Tangibility, Presence, Materiality, Reality in Artistic Creation with Digital Technology

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ABSTRACT

The democratization of Computer Arts and Computer Music has, due to dematerialization (virtualization) consequence of digital technologies, considerably widened the boundaries of creativity. As we are now entering a second phase that has been labeled “post-digital”, we are called to reconcile this openness with notions such as embodiment, presence, enaction and tangibility. These notions are in our view inherently linked to creativity. Here we outline some approaches to this problem under development within the “European Art-Science-Technology Network” (EASTN[1]). Several areas of artistic creation are represented (Music, Animation, Multisensory Arts, Architecture, Fine Arts, Graphic communication, etc.). A main objective of this network is to establish common grounds through collaborative reflection and work on the above notions, using the concept of *tangibility* as a focal point. In this paper we describe several different approaches to the tangibility, in relation to concepts such as reality, materiality, objectivity, presence, concreteness, etc. and their antonyms. Our objective is to open a debate on tangibility, in the belief that it has a strong unifying potential but is also at the same time presents challenging and difficult to define. Here we present some initial thoughts on this topic in a first effort to bring together the approaches that arise from the different practices and projects developed within the partner institutions involved in the EASTN network.

1. CONTEXT

The European Art-Science-Technology Network, which is supported by the European Union under its Culture Program[2], arose from the initiative of several European institutions involved in research, technological development, creation and teaching in the field of digital technologies applied to artistic creation. These institutions are: The ACROE and the ICA Laboratory (Grenoble - France), the Cardiff School of Art & Design (Cardiff - UK), Fab Lab Barcelona and the Institute for Advanced Architecture of Catalonia (Barcelona - Spain), the Center for Art and Media (ZKM, Karlsruhe - Germany) and the Department of Audio and Visual Arts of the Ionian University (Corfu - Greece).
Several areas of artistic creation are represented within the consortium: Music, Animation, Multi-sensory Arts, Architecture, Fine Arts, Graphic communication, etc. Discussions within this team led to the identification of key concepts such as materiality (or immateriality), reality, sense of presence, incorporation and embodiment. These concepts appear in the context of digitally mediated technologies, and in particular in the domain of artistic creation, as a consequence of the dematerialization effects of digital technologies. By dematerialization we mean the uncoupling of data, models and processes from the physical processes, which they represent. While this dematerialization opens up a vast degree of freedom which considerably pushes the boundaries of creativity, at the same time it creates the need to recover the fundamental conditions of creative processes by rediscovering or redefining the alliance between immateriality and materiality. The term "tangibility” may play a key role in this search. Yet there is still need to define this terms and its possible interpretations more clearly.

This paper does not present a state of the art or an exhaustive overview of the issue. It proposes to shed light, from the experience of the current partners of the EASTN project, expressing several complementary tendencies and points of view, in order to initiate and stimulate a debate on the concepts involved.

[1] www.eastn.eu
[2] ec.europa.eu/culture

2. TO BE OR NOT TO BE … "TANGIBLE"

2.1 Human – Computer – Environment interactions

Our proposed starting point is the proposition that digital technologies deal with information, not with matter in a physical sense. While information requires physical media to be created, processed, transmitted, stored and preserved, it is regarded as representing something different than these media. In other words, we can consider digital computing devices as belonging to a world of information carried by symbols, "digital symbols" or bits, and processed by operations, boolean operators, applied on these symbols. This makes out the abstract and intangible character of the digital, since "touching" symbols is not possible and lies outside the metaphorical framework of the digital. Even if these symbols and operations are carried by matter (electrons, electric wires, electronic circuits), we can only experience their function and evolution indirectly (if at all). And in order to use them to achieve a predefined goal, we need to apply arbitrarily defined correspondences between the logical / symbolic and the physical / material. The issue of tangibility arises from this condition.

In order to act on the computer, the human has no other means than his/her voice, body, and gestures. Devices are needed in a way to establish links between the physical phenomena produced by voice or by gestures and the symbols of the digital domain.

