is progressively transformed in an instrumentalist, so being a part of the instrument *("its human nature")*. All along the playing of the instrument by his instrumentalist, the instrument became his own. Because the instrument is intrinsically a physical external object, the human being has always and at each time the capability to leave instantaneously the instrumental state and to render the instrument to its status of a trivial physical object of the environment. Alternately, the instrument plays as a temporary extension of the human organology and as a part of the external environment. Thus, it is a locus on which some complex cognitive processes can take place. The symmetric process, strictly correlative to the embodiment process here, and permitted by principle by the status of external object, is the disembodiment process.

So, the mutation process of an object into instrument (and of the human into an instrumentalist) is the support – as well as the material representation – of the dual cognitive processes of embodiment and disembodiment, the first one stressing his integration within the world and the second one, maintaining his individuality. The precise point and instant during which the object becomes in physical contact with the human body is then of an existentialistic critical point. First, it is no less than the point in which the human cognitively creates the notion of the sense of matter. That consists not only in the notion of the object in the sense of non simultaneous space occupation, such one being also supported by visual or tactile experiences. It also consists in the experience of something that is, at the first, resistant [3] and more, of something that opposes and proposes complex behaviors to human sensory-motor acts: from elasticity and viscosity to dry friction and other more complex ones. Such behaviors are precisely learned and intimately used by humans during the instrumental playing: playing musical instruments, molding a soft paste, manual drawing, etc (Figure 6).

Figure 6. Three emblematic cases of the instrumental situation

3. PROPERTIES OF INSTRUMENALL HUMAN-WORLD RELATIONSHIP

Since primary experiences such as those in which a human hits a tree with another piece of wood to alert his congeners by means of specific sounds and rhythms, the fundamentals of the instrumental paradigm were launched. In this paragraph, we enounce, in three points, the main properties of what is for us « an instrument », in order to examine further what is the epistemological break introduced by the information technologies and how it can be crossed over.

3.1 The instrument as a physical object

In the instrumental relationship between humans and the world, an instrument is, at first, a part of the physical word, i.e. a physical object, chosen by humans and modeled or not by them. Moreover, it is used to perform a task that humans cannot perform without it. In this respect, it provides morphological, physical and functional adaptations of the human morphology to the physical world. As an example of morphological adaptation, a screwdriver allows to perform continuous rotation that is impossible to perform only by hand and fingers. As example of physical adaptation, the wax spread under skis optimizes the dynamic adherence in order to move faster. As an example of functional adaptation, a musical instrument is a physical object that transforms gestures into sounds, in order to enlarge the capabilities of the human beings to produce sounds, because, except with his vocal cords, the human is a very poor acoustic vibrating structure. Thus, as the Janus figure, an instrument has two faces, and one can say, strictly speaking, that it is an interface.

Alternately, it can be considered as a part of the physical environment, seen or heard by humans, or an extension of human body when near the body and taken in hand. As when an object is not in hands, its appraisal by human can be perceptual or formal.

But when in hand and during the performance of the task, it is felt, and consequently known, through the human sensory-motor capabilities so that one cannot say who manipulates which and vice-versa (of the human and of the object). Human and object constitute a single system, we can say a single instrumental system, mediating a human intention (implicit or explicit) to others humans through the performed task.

Consequently, we cannot speak of instrument or instrumentalist, separately, but only of the instrumental relationship between them, during which they constitute a single instrumental system.

3.2 The instrumental system as a dynamic system

Such an instrumental system exhibits specific and rich properties. The relation between the human and the physical object is more than a sensory-motor relation like hand-vision sensory-motor relationship when showing an object by pointing it with the finger. When in hand, human body and the physical object are not only like two things in contact. They constitute an inseparable closed loop dynamic system (Figure 7), really a single object.

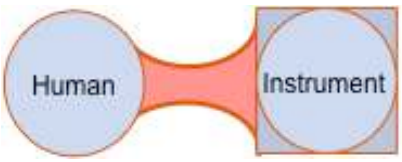

Figure 7. The intimate instrumental relationship[2]

This single object is a complex dynamic system composed of an active part and of passive part as shown in the Figure 8. We use the term "active", not in the sense that humans are subjects able to have intentions, but in the sense that a system embeds an internal source of energy able to internally modify its internal states. Indeed, the human bodies have the capability to modify the tonicity of their muscles during a jump. It is not necessary that the instrument is also active to dispose of the minimal functionalities able to characterize the instrumental system as a dynamic system.

