Human-Machine Co-Creativity

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A Reflection on Symbolic Indisciplines

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Is it possible to conceive a kind of musical significance that would be carried by both human and artificial agents, cooperating together, especially if it is supported by a vision unfettered from rigidity of genres and disciplines? Such an approach would be truly "indisciplinary", allowing thinking and practice at the fringes of arts and sciences, while staying clear from an indistinct form of fusion (music is music, science is science) or a simple utilitarian distribution of tasks between engineer and artist (as is commonly practiced in the music industry for the development of new production tools or recommendation technologies). The music gathered in this CD is the result of a full experience of collective indiscipline, exploring free improvisation as a domain of expression for a shared musicality between humans and "machines" (including abstract mechanisms such as algorithms) in a context where each learns from and progresses with the other, and where they challenge each other. The release of these pieces, recorded over many years of close-knit collaboration between Bernard Lubat, Marc Chemillier and the author (with their respective machines), offers an opportunity to revisit these ideas and attempt to conceptualize them to some extent, even if our claim of "indiscipline" as pertaining to the freedom of improvisation might seem contradictory to abstract reasoning: this is why we ask the reader to regard this reflection as a rather free improvisation (of thought), an attempt to give oneself relevant tools to apprehend what has surfaced from all this music—sometimes noise—and these ideas, in the course of years of experimentation.

According to Eva Carpigo and her colleagues, who co-directed in 2016 a special issue of the *Revue de sciences sociales* devoted to this notion, indiscipline in research is based on several heuristic factors (conducive to the rapid, intuitive and practical discovery of new ideas), including a "transdisciplinary approach that brings together a sum of knowledge and a set of methods capable of grasping the complexity of reality without disjointing it" and the kind of reflexivity that requires the integration of one's personal feed-back into the perspective of the particular research field (which we believe implies some form of learning). It is this very idea of indiscipline that we want to put to the test by confronting it with the artistic and technological practice reflected in this CD, because it involved, for its actors, a radical disruption of their creative modalities, as "machines" entered the game. Thus, the notion of creativity comes to play a central role in elucidating this issue.

Margaret Boden, a specialist in cognitive psychology who reflected on artificial intelligence, has proposed an interesting definition of the notion of creativity in her book *Dimensions of Creativity* (MIT Press, 1994). In her own words, "creativity is the ability to come up with ideas or artifacts that are new, surprising, and valuable". There are three main forms of creativity, in correlation to three types of surprise: it can be combinatory, exploratory or transformative.

Combinatorial creativity produces previously unseen combinations of known elements, as is common in poetry ("Beautiful as the accidental encounter, on a dissecting table, of a sewing machine and an umbrella", Lautréamont), or to pursue a scientific analogy: an algorithm can be inspired by a biological structure.

Exploratory creativity visits preconfigured conceptual spaces, theoretical or aesthetic fields that constitute structured styles of thought, within which intellectual excursions can produce new ideas and artifacts, but without altering the space's boundaries. The tonal system constitutes a perfect example in the field of music: all sonatas are different, but they constitute patterns of tension and relaxation in the same harmonic space (the classical chords arranged in the different tonalities) based on strong polarities.

Transformative creativity drastically changes the mental space that served as a frame of reference by giving rise to thoughts that were literally inconceivable before. One example is the "epistemological break", a topic dear to philosopher Gaston Bachelard in the philosophy of science, or the "Schoenberg case" (in the words of E. Buch) which frees itself from any form of tonal hierarchy in music. Bernard Lubat also mentions the fact that, with its curious cocktail of laborious stupidity and dazzling inspiration, the machine seems, in his words, to "liberate" him, perhaps from specific habits or automatisms.

In other words, our inner atlases can be roamed and even modified by creative thinking, in order for the "unthought" to find its way. Or even so that the unthinkable might emerge. What connections can we then find in the fields of art and science between indiscipline as a commitment to a decompartmentalised form of research, and creativity with its various modes of emergence?

This particular question arises in the increasingly frequent situation in Computer Music where part of what was once exclusively the domain of human creativity is delegated to the machine. This is notably the case with musical AI (Artificial Intelligence), which makes it possible to build autonomous creative agents freely interacting with musicians on stage, as we can hear in this CD's live recordings, in dialogue or counterpoint with Bernard Lubat's piano. Algorithmic generation and the dynamic composition of complex temporal and spatial relationships combine to provide game partners that are facetious enough to constantly sustain and revive the interest of seasoned musicians such as Bernard Lubat.