The use of the results may be of two different natures. It may be direct, involving the human senses. In this case, there is a necessity for devices that establish links between digital symbols and natural perception: the hearing, the sight and the tactilo-proprio-kinesthetic (haptic) senses. It may also be indirect, or more precisely resulting in a physical transformation of something in the human's environment. In this case, the digital phenomena must be linked to devices that control energy in motors (actuators) and engines that act, modify, transform the matter in our environment. And finally – but this cannot be done entirely without the help of the human, that is to say without some links of the first type evoked above – digital processes may be controlled or at least influenced by phenomena of the physical environment. In this case, devices are needed to link the phenomena to the digital symbols. These devices are called sensors. Sensors, display devices and actuators are then necessary and complementary basic components of any system involving computer for human-computer-environment interactions.

The "interfaces" going from human action or physical environment to digital world and from digital world to human senses or to physical world, can be configured in various ways. Some characteristic cases are:

- The computer and interfaces can be configured to imitate in all respects the behavior of a physical object, such as a musical instrument or a material object that we can animate. This is the case in the "Multisensory and Interactive Simulation of Physical Objects" presented below. We can say that the computer here plays the role of an "instrument". Strictly speaking, this device is not an instrument in the physical sense since it treats symbols. One could more appropriately characterize it as "metaphorical insttument".
- The computer can act as tool for creating models of a physical environment in order to support creation and manipulation of abstractions. In this case the digital tool is used in a manner analogous to earlier non-digital ones, such as the symbolic techniques that are used for example in mathematics to solve equations or to perform calculations. Graphical programming environments as well as WIMP based software are commonly used as interfaces for this type of use. This type of tool can support and stimulate work on the conceptual level by providing different types of graphic representations as well as the possibility to manipulate those representations in order to configure them. In contrast to the first configuration described above, this case here cannot be metaphorically compared to an "instrument" for direct interaction with the senses, but is more akin to a tool for representing abstractions and manipulating these representat ions that accompanies and supports thinking about these abstractions.
- In a third case, physical objects can be equipped with sensors and actuators to create self contained systems with their own properties and behavior, with which the human may interact. The sensors and actuators being connected to the computer are respectively inputs and outputs to and from digital processes. An underlying limitation of this configuration is that only the interface is tangible, while the processes and concepts that are specified and controlled remain hidden.
- A further case, can be represented as a virtual world built inside the computer superimposed to the real world through specific visual display devices. These to see the real and the virtual worlds at the same time while actions are detected in relation with someone position or movement in the real world and then used to create or modify the virtual one. This is called "Augmented Reality" (see for example [1][2]).
- And finally, the computer can control motors and various actuators of machines and devices acting on the real physical world and even transforming it. Here, by involving robots, machine-tools, milling machines, multi-axis CNC machines and others, or 3D printers and plotters, the computer is used to act on or to transform the physical world, but also to build sophisticated objects that can then be used as instruments, tools, parts of machine, etc. and interact with human, computer or the both.

These examples, can be classified into two groups, which are in a symmetrical relation to each other: The first is related to the science and technology of Human Computer Interaction, including technologies of Virtual and Augmented Reality. In this situation, the human is "real" and is interacting with the computer, which then is an "artificial world". The second is related to Robotics and Artificial Intelligence, where we can say that the computer is placed on a par with the human and plays a role, with increased functionality and performance, comparable to that of an "artificial human" interacting with the environment. These two complementary groups are proposed here as the two main metaphors for the analysis of man-computer-environment interactions in the present context.

We can summarize this as a triangular system between human, computer and physical environment, and with the three kinds of resulting interactions. Even if the effective and various situations involving computers are generally more complex, we can say that they are always understandable as more or less complex networks made of this basic mesh. And then we have here the global frame to approach and discuss the question of Tangibility.

2.2 A cloud of terms and concepts

2.2.1 Tangibility

In its simplest sense, tangibility is the property of an entity to be accessible to the sense of touch. This indicates two aspects: touch is perception, but also action. The sense of touch develops in the action of touch. In order to perceive the shape of objects, their weight, their texture, the way in which they can be shaped or deformed, we must interact with them. The "pure" Touch is a borderline case and very reduced sense.

But there is also a broader sense. Figuratively, in common usage, a thing is tangible if it is real, not only imaginary, if it is defined and not vague or elusive. In the legal field, a property is tangible if it has an actual physical existence, as real estate or chattels, and therefore capable of being assigned a value in monetary terms.

