ICMC 2013 Keynote Address, The place and meaning of *computing* in a sound relationship of man, machines, and environment

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Abstract

The following text was prepared by the author for his keynote speech at the opening session of the International Computer Music Conference 2013 (12.08.2013 State Theatre Centre, Perth, Western Australia). It discusses the relationship between computing resources and the hybrid technological infrastructures necessary in sound- and music-making practices, as well as to the surrounding physical space where such practices take place. A brief historical survey is outlined of the subsequent connotations of computational tasks and their coupling (or decoupling) to the physical environment: from "calculation", to "communication", to "media processing", to today's "embedded (or physical or tangible) interfaces". In the latter case, a comprehensive view of the "performance ecosystem" seems generally useful to ponder the stronger and stronger integration of different agencies involved, together with a practice-based account situating the performer's (and listener's) body in this ecosystem. As an example, the author illustrates a sound installation work of his own, based on the structural coupling between the acoustics of a room environment and the technical equipment (computational resources, pro- and consumer-level electroacoustic transducers, and mechanical resonators). Albeit personal, the example hopefully illustrates broader artistic concerns and practices in which data from various sources in the environment are admitted as component parts of the computing process. It is suggested that a notion of "computing" seems to materialize here; one that can't be reduced to "information processing", and gets closer to a broader view of "embodied and situated cognition" rooted in the biology of cognition and the epistemology of living systems.

Introduction

Computing, and music computing in particular, is today going through a variety of changes and developments. I'd like to pick some of those that seem most relevant for current sound-making creative practices, particularly in light of the ICMC 2013 theme: "international developments in electroacoustics". My discussion moves from the very trivial observation that, in fact, one always needs analog electroacoustic equipment in order to turn digital signals into sound, and vice versa. More generally, in order to make sense of what in the world can be computed – provided there is anything really computable in music-related activities – one always needs non-digital as well as digital resources.

However, today the particular manner in which digital technologies are sided by, and integrated in, different but overlapping technological layers, seems to be increasingly significant to practitioners. This is clear from contemporary live performance practices, where computing devices typically do not stand alone, but are rather embedded in a larger "performance ecosystem" [1]. Here, other technological layers and agencies play an (equally?) important role, whether they are human agencies (performers), mechanical agencies (music instruments and various infrastructures), or devices ranging from basic analog gear to "software ecosystems" . More generally, what counts in this notion is the array of looser or tighter relations among the agents involved in the performance process, as well as their relationship to the physical space where the performance takes place. Significantly, a practice-led account becomes increasingly necessary to properly situate the performer's (and listener's) body in such approaches to musical performance [2].

One may ask: where does computing take place in such circumstances? What is its role within the larger infrastructures that are needed for any computer music to exist, and what is the role of the infrastructure components for any computing to actually take place? I think answers may vary depending on what we mean by "computing". Far from being timeless or universal, the term has taken on different connotations over the course of modern history.

Early connotations of "computing"

In early information theory and early cybernetics (first half of the 20th century), the computer existed first and foremost as a kind of refined and programmable "calculator", hosted in very peculiar installments that were mostly closed to the outside world - i.e. in the rather anodyne environment of mainframe computer centers. That was before (and after) the advent of "commercial computing", which historians date to the years 1945-1955 [3]. In that context, computing was largely understood as a tool necessary in mainstream academic research (and not only in the hard sciences: the "electronic brain" metaphor was quickly adopted in psychology and social sciences). The only exchange between the number-

crunching engines and the physical world was through the input/output channels necessary to instruct the machine to execute the requested tasks, and to observe the end results of the execution. The transition from mainframe computers to "minicomputers" (1960s), and then "personal computers" (late 1970s), preserved the connotation of advanced research and science, but it was not without a gradual but substantial shift, partly reflecting a new ideology of non-academic research (or at least, research freed from investments in mainstream science). With the era of "home computing" in the early 1980s, a shift in the way computing was represented and imagined took place. Due to the ease with which documents could be produced, and other office-related work activities accomplished (beside entertainment like computer games), the place of computing moved from "calculation" to "communication". The shift was complete in the 1990s with the coming of age of massive telecommunication networks and the popularization of the internet through the world-wide-web built on top of it. By way of its hidden number crunching, the computer became for most of us a device for homework and personal communication, and then eventually a terminal connecting to "social (digital) networks" (2000s). In other words, the computer became the "communication terminal" with which we have been familiar for the last two decades, and that today is being reinforced by "cloud computing" and "big data".