[2] Thanks to Jean-Loup Florens for his particularly expressive representation of the coupling human - physical object.

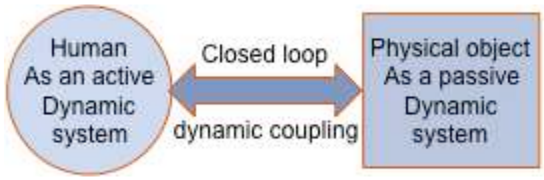

Figure 8. The basic instrumental system as a dynamic closed-loop system

Considering the instrumental system as a dynamic complex system allows to better understand why it is able to exhibit features that cannot be found in other types of human-world relationships, for example in the hand-vision relationship. Indeed, the instrumental system composed of the closed-loop coupling between a human and a physical object exhibits dynamic properties such as energetic exchanges consistency, reactivity or dynamic adaptation. Such properties are not necessary to perform types of tasks such as those that can be performed through formal communication by signs and languages or by open-loop command systems. But they are necessary to perform tasks that, either by principle or until new technologies prove otherwise, cannot be performed by the first types of tools. The distinction between both is well represented by the concept of ergotic and non-ergotic tasks proposed by C. Cadoz [1]. Let us illustrate that with emblematic cases as those shown in Figure 6: playing a cello, rubbing a surface and sculpting with clay. During such instrumental performances, the physical body of the instrumentalist and the instrument are closely dynamically coupled, being then able to produce non-predictable emergent effects: timbre changing, sticking, cracking, breaking, transients, bifurcations, stability regions, etc. In the finger-glass system, the sound can appear or not; timbre can change or not. And all of these effects cannot relate simply to only parameters control processes: the intensity of the sound is not directly correlated only to the pressure force or to the finger velocity. When the sound is started, the pressure and the velocity can be relaxed to maintain it. It is the same in the bowed string playing during which human gestures are able to manage very complex dynamic patterns: relaxing the pressure, increasing or decreasing the velocity of the bow, at the right state of this complex dynamic system, etc. When succeeding in such tasks, the expression used is: "*He/she is one with his/her instrument*".

4. CONDITION FOR EMBODIMENT IN DIGITAL INSTRUMENTAL RELATIONSHIP

4.1 Digital instrumental relationship as a representation

In the previous paragraph, we detailed basic functional, technical and cognitive properties of the instrumental relationship. We do not pretend to have exhausted all the questions around it. But, we hope, at first, that the reader is now convinced of the necessity of such relationship. Nevertheless, all the topics discussed above are necessary for examining why and how the instrumental relationship can be implemented in information technologies.

One can consider that mechanical instruments perfectly serve all the instrumental tasks and that electrical, and/or computer technologies, have been designed to develop other types of tools for other types of tasks. Let us notice that the constraints imposed by mechanics in the optimal design of such instruments is a critical limitation for the three types of adaptivity we spoke above: morphological, physical and functional. No doubt that electromechanical teleoperated master-slave systems designed to extend the space, to improve the accuracy of the manipulation, or to secure humans who are manipulating, were necessary. No doubt neither that synthesis processes enlarge considerably the variety of sounds and images that humans are able to produce. But what is the main and fundamental difference between a pure mechanical instrument, such as a violin or a puppet, and electrical or information-based ones? A first and obvious answer is: In such implementation of the relationship between the human and the system which performs the task, the coupling, as described before, as well as the sensations of the matter which naturally exist in mechanical interaction, are lost. They are not naturally supported by electrical technologies, and thus, if necessary, we have to (re) construct them.

Such a very simple observation first leads to one remark, and secondly to one new concept. First, the mediated relation between humans and the physical world by means of electrical and computer technologies cannot be an instrumental relationship. And second the electrical-based instrumental relationship that could exhibit the main properties of the mechanical one, cannot be anything else than a representation of the instrumental situation, as introduced by C. Cadoz [4] and developed in [5][6]. Such representation has not to be understood as a representation of specific instrumental cases, such as playing violin or piano, but the representation of the principles of the instrumental situation. Consequently, we ask, and try to answer, on what are the main technological and conceptual bottlenecks for the implementation of a representation of the instrumental relationship within electrical and computer technologies.