In the domain of Human Computer Interaction, the term Tangibility appeared at the end of the 1990's in the expression "Tangible User Interfaces". In their paper, Ishii and Elmer [3] introduced the notion of "*Tangible Bits",* allowing users *"to grasp and manipulate bits (...) by coupling the bits with everyday physical objects*". This is of course a metaphor since, as said before, bits are not objects but symbols. It is important to see here that, (i) this is the everyday physical object that is tangible, not the bits, (ii) this object is not "coupled" with bits, but a (reduced) part of its properties and movements are detected (thanks to sensors) and used as input of the computer.

2.2.2 Reality, Materiality, Objectivity, Presence, Concretnesse, etc.

The term "Tangibility" is attractive because it is clearly an expression of a need that is not satisfied with the computer. But beyond the "buzz-word" there are important questions, and because it is polysemic it is rich and promising. It is sufficient, to give an idea of its richness, to mention some elements of the "cloud" of words to which it is often associated. A simple list of terms appearing as synonyms, and a list of opposing pairs of antonymic words, allows getting an idea.

Reality, materiality, objectivity, presence, concreteness, just to name a few, are often encountered as synonyms. But it is easy to note that they are not equivalent. For example, one thing can be real (a feeling, an emotion, suffering or joy) without being material or concrete. One thing may be present, or at least may seem present, without being real: the successful synthesis of a digital sound, for example the sound of a vibrating string with a physical modeling simulation may give the feeling, or even the certainty that a string is present where we listen to the sound, while there is no corresponding physical reality. But perhaps the term "re-presentation" (to present again) is more convenient here!

It is also interesting to place each of these terms in front of those who are supposed to be their antonym. We can then discover some inherent semantic difficulties. For example, "subjective" is not necessarily synonymous with "non-objective"! And of course, crossing of couple of terms sometimes is completely meaningless: for example, "non-material", as antonym of "material", is not equivalent to "abstract" as antonym of "concrete".

It is also interesting to consider some pairs of terms, associated in some expressions, where we cannot determine if they are mutually qualifying or are antonyms. The most dramatic example (as one of the authors has shown in his book "Réalités Virtuelles" [4] is "Virtual Reality" itself. It is indeed impossible (because the two uses exist) to determine whether the virtuality is here a qualifier of certain realities or if it is used as an antinomy of reality. In this case, this expression is an oxymoron, i.e. an expression which is contradictory in itself, something like "to be AND not to be" at the same time!

2.2.3 Enaction

It is now well understood that action generally goes with perception (and in numerous case is impossible without perception) and conversely, that perception needs almost always action. It is obvious for the gestural channel, which is both a channel for acting and sensing (by the touch and the tactilo-proprio-kinesthetic, TPK sense) and more, that the TPK sense is intrinsically an action-perception loop [5]. This is a reason why we can say that the "touch" is enactive. But the enaction concept [6, 7, 8] is wider: It concerns not only the intimate touch loop, but also, at different scales, the loops involving gestural action, auditory perception, gestural action and visual perception, gestural action and multisensory perception.

The enaction concept is then totally relevant in the discussion about tangibility.

Thus, we must admit that the concept is rich and complex and that it is not possible to give an initial unambiguous definition. The meaning of "Tangibility" is a work in progress, under the large and recent development of digital technologies. We propose in the next section to try to "make this notion more tangible" by providing several specific insights based on the works of different teams and institutions, some on them being in relation with the present EASTN network.

3. DIFFERENT APPROACHES TO TANGIBILITY

3.1 Simulated matter – Evoked matter

By Annie Luciana – ICA Lab – *Grenoble Institute of Technology (France)*

In [9] Annie Luciana introduces the term of "simulated matter" as a new field to be explored by artistic creation. She showed that, since the first phase of real phenomenon observation or capture aiming to digitally represent it, a substantial reduction occurs: only specific aspects of this phenomenon, those that can actually be captured or analyzed according to specific fields of science, are selected and represented: for instance, the audio signal, the 3D spatial form, the displacement of a body into space, etc. This remark seems obvious. But it means no less than all other properties involved in the phenomenological experience of the human being in its relation with the real world were lost. Among them, a crucial one is the "physical matter", out of which things are made.

Beside, the very new expansion of the possibilities open by digital instruments, they dramatically shared a common property that is "*an absence"*, and an absence of what? "*The true absence of the physical matter*", as exemplified by most of 3D shape modeling software or by most of Digital Musical Instruments.