Robert Rowe, a professor at New York University, makes use of an expression which we find both more measured than "AI" and better suited to all the technologies whose aim is to confer a form of musical intelligence to the machine. The title of his work is "*Machine Musicianship*" (MIT Press, 2001), for which it would be difficult to find a French equivalent, for example the automatic translator DeepL (itself a product of AI) hesitates between "machinerie musicale" (musical machinery) and "musique mécanique" (mechanical music). We could attempt to encompass it within the terms of "musicalité artificielle" (artificial musicality), in the sense of a musical know-how that the machine acquired thanks to the programming of formal models (derived from "musical mathematics") or machine learning (an AI methodology) through exposure to a corpus of music or confrontation with live situations.

What form of tasks delegation, of autonomous creativity, or even of indiscipline can artificial organisms (endowed by us with a form of musicality) claim? Furthermore, aren't we on the verge of *aporia* (an insoluble contradiction) when we rely on the notion of creativity while dealing with machines?

In our recent research, we have sought to remedy this question and the serious issues it raises by introducing the notion of "co-creativity": creativity distributed between humans and machines engaging in intense situations of symbolic interaction. But what exactly do we mean by symbolic interaction? New interactive systems oriented towards improvisation are based on the evaluation of the past, listening to the ongoing sound context, as well as predicting (and updating) their anticipation and decision strategies at different time scales, from reactive time to projections in the future structured by micro- and macro-scenarios. Attributes such as intentionality, relevance, adequacy, aim, discovery and style are then shared between human and artificial agents engaged in cross-learning processes, because humans learn and progress as much as machines in these unprecedented interactions. Musicians using the computer systems that we can hear on this record most often confirm the fact that they would not perform in the same way without the machine, while the temporality of the recorded sessions shows a technical and thematic evolution of human as well as artificial agents, which strongly suggests the idea of coevolution. What we qualify as "symbolic interaction" in the musical domain is this particular situation of adaptive interdependence, as opposed to classical electronic/digital interactions which mainly focus on sound processing, as it involves every level of musical representation, from the signal to the symbolic (structures), even potentially including real and simulated cognitive modalities.

These symbolic systems in which "musicality" is distributed between human and artificial agents grant them, in our opinion, a possibility of co-creativity that would have the following characteristics:

- It arises from the emergence of concomitant musical contributions woven between humans and machines, which cannot simply be reduced to the sum of their individual components.
- The resulting surprises lead to changes in the internal state of the performers according to complex dynamics that can generate calm and static passages, continuous evolution, or violent ruptures. Bernard Lubat's live concert recordings contained on this CD offer a wealth of examples. Such an emergence phenomenon is characteristic of the non-linear dynamics of complex systems as studied in complexity theory.
- It stems from generative learning mechanisms that are both cross-referenced and reflexive, since the input signal at time t for each agent combines the production of the other agents and its own, with the memory of previous productions as well. One might find an illustration of such a process at the beginning of the New York concert in which Lubat and the machine pursue each other from the get-go, seemingly echoing each other, while evolving in both a contrasted and correlational fashion. This association creates the possibility of reinforcement mechanisms (of elements, patterns, sentences) in artificial and natural memories, according to the other's implicit intentions as assumed by each agent.

Considering our two previous points, it appears clearly that none of the agents would perform in the same way in a solo situation, thus co-creativity is not the simple sum of individual creativity, but the irruption of new irreducible forms, which do not fit into the mould of conventions (another way of evoking indiscipline, perhaps).