The information technologies started from the notions of electrical transducers and signals. Indeed, electrical transducers and signals, and thus, all the electrical sciences including computer sciences, operate the fundamental historical shift from mechanically coupled systems to input-output systems [7], breaking the mechanical-based closed loop and thus having to represent it as well in the formal representations as in the electrical and information systems. The input-output representation formalism introduces a causality, that does not exist in the mechanical systems, between what is the input and what is the output. Consequently, in the representation of coupled systems, it obliges to separate the two intimately stuck parts, for example the cellist and the cello, each of them being then represented by an input-output block as shown in the Figure 9. It obliges then to represent their coupling by connecting the output of the one onto the input of the other. So the representation of the instrumental system introduces a cascade of two causal relations: the cellist is considered as an input of the cello and the cello as an input of the cellist.

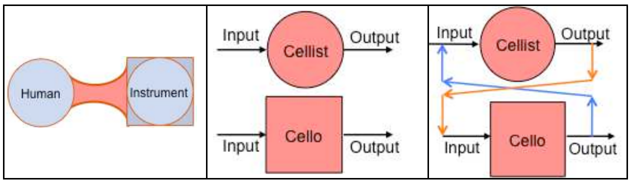

Figure 9. The two shifts in the representation of the instrumental system. Left: the instrumental system; Middle: its splitting in two input – output systems; Right: the input-output representation of their coupling

The input-output representations ground the sensors-actuators (more generally transducers) and signals technologies and information systems, and vice-versa. The outputs of a system are then sensors that acquire its behaviors and transform them into signals and the inputs are actuators that receive these signals. We do not discuss about the reduction due to the fact that the sensors, the actuators and the signals so produced represent only some parts of the physical behaviors[3]. But, we will focus on the fact that the coupling is not totally representable in electrical and in computers systems. Then, the questions are: Is it possible to restore the sensation of physical matter? How can we implement the input-output correlations to preserve the representation of the coupling? In the following, we propose two aspects, one conceptual, two technological, which can help us to answers such questions.

4.2 "Transparency of the system or new representation of the instrumental universe"

The approach we present here differs conceptually and pragmatically from that which is usual in teleoperation in the field of robotics. A common engineering goal in Robotics and teleoperation is to replicate at the best a real situation. The concept is that of "transparency" of the new electromechanical system, i.e. how can we render the behaviors introduced by the new electromechanical system as transparently as possible? This concept derivates from the electrical teleoperation in which one tried to render the new components added to the mechanical teleoperation as functionally "transparent". Although the answer is that it is not absolutely possible [8][9], the main stream in teleoperation worked to solve this question of transparency.

Our approach is near from a more anthropological point of view. It does not consist in reproducing existing instrumental situations by rendering the specificities brought by novel technologies as non-existent as possible, but in developing new instruments under specific conditions and assumptions. These conditions are to take care of the fundamentals of human-world couplings, in order to develop not only new systems, but those that will be able to preserve the fundamentals expressed above and

[3] That is of course a true critical question, widely examined in electrical engineering and transducers theories and systems.

to experiment their role in human cognition as well in the performance of the tasks. Our approach is then task-independent, and can be expressed as: how do we specify the scheme represented on the right of the Figure 9 and implement it in information technologies to obtain, at the best for the human, the instrumental situation represented on the left of the same Figure 9? A temptation could be to consider that the answer could be only on the human side and that the question can be solved by human-based design of robotic systems after having performed psycho-physical and cognitive preliminary experiments. We outline here that it will be not sufficient: first because the instrumental problem is not the same as risen by transparency in the teleoperation chain [10]; secondly, because for centuries the instrumental paradigm has not consisted in copying previous instruments and previous situations, but in creating new instruments for new tasks for new instrumentalists, and thirdly, because the human-mechanical object system is not observable and needs new experimental workbenches to be better known. The basic technical schema that represents the instrumental situation within the domain of information technology is given in Figure 10.