When going back from real world to perception and sensitivity by means of "re-sensorialization", this "*physical matter lost*" leads to two opposite tracks:

One can rematerialize 3D forms thanks to a real physical matter, as done in industrial processes such as Computer Aided Design and Manufacturing and its wide popularization through FabLabs trends. We can speak of "shaping", i.e. a mapping process of the virtual dematerialized 3D shape onto a real physical matter. This is usually done using robots to shape a given physical matter with virtual shapes. No doubt that such processes enable to considerably enlarge the variety of shapes that can be produced "by ourselves" and are a new support for artistic creation linking imaginary virtual shapes and tangible experiences of them.

Another is to integrate the modeling of a physical matter itself within the virtual objects design process. In this case, the matter is virtual, digitally simulated, and processes of sensorialization are then required which necessarily introduce: the virtual matter gestural perception, allowing to manipulate it as if it is real by the means of adequate haptic feedback systems; the visual perception of the behaviors of this virtual matter, rendering as precisely as possible dynamic properties; and the auditory perception of the acoustical matter behaviors. Here is the notion of "simulated matter", shifting the virtual digital process from "*what is this thing*" to "*in what is this thing*". However, in such a case, going back to physical matter is, if not impossible, terribly limitative, stamping such process as very different to the materializing process adopted in the first track presented above.

The philosophical arguments for the benefit of the concept of "simulated matter" are two. First, A. Luciani shows in [9, 10, 11] that just a little drop of simulated matter enables to strongly evocate its materiality and, that it is not necessary to model this matter with a total physicist realism to trigger the sense of tangibility and of believability of a possible real thing. Just a kind of "thingy" is sufficient, the question being how can we discover it? Within the technical question of "simulated matter" is nested another concept, more in the field of cognition, called "evoked matter": what could be the minimum of evoked matter able to trigger the sense of believability of virtual artifacts? What could be the nature of haptic sensorialization – and more multisensory rendering - to render cognitively tangible something that it is objectively dematerialized? From what elements can we speak about "cognitive tangibility" instead of "real tangibility"? Many exciting questions that the technological as well as cognitive research will allow us to discover.

Secondly, behind this question, is the central concern for artistic creation which is of the modeling process, in other words in the discovery, the writing, the composition processes, etc. A. Luciani then assumes in [10] that the notion of "simulated matter" and "evoked matter" truly opens very new ways for artistic creation, as it allows at the same time to rehabilitate the necessity of the tangibility supported by the feeling of "in what is this thing" with the infinity of the space of the virtual simulated matter, which can become a feature to be written, modeled, composed.

3.2 Multisensory and Interactive Simulation of Physical Objects

By Claude Cadoz – ACROE – *Grenoble (France)*

The computer is used in this approach of the ACROE-ICA Lab. in Grenoble, as a means to simulate the physical world in such a way that the human can interact with this virtual world in the same way as with the real world.
If we focus on particular objects like instruments or tools for artistic creation (music, visual arts, etc.), this leads firstly to introduce devices that allow to establishing links between the gestures and digital symbols, and at the same time devices that establish links between digital symbols and hearing, sight, perception by the fingers, the hands and the body. The interaction through the gesture, which allows both emitting and receiving of information, requires special devices, which are today called gestural force feedback systems. It also requires dedicated devices to elaborate acoustic phenomena and also visible phenomena from digital electronic phenomena. They are digital / analogue converters followed by loud speakers, visual display devices, etc.

It is also necessary to program the computer to calculate, as a result of the gestural actions and with the required speed, digital sequences corresponding to mechanical, acoustic and visual phenomena. Moreover, these calculations must be achieved in such a way that all resulting perceptible phenomena behave exactly like in the case of a real physical object. This object may be defined according to a real existing object, but it may also be a chimera.

This approach is the subject of the work of ACROE and ICA laboratory (Grenoble Institute of Technology) for several decades. The recent developments in this approach put together high performance force-feedback devices developed by ACROE-ICA (the *Gamma Console*©, a force feedback system with 24 degrees of freedom) and the GENESIS environment for creating models in the CORDIS-ANIMA language, to simulate and to play them in real time [12, 13, 14, 15].