The example of symbolic interaction and co-creativity between human and machine agents is an aspect of computer music that Marc Chemillier and myself have tirelessly explored with Bernard Lubat and other major artists. It is also very interesting from a disciplinary point of view. First of all, in the field of computational sciences it brings together signal processing, machine learning, interaction architectures, multi-scale formalization of static and dynamic temporal structures, and autonomous agent systems. But this is not enough to take the whole measure of the problem: cognitive sciences are indispensable to apprehend the aspects related to listening, memory, agency (the capacity to act in context), judgement, and intentionality. George Lewis, inventor of the *Voyager* program (a major precursor of autonomous musical systems), has captured some of these problematics in his recent concept of "interpretive autonomy" where "the system decides for itself about how to relate what it 'hears' to what it plays"(*see his text in this booklet*). The sciences of music allow us to evaluate questions of stylistics, pertaining to the aesthetic field, or musical strategy in individual and collective engagement, but they are also governing the computer heuristics responsible for the discovery of musical structures, as well as those dealing with composition, in other words, the writing of sound, time, space and form. Our interest is even reaching out to the field of organology when it comes to embedding these processes at the heart of the musical instrument. Whether it is electronic, or an augmented acoustic instrument (using "active acoustics"), which we would now also like to equip with "machine musicianship", this aspect is essential in our future projects, as it might endow our computer tools with an indispensable "corporeality".

Finally, the predominant part that improvisation plays in these systems as well as their collective nature urges us not to overlook the important knowledge accumulated over the years by anthropological, linguistic and even ethological studies on the spontaneous production of exchanges mediated by speech or other sign systems, whether these exchanges be ritual, political, economic or erotic. This explains the importance of pluri- and inter-disciplinarity in the course of research concerning symbolic interaction, musical co-creativity, and involving technological systems. However, the overall process of artistic creation also conditions research goals, and pushes for an indisciplinary vision which might, in our opinion, articulate artistic practice with theoretical processes and technological developments. This vision would purposefully integrate the complex cycles of co-learning between humans and machines, which under certain circumstances fostered by improvisation practices are likely to break down the famous "boundaries" that usually delimit artistic and scientific activities. Returning to our initial definition we remain, however, sceptical in regards to a definition of transdisciplinarity such as the one championed by Edgar Morin, a fusion of knowledge and methods to "grasp the complexity of reality without dividing it". If we understand it as a form of knowledge whose unity would somehow reproduce real life, we are reluctant towards the anti-Cartesian flavour of this approach, at a time in history when the dangerous rise in popularity of all sorts of irrationality is urging us to beware of any kind of soft rationality. Although in a resolutely artistic fashion (in the spirit of art/science research), we remain firmly attached to objectivity, analytical approach and methodological clarity, a call back to

Cartesianism aiming at dividing complex problems into soluble parts that can be approached through calculation and logic. This probably comes from the fact that, in the end, we are algorithm programmers, therefore participating in a form of thought called “performative”, whose very statement directly accomplishes real-life perceptible results—on the condition that we identify computationally tractable problems and that they are formulated with the greatest accuracy (this is what a computer program looks like). In this apparent contradiction resides all the tension underlying the unprecedented adventure initiated between Bernard Lubat, Marc Chemillier and myself in 2004. This collaboration continues to this day, challenging itself to create borderline situations (cyber-human situations where creativity becomes actually shared), in order to test disciplinary boundaries, and explore new forms of cross-reflexivity between man and machine.

In this regard, the matter of the means of evaluation becomes critical. This is a recurring difficulty in the field of art/science research, as it is much more difficult to establish on the generative side of algorithms than on their analytical side. Concerning the statistical modelling of musical sequences, there are many techniques of information-theory measurements that can establish the statistical relationship between an artificial production and the theoretical source it is supposed to simulate (in other words, objectively measuring the fact that the artificial production “looks” like what a human being could have produced). Others have proposed their version of a “Turing test” (subjective assessment of the fact that the machine can “deceive” humans in a blind situation) to show the realism of these productions. In reality, these methods are of little value. It is extremely easy to deceive a listener with clever algorithms or to produce sequences with good statistical properties while being devoid of any artistic interest or of any capacity of arousing the slightest curiosity on the part of humans. All of this shows that certain systematic or probabilistic aspects of music can easily be mimicked. However, they do not in any way guarantee the emergence of creative behaviours, especially in regard to the third type of our typology: transformative creativity. One of the reasons for this is that these creative behaviours often stem from a singularity embedded within a temporality, whereas all the models mentioned previously aim towards the generality of an abstract system or the statistical distribution (often timeless) of underlying phenomena.