New connotations accompanied the more recent developments, though. One is a shift in which devices, still called "computers", are less "communication terminals" and more "media management centers", or "media processors" [4]. What is so peculiar in the latter idea is the notion of a kind of overarching media, a generalized instance of hypermedia, not aimed so much towards tasks of "mediation", but to tasks of "re-mediation" . Given the overwhelming amount of large-scale applications addressing massive audiences and accessing massive contents ("big data"), I tend to agree with this post-modernist account of the computer as enabling a reframing and a reenactment of contents previously belonging to separate media. However, and in contrast to the end-of-history idea it is too quickly associated with, I think that we should refrain from considering the postmodern account as reflecting the only and ultimate connotation of what computers may represent for us; at least not until creative, visionary artists and engineers engender an attitude of critical thinking about both what we do with our tools, as well as what we do of them (and that implies: of themselves artists and engineers).

Contrary to the notion that would have the current scenario flattened exclusively on the software level [5], I deem more relevant today a conception of software and digital media as integrated and rearranged across other technological layers and media that they cannot (re) mediate, and eventually strictly coupled with the physical space. A few years ago I read: "Now that computation's denial of physicality has gone as far as it can, it is time for the reclamation of [physical] space as a computation medium" [6].

Current "computing" connotations and research directions

Today, a relevant connoting potential lies in computing devices known as "microcontrollers", representing increasingly important components of everyday objects and sites. These allowing computation units to be packed into small to smaller circuit boards, with i/o channels connecting to the physical world (sensors, actuators and other transducers reaching into the environment). Sometimes we hear talks of "pervasive computing", or, more interestingly, "physical computing", which usually means that aspects of the environment are sensed by computer interfaces and drive ongoing computations, which in turn actuate changes in the environment. The dissemination of such computing units across artifacts and throughout the environment creates a network (or perhaps should we say a meshwork?) of mutually affecting processes and agencies. We are used to hearing about "tangible interfaces", or "physical interfaces", described as retaining and manipulating "referents" to real objects and spaces [7], and therefore offering a greater sensory richness and human significance than screen-based elements can afford [6]. Addressing the dynamics of "interaction" in contemporary digital music, [8] speak of "behavioral objects".

Such developments are part of an ongoing trend that can be seen to positively disrupt the previously encoded limits of computing. The CEOs of large corporations are increasingly employing the catchphrase "the internet of things" to describe physical computing, which confirms that the trend is opening up a potentially enormous market. Not surprisingly, occasions of a paradoxical triumphalism can be spotted: as far as music making and acoustic communications are concerned, this presents the risk of obscuring the more important cognitive and experiential phenomena involved in auditory experience and listening. I can't say whether it is a promise or a threat when, in a popular cookbook, a guru of physical computing shows us how to "create talking objects from anything" using "computers of all shapes and sizes" [9]. Will we survive a saturated acoustic semiosphere,

where anything can talk to us? And more to the point: what do we make of "talking", along the way?

Among the interesting creative efforts in the field of "audio physical computing", I'd like to mention the work of Andrea Valle, whose real-time "acoustic computer music" is made "by computational means, but (whose) sounds are generated from acoustic bodies" [10]. Some of his experimental projects present hybrid performance infrastructures, where acoustic or force feedback occurs across different technologies [11]. Equally relevant, albeit from a different perspective, is research work undertaken under the umbrella definition of "mechanical sound synthesis" [12] [13]. Of course, the latter perspective follows from elaborate physical modeling approaches, often targeted at "virtual" or "augmented reality" technologies. However, in such approaches I also see a potential for a stronger and more widely shared ecologically and physically ingrained awareness of what sound is and how we deal with it as human beings. In my personal view, issues surrounding "virtual reality" are today both scientifically and artistically less fruitful than a higher awareness of real world, situated and embodied perception and action.

Structural coupling and position

Our admittedly too short survey, then, ends up with four subsequent but often overlapping connotations of computing: "calculation", "communication", "media processing", and "embedded (or physical) interfaces". We can observe a displacement of computing devices as relative to the specific context in which they are set to work. Of course, with the move from mainframe computer rooms to wearable microcontrollers a lot has changed. But for the purposes of my discussion, let's keep to the following two points:

(1) *The potential complexity and richness in creative designs and projects increases as a larger and larger set of data streams (coming from different sources in the environment) is admitted to, and is coordinated to be part of, the computing process.* Digital computing is of course done in digital devices, according to any number of algorithms and programming styles, but the array of connections-to and dependencies-on non-digital signals and non-software events has become so large today as to make it difficult to consider these latter sources as mere "input data". That is, as something "external" that gets fed into and independent number-crunching process. What we see, here is a gradual move to a style of computation that does not so much take input from the environment as is coupled with the environment. At a meta-level, we can describe this process as a "structural coupling" of (so-called) internal computations and (so-called) external physical conditions. In such a situation, computing becomes neither an entirely deterministic process, nor an indeterministic one, but an active part of a larger complex system. It yields less into "resultant" output data, and more into "emergent" patterns or behaviors.