In this situation, it is legitimate to speak of tangibility if we consider the elementary meaning of this word, which is to "touch" the things. Indeed, using a force-feedback device, we actually touch matter: the one of the mechanical part of the device. Nevertheless, what is real and material is the device, but not the "object" with which we are interacting in this multisensory way. Actually, this object doesn't exist. However, what is very important here, since it is in fact the principle and the objective of this approach, is that we have the sensation of presence of this virtual object. For example, when we simulate a vibrating string that we pluck with a simulated plectrum through a force-feedback key, producing then the sound, the moving image and the haptic feeling in our fingers, we have the conviction that the object is here, is present here.

The next question may then be: why is this important? What's the point?

In fact, when we are confident that the object we have in front of us is real, that it is not only something coming from our imagination, then we are willing to consider it as a means, a tool that will help us to objectify and to express precisely our thoughts and our imagination for others. This is the way in which we behave with real instruments: as objects that are external to us and through which, when we play, we can create expressive sounds.

It is under these conditions of reality and materiality that the instrument can become a kind of organic extension of us.

The principle of Multisensory and Interactive Simulation of Physical Objects is then to try to implement all conditions, whereas we are interacting with a dynamic system of symbols, to procure the conviction that we are interacting with a real object.

This is not easily achievable. Indeed, if the conditions of interaction with the system are too abstract, too far away from what our gestural bodies and our sense organs are used to treat, that is at a minimum concrete physical phenomena directly producible by our gesture or perceivable by our senses, this incorporation, this embodiment does not happen, and the relationship with digital objects becomes totally different or incompatible with the finesse and richness that are necessary for expressiveness and sensitivity.

And finally, what emerges from this is that the sense of presence is not obviously related to reality. A subtle science is: how, using artifacts, to give the feeling of presence or the belief that what is in front of us is real, even if it is not true, allowing then in particular an embodiment, this last being at its turn so important and so necessary in a certain (large) part of the (artistic) creation process?

Another word can be introduced in the discussion: *Objectivity*. It was implicit in the previous arguments as soon as we said that we need to be sure that what we are confronted with is not only from our imagination, is not purely *subjective*. In order to get this, a first strategy of our cognitive system is to verify a permanency of the things while we are changing and acting ourselves.

So by comparing our voluntary actions and what varies and what remains invariant in the phenomena that we perceive in consequence of our actions, we can conclude that we have or not an object, in front of us, in an environment which is objective. This is what the Virtual Reality has achieved at its beginning (in the 1990's) in particular with the first immersive 3D visual displays, associated with 3D body movements sensors (head-mounted screen for example). While the person is moving, the computer recalculates the 3D scene in order to give to the observer the feeling that this scene is outside of him (objective) and that he is moving inside it.

In such a situation, even if the sense of presence is highly increased when we use gestural devices with force feedback, these devices are not absolutely necessary.

A large number of other strategies, often much more simple, can work very well. For example, it was already the case with the simple technique of perspective in classic drawing and painting. What is working here is a specific consistency inherent to the visual *stimuli* that map with those we would have in front of a real scene. If we accept to speak here yet of tangibility, we must consider that to touch the matter is not always necessary for it.

In fact, in the works of ACROE-ICA and in particular with the GENESIS software environment for musical creation, such sensory consistency is used, or more generally the paradigm of "physical metaphor". In the part of the user interface used to build the virtual objects, we allow to do this through a direct graphic manipulation of the components of the physical model on the screen. The screen is then a metaphor of a physical worktable.

Despite the fact that, in this case, there is no touch, it is this kind of "tangibility" which allows supporting and stimulating the conception, creation and construction of these "objects".

3.3 Designing and Making Digital/Physical Things by Physical/Digital Means

By Alexandros Kontogeorgakopoulos – CSAD *(Cardiff School for Art and Design) – Cardiff – Wales.*

The world of fabrication and digital arts are nowadays easily combined and mixed through the digital fabrication revolution and the digital computation revolution [16]: in the same moment and place we can design and build the physical object, the hardware, the software and through transducers (sensors and actuators) link the physical and the virtual world dynamically. Our belief is that the digital artists should be exposed in the physical and virtual world simultaneously. Our aim is to bring the virtual even closer together with the physical workbench.