The reason why we put forward the specificity of co-creative situations is that in them something special is taking place from the point of view of role-boundaries and reflexivity. Very often the researcher becomes more involved as a musician, entering a double learning loop with the machine. The latter acquires a certain level of reflexivity, as we have seen, since it can theoretically analyse its own productions as they meet those of the musicians. For example, the SoMax software, which we hear distinctly reacting (with wind orchestrations) to Lubat’s voice as soon as it appears in the Philadelphia concert, is memorizing what it picks up from the microphone and analysing it as well as a flow of musical events. The software also keeps track of what it generates. It is the resolution of these two simultaneous “past” streams of the performance into a possible common future that allows SoMax to decide how to move forward at each step. Of course, the human musician listens to the machine and makes their own predictions, and both systems constantly adjust their anticipation according to the confirmations or surprises that occur. Such encounters between reciprocal intentionality (when predictions work and match each other), if they are frequently repeated, act like implicit signals of judgement, of agreement, and therefore of reinforcement (we have a tendency to maintain what has provoked an expected response, or to reproduce later what

has provoked a pleasing surprise). These signals replace an explicit human evaluation/supervision, which would often be difficult to set up, by revealing in an indirect way, through the dynamics of the music alone, the amount of interest inspired by the productions of the machines. A notion of shared musical relevance is then established, giving us a glimpse of this "distributed musicality" we mentioned at the beginning of this essay.

This brings us to complete our initial indisciplinary proposition with the notion of a double reflexivity inherent to the situation of "cyber-human" interplay (i.e. one in which a continuity of analysis and production is established between humans and machines, just as the so-called "cyber-physical" technologies establish a continuity between the digital and physical worlds). The researcher/musician and the machine engage in an interwoven process of listening and accelerated learning, integrating the other's judgement in a double feedback loop. These judgements are not expressed with a metalanguage (an annotation) but in the very language and temporality of the artistic medium. Indeed, rather than indicating "I like", "I don't like", "this is sad", "this is a harmonic modulation", as can be found in the annotated musical corpuses used to train machine learning systems in MIR (Music Information Retrieval) to recognize music features automatically, it is through their musical reactions during live improvisation that artificial and human agents implicitly express judgements and comments about each other. We make the claim (and this is still another form of indiscipline) that these implicit mechanisms, correctly observed and exploited, can constitute a source of knowledge that will eventually help enrich musical algorithms and AI, while steering clear of the pitfall of normative aesthetics (I annotate by conveying the clichés of a dominant culture, sometimes reactionary but always conventional), which plagues research and industrial applications of MIR (recommendation engines in e-commerce, etc.).

Abraham Moles, a visionary of computer music (and of sociology and aesthetics as well), already established this view in his pioneering book *Art et Ordinateur* (Casterman, Paris, 1971). For Moles, forms do not exist in themselves, they are the product of the action of the receiver on the message. Hence it appears that shapes are also the result of a continuous (and creative) learning by the receiver. Moreover, Moles ventured that a creative artificial generator should also include in its model its own critic, capable of producing a value judgement. This prophetical idea has recently been brought up to date in the field of artificial intelligence with "Generative Adversarial Networks" (GANs), a form of "deep learning" in which a producing machine (the generator) is confronted with a "judging" machine (the discriminator) that tries to determine whether the production is natural or artificial. The productive machine becomes progressively better since its learning criterion is precisely to deceive its judge. However, recent research on GANs has indicated that the credibility of the generator (as a potentially creative subject) could be better assessed by the judge if the latter was able to measure, in addition to its realism, the level of conformity or originality of said generator. Regarding the objects produced by the generator, one could then encourage maximum deviation from previously known styles, in order to teach it to be more creative! This is perhaps an interesting strategy to avoid falling into the trap of perpetually reproducing banalities inherent to AI and big data, and to stimulate artificial musicality. However, while there is certainly a virtual critic in Moles' original vision, the question of evaluation criteria remains unanswered in his work, which is precisely what we hope to get around with the double reflexivity of interacting co-creative entities, by provoking an eminently indisciplined collective behaviour through their

rich and sometimes unexpected excursions. We sincerely hope that the performances recorded on this CD will convince the listener further.

This text is a revised and expanded version of Gérard Assayag's communication at the symposium "Les sciences de la musique : de nouveaux défis dans une société en mutation" on January 18, 2019 at the Maison des Sciences de l'Homme Paris Nord.