(2) *As the relationship of the computing equipment to the surrounding environment changes, so too does our position in the environment as relative to the computing equipment.* (It has not happened by chance that, more and more often, people using computers in their music performances prefer not to stand or sit before the computer screen, but rather focus on other centers of attention and activities.) In my admittedly too short survey, "computer musicians" started out by standing or sitting inside mainframe computer installments (figure 1); here, all that occurred used to take place in the form of coded instructions coming from, and passing across, i/o channels (e.g. punch cards), and was accurately delivered in symbolic form by highly specialized personnel. We began, first, by sitting before the computer - or its monitor screen (figure 2). And we ended, later on, by moving around the room and across the streets, with networked computing, microcontroller interfaces, "cloud computing", etc. (figure 3). In other words, musicians using computer resources literally moved from within an environment made of computer hardware parts (where computing literally environs, surrounds, and envelopes us) to an environment hosting one ore more computer stations. And finally, we moved to an environment where computing units are spread all around, absorbed into many of the objects and surfaces that make up the environment itself.

At this point, some words are necessary concerning the notion of "environment", as I have left it rather undetermined so far. Following the ecological and biological sciences, we should consider "environment" not as the generic surrounding physical space, but as a segment or selection of forces and agencies in that space, and which are meaningful to the functionality of the system under consideration. The environment is the particular section or "niche" of the physical world, which "unfolds in relation" to the living beings inhabiting that niche [14].

Because human beings are able to shape their environment, today they seem to be shaping for themselves environments that have calculative capabilities. On the other hand, what counts as "environment" for devices such as microcontrollers and computer interfaces is a limited set of selected features, or properties, in the physical space. (For example, the

"home" of "home computers" may be an "environment" to us, but it is not to the computer, despite the fact that many of the the functionalities expected of a "home" are necessary for the computer to work.) By purposefully specifying the features in the physical space that are sensed and acted upon by our computer interfaces, we specify what counts as "environment" to these devices. By purposefully specifying the possible interactions between devices in the environment (figure 4), we are defining a potential "ecosystem" - a web of interacting forces whose global behavior is brought about by local exchanges of energy (sound) and information (environmental traces taken on, and carried by, sound).

This brings us to a position from which, I think, we can better tackle the questions posed at the beginning of this paper. However, before we go back there, I'd like to briefly describe one of my own works that reflects - albeit in a very personal manner - some of the issues we are dealing with.

An example from my own work

Condotte Pubbliche (public conducts) is an "ecosystemic sound construction" that requires two small microphones and two earpieces (earphones, i.e. "small speakers"), all secured inside two brass pipes (strong mechanical resonators) which in turn lie on two standard near-field speakers sitting on ground (figure 5). It also utilizes a condenser microphone hanging from above, and a piezo disc lying on the floor (if the floor surface is in wood).

All transducers are bridged among them via an audio interface and some self-authored signal processing software, in such a way as to create a multiple feedback delay network (figure 6). Based on room noise, sounds are born of the local feedback conditions (Larsen tones) inside the pipes and across the surrounding room. The computer runs simple processing methods to automatically adjust gain levels. It also runs basic signal transformations, in ways regulated by constant adaptation to properties "observed in" (or "information extracted from", if you prefer) the total room sound. To the latter end, real-time signal-level descriptors are used to modulate the variables of signal processing transformations in a self-regulating manner. Besides background noise, and any noise events eventually caused by the visitors, the "room sound" includes the sound delivered by the setup itself: no clear distinction is made between the "system's own" voice and the sounds "foreign" to it. We thus have a larger system that, by definition, includes the acoustic space in its processes. In the real-time process, everything that can effectively generate, filter, and channel sound has some influence on the sonorities emerging in the feedback network, as well as on the temporal unfolding of the continuing sound flow. The approach is defined "ecosystemic" in the sense that all compositional designs and empirical adjustments are necessarily addressed both to "system" (gathering of objects and functions) and "oikos" (the host space). Or, more precisely, they are addressed to their permanent exchange and relationship: their "structural coupling". The task of composition therefore becomes one of "composing the interactions" [15] [16].