Particularly Cardiff School of Art and Design (CSAD) strongly emphasizes and celebrates the fact that the artist (and designer) is able today probably for the first time in history to easily design, fabricate and experience simultaneously physical systems and virtual systems with the help of computer tools. Digital fabrication gives access to everyone to design and produce tangible objects. Machines for personal digital fabrication include

CNC milling machines, laser cutters, 3D printers and plotters. Digital fabrication laboratories (from specialized workshops to the widespread Fab Lab network[3]) facilitated significantly the bridge between the tangible and the intangible. Therefore the concept of tangibility is deeply related to the harmonious combination of bits and atoms in the artistic work and in the workflow: how (what and why) we make physical things digitally and how (what and why) we make digital things physically. The passage from data to things and from things to data can open up many new possibilities in artistic creation with digital technology. An interesting research, which employs digital fabrication technologies for the design and the fabrication of acoustic instruments, is the 3D printed flute [17]. Another project, which combines both 3D printed wind instruments augmented with electronic sensors and visualization algorithms, is *The God Article* project [18]. An interactive composition is currently under development by Alexandros Kontogeorgakopoulos which uses the idiosyncrasies of both the physical and the digital part of the developed wind instrument. Other examples of CSAD's creative and research projects so far are related to active haptic interactions (touch immaterial things), augmented realities (see immaterial things), sound synthesis (listen to immaterial sounds) and digital fabrication (make material things digitally) [19].

We believe that materiality and virtuality will converge in our near future (if they have not converged yet!) and therefore a different concept about tangibility will emerge. It is the artists and designers roles to explore creatively through their work the interactions we have as humans with digital and physical objects, gain a sensory understanding of how code and matter can be formed and manipulated by the creative mind and the skillful hand and what tangibility means in our society today. The Fab Lab movement introduced by Neil Gershenfield [16, 20] is not only a revolution related manufacturing and personal fabrication but also a means to rethink about tangibility in the digital arts.

3.4 Immediacy - intimacy and manipulation – Extension of the Tangibility metaphor

By Iannis Zannos – Ionian University – *Corfu – Greece.*
Considering the sense of Tangible as that which can be perceived through touch, and that which can be touched, it is possible to identify two aspects which distinguish the idea of tangibility from concepts related to the other senses. These aspects are: "immediacy" (or "intimacy") and "manipulation".

The first aspect, immediacy or intimacy refers to the fact that the sense of touch relies on immediate physical contact with the perceived object, as opposed to senses such as hearing, vision or smell, which connect to the object via an intermediate medium/channel over distance. In that sense, tangibility gives us the most intimate experience of an object. Analyzing this further, one observes that experiencing objects through touch requires a different type of focusing of attention than with other senses. To know an object through touch involves active exploration of the object over time through physical movement. While vision and hearing also involve time and active focus of attention, the type of attention and the rate of flow as well as the type of information received through these senses is different than that of touch. Thus, an objective of research in tangibility is to specify these differences in greater detail and to characterize the type of information as well as the flow mechanism for receiving that information through the different sense channels.

The second aspect, "manipulation", is one in which perhaps tangibility distinguishes itself most strongly from all other modalities of the senses. Touching is our primary means of effecting changes on objects in our environment. Also, touching is the only modality that works equally in both directions: the same action of touching is at the same time an input and an output act. By comparison, the other sense channels require different means for input (hearing of sound through the ears, seeing through the eyes) and output (creating sounds through voice or other means, displaying objects visibly).

Both this and the fact that touching involves direct physical contact give tangibility a clearly prominent status among other modalities with respect to immediately affecting objects in our environment. Consequently, when looking for metaphorical extensions of tangibility as a concept, the characteristics of immediacy and manipulation provide a potent frame of reference, or a clearly perceptible point of departure.

Two approaches are proposed here to explore these metaphorical extensions.

One is by substituting through other, indirect, means for the aspects of tangibility that are lacking in other media, as is done for example in manipulation of virtual objects through gestures. The other one is to strive to imitate or create the characteristics of the tangible mode of operation in modalities that are essentially far removed from the realm of tangibility. This can mean many things. For example, it may be valuable to try and develop modes of operation on virtual programming objects in code that are as immediate as possible in their effect, and that allow one to manipulate the structure of objects as directly as possible. Detailed knowledge of the way that tangible media work can thus leads to new ways of interacting with the intangible.

Another way can be to strive to imitate or impart the (subjective) sense of the tangible through other means, in other words, to use sound or images to express experiences that belong to the realm of the tangible. The approach outlined above involves a combination of analytical, empirical and experimental/constructive activities that complement each other. If there are any new paradigms waiting to be discovered in the realm of tangibility, these can best be sought through concerted efforts.