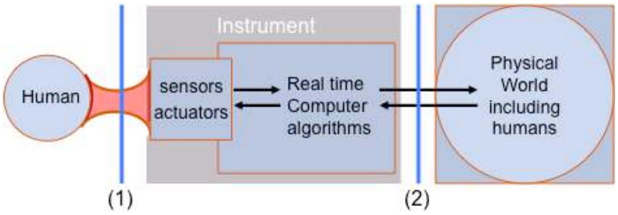

Figure 10. The representation if instrumental situation in the framework of Information Technology

Notice that in the part of the instrument: (1) sensors and actuators are electromechanical devices that have to be designed to preserve the properties of the instrumental coupling as sketched before; and (2) the real time computer algorithms have to maintain the consistency of the instrumental coupling between the inputs and the outputs of the interaction devices.

Notice that, if we called Z1 the impedance on frontier (1) of the right part of the whole system seen by the left part of the human and Z2 the impedance on frontier (2), the transparency assumption leads to have Z1=Z2, that corresponds to a deny of the intermediate instrumental part. Conversely, the instrumental concept allows that Z1≠Z2. This means that the design the new "instrument" allows to render it to support at the best the "embodiment" and the "second nature" processes.

Thus, the question becomes: what are the necessary and minimal conditions we must preserve to benefit from instrumental properties from the human side when shifting the technologies. We can say, what could be the "task-independent axioms" of the instrumental situation.
We now sketch two minimal elements of these basic properties, and their correlated technological needs.

4.3 A first minimal dynamic property: perceiving the resistance of the matter

First of all, when used in computer technologies, i.e. when the system that receives the inputs from sensors and produces the outputs to actuators, is based on or includes computers, the causality introduced between inputs and outputs is transformed in a temporal causality. Indeed, a non instantaneous computation process is inserted between the inputs and the outputs. In the electromechanical coupling between humans and such systems by force feedback transducers, this question is related to that of the bandwidth of the system device / computer algorithms. This bandwidth obviously depends on the dynamical properties of the device itself but also on the computer algorithms and the communications systems between both. These two last can be expressed by the temporal latency between the outputs of the device (resp. inputs of the computer) and its inputs (resp. outputs of the computer). The higher this bandwidth is, and lower the latency is, the better the restitution of coupling between rigid systems will be. That is a critical point in force feedback transducers design, known under the terms "Stability" or "Bandwidth problem" [11].

Having in mind the previous discussions [3] about the fact that the contact situation conveys the sense of resistance of the external matter and further of the matter itself, the rendering of contacts is also a critical point for a perceptual, cognitive, and further existentialistic point of view on the side of the human being. Consequently, all the technical components (force feedback transducers including sensors, actuators, mechanical embedding of them and electronic regulation processes) must be used coherently and consistently to render, at the best - the interaction during collisions and contacts between a human and a simulated resistant matter in the computer. It will be in the same time a workbench in order to experiment (1) what is the cognitive role of the contact situation in the trade-off from "environment" to "instrument" via the intermediate stages of "object - near the hand" and the "object – in – hand"; and (2) how it could be a necessary component for considering the instrument as a "second nature" of the instrumentalist. Couroussé and colleagues, in [12] tacked these questions in a specific research on haptic-audio tapping. Using the high quality TELLURIS platform, in which all the systems and processes run at 44 kHz, they show that, when hitting an acoustical surface, the properties of the matter (its non-linear elasticity and viscosity), are influencing the maximum of the frequency of the hits. To sum up, according to the critical role played by the existence of the matter, revealed during the contact and collision situation, in the instrumental situation, the rigidity during contact is the first axiom of the instrumental relationship to be rendered at the best in the framework on information technologies.

We saw that our approach is different for conceptual reasons of that of teleoperation, based on the transparency concept. It is also technically different than the main stream of researches in Virtual Realities. In Virtual environments and virtual reality systems, most of the work is dedicated to the immersion of humans within virtual environments. This immersion is simultaneously physical by means of systems such as Caves in which 3D images and sounds are surrounding the human beings, and virtual by means of avatars of the human beings representing them in the virtual environment. The core problem here is the wideness of the represented spatial environments and systems that put the emphasis on the navigation and the exploration of large spatial and geometrical 3D scenes. The collisions problem is processed from a geometrically-based point of view, the critical problem being that of the geometrical computation of the intersection between two complex geometrical shapes to prevent interpenetration. There are many works developed in computer graphics and applied in teleoperation when complex manufactured objects are colliding. The related scientific questions are summarized in [13]. In such applications, the dynamic of the contact remains a secondary problem, while it is one of the first generic properties that systems have to render in the instrumental paradigm, as it works in the musical creation.