In principle, the process thus implemented should be able to unfold by regulating its own behavior, non-supervised, and exhibiting some level of systemic autonomy (i.e. self-regulating behavior, self-determination) . For this to happen, the system loops back onto itself through the environment: we can say that some level of "autonomy" (systemic closure) can only be achieved by way of a continuing openness, and some degree of "heteronomy" (systemic openness).
Figure 7 is an image of the *Condotte Pubbliche* first realization. Here you see a dark blanket hiding the speakers and the computer equipment beneath. But its function is also one of causing diffractions in the sound waves transferring from the two speakers into the pipes, and into the microphones sitting in the pipes. Everything in the piece has a sound-related function.

This work was born as an installation project, but I eventually devised ways to use it in performance contexts. Indeed, a performer can locate spots and surfaces in the complete setup that lend themselves to be efficiently acted upon, searching the affordances that allow for possible gestures, and for actions enabling her/him to enter the sonic process and play a role in it. One can act, for instance, close to the pipe ends or against them, using either mouth or hands. The aim would be to explore system behaviors that could not be manifest were the piece running unattended. This turns the "installation" into a kind of "instrument", or better, a sound generating device that includes the environment as a part of it - the same environment in which the performer acts as part of the sound generation process. The form of presentation therefore becomes uncertain: is it an installation or a performance? Or is it an instrument to play with? This is the kind of ambiguity that, in past decades, has characterized the work of such illustrious electronic music pioneers as Alvin Lucier and David Tudor, of course. Is the artistic content to be found in the sound atmosphere the work creates, or in the process that are running? I will leave such questions there.

In any case, performers will find themselves in a situation where they have to permanently negotiate their own freedom of action within the global behavior of the autonomous ecosystemic process. It becomes a question of taking part in a situation, maybe setting aside one's own wanted actions. What a performer does here is not a matter of "interacting with a computer"; neither is it looking for a specific, stipulated output sound. S/he is but a part of a whole network, made of mechanical, analog and digital components, each leaving its own trails behind, that might become audible or might just remain silent and unspoken. In a sense, the performer becomes another component of what counts as "environment" to the technical setup. S/he represents another source of sound and another source of (self) regulation - another agency, surely a particularly sensible and intelligent one, but also a fragile one. S/he cannot "direct" or "lead" the system. One can say that the equipment acts onto itself through the performer. Or, if you prefer, the performer acts onto her/himself through the environment and the computer. It is a matter of where you start reading the process. Each gesture on the performer's side enters a continuous flow of mutually affecting event streams - sonically revealing a veritable "ecology of actions" (to use a definition by the epistemologist Edgar Morin). As is typical in systems exhibiting "distributed causation", it is difficult if not impossible to say what is the very source to this or that event of sound, as the particular causes may be so deeply disseminated across the history of previous and current sonic interactions. Performing therefore becomes a question of "listening, and taking action". It also becomes a question of taking and releasing control. In our overly digitized world, this "taking and releasing control" is significant, in my mind at least, to issues of subjectivity and intersubjectivity; identity and transformation; self and non-self: issues that are the flesh and bones of our daily life. What is to be heard consists mostly of the audible traces left behind by the dynamical relationship of components sharing the same place and the same time, keeping and losing control over one another's actions.

Computing and composing: conclusions

What is the place of computing in *Condotte Pubbliche*? Sure, we have a very important software component, executing (on a standard notebook) a variety of digital signal processing algorithms (implemented with Pure Data or Kyma). This cannot be set aside. However, the software component alone can hardly account for the kind of system dynamics, nor for the audible traces it leaves behind. It's rather the tight but time-changing interconnections of the different component layers that are responsible. We have a small infrastructure of interlaced technological layers, each contributing to the entire process in its own way. For example, the earpieces (with their limited frequency and dynamics responses) and the pipes (with their specific acoustics) are surely responsible for characteristic spectral colorations. Many small nuances, and the overall system's acoustic efficiency, largely depend on the room acoustics and the characteristics of the particular transducers involved. Besides, to sonically exist, the piece needs a real space; a room, perhaps, to be inhabited rather than merely "occupied". An area in which different process trails and sound traces entangle, so as to form the "environment" to the work. It needs the background noise, or any other acoustic perturbation in a socially enlivened room. In this regard, Condotte Pubbliche comes close to the third of my Audible Ecosystemics, the 2005 solo performance Background Noise Study [17] [18].