4. CONCLUSION

The above presentations describe different approeaches and thoughts on the notion of tangibility. A convergence of concerns is discernible, centering on the need to combine the versatility and freedom of digital technologiese, with the immediacy and physicality of tangible interfaces. This can otherwise be described as the need to combine

[3] https://www.fablabs.io/

virtual/symbolic/intangible with real/physical/tangible aspects. This short and incomplete overview outlines various attempts to achieve this "coming back". Each of them can be characterized by, the nature, the meaning, the mode of combining the relation between the world of physical objects or objective phenomena and the world of digital symbols.

For instance, in the multisensory and interactive simulation of physical objects, there is a cognitive reference to the real world and the real matter, a digital modeling of this reference in the computer, and a "come back to reality" through digital to physical transducers and in particular the bidirectional transducers in the case of gesture.

At the other side, in designing and making digital/physical things by digital/physical means, there are two purposes. One is simply to go from the digital world, whatever the way in which it is built, to real and true material objects (made of atoms) that can be used as our ordinary objects, our tools, or even our houses. This was the purpose and the function of the first CNC machines. The second purpose is to try to dissolve the boundary between the digital world and the physical world.

This raises in a certain way the same key question as the physical objects simulation, which is, "*is it actually possible?*"

In the extension of the tangibility metaphor, there is a third purpose, which may combine with the previous in many ways, which is to try to give to entities which are not real, not concrete, even purely symbolic, the status and the "presence" of real or material objects that we can manipulate.

Pushed to the extreme exaggeration for the sake of argument, it raises a very interesting and intriguing question: "*is it possible, and to what extent, to "touch" and "feel" abstractions?*" Or, conversely, "*is an abstraction not precisely characterized by the fact that it cannot be touched or felt?*"

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Endnotes

• ACROE (Grenoble - France), well-known as a pioneer in physical modeling for artistic creation and in design of force-feedback gestural devices and multisensory real-time simulation platforms, aiming to turn the computer into a true instrument for artistic creation. ACROE has also developed several computer environments for artistic creation, in particular GENESIS for computer music and MIMESIS for animated image.

• ICA Lab. (Engineering for Artistic Creation Laboratory, Grenoble - France), created at Grenoble Institute of Technology (GIT) in 1999. It is, in partnership with the ACROE, in charge of research on science and technology of artistic creation in music, animated image and multisensory arts. It is also in charge of academic teaching through the Art Science and Technology (AST) master degree's and the AST platform.

• Cardiff School of Art & Design[4] (CSAD), first opened in 1865 as Cardiff School of Art is today part of Cardiff Metropolitan University. It is one of the oldest Art Schools in the UK and its undergraduate and post graduate courses includes Fine Art, Ceramics, Artist Design Maker, Textiles, Illustration, Graphic Communication, Product Design and Architectural Design and Technology. CSAD is a lead partner in the Wales Institute of Research in Art and Design and it is part of the Fab Labs collaborative global network as Cardiff Fab Lab.

• Fab Lab Barcelona[5] – Advanced Architecture of Catalonia[6] (Barcelona - Spain) is a cutting edge education and research center dedicated to the development of architecture capable of meeting the worldwide challenges in the construction of habitability in the early 21st century. It is one of the leading laboratories of the worldwide Fab Labs network, gathering innovative workshop equipped with small-scale and large-scale, traditional and digital, fabrication tools.

• The Center for Art and Media[7] (ZKM) in Karlsruhe holds a unique position in the world. Its work combines production and research, exhibitions and events, coordination and documentation. ZKM's Institute for Music and Acoustics (IMA) is a creative hub that aims at developing new technologies in digital music such as the Klangdom, a unique 43-channel loudspeaker, and its driving software, Zirkonium. IMA also supports the creation of new compositions through artist residencies, production support and by organizing a series of concerts open to the general public.

• The Ionian University (IU) in Corfu, involves two of its departments, combining education, research and production, in this network. The Department of Audiovisual Arts (AVARTS), specialized in interactive digital arts of sound and image, photography, audio and visual design. The Music Department, which focuses with the EPHMEE (Electroacoustic Music Research and Applications Laboratory) on the study and production of original work within the field of sonic art and technology.

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