4.4 A second minimal dynamic property : perceiving the dynamic texture of the matter

Having created the minimal conditions to restore the sense of the matter through its physical resistance within information-based technological systems, and reminding, as explained above, that humans use the other properties of the matter (other than and in addition with its resistance) in the instrumental tasks, a second stage consists in restoring such behaviors as well as possible. Some other behaviors of the matter such as all the viscoelastic effects able to render all types of deformability are easily derived from the rigidity effects discussed above. The second critical dynamic feature for most of complex instrumental tasks is then the friction effect. Different from the collision processing that led to much work in virtual reality, there are very few works that tackle the friction effect. Florens and coworkers [14] [15] demonstrate that when the friction between a bow and a string is simulated by the computer and returned to the force feedback transducer manipulated by the instrumentalist at a high frequency, typically 1500 Hz in [14] and 44 kHz in [15], the sensation of the presence of the vibrating bowed string increased significantly. The instrument became more and more playable and new gestures and exploratory manipulations happened due to the fact of wide possibilities of dynamic gestural adaptations and learning, by allowing the instrumentalist to play with non predictable effects as those occurring in the bow-string interaction. Hereto, the rendering, at the best, of the usual properties of the matter when instrument are in hand, such as friction, will allow to better know what is its role in the cognitive appraisal of the instrumental situation and in different criteria characterizing the performed task: efficiency, playability, handleability, creativity.

5. CONCLUSION AND FURTHER QUESTIONS

We compared two complementary human-word relationships.

In a first situation, in which we are immersed in a landscape, humans develop the sense of “being there”, looking far away from his (her) place towards large scales by means of exteroceptive sensory modalities such as vision and audition. Such a situation, drastically extended by networked and distant exploration, can be seen as a definition of “immateriality” and its correlative concept of infinity.

In a second situation, in which humans are confronted face-to-face to a thing, placed in vis-à-vis, extracted from a surrounding environment to acquire the state of an “object” able to be handled, humans develop the sense of “being with”. Progressively, objects are transformed into instruments and humans into instrumentalists. Such a situation leads to the embodiment of the object as a “second nature “ or as a part of the human body or as an extension of the human organology. It can then be seen as a definition of “tangibility” with its correlative concept of instrumental embodiment.

We developed here the idea that to implement such an instrumental situation in a computer context, not in the aim to mimic our relation with the mechanical world or to mimic the notion of tangibility in the real mechanical universe, but rather, in order to have at our disposal within the new contemporary digital creative context, the minimal properties necessary to ground the embodiment process, some properties of the instrumental relation ship have to be reached.

We have not examined here questions such as the morphological ones (number of sensors and actuators and morphological arrangements). They undoubtedly play an important role in human manipulation of physical objects. Indeed, some drastic limitations of the existing force feedback devices are related to the fact that they allow only punctual contacts. However, we demonstrated that dynamic properties of the close-loop coupling between human and a physical object, are a necessary condition, (even if it is not a sufficient one), to have access to behaviors that are the specificities of the instrumental system and that cannot emerge otherwise. Based on primary functions of the instrumental paradigm, we showed how the central concept of teleoperation, i.e. the transparency of the electrical and information parts of the system, despite the huge development of interactive teleoperators including haptics, does not match with the instrumental paradigm. We showed also that Virtual Reality, despite the wide uses of haptic devices, does not fit either within such an instrumental paradigm. So, the field of instrumental situations in computerized environments remains to be developed and is still a subject for the future. We have to know more, to build more, to experiment more around the non trivial concept of instrument and instrumental relationship, from an anthropological point of view, within the scope of information technologies.

Several other fundamental issues remain pending. Taking the examples of Arts, such as Musical Arts, Visual Dynamic Arts, Choreographic Arts, no doubt that the instrumental relation, in the meanings developed in this paper, is fundamental to produce subtle sensory effects. But further, if we include the very long process to design an instrument, process in which the physical matter is also pointed out, we could see that the instrument is not only a way to adapt the human and the world to perform tasks that humans cannot do, but more a way to organize and structure, in the same movement, the physical world and the human gestures.

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