Let's now enlarge the perspective again, and shift from my personal efforts to a broader view. What is the place of computing resources in music-making practices where those resources are coupled to the environment via overlapping, hybrid technical infrastructures? What is the precise function of computational activities, once they are heterogeneously and heteronomically driven, and maybe dispersed in objects and appliances scattered across the environment? I see a possible connection, here, to a much broader view once put forth by cybernetic pioneer Heinz von Foerster, who used to explain the Latin term "computare" (computing) as meaning "to consider or to contemplate things together" [19]. In this view, "computing" means "handling mutual relationships". Today, with our ubiquitous microcontrollers and apps, computing is indeed less "information processing" and more "coordinating the interconnections of disparate agencies".

This is all very general and admittedly too broad. Yet, if I may dare, my recourse to von Foerster is because, in the end, "composition" itself means "putting things together (Latin "componere", Greek "synthesis"). There is a similar notion of "caring for the interactional dynamics among different component parts". In creative explorations where computing units are interfaced with non-digital devices in an overriding set of ecosystemic dynamics, computing can be said to take place across the tripolar, recursive relationship of equipment, environments, and human beings. The relationship is recursive in the sense that it consists in a dense vector of mutual influences among component parts, which makes it impossible to separate input and output, cause and effect. Here, computing

is no longer the implementation of i/o functions: all output is input (and vice versa), all effect is cause (and vice versa).

In the way I am using it here, however, the qualification "recursive" also suggests something else. At any specific time, the current system state is the achievement brought about throughout the history of all previous states: the ecosystem process always operates in the here-and-now, and the complete sequence of past exchanges and interactions de facto set the conditions to current operations. It is a flux, a line of events, not a step-wise process: our softwares may work based on symbolic representations of time and punctuated, discrete events, and yet that would still remain within the operation of just one technological layer, and not that of the whole computing unit. Once set on the run, the man-machine-environment relationship unfolds in time as a kind of narrative, reflecting the actualization of past events in the configuration of the present. Beside, current emergent behavior may bind the potential of future patterns, and even prevent or submerge possible system states (a token of "downward causation"). In that sense, the process may reveal overall orientations and directions that are not stipulated.

In interdisciplinary work at the border between computer science, philosophy and post-computational cognitive science [20] [21], such features would be considered typical of living systems, i.e. systems whose activity is largely directed towards maintaining and transforming themselves by way of their permanent exchange with the segment of physical space that counts as environment. There, "computing" is equaled to "cognizing", and becomes a question of lived stories feeding back and forth across and through layers of different physical substances; none of which is digital, except perhaps for the threshold logics of the single neuron!

If we regard music as audible phenomena brought forth in a sound recursive relationship of man, machines, and environment, then the place of "computing" in "music computing" is nowhere and everywhere along the trails and paths: it's more in the way things connect among them, than in the things connected; more in the lines than in the nodes. And in the very way in which we stand and dwell in the environment.

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Notes

1. The debate on this issue was initially raised, a.o., in [22]. It mirrored broader philosophical questions often disputed at that time and in earlier decades e.g. [23].

2. The notion of "software ecosystem" has come to mean "networks of mutually coordinated software applications". While it lends itself well to software analysis issues [24], it remains merely and loosely metaphoric and has raised criticism. Richard Stallman considers it an entirely faulty if dangerous metaphor, because it conveys the view that artifacts - such as human-made networks, and even social networks - can be as void of implications of "intentionality" and "ethics" as natural ecosystems are [25].

3. That is, the mediation of other media, the processing and reframing of contents produced in other media, either older or newer ones, maybe designed specifically to be remediated [26].

4. According to anthropologist Tim Ingold, by insistently speaking of "networks" we end up experiencing the world in terms of a grid of "interconnected points", although the lived experience of our multifaceted relationship to the world is, in his terms, more like "interwoven lines" [14]. In other words, the "lines" (how we move from one point to another) are more central in our dwelling in the world: a metaphor of finely-threaded lines - such as the "meshwork" - should be preferred.

5. As of summer 2013, Intel corporation is making agreements with the microcontroller company, Arduino, to release Galileo, a small-size "Arduino-friendly" board designed to lead innovative "embedded interactive" designs. The project adopts Arduino's open-source ("we will learn from you", said the Intel chief executive to Arduino's father, Massimo Banzi, as they announced the collaboration; see [27]). This move could also be seen to rival the popular Raspberry Pi, a microcontroller device currently popular among computer music research projects (see various contributions to the ICMC 2013).

6. This was made clear, even before Gibson's ecological approach on perception [28], in pioneering research by Jacob von Uexküll in the 1930s, with his notion of Umwelt [29].

7. We usually conceptualize perception as a matter of poking information in the environment (so we may turn it into a task of "information processing", as in various styles of reductionist cognitive science). However, what we call "information" is not something of, nor in, the environment: "information" is inferences our body

builds upon data gathered by sense descriptors (system terminals) in order for us to define what counts as "environment" in physical space. In fact, "the environment contains no information; the environment is as it is" [30].

8. "Autonomy" is often taken as a self-explanatory notion, but closer analysis and attempts to formalise it are at an early stage. In the context of music-generating systems, see the introductory discussion of [31].

9. The DSP methods involved in the Audible Ecosystemic series of work (2002-2005) are more demanding and computationally expensive than Condotte Pubbliche. I have developed them on the Kyma workstation, which includes its own dedicated number-crunching hardware.

10. Two examples I came across recently are O.Bown and M.Young's performance Chatter Boxes and Raspberry PI Orchestra (2013), and SkypeBack, an extension of my Feedback Study (2004) recently proposed by Kevin Hay and Tam Treanor in Glasgow, as part of a BYOB "Bring Your Own Beamer" collective performance (2012).

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FIGURES

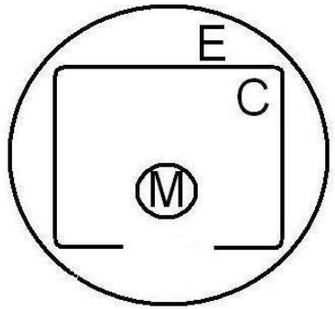

Figure 1. In figures 1-4, E stands for Environment, C for Computer, M for human being(s).

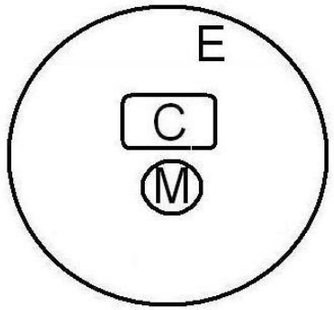

Figure 2.

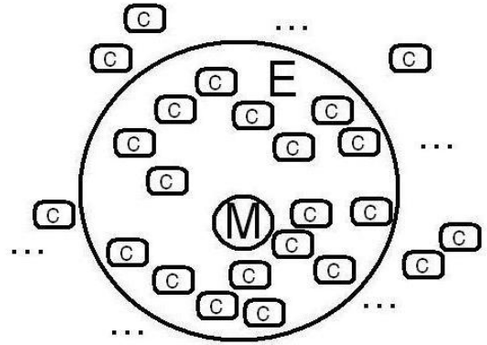

Figure 3.

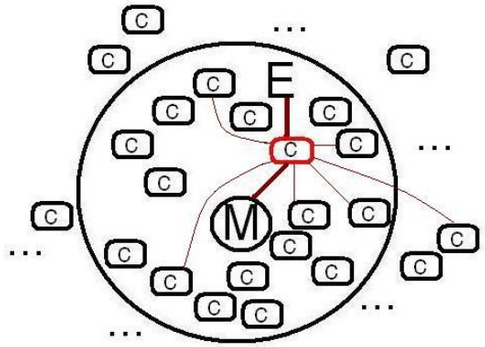

Figure 4.

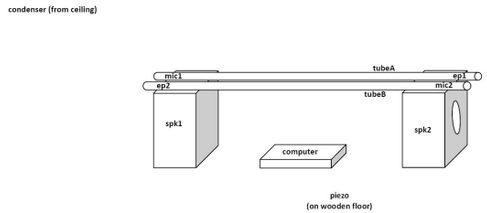

Figure 5. *Condotte Pubbliche.* Schematics of technical setup.

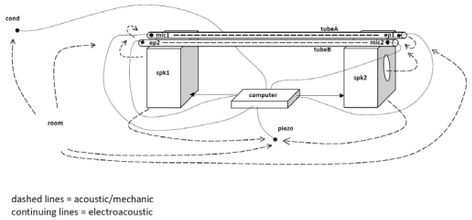

Figure 6. *Condotte Pubbliche.* Schematics of acoustic connections (dashedlines) and electroacoustic (continuing lines) connections.

Figure 7. Partial view of *Condotte Pubbliche* (Galerie Mario Mazzoli, PotzdamerStrasse, Berlin, March-May 2011).